A LEVEL Cambridge Topical Past Papers

PHYSICS

PAPER 2 2017 — 2023

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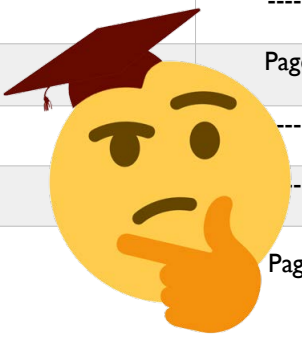


1 – (9702/21_Summer_2017_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) Determine the SI base units of stress.
Show your working.

base units .....[2]

(b) A beam PQ is clamped so that the beam is horizontal. A mass M of 500 g is hung from end Q and the beam bends slightly, as illustrated in Fig. 1.1.

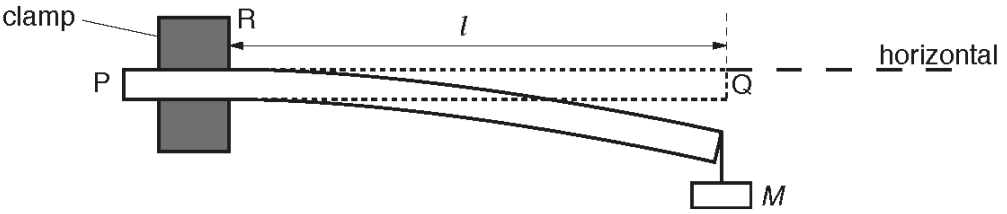


Fig. 1.1

The length l of the beam from the edge of the clamp R to end Q is 60.0 cm. The width b of the beam is 30.0 mm and the thickness d of the beam is 5.00 mm. The material of the beam has Young modulus E.

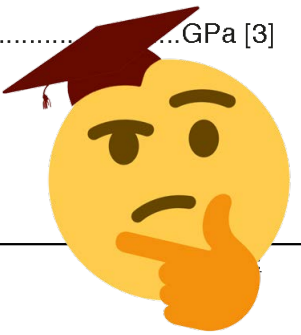
The mass M is made to oscillate vertically. The time period T of the oscillations is 0.58 s.

The period T is given by the expression

$$T = 2\pi\sqrt{\frac{4Ml^3}{Ebd^3}}.$$

(i) Determine E in GPa.

E = ...GPa [3]



(ii) The quantities used to determine E should be measured with accuracy and with precision.

1. Explain the difference between accuracy and precision.

accuracy: .....

.....

precision: .....

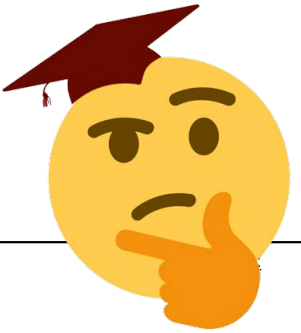
.....
[2]

2. In a particular experiment, the quantities l and T are measured with the same percentage uncertainty. State and explain which of these two quantities contributes more to the uncertainty in the value of E.

.....

.....

.....[1]



2 – (9702/22_Summer_2017_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) State two SI base units other than kilogram, metre and second.

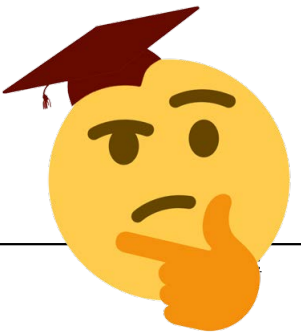
1. .....

2. .....

[1]

(b) Determine the SI base units of resistivity.

base units .....[3]



(c) **(i)** A wire of cross-sectional area $1.5\,mm^2$ and length $2.5\,m$ has a resistance of $0.030\,\Omega$. Calculate the resistivity of the material of the wire in $n\Omega\,m$.

resistivity = ...$n\Omega\,m$ [3]

(ii) **1.** State what is meant by *precision*.

.....

.....

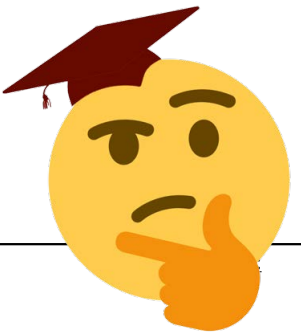
2. Explain why the precision in the value of the resistivity is improved by using a micrometer screw gauge rather than a metre rule to measure the diameter of the wire.

.....

.....

.....

[2]



3 – (9702/23_Summer_2017_Q1) – *Physical Quantities & Units*

(a) Two forces, with magnitudes 5.0 N and 12 N, act from the same point on an object. Calculate the magnitude of the resultant force *R* for the forces acting

(i) in opposite directions,

R = ... N [1]

(ii) at right angles to each other.

R = ... N [1]

(b) An object X rests on a smooth horizontal surface. Two horizontal forces act on X as shown in Fig. 1.1.

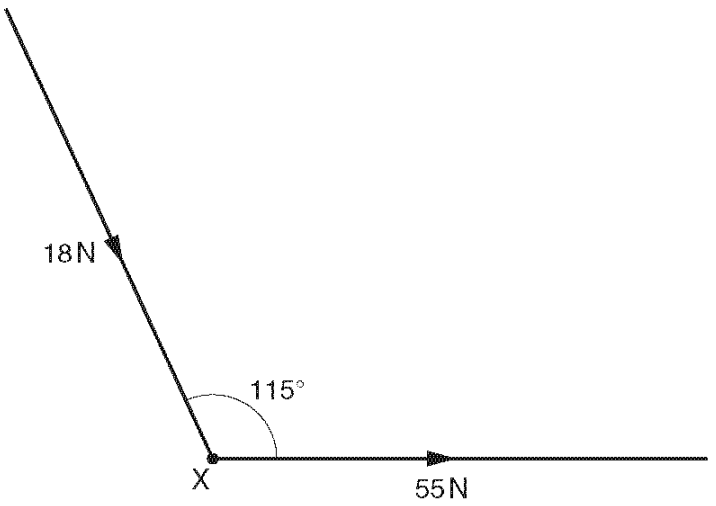
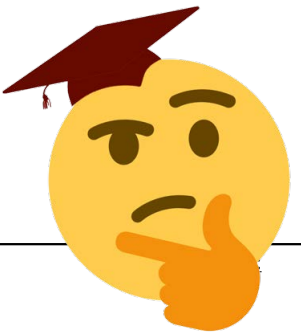


Fig. 1.1 (not to scale)

A force of 55 N is applied to the right. A force of 18 N is applied at an angle of 115° to the direction of the 55 N force.



(i) Use the resolution of forces or a scale diagram to show that the magnitude of the resultant force acting on X is 65 N.

[2]

(ii) Determine the angle between the resultant force and the 55 N force.

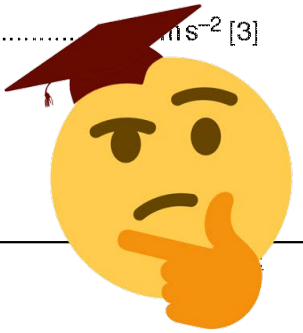
angle = ... ° [2]

(c) A third force of 80 N is now applied to X in the opposite direction to the resultant force in **(b)**.

The mass of X is 2.7 kg.

Calculate the magnitude of the acceleration of X.

acceleration = ... m s^{-2} [3]



4 – (9702/21_Winter_2017_Q1) – *Physical Quantities & Units, Kinematics, Dynamics*

(a) The drag force F_D acting on a sphere moving through a fluid is given by the expression

$$F_D = K\rho v^2$$

where K is a constant,
ρ is the density of the fluid
and v is the speed of the sphere.

Determine the SI base units of K.

base units .....[3]

(b) A ball of weight 1.5 N falls vertically from rest in air. The drag force F_D acting on the ball is given by the expression in **(a)**. The ball reaches a constant (terminal) speed of $33\,m\,s^{-1}$.

Assume that the upthrust acting on the ball is negligible and that the density of the air is uniform.

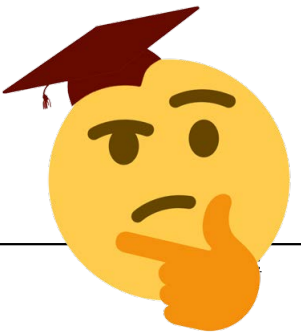
For the instant when the ball is travelling at a speed of $25\,m\,s^{-1}$, determine

(i) the drag force F_D on the ball,

F_D = ... N [2]

(ii) the acceleration of the ball.

acceleration = ... $m\,s^{-2}$ [2]



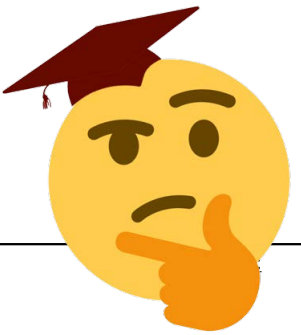
(c) Describe the acceleration of the ball in **(b)** as its speed changes from zero to $33\,m\,s^{-1}$.

.....

.....

.....

.....[3]



5 – (9702/23_Winter_2017_Q1) – *Physical Quantities & Units*

(a) **(i)** Define *power*.

.....

.....[1]

(ii) Show that the SI base units of power are $kg\,m^2s^{-3}$.

[1]

(b) All bodies radiate energy. The power P radiated by a body is given by

$$P = kAT^4$$

where T is the thermodynamic temperature of the body,
A is the surface area of the body
and k is a constant.

(i) Determine the SI base units of k.

base units .....[2]

(ii) On Fig. 1.1, sketch the variation with T^2 of P. The quantity A remains constant.

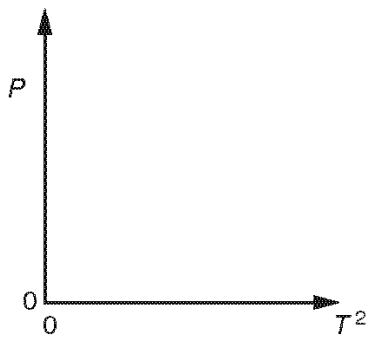
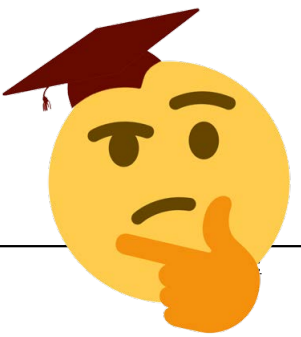


Fig. 1.1

[1]



6 – (9702/21_Summer_2018_Q1) – *Physical Quantities & Units, Kinematics*

(a) State what is meant by a *scalar* quantity and by a *vector* quantity.

scalar: .....

.....

vector: .....

.....

[2]

(b) Complete Fig. 1.1 to indicate whether each of the quantities is a vector or a scalar.

quantity	vector or scalar
power	
temperature	
momentum	

Fig. 1.1

[2]

(c) An aircraft is travelling in wind. Fig. 1.2 shows the velocities for the aircraft in still air and for the wind.

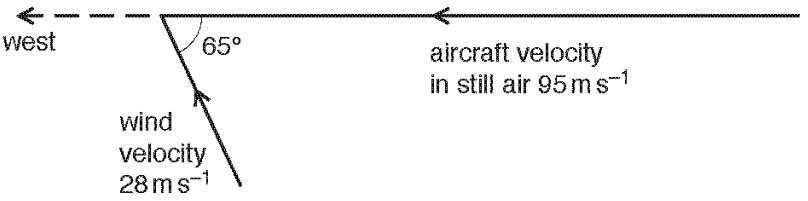
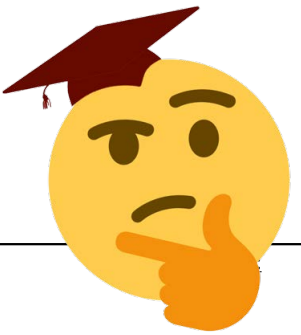


Fig. 1.2

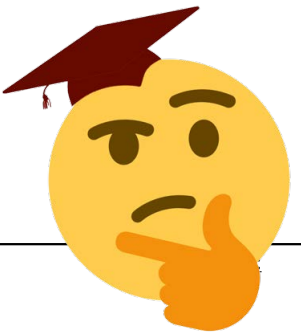
The velocity of the aircraft in still air is $95\,m\,s^{-1}$ to the west.
The velocity of the wind is $28\,m\,s^{-1}$ from 65° south of east.

(i) On Fig. 1.2, draw an arrow, labelled R, in the direction of the resultant velocity of the aircraft. [1]



(ii) Determine the magnitude of the resultant velocity of the aircraft.

magnitude of velocity = ... $m\,s^{-1}$ [2]



7 – (9702/22_Summer_2018_Q1) – *Physical Quantities & Units*

(a) Define *force*.

.....[1]

(b) State the SI base units of force.

.....[1]

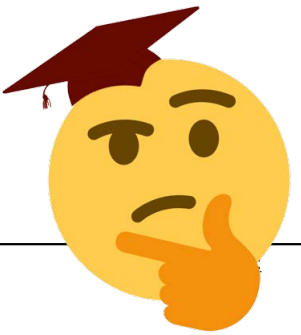
(c) The force F between two point charges is given by

$$F = \frac{Q_1 Q_2}{4\pi r^2 \varepsilon}$$

where Q_1 and Q_2 are the charges,
r is the distance between the charges,
ε is a constant that depends on the medium between the charges.

Use the above expression to determine the base units of ε.

base units .....[2]



8 – (9702/23_Winter_2018_Q1) – *Physical Quantities & Units, Forces, Density & Pressure, Deformation Of Solids*

(a) Mass, length and time are all SI base quantities.

State two other SI base quantities.

1. .....

2. .....

[2]

(b) A wire hangs between two fixed points, as shown in Fig. 1.1.

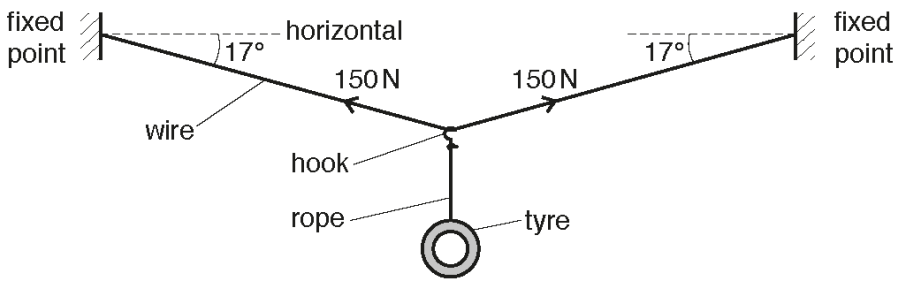


Fig. 1.1 (not to scale)

A child's swing is made by connecting a car tyre to the wire using a rope and a hook. The system is in equilibrium with the wire hanging at an angle of 17° to the horizontal. The tension in the wire is 150 N. Assume that the rope and hook have negligible weight.

(i) Determine the weight of the tyre.

weight = ... N [2]

(ii) The wire has a cross-sectional area of $7.5\,mm^2$ and is made of metal of Young modulus 2.1×10^{11} Pa. The wire obeys Hooke's law.

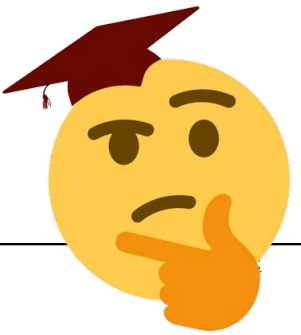
Calculate, for the wire,

1. the stress,

stress = ... Pa [2]

2. the strain.

strain = ... [2]



9 – (9702/22_Winter_2018_Q2) – *Physical Quantities & Units, Forces, Density & Pressure*

(a) The kilogram, metre and second are all SI base units.

State two other SI base units.

1. .....

2. .....
[2]

(b) A uniform beam AB of length 6.0 m is placed on a horizontal surface and then tilted at an angle of 31° to the horizontal, as shown in Fig. 2.1.

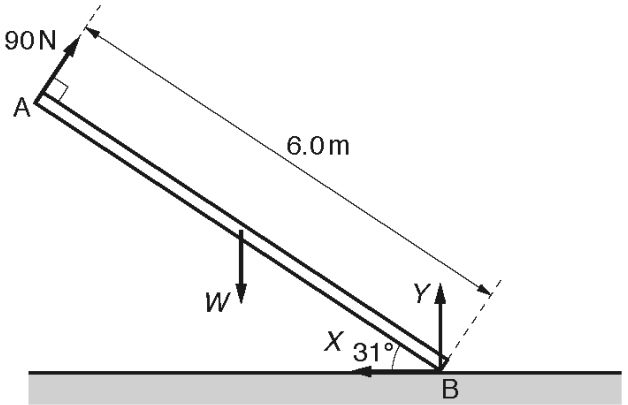


Fig. 2.1 (not to scale)

The beam is held in equilibrium by four forces that all act in the same plane. A force of 90 N acts perpendicular to the beam at end A. The weight *W* of the beam acts at its centre of gravity. A vertical force *Y* and a horizontal force *X* both act at end B of the beam.

(i) State the name of force *X*.

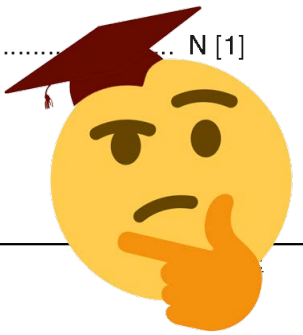
.....[1]

(ii) By taking moments about end B, calculate the weight *W* of the beam.

W = ... N [2]

(iii) Determine the magnitude of force *X*.

magnitude of force *X* = ... N [1]



10 – (9702/21_Summer_2019_Q1) – *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a) Define *velocity*.

.....

.....[1]

(b) The speed v of a sound wave through a gas of pressure P and density ρ is given by the equation

$$v = \sqrt{\frac{kP}{\rho}}$$

where k is a constant that has no units.

An experiment is performed to determine the value of k. The data from the experiment are shown in Fig. 1.1.

quantity	value	uncertainty
v	$3.3 \times 10^2\,\mathrm{m\,s^{-1}}$	± 3%
P	$9.9 \times 10^4\,\mathrm{Pa}$	± 2%
ρ	$1.29\,\mathrm{kg\,m^{-3}}$	± 4%

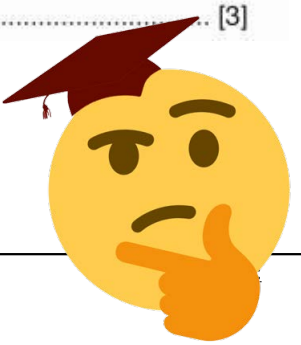
Fig. 1.1

(i) Use data from Fig. 1.1 to calculate k.

k = ... [2]

(ii) Use your answer in **(b)(i)** and data from Fig. 1.1 to determine the value of k, with its absolute uncertainty, to an appropriate number of significant figures.

k = ... ± ..... [3]



11 - (9702/23_Summer_2019_Q1) - *Current Of Electricity, Physical Quantities & Units*

(a) **(i)** Define *resistance*.

.....

.....[1]

(ii) A potential difference of 0.60 V is applied across a resistor of resistance 4.0 GΩ.

Calculate the current, in pA, in the resistor.

current = ... pA [2]

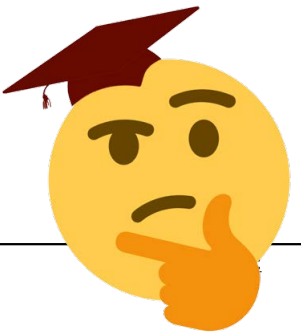
(b) The energy E transferred when charge Q moves through an electrical component is given by the equation

$$E = QV$$

where V is the potential difference across the component.

Use the equation to determine the SI base units of potential difference.

SI base units ..... [3]



12 – (9702/21_Winter_2019_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) Make estimates of:

(i) the mass, in g, of a new pencil

mass = ... g [1]

(ii) the wavelength of ultraviolet radiation.

wavelength = ... m [1]

(b) The period T of the oscillations of a mass m suspended from a spring is given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where k is the spring constant of the spring.

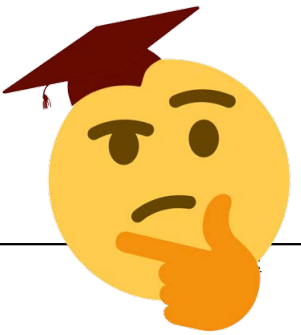
The manufacturer of a spring states that it has a spring constant of $25\,\mathrm{N\,m^{-1}} \pm 8\%$. A mass of $200 \times 10^{-3}\,\mathrm{kg} \pm 4 \times 10^{-3}\,\mathrm{kg}$ is suspended from the end of the spring and then made to oscillate.

(i) Calculate the period T of the oscillations.

T = ... s [1]

(ii) Determine the value of T, with its absolute uncertainty, to an appropriate number of significant figures.

T = ... ± ..... s [3]



13 – (9702/22_Winter_2019_Q1) – *Physical Quantities & Units*

(a) Distinguish between vector and scalar quantities.

.....

.....

..... [2]

(b) The electric field strength E at a distance x from an isolated point charge Q is given by the equation

$$E = \frac{Q}{x^2 b}$$

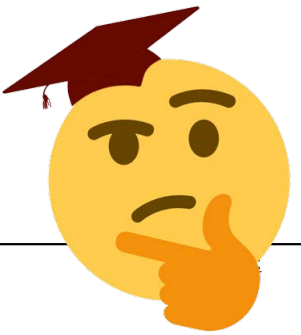
where b is a constant.

(i) Use the definition of electric field strength to show that E has SI base units of $kg\,m\,A^{-1}\,s^{-3}$.

[2]

(ii) Use the units for E given in **(b)(i)** to determine the SI base units of b.

SI base units of b ..... [2]



14 – (9702/21_Summer_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) Use an expression for work done, in terms of force, to show that the SI base units of energy are $kg\,m^2\,s^{-2}$.

[2]

(b) **(i)** The energy E stored in an electrical component is given by

$$E = \frac{Q^2}{2C}$$

where Q is charge and C is a constant.

Use this equation and the information in **(a)** to determine the SI base units of C.

SI base units ..... [2]

(ii) Measurements of a constant current in a wire are taken using an analogue ammeter.

For these measurements, describe one possible cause of:

1. a random error

.....

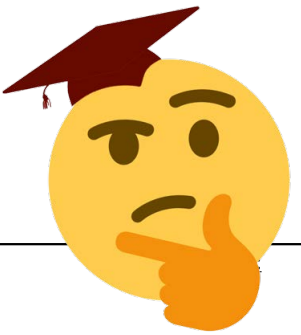
.....

2. a systematic error.

.....

.....

[2]



15 - (9702/22_Summer_2020_Q1) - *Physical Quantities & Units*

(a) Define *velocity*.

.....

..... [1]

(b) The drag force F_D acting on a car moving with speed v along a straight horizontal road is given by

$$F_D = v^2Ak$$

where k is a constant and A is the cross-sectional area of the car.

Determine the SI base units of k.

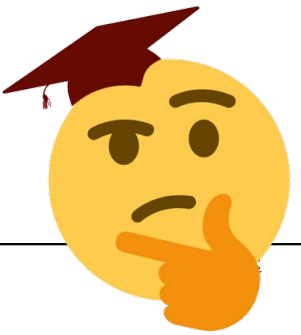
SI base units ..... [2]

(c) The value of k, in SI base units, for the car in **(b)** is 0.24. The cross-sectional area A of the car is $5.1\,m^2$.

The car is travelling with a constant speed along a straight road and the output power of the engine is 4.8×10^4 W. Assume that the output power of the engine is equal to the rate at which the drag force F_D is doing work against the car.

Determine the speed of the car.

speed = ... $m\,s^{-1}$ [3]



16 – (9702/23_Summer_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) State **one** similarity and **one** difference between *distance* and *displacement*.

similarity: .....

.....

difference: .....

.....

[2]

(b) A student takes several measurements of the same quantity. This set of measurements has high precision, but low accuracy.

Describe what is meant by:

(i) *high precision*

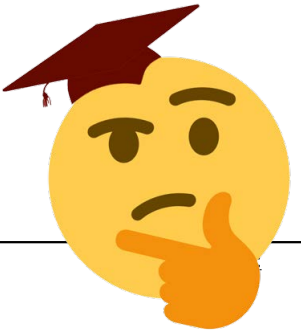
.....

..... [1]

(ii) *low accuracy*.

.....

..... [1]



17 – (9702/23_Winter_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) An electromagnetic wave has a wavelength of 85 μm.

(i) State the wavelength, in m, of the wave.

wavelength = ... m [1]

(ii) Calculate the frequency, in THz, of the wave.

frequency = ... THz [2]

(iii) State the name of the region of the electromagnetic spectrum that contains this wave.

..... [1]

(b) The current I in a coil of wire produces a magnetic field. The energy E stored in the magnetic field is given by

$$E = \frac{I^2 L}{2}$$

where L is a constant.

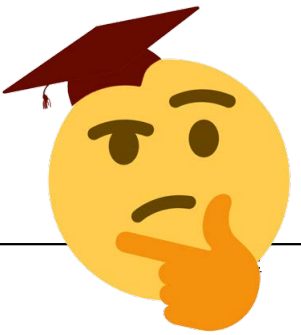
The manufacturer of the coil states that the value of L, in SI base units, is $7.5 \times 10^{-6} \pm 5\%$. The current I in the coil is measured as (0.50 ± 0.02) A.

The values of L and I are used to calculate E.

Determine the percentage uncertainty in the value of E.

percentage uncertainty = ... % [2]

[Total: 6]



18 – (9702/22_Summer_2021_Q1) – *Physical Quantities & Units, Forces, Density & Pressure*

(a) Complete Table 1.1 by stating whether each of the quantities is a vector or a scalar.

Table 1.1

quantity	vector or scalar
acceleration	
electrical resistance	
momentum	

[2]

(b) State the conditions for an object to be in equilibrium.

.....

.....

.....

..... [2]

(c) A floating solid cylinder is attached by a wire to the sea bed, as shown in Fig. 1.1.

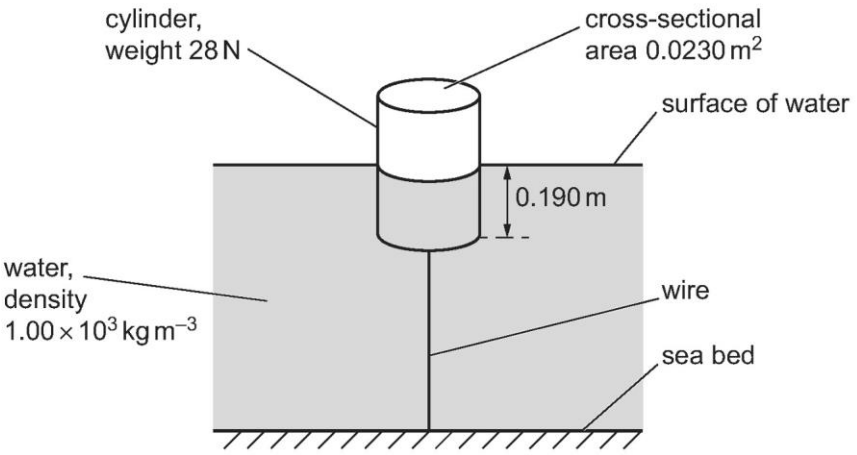
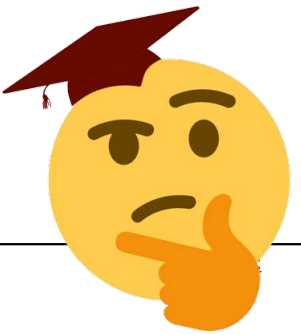


Fig. 1.1 (not to scale)

The density of the water is $1.00 \times 10^3\,kg\,m^{-3}$. The base of the cylinder is at a depth of 0.190 m below the surface of the water. The cylinder has a weight of 28 N and a cross-sectional area of $0.0230\,m^2$.

The wire and the central axis of the cylinder are both vertical. The cylinder is in equilibrium.



(i) Calculate, to three significant figures, the upthrust acting on the cylinder due to the water.

upthrust = ... N [2]

(ii) Show that the tension T in the wire is 15 N.

[1]

(iii) The wire has a cross-sectional area of $3.2\,mm^2$.

Calculate the stress in the wire.

stress = ... Pa [2]

(iv) The surface of the water gradually rises until it is level with the top face of the cylinder.

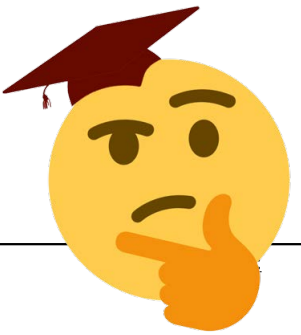
State and explain, qualitatively, the variation of the strain energy stored in the wire as the water surface rises.

.....

.....

.....

..... [2]



19 – (9702/23_Summer_2021_Q1) – *Physical Quantities & Units*

(a) A property of a vector quantity, that is not a property of a scalar quantity, is direction. For example, velocity has direction but speed does not.

(i) State **two** other scalar quantities and **two** other vector quantities.

scalar quantities: ..... and .....

vector quantities: ..... and .....
[2]

(ii) State **two** properties that are possessed by both scalar and vector physical quantities.

1. .....

2. .....
[2]

(b) A ship at sea is travelling with a velocity of $13\,m\,s^{-1}$ in a direction 35° east of north in still water, as shown in Fig. 1.1.

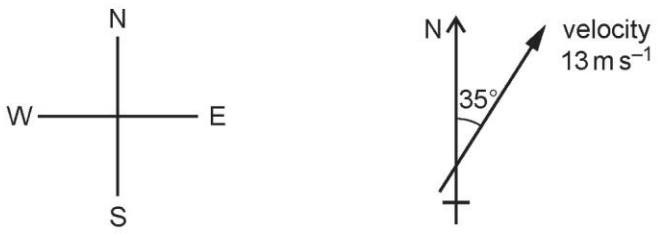
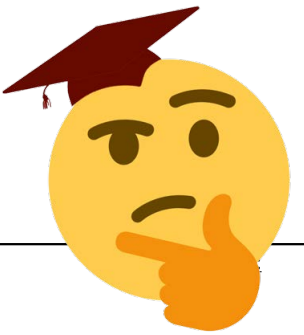


Fig. 1.1

(i) Determine the magnitudes of the components of the velocity of the ship in the north and the east directions.

north component of velocity = ... $m\,s^{-1}$

east component of velocity = ... $m\,s^{-1}$
[2]



(ii) The ship now experiences a tidal current. The water in the sea moves with a velocity of $2.7\,m\,s^{-1}$ to the west.

Calculate the resultant velocity component of the ship in the east direction.

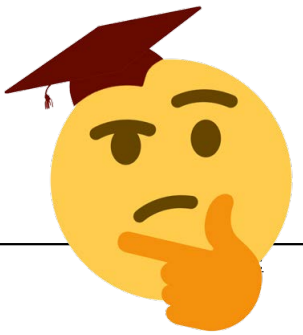
resultant east component of velocity = ... $m\,s^{-1}$ [1]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to determine the magnitude of the resultant velocity of the ship.

magnitude of resultant velocity = ... $m\,s^{-1}$ [2]

(iv) Use your answers in **(b)(i)** and **(b)(ii)** to determine the angle between north and the resultant velocity of the ship.

angle = ...° [2]



20 – (9702/22_Winter_2021_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) A unit may be stated with a prefix that represents a power-of-ten multiple or submultiple.

Complete Table 1.1 to show the name and symbol of each prefix and the corresponding power-of-ten multiple or submultiple.

Table 1.1

prefix	power-of-ten multiple or submultiple
kilo (k)	10^3
tera (T)	
( )	10^{-12}

[2]

(b) In the following list, underline all the units that are SI base units.

ampere coulomb metre newton [1]

(c) The potential difference V between the two ends of a uniform metal wire is given by

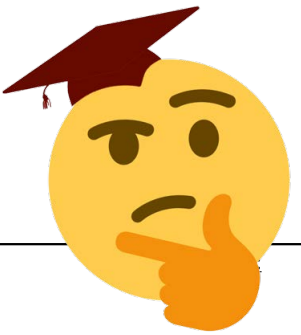
$$V = \frac{4\rho L I}{\pi d^2}$$

where d is the diameter of the wire,
I is the current in the wire,
L is the length of the wire,
and ρ is the resistivity of the metal.

For a particular wire, the percentage uncertainties in the values of some of the above quantities are listed in Table 1.2.

Table 1.2

quantity	percentage uncertainty
d	±3.0%
I	±2.0%
L	±2.5%
V	±3.5%



The quantities listed in Table 1.2 have values that are used to calculate ρ as $4.1 \times 10^{-7}\,\Omega\,\text{m}$.

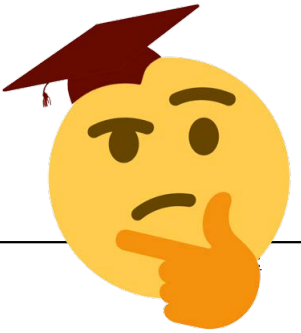
For this value of ρ, calculate:

(i) the percentage uncertainty

percentage uncertainty = ...% [2]

(ii) the absolute uncertainty.

absolute uncertainty = ... $\Omega\,\text{m}$ [1]



21 – (9702/22_Summer_2022_Q1) – *Physical Quantities & Units*

(a) In the following list, underline all units that are SI base units.

ampere degree Celsius kilogram newton [1]

(b) Fig. 1.1 shows a horizontal beam clamped at one end with a block attached to the other end.

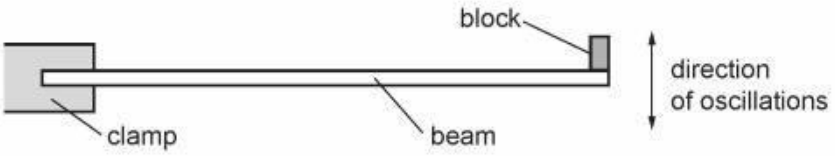


Fig. 1.1

The block is made to oscillate vertically.

The Young modulus E of the material of the beam is given by

$$E = \frac{kM}{T^2}$$

where M is the mass of the block,
T is the period of the oscillations
and k is a constant.

A student determines the values and percentage uncertainties of k, M and T.
Table 1.1 lists the percentage uncertainties.

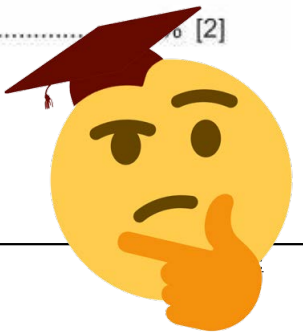
Table 1.1

quantity	percentage uncertainty
k	±2.1%
M	±0.6%
T	±1.5%

The student uses the values of k, M and T to calculate the value of E as 8.245×10^9 Pa.

(i) Calculate the percentage uncertainty in the value of E.

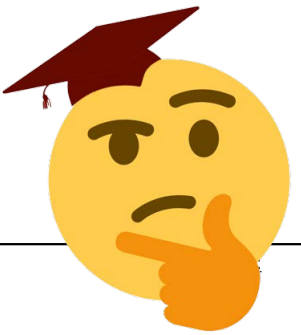
percentage uncertainty = ... % [2]



(ii) Use your answer in **(b)(i)** to determine the value of E, with its absolute uncertainty, to an appropriate number of significant figures.

E = (..... ± .....) × 10^9 Pa [2]

[Total: 5]



22 – (9702/23_Summer_2022_Q1) – *Physical Quantities & Units*

A solid metal sphere has a diameter of (3.42 ± 0.02) cm and a mass of (67 ± 2) g.

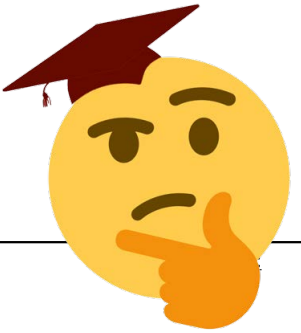
(a) Calculate the density, in $g\,cm^{-3}$, of the metal.

density = ... $g\,cm^{-3}$ [3]

(b) Determine the percentage uncertainty in the density.

percentage uncertainty = ...% [2]

[Total: 5]



23 – (9702/21_Winter_2022_Q1) – *Physical Quantities & Units*

(a) The boxes in Fig. 1.1 contain terms on the left-hand side and examples of these terms on the right-hand side.

Draw a line between each term on the left and the correct example on the right.

base quantity	coulomb
base unit	electric current
derived quantity	force
derived unit	kilogram

Fig. 1.1

[2]

(b) A set of experimental measurements is described as precise and not accurate.

State what is meant by:

(i) precise

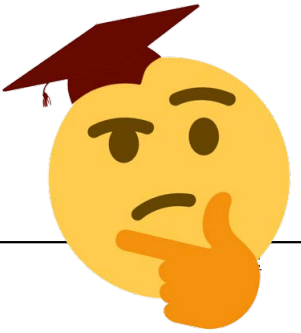
.....

..... [1]

(ii) not accurate.

.....

..... [1]



(c) An object of mass m travels with speed v in a circle of radius r. The force F acting on the object is given by

$$F = \frac{mv^2}{r}.$$

The percentage uncertainties of three of the quantities are given in Table 1.1.

Table 1.1

quantity	percentage uncertainty
F	±3%
m	±4%
r	±5%

The value of v is determined from F, m and r.

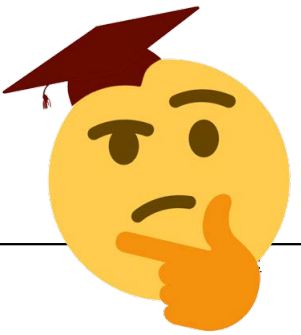
(i) Calculate the percentage uncertainty in v.

percentage uncertainty = ... % [2]

(ii) The value of v is $15.0\,\mathrm{m\,s^{-1}}$.

Calculate the absolute uncertainty in v.

absolute uncertainty = ... $\mathrm{m\,s^{-1}}$ [1]



24 – (9702/21_Summer_2023_Q1) – *Physical Quantities & Units*

(a) **(i)** Define power.

.....

..... [1]

(ii) Use the definition of power to show that the SI base units of power are $kg\,m^2s^{-3}$.

[1]

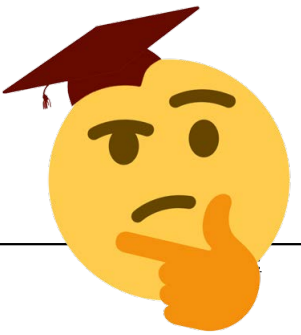
(b) The intensity I of a sound wave moving through a gas is given by

$$I = f^2A^2vk$$

where f is the frequency of the wave,
A is the amplitude of the wave,
v is the speed of the wave
and k is a constant that depends on the gas.

Determine the SI base units of k.

SI base units ..... [3]



25 - (9702/22_Summer_2023_Q1) - *Physical Quantities & Units*

(a) **(i)** Define pressure.

.....

..... [1]

(ii) Use the answer to **(a)(i)** to show that the SI base units of pressure are $kg\,m^{-1}\,s^{-2}$.

[1]

(b) A horizontal pipe has length L and a circular cross-section of radius R. A liquid of density ρ flows through the pipe. The mass m of liquid flowing through the pipe in time t is given by

$$m = \frac{\pi(p_2 - p_1)R^4\rho t}{8kL}$$

where p_1 and p_2 are the pressures at the ends of the pipe and k is a constant.

Determine the SI base units of k.

SI base units ..... [3]

(c) An experiment is performed to determine the value of k by measuring the values of the other quantities in the equation in **(b)**.

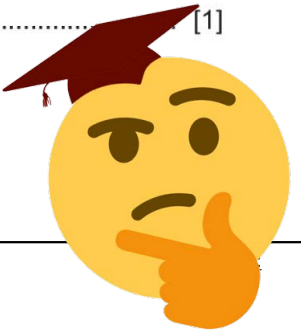
The values of L and R each have a percentage uncertainty of 2%.

State and explain, quantitatively, which of these two quantities contributes more to the percentage uncertainty in the calculated value of k.

.....

.....

..... [1]



26 – (9702/23_Summer_2023_Q1) – *Physical Quantities & Units, Kinematics*

A well has a depth of 36 m from ground level to the surface of the water in the well, as shown in Fig. 1.1.

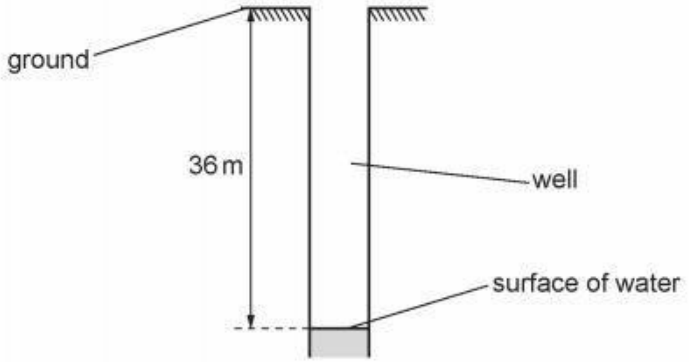


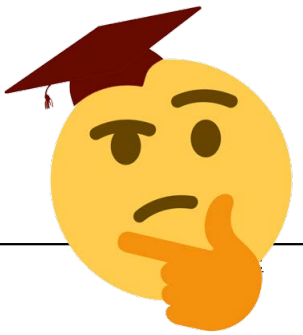
Fig. 1.1 (not to scale)

A student wishes to find the depth of the well. The student plans to drop a stone down the well and record the time taken from releasing the stone to hearing the splash made by the stone as it enters the water.

(a) Assume that air resistance is negligible and that the stone is released from rest.

Calculate the time taken for the stone to fall from ground level to the surface of the water.

time = ... s [2]



(b) The time recorded by the student using a stop-watch is not equal to the time in **(a)**.

Suggest **three** possible reasons, other than the effect of air resistance, for this difference.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

(c) The student repeats the experiment three times and uses the results to calculate the depth of the well. The values are shown in Table 1.1.

Table 1.1

	1st experiment	2nd experiment	3rd experiment
depth/m	54.4	53.9	54.1

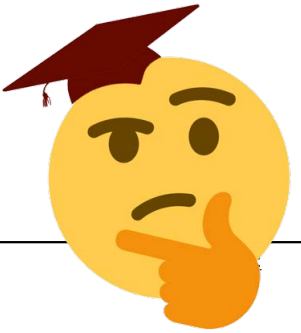
The true depth of the well is 36.0 m. Explain why these results may be described as precise but not accurate.

.....

.....

.....

..... [2]



27 – (9702/21_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) Compare scalar and vector quantities.

.....

.....

..... [2]

(b) The radius of a small sphere is determined from a measurement of the volume of the sphere. The sphere is submerged in water, displacing some of the water into a measuring cylinder as shown in Fig. 1.1.

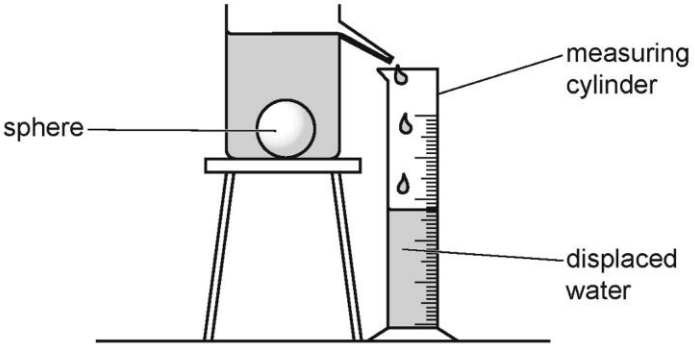


Fig. 1.1 (not to scale)

The measured volume of displaced water is $(28.0 \pm 0.5)\,cm^3$.

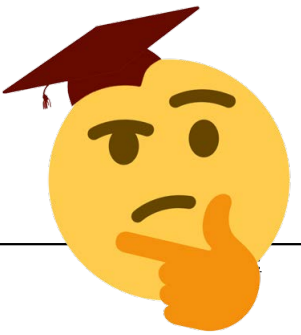
Calculate:

(i) the radius, in cm, of the sphere

radius = ... cm [1]

(ii) the percentage uncertainty in the radius of the sphere.

percentage uncertainty = ... % [2]



28 – (9702/22_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a) In the following list, underline **all** quantities that are SI base quantities.

charge electric current force time [1]

(b) Under certain conditions, the distance s moved in a straight line by an object in time t is given by

$$s = \frac{1}{2}at^2$$

where a is the acceleration of the object.

State **two** conditions under which the above expression applies to the motion of the object.

1 .....

2 .....
[2]

(c) The variation with time t of the velocity v of a car that is moving in a straight line is shown in Fig. 1.1.

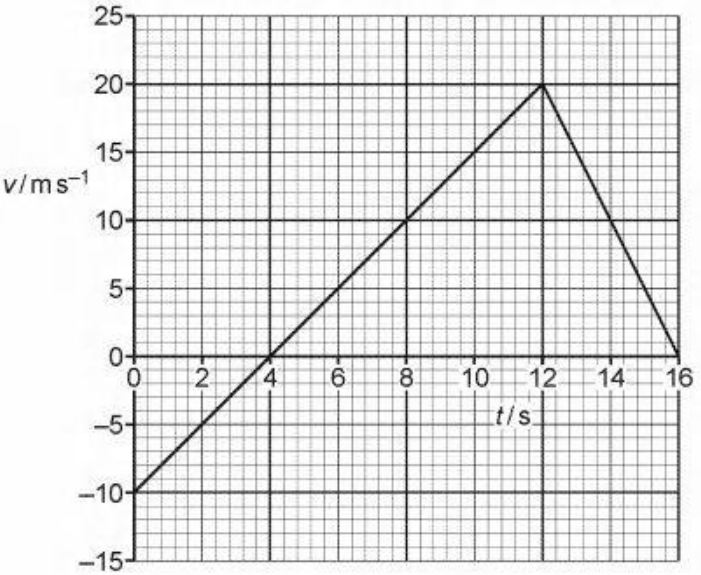


Fig. 1.1

(i) Compare, qualitatively, the acceleration of the car at time t = 8.0 s and at time t = 14.0 s in terms of:

- magnitude

.....

.....

- direction.

.....

.....
[2]

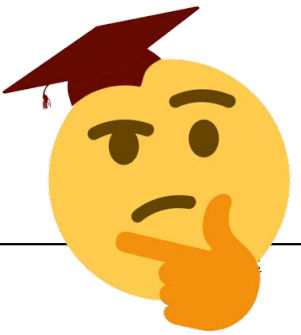
(ii) Determine the magnitude of the acceleration of the car at time t = 4.0 s.

acceleration = ... $m\,s^{-2}$ [2]

(iii) The car is at point X at time t = 0.

Determine the magnitude of the displacement of the car from X at time t = 12.0 s.

displacement = ... m [2]



29 – (9702/23_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) Table 1.1 lists some physical quantities. Complete the table by placing a tick (✓) next to the scalar quantities.

Table 1.1

acceleration	
charge	
momentum	
power	
upthrust	

[1]

(b) A uniform cylinder has diameter D, length L and mass M.
The density ρ of the cylinder is given by

$$\rho = \frac{4M}{\pi D^2 L}.$$

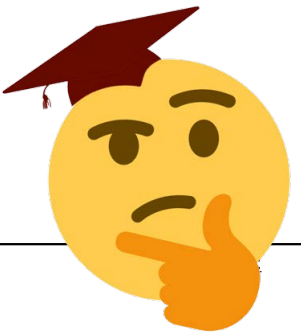
Table 1.2 shows the data obtained from an experiment to determine the density of the cylinder.

Table 1.2

quantity	measurement	percentage uncertainty
D	(26.2 ± 0.1) mm	.....%
L	(162 ± 1) mm	.....%
M	(247 ± 1) g	0.4%

(i) Calculate the percentage uncertainties in D and L. Write your answers in Table 1.2.

[1]

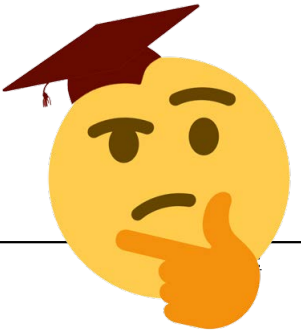


(ii) Calculate the density of the cylinder. Give your answer to three significant figures.

density = ... $kg\,m^{-3}$ [2]

(iii) Calculate the percentage uncertainty in the density.

percentage uncertainty = ... % [2]



1 – (9702/21_Summer_2017_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) Determine the SI base units of stress.
Show your working.

base units .....[2]

(b) A beam PQ is clamped so that the beam is horizontal. A mass M of 500 g is hung from end Q and the beam bends slightly, as illustrated in Fig. 1.1.

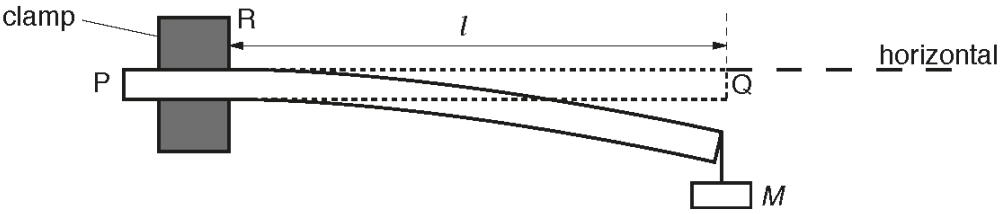


Fig. 1.1

The length l of the beam from the edge of the clamp R to end Q is 60.0 cm. The width b of the beam is 30.0 mm and the thickness d of the beam is 5.00 mm. The material of the beam has Young modulus E.

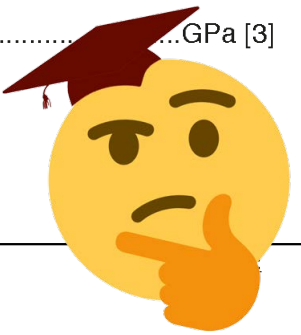
The mass M is made to oscillate vertically. The time period T of the oscillations is 0.58 s.

The period T is given by the expression

$$T = 2\pi\sqrt{\frac{4Ml^3}{Ebd^3}}.$$

(i) Determine E in GPa.

E = ...GPa [3]



(ii) The quantities used to determine E should be measured with accuracy and with precision.

1. Explain the difference between accuracy and precision.

accuracy: .....

.....

precision: .....

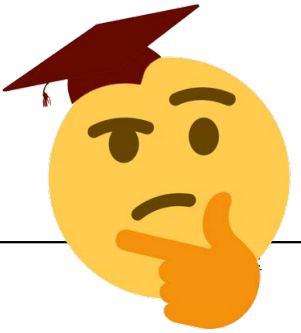
.....
[2]

2. In a particular experiment, the quantities l and T are measured with the same percentage uncertainty. State and explain which of these two quantities contributes more to the uncertainty in the value of E.

.....

.....

.....[1]



2 – (9702/22_Summer_2017_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) State two SI base units other than kilogram, metre and second.

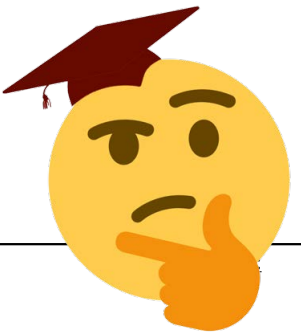
1. .....

2. .....

[1]

(b) Determine the SI base units of resistivity.

base units .....[3]



(c) **(i)** A wire of cross-sectional area $1.5\,mm^2$ and length $2.5\,m$ has a resistance of $0.030\,\Omega$. Calculate the resistivity of the material of the wire in $n\Omega\,m$.

resistivity = ...$n\Omega\,m$ [3]

(ii) **1.** State what is meant by *precision*.

.....

.....

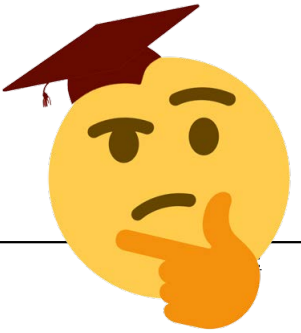
2. Explain why the precision in the value of the resistivity is improved by using a micrometer screw gauge rather than a metre rule to measure the diameter of the wire.

.....

.....

.....

[2]



3 – (9702/22_Winter_2017_Q1) – *Measurement Techniques*

One end of a wire is connected to a fixed point. A load is attached to the other end so that the wire hangs vertically.

The diameter d of the wire and the load F are measured as

$d = 0.40 \pm 0.02\,\text{mm}$,
$F = 25.0 \pm 0.5\,\text{N}$.

(a) For the measurement of the diameter of the wire, state

(i) the name of a suitable measuring instrument,

.....[1]

(ii) how random errors may be reduced when using the instrument in **(i)**.

.....

.....

.....[2]

(b) The stress σ in the wire is calculated by using the expression

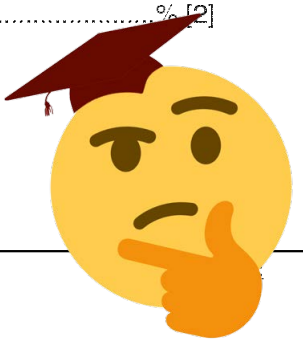
$$\sigma = \frac{4F}{\pi d^2}.$$

(i) Show that the value of σ is $1.99 \times 10^8\,\text{N m}^{-2}$.

[1]

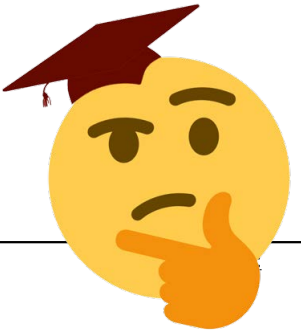
(ii) Determine the percentage uncertainty in σ.

percentage uncertainty = ...% [2]



(iii) Use the information in **(b)(i)** and your answer in **(b)(ii)** to determine the value of σ, with its absolute uncertainty, to an appropriate number of significant figures.

σ = ... ± ..... N m^{-2} [2]



4 – (9702/23_Summer_2018_Q1) – *Measurement Techniques*

(a) An analogue voltmeter is used to take measurements of a constant potential difference across a resistor.

For these measurements, describe **one** example of

(i) a systematic error,

.....

.....[1]

(ii) a random error.

.....

.....[1]

(b) The potential difference across a resistor is measured as 5.0 V ± 0.1 V. The resistor is labelled as having a resistance of 125 Ω ± 3%.

(i) Calculate the power dissipated by the resistor.

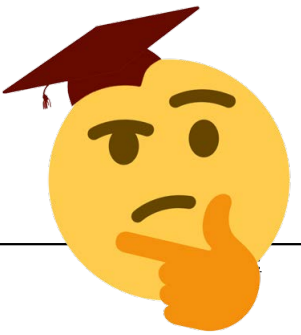
power = ... W [2]

(ii) Calculate the percentage uncertainty in the calculated power.

percentage uncertainty = ... % [2]

(iii) Determine the value of the power, with its absolute uncertainty, to an appropriate number of significant figures.

power = ... ± ..... W [2]



5 – (9702/21_Summer_2019_Q1) – *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a) Define *velocity*.

.....

.....[1]

(b) The speed v of a sound wave through a gas of pressure P and density ρ is given by the equation

$$v = \sqrt{\frac{kP}{\rho}}$$

where k is a constant that has no units.

An experiment is performed to determine the value of k. The data from the experiment are shown in Fig. 1.1.

quantity	value	uncertainty
v	$3.3 \times 10^2\,\mathrm{m\,s^{-1}}$	± 3%
P	$9.9 \times 10^4\,\mathrm{Pa}$	± 2%
ρ	$1.29\,\mathrm{kg\,m^{-3}}$	± 4%

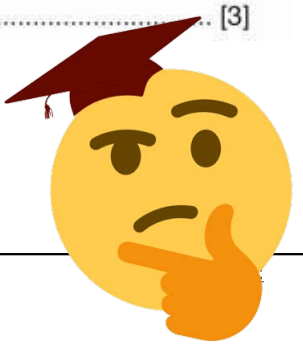
Fig. 1.1

(i) Use data from Fig. 1.1 to calculate k.

k = ... [2]

(ii) Use your answer in **(b)(i)** and data from Fig. 1.1 to determine the value of k, with its absolute uncertainty, to an appropriate number of significant figures.

k = ... ± ..... [3]



6 – (9702/22_Summer_2019_Q1) – *Measurement Techniques*

(a) The diameter d of a cylinder is measured as 0.0125 m ± 1.6%.

Calculate the absolute uncertainty in this measurement.

absolute uncertainty = ... m [1]

(b) The cylinder in **(a)** stands on a horizontal surface. The pressure p exerted on the surface by the cylinder is given by

$$p = \frac{4W}{\pi d^2}.$$

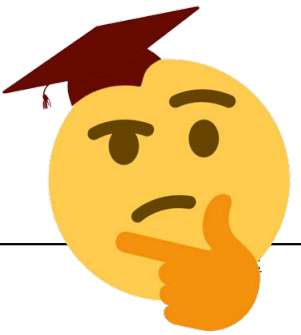
The measured weight W of the cylinder is 0.38 N ± 2.8%.

(i) Calculate the pressure p.

p = ... $N\,m^{-2}$ [1]

(ii) Determine the absolute uncertainty in the value of p.

absolute uncertainty = ... $N\,m^{-2}$ [2]



7 – (9702/21_Winter_2019_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) Make estimates of:

(i) the mass, in g, of a new pencil

mass = ... g [1]

(ii) the wavelength of ultraviolet radiation.

wavelength = ... m [1]

(b) The period T of the oscillations of a mass m suspended from a spring is given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where k is the spring constant of the spring.

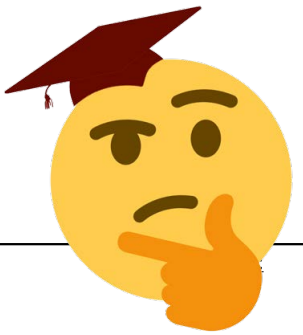
The manufacturer of a spring states that it has a spring constant of $25\,\mathrm{N\,m^{-1}} \pm 8\%$. A mass of $200 \times 10^{-3}\,\mathrm{kg} \pm 4 \times 10^{-3}\,\mathrm{kg}$ is suspended from the end of the spring and then made to oscillate.

(i) Calculate the period T of the oscillations.

T = ... s [1]

(ii) Determine the value of T, with its absolute uncertainty, to an appropriate number of significant figures.

T = ... ± ..... s [3]



8 – (9702/21_Summer_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) Use an expression for work done, in terms of force, to show that the SI base units of energy are $kg\,m^2\,s^{-2}$.

[2]

(b) **(i)** The energy E stored in an electrical component is given by

$$E = \frac{Q^2}{2C}$$

where Q is charge and C is a constant.

Use this equation and the information in **(a)** to determine the SI base units of C.

SI base units ..... [2]

(ii) Measurements of a constant current in a wire are taken using an analogue ammeter.

For these measurements, describe one possible cause of:

1. a random error

.....

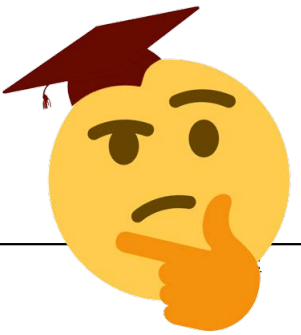
.....

2. a systematic error.

.....

.....

[2]



9 – (9702/23_Summer_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) State **one** similarity and **one** difference between *distance* and *displacement*.

similarity: .....

.....

difference: .....

.....

[2]

(b) A student takes several measurements of the same quantity. This set of measurements has high precision, but low accuracy.

Describe what is meant by:

(i) *high precision*

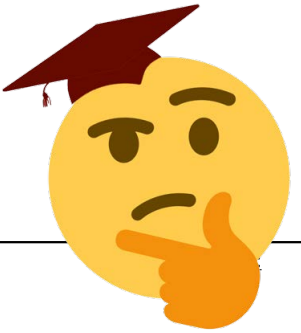
.....

..... [1]

(ii) *low accuracy*.

.....

..... [1]



10 – (9702/23_Winter_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) An electromagnetic wave has a wavelength of 85 μm.

(i) State the wavelength, in m, of the wave.

wavelength = ... m [1]

(ii) Calculate the frequency, in THz, of the wave.

frequency = ... THz [2]

(iii) State the name of the region of the electromagnetic spectrum that contains this wave.

..... [1]

(b) The current I in a coil of wire produces a magnetic field. The energy E stored in the magnetic field is given by

$$E = \frac{I^2 L}{2}$$

where L is a constant.

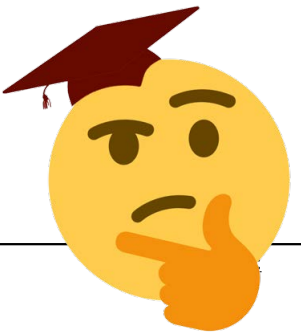
The manufacturer of the coil states that the value of L, in SI base units, is $7.5 \times 10^{-6} \pm 5\%$. The current I in the coil is measured as (0.50 ± 0.02) A.

The values of L and I are used to calculate E.

Determine the percentage uncertainty in the value of E.

percentage uncertainty = ... % [2]

[Total: 6]



11 – (9702/21_Summer_2021_Q1) – *Measurement Techniques, Forces, Density & Pressure*

(a) Define *density*.

.....

..... [1]

(b) Fig. 1.1 shows a solid pyramid with a square base.

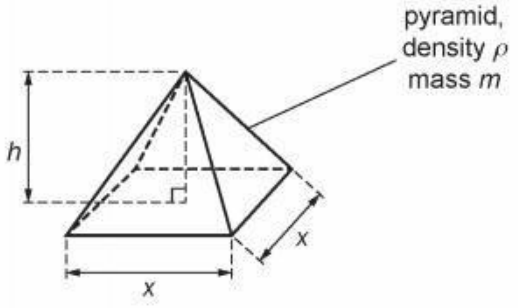


Fig. 1.1

The mass m of the pyramid is given by

$$m = \frac{1}{3}\rho h x^2$$

where ρ is the density of the material of the pyramid,
h is the height, and
x is the length of each side of the base.

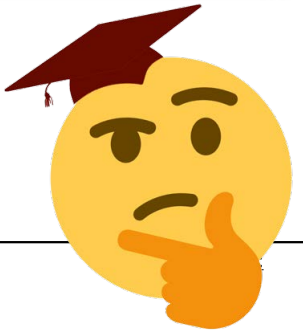
Measurements are taken as shown in Table 1.1.

Table 1.1

quantity	measurement	percentage uncertainty
m	19.5 g	±2%
x	4.0 cm	±5%
h	4.8 cm	±4%

(i) Calculate the absolute uncertainty in length x.

absolute uncertainty = ... cm [1]



(ii) The density ρ is calculated from the measurements in Table 1.1.

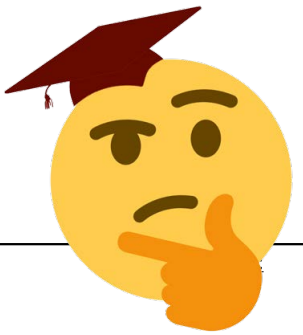
Determine the percentage uncertainty in the calculated value of ρ.

percentage uncertainty = ... % [2]

(c) The square base of the pyramid in **(b)** rests on the horizontal surface of a bench.

Use data from Table 1.1 to calculate the average pressure of the pyramid on the surface of the bench. The uncertainty in your answer is not required.

pressure = ... Pa [3]



12 – (9702/21_Winter_2021_Q1) – *Measurement Techniques, Forces, Density & Pressure*

(a) Define *density*.

.....

..... [1]

(b) A smooth pebble, made from uniform rock, has the shape of an elongated sphere as shown in Fig. 1.1.

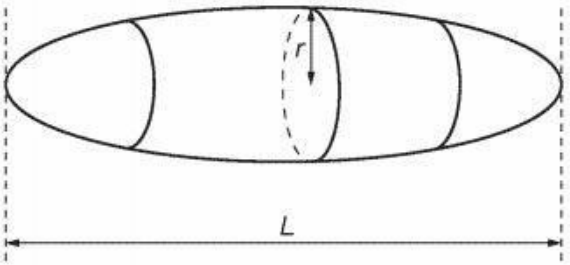


Fig. 1.1

The length of the pebble is L. The cross-section of the pebble, in the plane perpendicular to L, is circular with a maximum radius r.

A student investigating the density of the rock makes measurements to determine the values of L, r and the mass M of the pebble as follows:

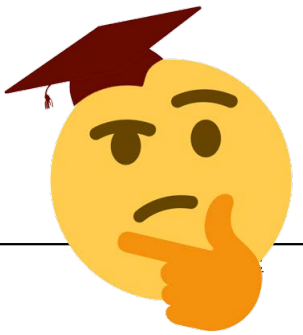
$$L = (0.1242 \pm 0.0001)\,\text{m}$$
$$r = (0.0420 \pm 0.0004)\,\text{m}$$
$$M = (1.072 \pm 0.001)\,\text{kg}.$$

(i) State the name of a measuring instrument suitable for making this measurement of L.

..... [1]

(ii) Determine the percentage uncertainty in the measurement of r.

percentage uncertainty = ... % [1]



(c) The density ρ of the rock from which the pebble in **(b)** is composed is given by

$$\rho = \frac{Mr^n}{kL}$$

where n is an integer and k is a constant, with no units, that is equal to 2.094.

(i) Use SI base units to show that n is equal to –2.

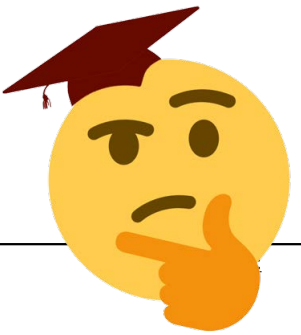
[2]

(ii) Calculate the percentage uncertainty in ρ.

percentage uncertainty = ... % [3]

(iii) Determine ρ with its absolute uncertainty. Give your values to the appropriate number of significant figures.

ρ = (..... ± .....) kg m^{-3} [3]



13 – (9702/22_Winter_2021_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) A unit may be stated with a prefix that represents a power-of-ten multiple or submultiple.

Complete Table 1.1 to show the name and symbol of each prefix and the corresponding power-of-ten multiple or submultiple.

Table 1.1

prefix	power-of-ten multiple or submultiple
kilo (k)	10^3
tera (T)	
( )	10^{-12}

[2]

(b) In the following list, underline all the units that are SI base units.

ampere coulomb metre newton [1]

(c) The potential difference V between the two ends of a uniform metal wire is given by

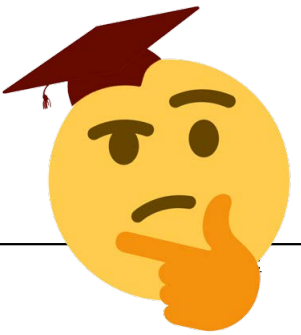
$$V = \frac{4\rho L I}{\pi d^2}$$

where d is the diameter of the wire,
I is the current in the wire,
L is the length of the wire,
and ρ is the resistivity of the metal.

For a particular wire, the percentage uncertainties in the values of some of the above quantities are listed in Table 1.2.

Table 1.2

quantity	percentage uncertainty
d	±3.0%
I	±2.0%
L	±2.5%
V	±3.5%



The quantities listed in Table 1.2 have values that are used to calculate ρ as $4.1 \times 10^{-7}\,\Omega\,\text{m}$.

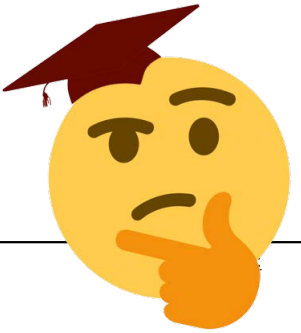
For this value of ρ, calculate:

(i) the percentage uncertainty

percentage uncertainty = ...% [2]

(ii) the absolute uncertainty.

absolute uncertainty = ... $\Omega\,\text{m}$ [1]



14 - (9702/23_Winter_2022_Q1) - *Measurement Techniques*

The rate of flow Q of a liquid along a narrow pipe of length L and radius r is given by

$$Q = \frac{\alpha r^4}{L}$$

where α is a constant.

An experiment is carried out to determine the value of α. The data from the experiment are shown in Table 1.1.

Table 1.1

quantity	value	percentage uncertainty
Q	$2.72 \times 10^{-8}\,m^3\,s^{-1}$	±3%
r	$7.1 \times 10^{-5}\,m$	±2%
L	$2.5 \times 10^{-2}\,m$	±4%

(a) Use information in Table 1.1 to show that the SI base unit of α is s^{-1}.

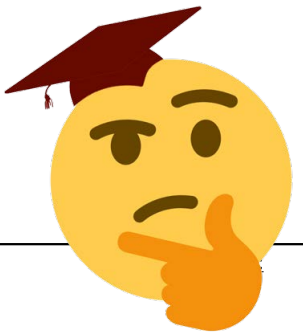
[1]

(b) Show that the percentage uncertainty in α is 15%.

[1]

(c) Calculate α with its absolute uncertainty. Give your answer to an appropriate number of significant figures.

α = (..... ± .....) × $10^7\,s^{-1}$ [3]



15 - (9702/21_Winter_2022_Q2) - *Measurement Techniques*

A steel ball is projected horizontally from the top of a table, as shown in Fig. 2.1.

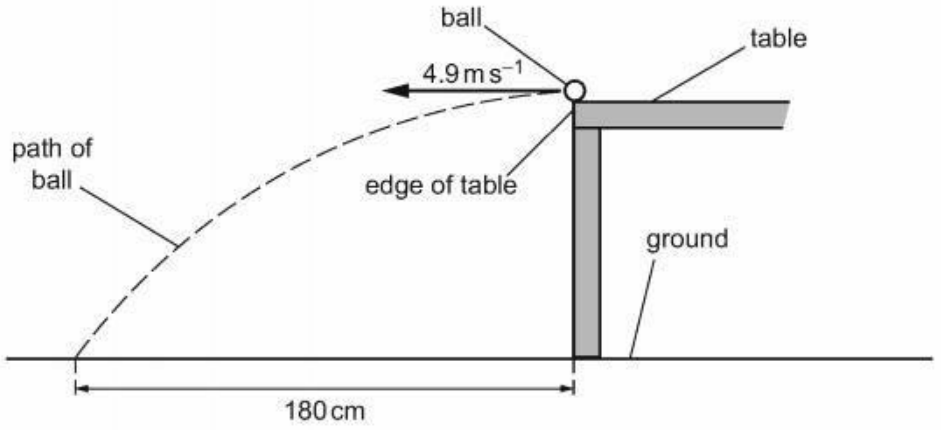


Fig. 2.1 (not to scale)

The ball is projected horizontally at a speed of $4.9\,m\,s^{-1}$. The ball lands on the ground a horizontal distance of 180 cm from the edge of the table.

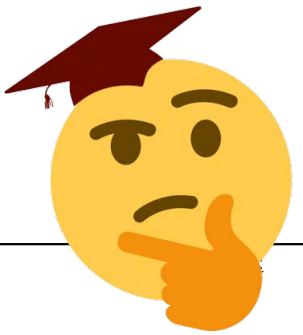
Assume that air resistance is negligible.

(a) **(i)** Calculate the time taken for the ball to reach the ground.

time = ... s [1]

(ii) Calculate the vertical component of the velocity of the ball as it hits the ground.

velocity = ... $m\,s^{-1}$ [2]



(iii) Determine the magnitude and the angle to the horizontal of the velocity of the ball as it hits the ground.

magnitude of velocity = ... $m\,s^{-1}$

angle to the horizontal = ... °

[3]

(b) The ball is projected by means of a compressed spring which is attached to a fixed block as shown in Fig. 2.2.

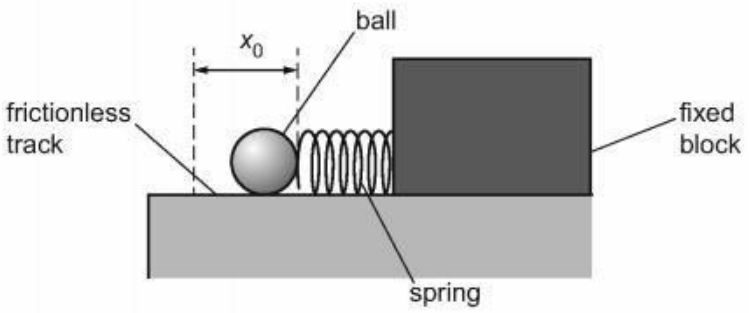


Fig. 2.2

The ball is placed on a frictionless track in front of the spring. The ball is then pulled back so that the spring has compression x_0.

When the spring is released, the ball is projected horizontally as shown in Fig. 2.3.

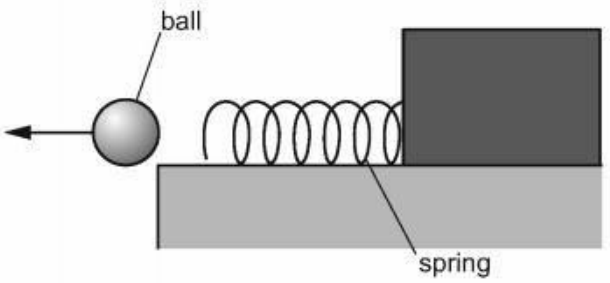
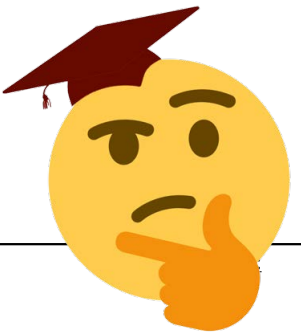


Fig. 2.3



The variation with compression x of the applied force F for the spring is shown in Fig. 2.4.

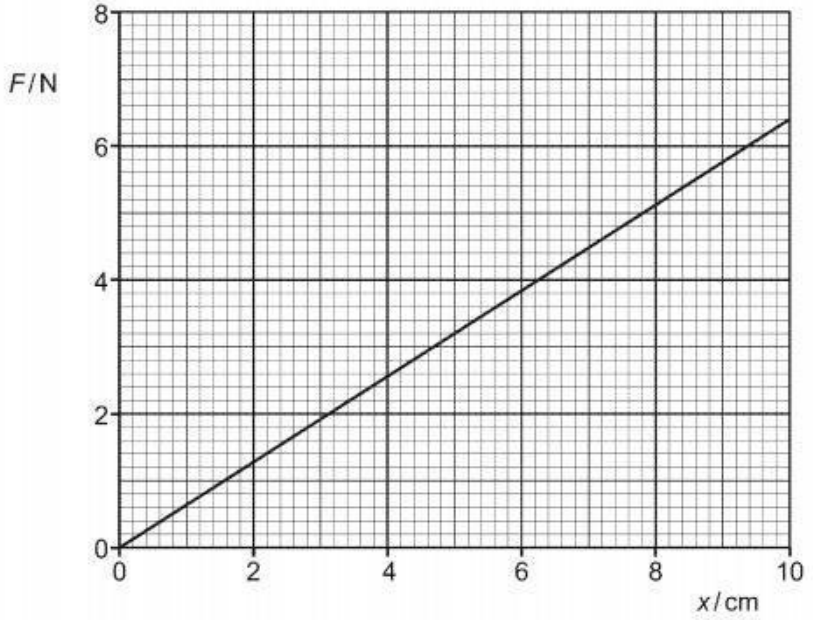


Fig. 2.4

The ball is a uniform sphere of steel of diameter 0.016 m and mass 0.017 kg.

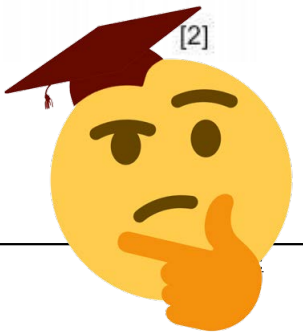
(i) Calculate the density of the steel.

density = ... $kg\,m^{-3}$ [3]

(ii) All of the elastic potential energy in the spring is converted into kinetic energy of the ball. The speed of the ball as it leaves the spring is $4.9\,m\,s^{-1}$.

Show that the maximum elastic potential energy of the spring is 0.20 J.

[2]



(iii) Use Fig. 2.4 to determine the spring constant k of the spring.

k = ... $N\,m^{-1}$ [2]

(iv) Use your answer in **(b)(iii)** and the value of energy given in **(b)(ii)** to determine the compression x_0 of the spring.

x_0 = ... m [2]

(c) The steel ball is replaced by a polystyrene ball of the same diameter but of much lower mass. The spring is given compression x_0 and is then released.

Air resistance on this ball is **not** negligible after it leaves the spring.

Explain:

(i) why this ball leaves the spring with a greater speed than that of the steel ball

.....

.....

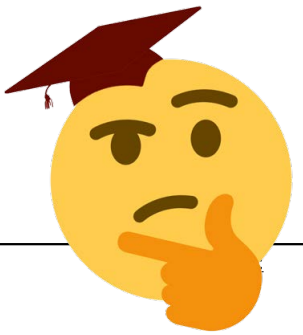
..... [1]

(ii) why this ball takes a longer time to reach the ground than the steel ball.

.....

.....

..... [1]



16 – (9702/21_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) Compare scalar and vector quantities.

.....

.....

..... [2]

(b) The radius of a small sphere is determined from a measurement of the volume of the sphere. The sphere is submerged in water, displacing some of the water into a measuring cylinder as shown in Fig. 1.1.

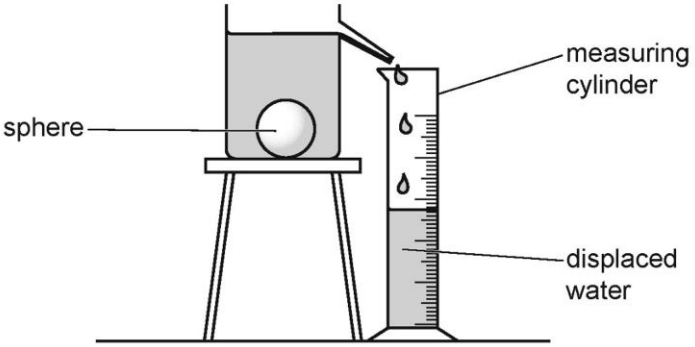


Fig. 1.1 (not to scale)

The measured volume of displaced water is $(28.0 \pm 0.5)\,cm^3$.

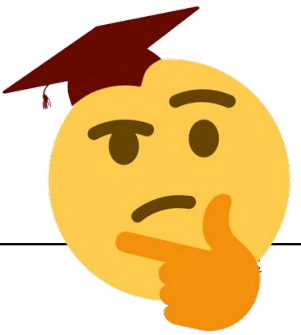
Calculate:

(i) the radius, in cm, of the sphere

radius = ... cm [1]

(ii) the percentage uncertainty in the radius of the sphere.

percentage uncertainty = ... % [2]



17 – (9702/22_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a) In the following list, underline **all** quantities that are SI base quantities.

charge electric current force time [1]

(b) Under certain conditions, the distance s moved in a straight line by an object in time t is given by

$$s = \frac{1}{2}at^2$$

where a is the acceleration of the object.

State **two** conditions under which the above expression applies to the motion of the object.

1 .....

2 .....
[2]

(c) The variation with time t of the velocity v of a car that is moving in a straight line is shown in Fig. 1.1.

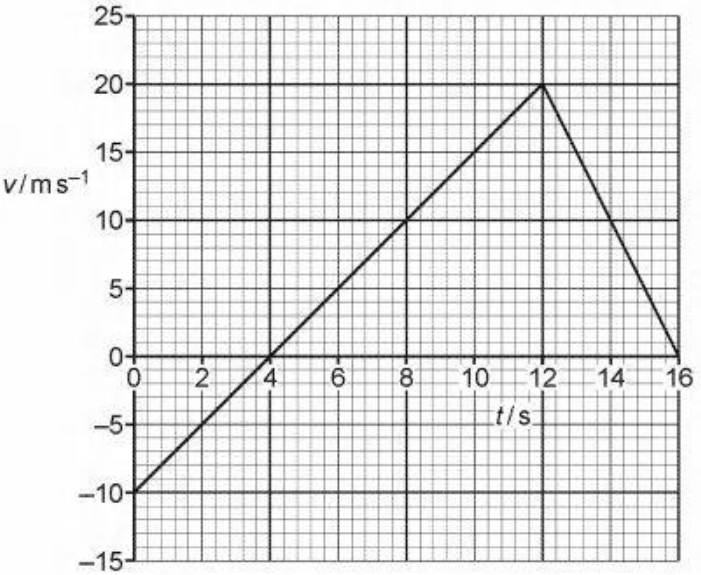


Fig. 1.1

(i) Compare, qualitatively, the acceleration of the car at time t = 8.0 s and at time t = 14.0 s in terms of:

- magnitude

.....

.....

- direction.

.....

.....
[2]

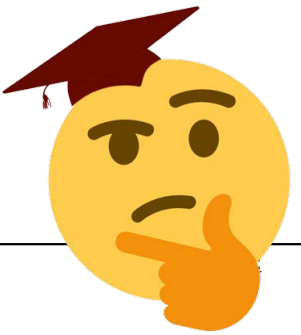
(ii) Determine the magnitude of the acceleration of the car at time t = 4.0 s.

acceleration = ... $m\,s^{-2}$ [2]

(iii) The car is at point X at time t = 0.

Determine the magnitude of the displacement of the car from X at time t = 12.0 s.

displacement = ... m [2]



18 – (9702/23_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a) Table 1.1 lists some physical quantities. Complete the table by placing a tick (✓) next to the scalar quantities.

Table 1.1

acceleration	
charge	
momentum	
power	
upthrust	

[1]

(b) A uniform cylinder has diameter D, length L and mass M.
The density ρ of the cylinder is given by

$$\rho = \frac{4M}{\pi D^2 L}.$$

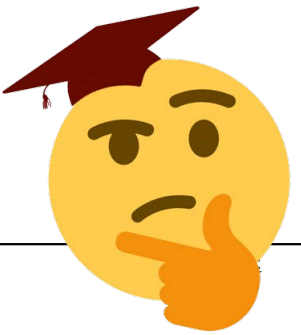
Table 1.2 shows the data obtained from an experiment to determine the density of the cylinder.

Table 1.2

quantity	measurement	percentage uncertainty
D	(26.2 ± 0.1) mm	.....%
L	(162 ± 1) mm	.....%
M	(247 ± 1) g	0.4%

(i) Calculate the percentage uncertainties in D and L. Write your answers in Table 1.2.

[1]

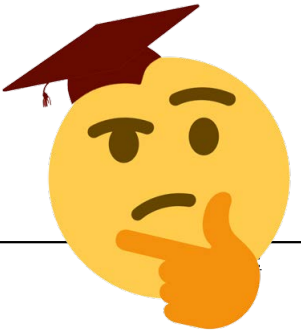


(ii) Calculate the density of the cylinder. Give your answer to three significant figures.

density = ... $kg\,m^{-3}$ [2]

(iii) Calculate the percentage uncertainty in the density.

percentage uncertainty = ... % [2]



1 – (9702/22_Summer_2017_Q2) – *Kinematics, Work, Energy & Power*

(a) Define *velocity*.

.....

.....[1]

(b) A ball of mass 0.45 kg leaves the edge of a table with a horizontal velocity v, as shown in Fig. 2.1.

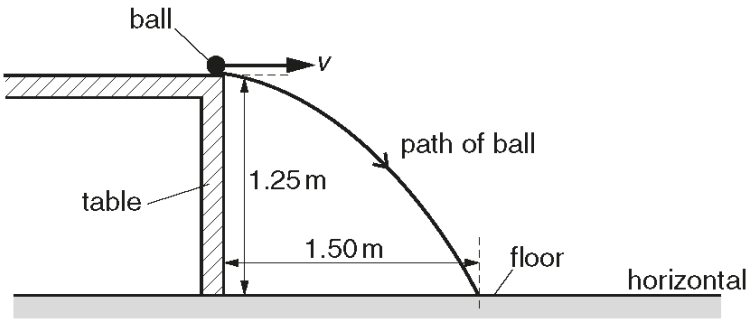


Fig. 2.1

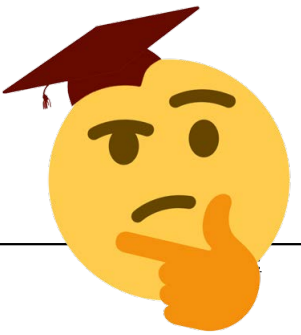
The height of the table is 1.25 m. The ball travels a distance of 1.50 m horizontally before hitting the floor.

Air resistance is negligible.

Calculate, for the ball,

(i) the horizontal velocity v as it leaves the table,

v = ...m s^{-1} [3]



(ii) the velocity just as it hits the floor,

magnitude of velocity = ...m s^{-1}

angle to the horizontal = ... °

[4]

(iii) the kinetic energy just as it hits the floor,

kinetic energy = ... J [2]

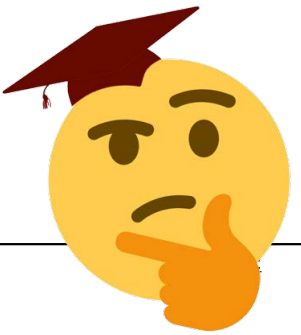
(iv) the loss in gravitational potential energy as it falls from the table to the floor.

loss in potential energy = ... J [2]

(c) Explain why the kinetic energy of the ball in **(b)(iii)** does not equal the loss of gravitational potential energy in **(b)(iv)**.

.....

.....[1]



2 – (9702/23_Summer_2017_Q2) – *Kinematics, Dynamics*

(a) State Newton's second law of motion.

.....

.....[1]

(b) A constant resultant force F acts on an object A. The variation with time t of the velocity v for the motion of A is shown in Fig. 2.1.

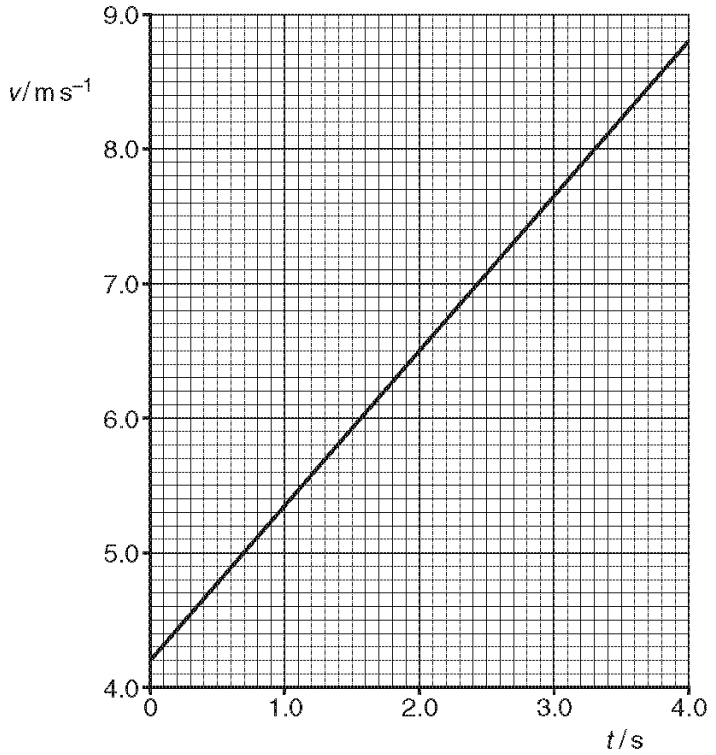


Fig. 2.1

The mass of A is 840 g.

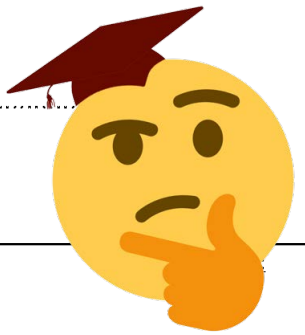
Calculate, for the time $t = 0$ to $t = 4.0$ s,

(i) the change in momentum of A,

change in momentum = ... kg m s^{-1} [2]

(ii) the force F.

F = ...



(c) The force F is removed at $t = 4.0\,\text{s}$. Object A continues at constant velocity before colliding with an object B, as illustrated in Fig. 2.2.

Fig. 2.2

Object B is initially at rest. The mass of B is 730 g.
The objects A and B join together and have a velocity of $4.7\,\text{m}\,\text{s}^{-1}$.

(i) By calculation, show that the changes in momentum of A and of B during the collision are equal and opposite.

[2]

(ii) Explain how the answers obtained in **(i)** support Newton's third law.

.....

.....

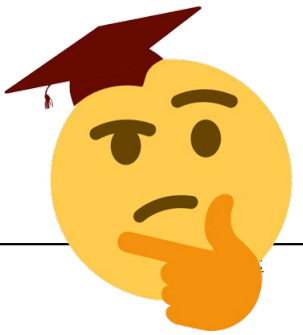
.....

.....[2]

(iii) By reference to the speeds of A and B, explain whether the collision is elastic.

.....

.....[1]



3 – (9702/21_Winter_2017_Q1) – *Physical Quantities & Units, Kinematics, Dynamics*

(a) The drag force F_D acting on a sphere moving through a fluid is given by the expression

$$F_D = K\rho v^2$$

where K is a constant,
ρ is the density of the fluid
and v is the speed of the sphere.

Determine the SI base units of K.

base units .....[3]

(b) A ball of weight 1.5 N falls vertically from rest in air. The drag force F_D acting on the ball is given by the expression in **(a)**. The ball reaches a constant (terminal) speed of $33\,m\,s^{-1}$.

Assume that the upthrust acting on the ball is negligible and that the density of the air is uniform.

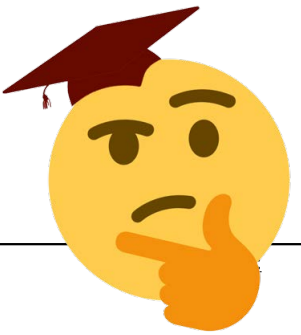
For the instant when the ball is travelling at a speed of $25\,m\,s^{-1}$, determine

(i) the drag force F_D on the ball,

F_D = ... N [2]

(ii) the acceleration of the ball.

acceleration = ... $m\,s^{-2}$ [2]



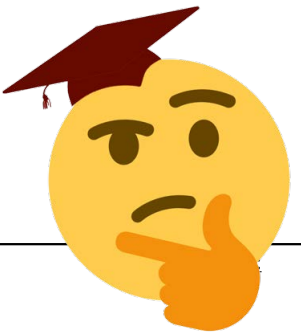
(c) Describe the acceleration of the ball in **(b)** as its speed changes from zero to $33\,m\,s^{-1}$.

.....

.....

.....

.....[3]



4 – (9702/21_Winter_2017_Q2) – *Kinematics*

The variation with time t of the velocity v of two cars P and Q is shown in Fig. 2.1.

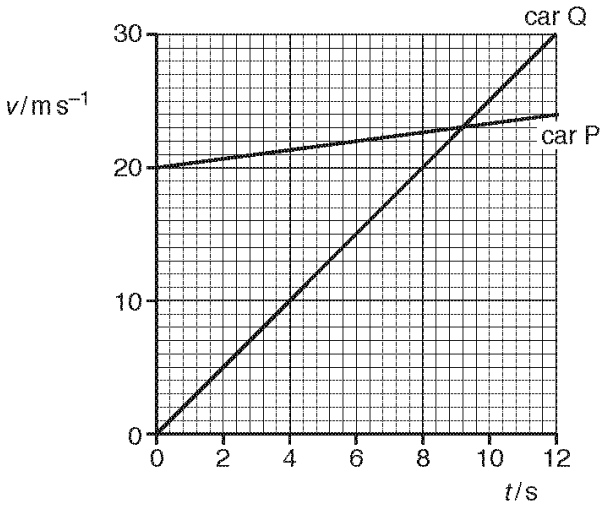


Fig. 2.1

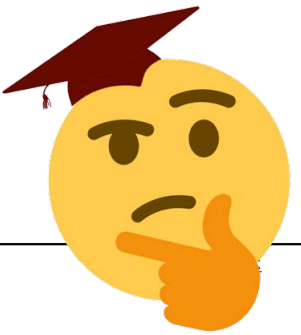
The cars travel in the same direction along a straight road.
Car P passes car Q at time $t = 0$.

(a) The speed limit for cars on the road is $100\,\text{km}\,\text{h}^{-1}$. State and explain whether car Q exceeds the speed limit.

.....[1]

(b) Calculate the acceleration of car P.

acceleration = ... $\text{m}\,\text{s}^{-2}$ [2]



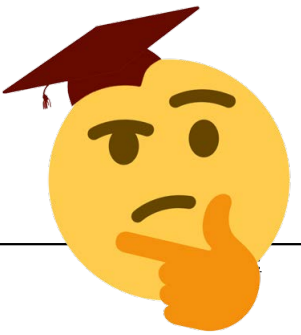
(c) Determine the distance between the two cars at time $t = 12\,s$.

distance = ... m [3]

(d) From time $t = 12\,s$, the velocity of each car remains constant at its value at $t = 12\,s$.

Determine the time t at which car Q passes car P.

t = ... s [2]



5 – (9702/22_Winter_2017_Q3) – *Kinematics, Dynamics, Forces, Density & Pressure*

A spring is attached at one end to a fixed point and hangs vertically with a cube attached to the other end. The cube is initially held so that the spring has zero extension, as shown in Fig. 3.1.

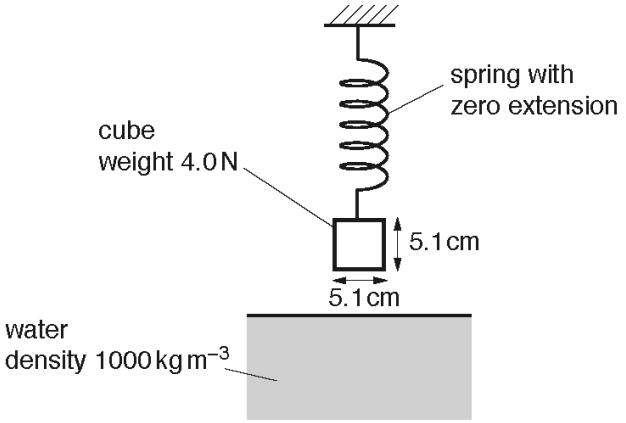


Fig. 3.1

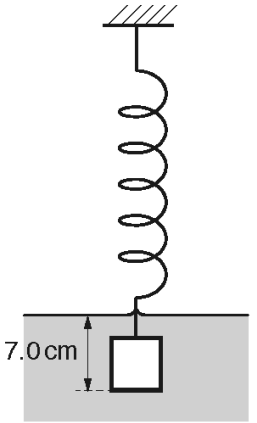


Fig. 3.2

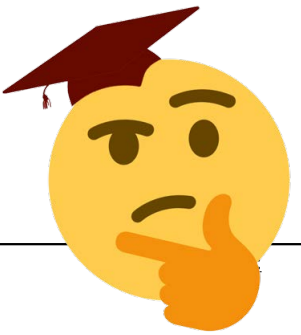
The cube has weight 4.0 N and sides of length 5.1 cm. The cube is released and sinks into water as the spring extends. The cube reaches equilibrium with its base at a depth of 7.0 cm below the water surface, as shown in Fig. 3.2.
The density of the water is 1000 kg m^{-3}.

(a) Calculate the difference in the pressure exerted by the water on the bottom face and on the top face of the cube.

difference in pressure = ... Pa [2]

(b) Use your answer in **(a)** to show that the upthrust on the cube is 1.3 N.

[2]



(c) Calculate the force exerted on the spring by the cube when it is in equilibrium in the water.

force = ... N [1]

(d) The spring obeys Hooke's law and has a spring constant of $30\,N\,m^{-1}$.

Determine the initial height above the water surface of the base of the cube before it was released.

height above surface = ... cm [3]

(e) The cube in the water is released from the spring.

(i) Determine the initial acceleration of the cube.

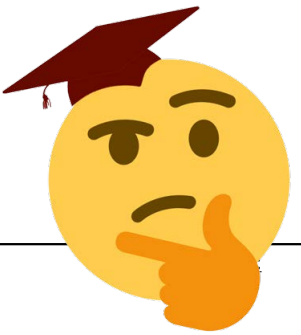
acceleration = ...$m\,s^{-2}$ [2]

(ii) Describe and explain the variation, if any, of the acceleration of the cube as it sinks in the water.

.....

.....

.....[2]



6 – (9702/21_Summer_2018_Q1) – *Physical Quantities & Units, Kinematics*

(a) State what is meant by a *scalar* quantity and by a *vector* quantity.

scalar: .....

.....

vector: .....

.....

[2]

(b) Complete Fig. 1.1 to indicate whether each of the quantities is a vector or a scalar.

quantity	vector or scalar
power	
temperature	
momentum	

Fig. 1.1

[2]

(c) An aircraft is travelling in wind. Fig. 1.2 shows the velocities for the aircraft in still air and for the wind.

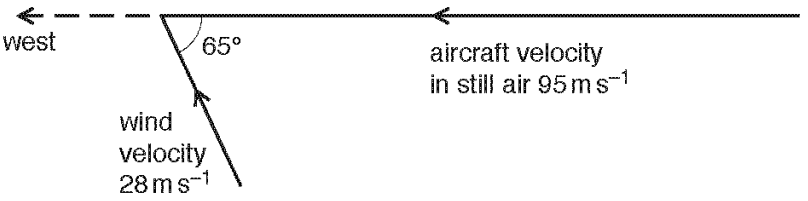
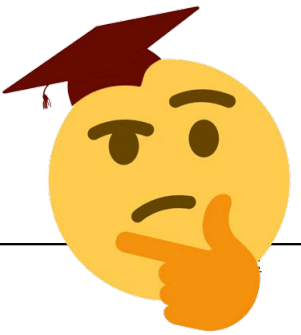


Fig. 1.2

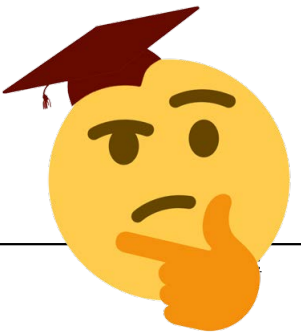
The velocity of the aircraft in still air is $95\,m\,s^{-1}$ to the west.
The velocity of the wind is $28\,m\,s^{-1}$ from 65° south of east.

(i) On Fig. 1.2, draw an arrow, labelled R, in the direction of the resultant velocity of the aircraft. [1]



(ii) Determine the magnitude of the resultant velocity of the aircraft.

magnitude of velocity = ... $m\,s^{-1}$ [2]



7 – (9702/21_Summer_2018_Q2) – *Dynamics, Kinematics, Work, Energy & Power*

(a) State Newton's first law of motion.

.....

.....[1]

(b) A block of weight 15 N hangs by a wire from a remotely controlled aircraft, as shown in Fig. 2.1.

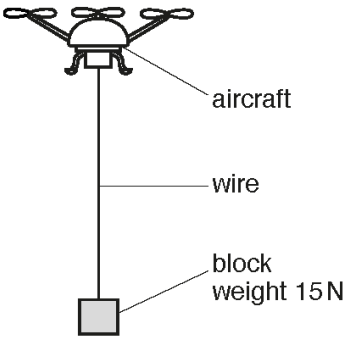


Fig. 2.1

The aircraft is used to move the block only in a vertical direction. The force on the block due to air resistance is negligible.

The variation with time t of the vertical velocity v of the block is shown in Fig. 2.2.
The velocity is taken to be positive in the upward direction.

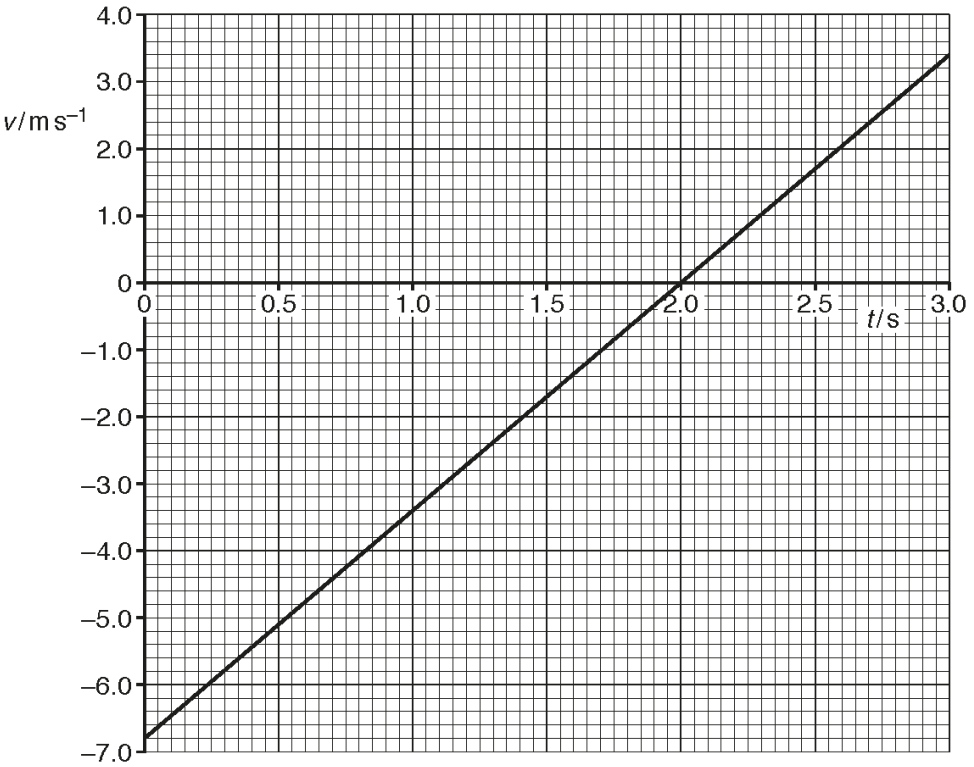
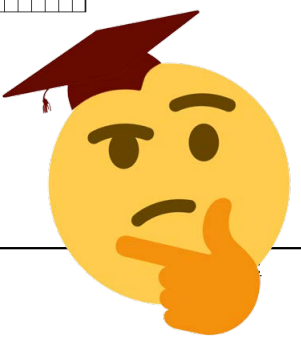


Fig. 2.2



(i) Determine, for the block,

1. the displacement from time $t = 0$ to $t = 3.0\,s$,

magnitude of displacement = ... m

direction of displacement .....

[3]

2. the change in gravitational potential energy from time $t = 0$ to $t = 3.0\,s$.

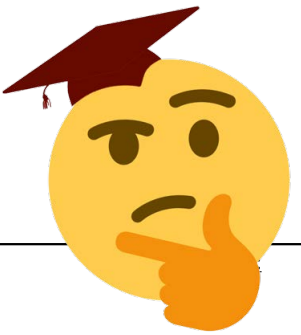
change in gravitational potential energy = ... J [2]

(ii) Calculate the magnitude of the acceleration of the block at time $t = 2.0\,s$.

acceleration = ... $m\,s^{-2}$ [2]

(iii) Use your answer in **(b)(ii)** to show that the tension T in the wire at time $t = 2.0\,s$ is $20\,N$.

[2]



(iv) The wire has a cross-sectional area of $2.8 \times 10^{-5}\,m^2$ and is made from metal of Young modulus 1.7×10^{11} Pa. The wire obeys Hooke's law.

Calculate the strain of the wire at time $t = 2.0\,s$.

strain = ... [3]

(v) At some time after $t = 3.0\,s$ the tension in the wire has a constant value of 15 N.

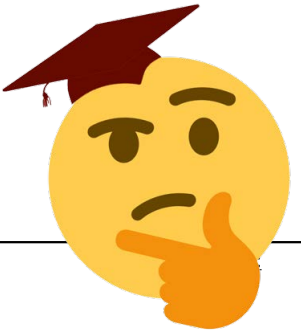
State and explain whether it is possible to deduce that the block is moving vertically after $t = 3.0\,s$.

.....

.....

.....

.....[2]



8 – (9702/22_Summer_2018_Q2) – *Kinematics, Dynamics*

(a) State the principle of conservation of momentum.

.....

.....

.....[2]

(b) A stationary firework explodes into three different fragments that move in a horizontal plane, as illustrated in Fig. 2.1.

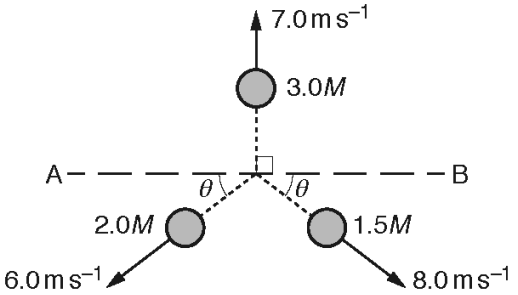


Fig. 2.1

The fragment of mass 3.0M has a velocity of 7.0 m s^{-1} perpendicular to line AB.
The fragment of mass 2.0M has a velocity of 6.0 m s^{-1} at angle θ to line AB.
The fragment of mass 1.5M has a velocity of 8.0 m s^{-1} at angle θ to line AB.

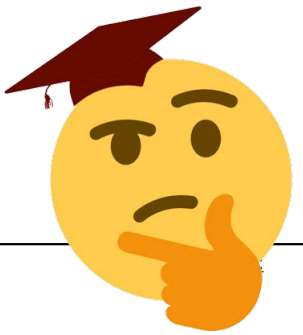
(i) Use the principle of conservation of momentum to determine θ.

θ = ... ° [3]

(ii) Calculate the ratio

$$\frac{\text{kinetic energy of fragment of mass } 2.0M}{\text{kinetic energy of fragment of mass } 1.5M}.$$

ratio = ...[2]



9 – (9702/21_Summer_2018_Q3) – *Kinematics, Dynamics*

(a) State what is meant by the *mass* of a body.

.....

.....[1]

(b) Two blocks travel directly towards each other along a horizontal, frictionless surface. The blocks collide, as illustrated in Fig. 3.1.

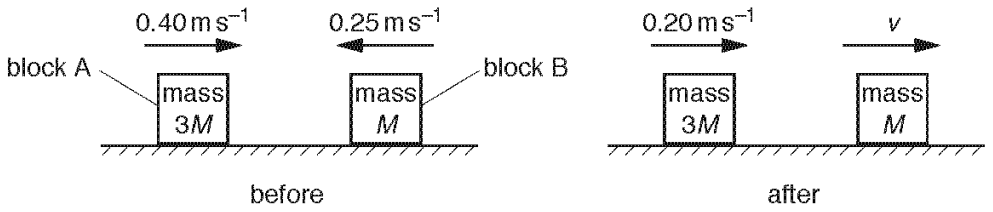


Fig. 3.1

Block A has mass 3*M* and block B has mass *M*.
Before the collision, block A moves to the right with speed $0.40\,m\,s^{-1}$ and block B moves to the left with speed $0.25\,m\,s^{-1}$.
After the collision, block A moves to the right with speed $0.20\,m\,s^{-1}$ and block B moves to the right with speed *v*.

(i) Use Newton's third law to explain why, during the collision, the change in momentum of block A is equal and opposite to the change in momentum of block B.

.....

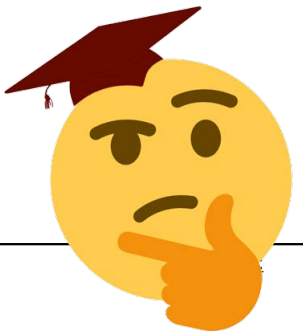
.....

.....

.....[2]

(ii) Determine speed *v*.

v = ... $m\,s^{-1}$ [3]



(iii) Calculate, for the blocks,

1. the relative speed of approach,

relative speed of approach = ... $m\,s^{-1}$

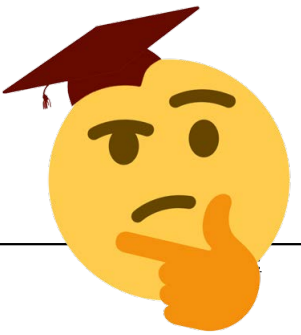
2. the relative speed of separation.

relative speed of separation = ... $m\,s^{-1}$
[2]

(iv) Use your answers in **(b)(iii)** to state and explain whether the collision is elastic or inelastic.

.....

.....[1]



10 – (9702/22_Summer_2018_Q3) – *Kinematics, Dynamics, Waves*

A child on a sledge slides down a steep hill and then travels in a straight line up an ice-covered slope, as illustrated in Fig. 3.1.

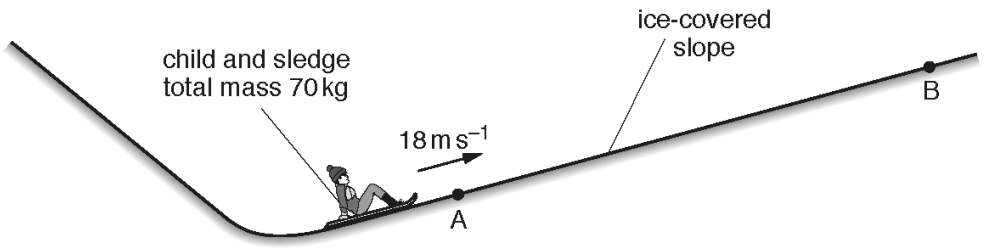


Fig. 3.1 (not to scale)

The sledge passes point A with speed $18\,\mathrm{m\,s^{-1}}$ at time $t = 0$ and then comes to rest at point B. The child applies a brake to the sledge at point B. The brake does not keep the sledge stationary and it immediately slides back down the slope towards A.

The variation with time t of the velocity v of the sledge from $t = 0$ to $t = 24\,\mathrm{s}$ is shown in Fig. 3.2.

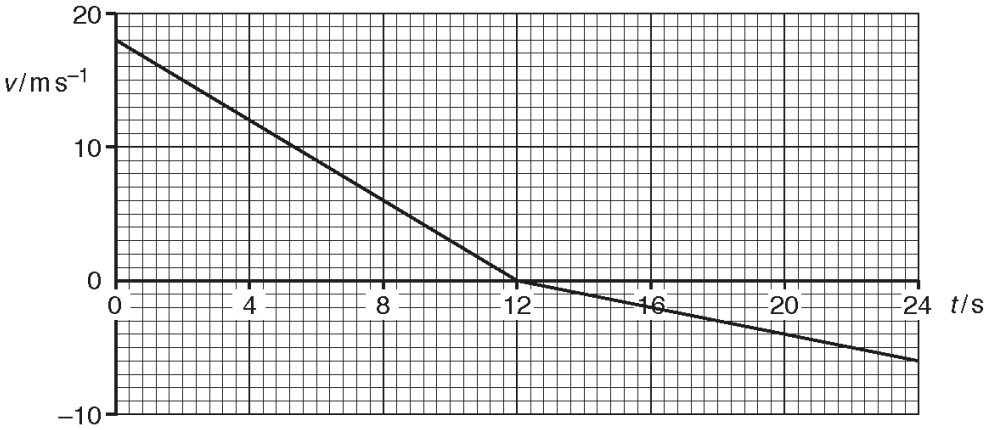
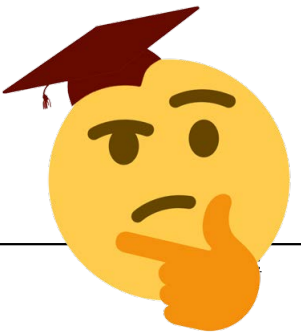


Fig. 3.2

(a) State the time taken for the sledge to travel from A to B.

time = ... s [1]



(b) Determine the displacement of the sledge up the slope from point A at time $t = 24$ s.

displacement = ...m [3]

(c) Show that the acceleration of the sledge as it moves from B back towards A is $0.50\,\text{m}\,\text{s}^{-2}$.

[2]

(d) The child and sledge have a total mass of 70 kg. The component of the total weight of the child and sledge that acts down the slope is 80 N.

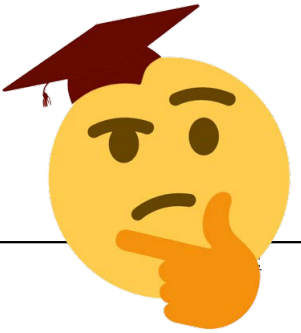
Determine

(i) the frictional force on the sledge as it moves from B towards A,

frictional force = ... N [2]

(ii) the angle θ of the slope to the horizontal.

θ = ... ° [2]



(e) The child on the sledge blows a whistle between $t = 4.0\,\text{s}$ and $t = 8.0\,\text{s}$. The whistle emits sound of frequency 900 Hz. The speed of the sound in the air is $340\,\text{m}\,\text{s}^{-1}$. A man standing at point A hears the sound.

Use Fig. 3.2 to

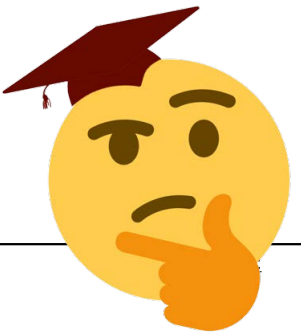
(i) determine the initial frequency of the sound heard by the man,

initial frequency = ... Hz [2]

(ii) describe and explain qualitatively the variation, if any, in the frequency of the sound heard by the man.

.....

.....[1]



11 - (9702/23_Summer_2018_Q3) - *Kinematics, Dynamics, Work, Energy & Power*

A ball is thrown vertically upwards towards a ceiling and then rebounds, as illustrated in Fig. 3.1.

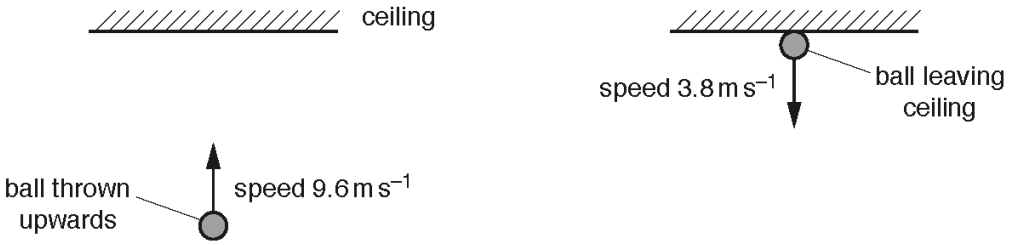


Fig. 3.1

The ball is thrown with speed 9.6 m s^{-1} and takes a time of 0.37 s to reach the ceiling. The ball is then in contact with the ceiling for a further time of 0.085 s until leaving it with a speed of 3.8 m s^{-1}. The mass of the ball is 0.056 kg. Assume that air resistance is negligible.

(a) Show that the ball reaches the ceiling with a speed of 6.0 m s^{-1}.

[1]

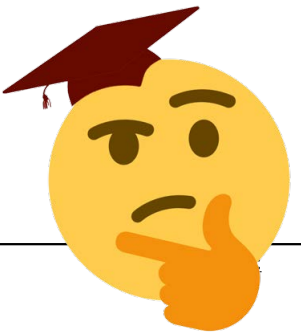
(b) Calculate the height of the ceiling above the point from which the ball was thrown.

height = ... m [2]

(c) Calculate

(i) the increase in gravitational potential energy of the ball for its movement from its initial position to the ceiling,

increase in gravitational potential energy = ... J [2]



(ii) the decrease in kinetic energy of the ball while it is in contact with the ceiling.

decrease in kinetic energy = ... J [2]

(d) State how Newton's third law applies to the collision between the ball and the ceiling.

.....

.....

.....

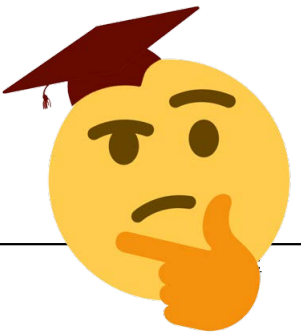
.....[2]

(e) Calculate the change in momentum of the ball during the collision.

change in momentum = ... N s [2]

(f) Determine the magnitude of the average force exerted by the ceiling on the ball during the collision.

average force = ... N [2]



12 – (9702/21_Winter_2018_Q1) – *Kinematics, Work, Energy & Power*

(a) Define

(i) *displacement*,

.....

..... [1]

(ii) *acceleration*.

.....

..... [1]

(b) A remote-controlled toy car moves up a ramp and travels across a gap to land on another ramp, as illustrated in Fig. 1.1.

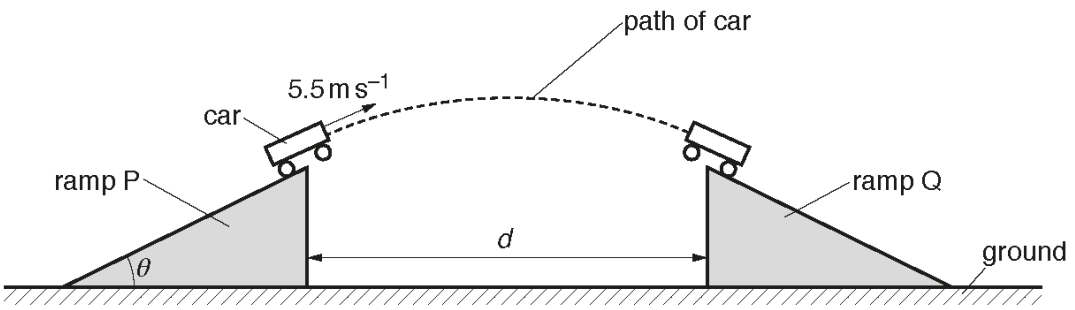


Fig. 1.1

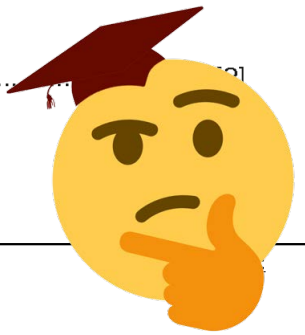
The car leaves ramp P with a velocity of $5.5\,\mathrm{m\,s^{-1}}$ at an angle θ to the horizontal. The horizontal component of the car's velocity as it leaves the ramp is $4.6\,\mathrm{m\,s^{-1}}$. The car lands at the top of ramp Q. The tops of both ramps are at the same height and are distance d apart. Air resistance is negligible.

(i) Show that the car leaves ramp P with a vertical component of velocity of $3.0\,\mathrm{m\,s^{-1}}$.

[1]

(ii) Determine the time taken for the car to travel between the ramps.

time taken = ...



(iii) Calculate the horizontal distance d between the tops of the ramps.

d = ... m [1]

(iv) Calculate the ratio

$$\frac{\text{kinetic energy of the car at its maximum height}}{\text{kinetic energy of the car as it leaves ramp P}}.$$

ratio = ... [3]

(c) Ramp Q is removed. The car again leaves ramp P as in **(b)** and now lands directly on the ground. The car leaves ramp P at time $t = 0$ and lands on the ground at time $t = T$.

On Fig. 1.2, sketch the variation with time t of the vertical component v_y of the car's velocity from $t = 0$ to $t = T$. Numerical values of v_y and t are not required.

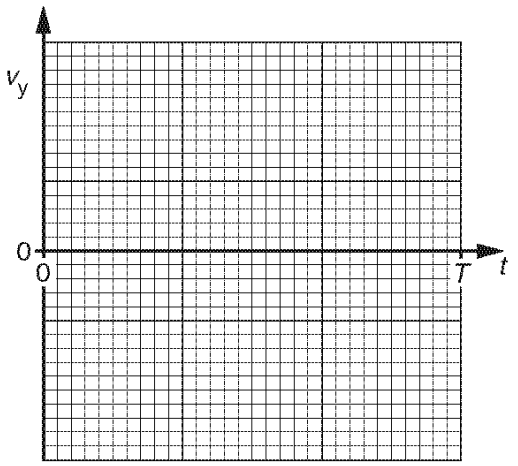
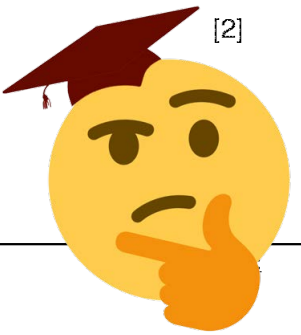


Fig. 1.2

[2]



13 – (9702/22_Winter_2018_Q1) – *Kinematics, Work, Energy & Power*

A golfer strikes a ball so that it leaves horizontal ground with a velocity of $6.0\,\mathrm{m\,s^{-1}}$ at an angle θ to the horizontal, as illustrated in Fig. 1.1.

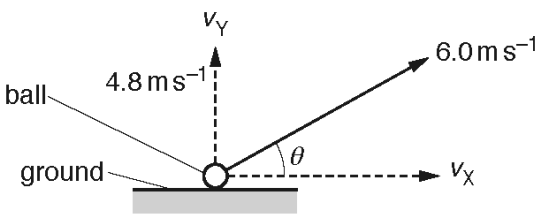


Fig. 1.1 (not to scale)

The magnitude of the initial vertical component v_Y of the velocity is $4.8\,\mathrm{m\,s^{-1}}$.
Assume that air resistance is negligible.

(a) Show that the magnitude of the initial horizontal component v_X of the velocity is $3.6\,\mathrm{m\,s^{-1}}$.

[1]

(b) The ball leaves the ground at time $t = 0$ and reaches its maximum height at $t = 0.49$ s.

On Fig. 1.2, sketch separate lines to show the variation with time t, until the ball returns to the ground, of

(i) the vertical component v_Y of the velocity (label this line Y), [2]

(ii) the horizontal component v_X of the velocity (label this line X). [2]

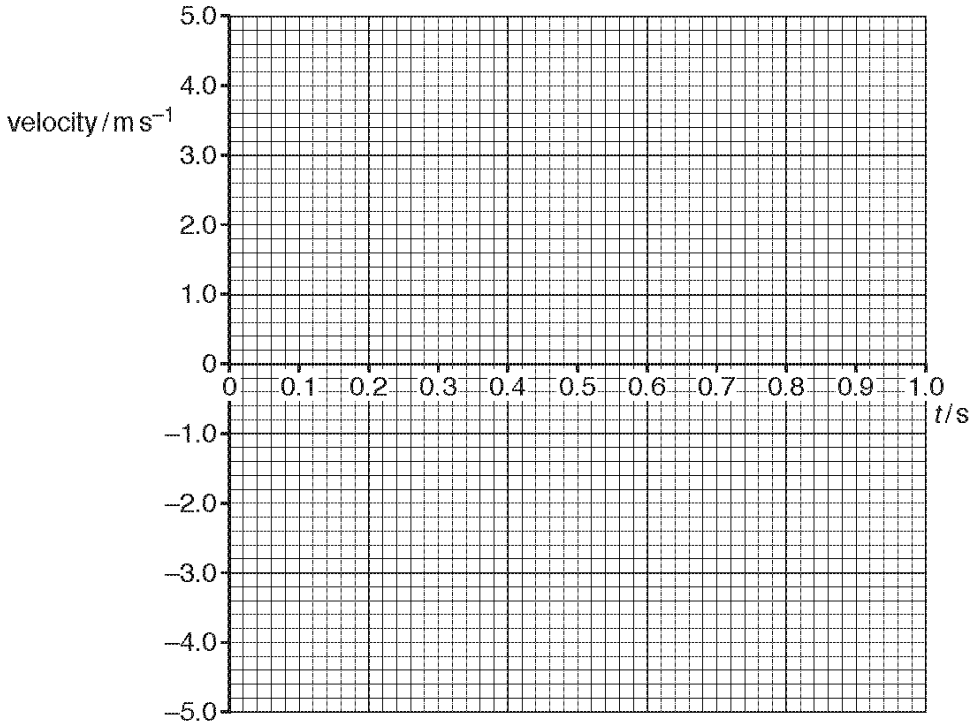
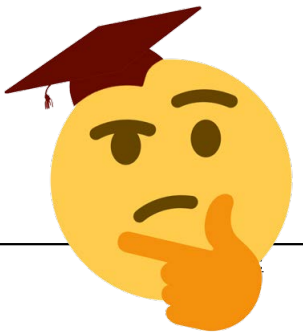


Fig. 1.2

(c) Calculate the maximum height reached by the ball.

maximum height = ... m [2]



(d) For the movement of the ball from the ground to its maximum height, determine the ratio

$$\frac{\text{kinetic energy at maximum height}}{\text{change in gravitational potential energy}}.$$

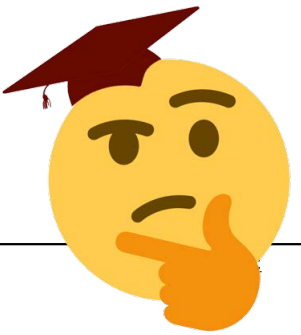
ratio = ...[4]

(e) In practice, significant air resistance acts on the ball. Explain why the actual time taken for the ball to reach maximum height is less than the time calculated when air resistance is assumed to be negligible.

.....

.....

.....[1]



14 – (9702/21_Winter_2018_Q5) – *Electric Fields, Particle & Nuclear Physics, Kinematics*

(a) State what is meant by an *electric field*.

.....

..... [1]

(b) A particle of mass m and charge q is in a uniform electric field of strength E. The particle has acceleration a due to the field.

Show that

$$a = \frac{Eq}{m}.$$

[2]

(c) A stationary nucleus X decays by emitting an α-particle to form a nucleus of plutonium, $^{240}_{94}Pu$, as shown.

$$X \longrightarrow {}^{240}_{94}Pu + \alpha$$

(i) Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...

number of neutrons = ...

[2]

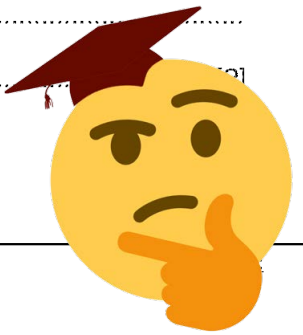
(ii) The total mass of the plutonium nucleus and the α-particle is less than that of nucleus X. Explain this difference in mass.

.....

.....

.....

..... [2]

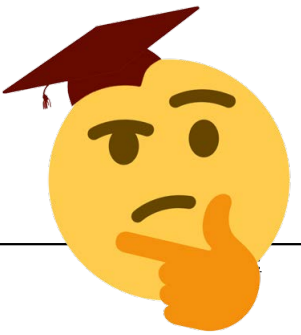


(iii) The plutonium nucleus and the α-particle are both accelerated by the same uniform electric field.

Use the expression in **(b)** to determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particle}}{\text{acceleration of the plutonium nucleus}}.$$

ratio = ... [2]



15 – (9702/21_Summer_2019_Q1) – *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a) Define *velocity*.

.....

.....[1]

(b) The speed v of a sound wave through a gas of pressure P and density ρ is given by the equation

$$v = \sqrt{\frac{kP}{\rho}}$$

where k is a constant that has no units.

An experiment is performed to determine the value of k. The data from the experiment are shown in Fig. 1.1.

quantity	value	uncertainty
v	$3.3 \times 10^2\,\mathrm{m\,s^{-1}}$	± 3%
P	$9.9 \times 10^4\,\mathrm{Pa}$	± 2%
ρ	$1.29\,\mathrm{kg\,m^{-3}}$	± 4%

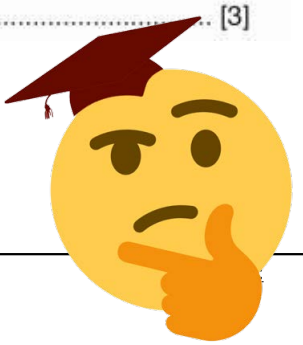
Fig. 1.1

(i) Use data from Fig. 1.1 to calculate k.

k = ... [2]

(ii) Use your answer in **(b)(i)** and data from Fig. 1.1 to determine the value of k, with its absolute uncertainty, to an appropriate number of significant figures.

k = ... ± ..... [3]



16 – (9702/22_Summer_2019_Q2) – *Kinematics, Dynamics, Electric Fields*

(a) State Newton's second law of motion.

.....

.....[1]

(b) A car of mass 850 kg tows a trailer in a straight line along a horizontal road, as shown in Fig. 2.1.

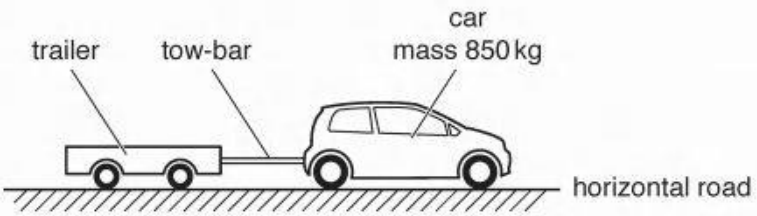


Fig. 2.1

The car and the trailer are connected by a horizontal tow-bar.

The variation with time *t* of the velocity *v* of the car for a part of its journey is shown in Fig. 2.2.

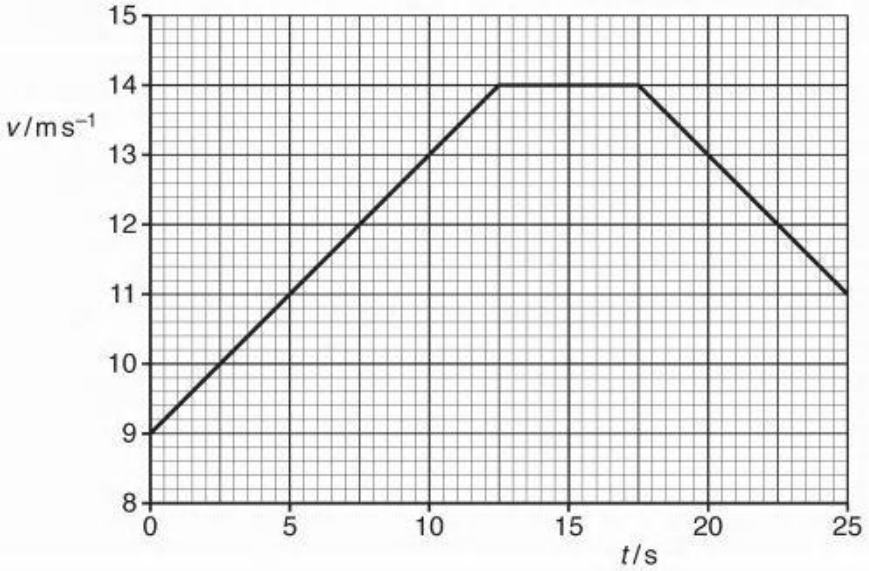
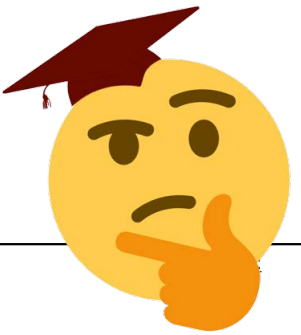


Fig. 2.2



(i) Calculate the distance travelled by the car from time $t = 0$ to $t = 10\,s$.

distance = ... m [2]

(ii) At time $t = 10\,s$, the resistive force acting on the car due to air resistance and friction is 510 N. The tension in the tow-bar is 440 N.

For the car at time $t = 10\,s$:

1. use Fig. 2.2 to calculate the acceleration

acceleration = ... $m\,s^{-2}$ [2]

2. use your answer to calculate the resultant force acting on the car

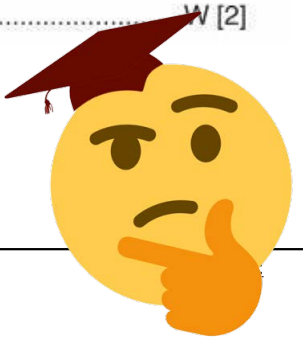
resultant force = ... N [1]

3. show that a horizontal force of 1300 N is exerted on the car by its engine

[1]

4. determine the useful output power of the engine.

output power = ... W [2]



(c) A short time later, the car in **(b)** is travelling at a constant speed and the tension in the tow-bar is 480 N.

The tow-bar is a solid metal rod that obeys Hooke's law. Some data for the tow-bar are listed below.

Young modulus of metal = 2.2×10^{11} Pa

original length of tow-bar = 0.48 m

cross-sectional area of tow-bar = 3.0×10^{-4} m^2

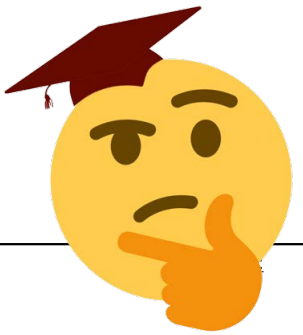
Determine the extension of the tow-bar.

extension = ... m [3]

(d) The driver of the car in **(b)** sees a pedestrian standing directly ahead in the distance. The driver operates the horn of the car from time $t = 15$ s to $t = 17$ s. The frequency of the sound heard by the pedestrian is 480 Hz. The speed of the sound in the air is 340 m s^{-1}.

Use Fig. 2.2 to calculate the frequency of the sound emitted by the horn.

frequency = ... Hz [2]



17 - (9702/21_Winter_2019_Q2) - *Kinematics, Dynamics, Electric Fields*

A small charged glass bead of weight 5.4×10^{-5} N is initially at rest at point A in a vacuum. The bead then falls through a uniform horizontal electric field as it moves in a straight line to point B, as illustrated in Fig. 2.1.

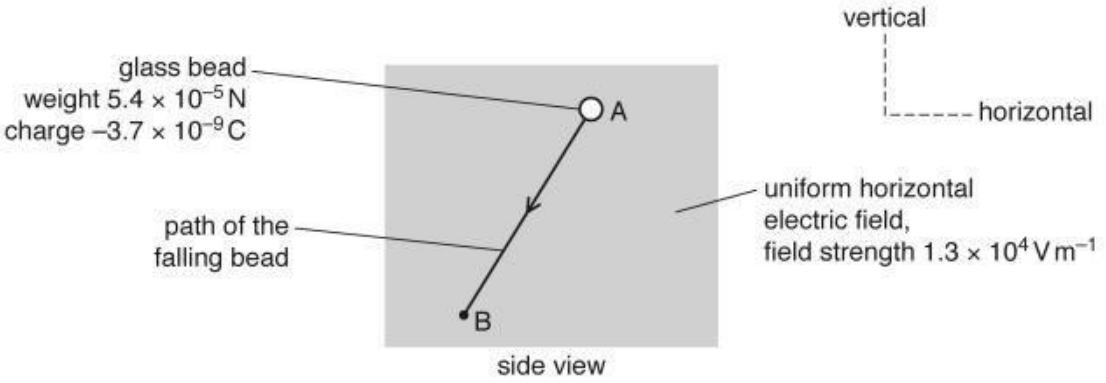


Fig. 2.1 (not to scale)

The electric field strength is 1.3×10^{4} V m^{-1}. The charge on the bead is -3.7×10^{-9} C.

(a) Describe how two metal plates could be used to produce the electric field. Numerical values are not required.

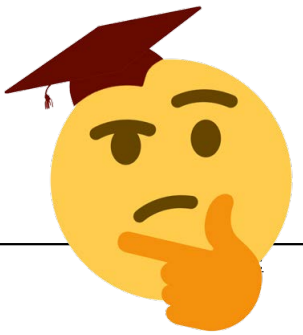
.....

.....

..... [2]

(b) Determine the magnitude of the electric force acting on the bead.

electric force = ... N [2]



(c) Use your answer in **(b)** and the weight of the bead to show that the resultant force acting on it is 7.2×10^{-5} N.

[1]

(d) Explain why the resultant force on the bead of 7.2×10^{-5} N is constant as the bead moves along path AB.

.....

.....

.....

..... [2]

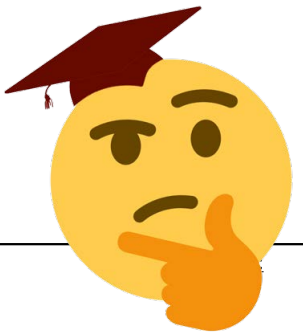
(e) **(i)** Calculate the magnitude of the acceleration of the bead along the path AB.

acceleration = ... $m\,s^{-2}$ [2]

(ii) The path AB has length 0.58 m.

Use your answer in **(i)** to determine the speed of the bead at point B.

speed = ... $m\,s^{-1}$ [2]



18 – (9702/22_Winter_2019_Q2) – *Kinematics*

(a) Define *acceleration*.

..... [1]

(b) A steel ball of diameter 0.080 m is released from rest and falls vertically in air, as illustrated in Fig. 2.1.

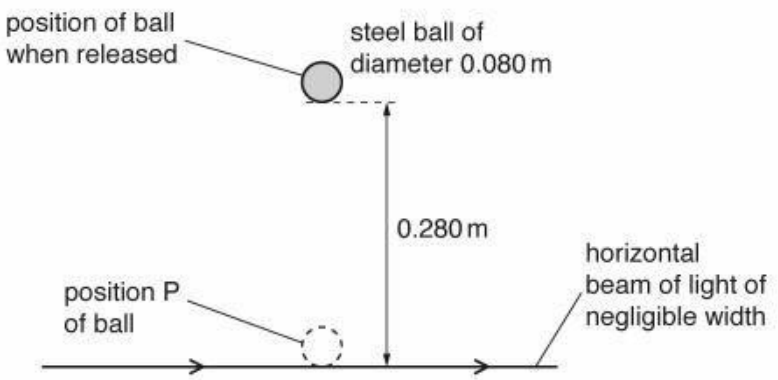


Fig. 2.1 (not to scale)

A horizontal beam of light of negligible width is a vertical distance of 0.280 m below the bottom of the ball when it is released. The ball falls through and breaks the beam of light.

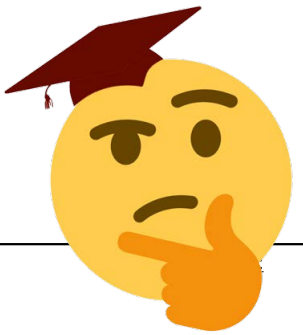
(i) Explain why the force due to air resistance acting on the ball may be neglected when calculating the time taken for the ball to reach the beam of light.

.....

..... [1]

(ii) Calculate the time taken for the ball to fall from rest to position P where the bottom of the ball touches the beam of light.

time taken = ... s [2]



(iii) Determine the time interval during which the beam of light is broken by the ball.

time interval = ... s [2]

(c) A different ball is released from the same position as the steel ball in **(b)**. This ball has the same diameter but a much lower density. For this ball, the force due to air resistance cannot be neglected as the ball falls.

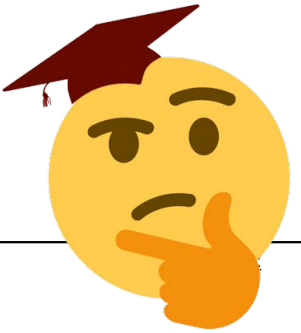
State and explain the change, if any, to the time interval during which the beam of light is broken by the ball.

.....

.....

.....

..... [2]



19 – (9702/23_Winter_2019_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a) State what is meant by *work done*.

.....

..... [1]

(b) A lift (elevator) of weight 13.0 kN is connected by a cable to a motor, as shown in Fig. 2.1.

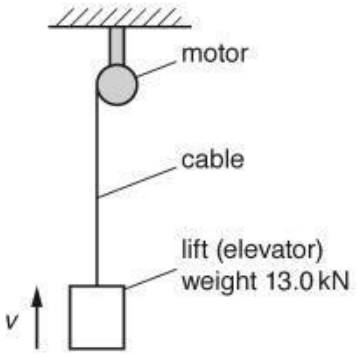


Fig. 2.1

The lift is pulled up a vertical shaft by the cable. A constant frictional force of 2.0 kN acts on the lift when it is moving. The variation with time *t* of the speed *v* of the lift is shown in Fig. 2.2.

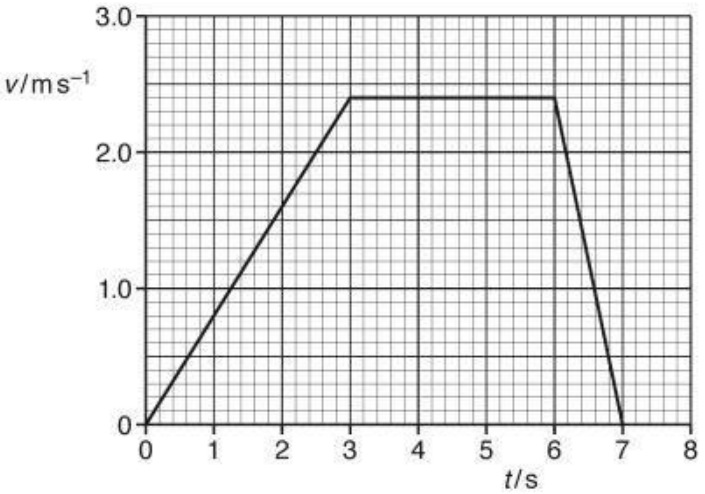
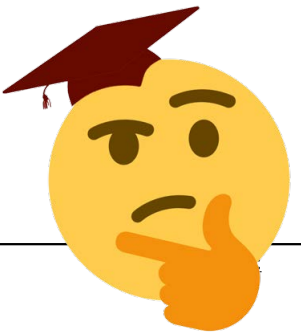


Fig. 2.2



(i) Use Fig. 2.2 to determine:

1. the acceleration of the lift between time $t = 0$ and $t = 3.0\,s$

acceleration = ... $m\,s^{-2}$ [2]

2. the work done by the motor to raise the lift between time $t = 3.0\,s$ and $t = 6.0\,s$.

work done = ... J [2]

(ii) The motor has an efficiency of 67%. The tension in the cable is $1.6 \times 10^4\,N$ at time $t = 2.5\,s$.

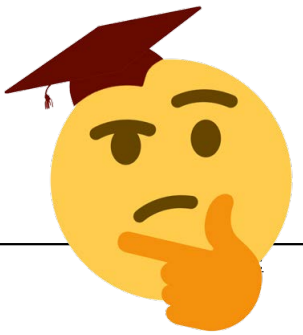
Determine the input power to the motor at this time.

input power = ... W [3]

(iii) State and explain whether the increase in gravitational potential energy of the lift from time $t = 0$ to $t = 7.0\,s$ is less than, the same as, or greater than the work done by the motor. A calculation is not required.

.....

..... [1]



20 – (9702/23_Winter_2019_Q3) – *Kinematics, Electric Fields*

(a) State the property of an object that experiences a force when the object is placed in:

(i) a gravitational field

..... [1]

(ii) an electric field.

..... [1]

(b) A potential difference of 1.2×10^3 V is applied between a pair of horizontal metal plates in a vacuum, as shown in Fig. 3.1.

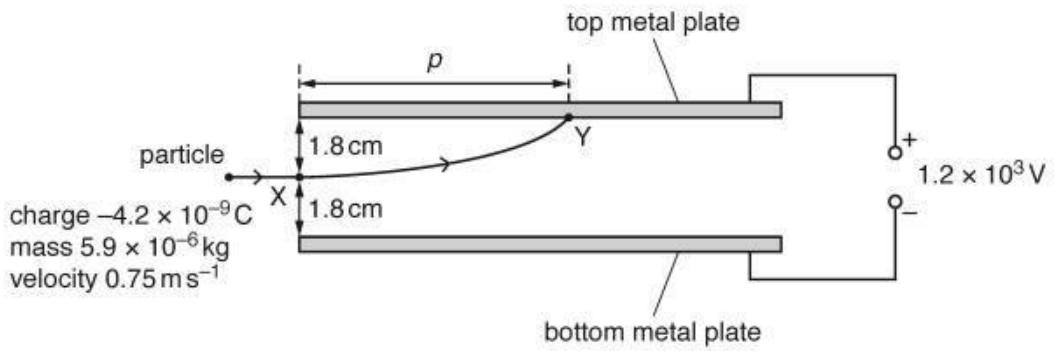


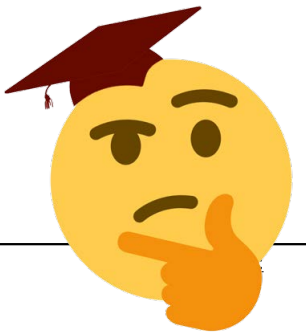
Fig. 3.1 (not to scale)

The separation of the plates is 3.6 cm. The electric field between the plates is uniform.

A particle of mass 5.9×10^{-6} kg and charge -4.2×10^{-9} C enters the field at point X with a horizontal velocity of $0.75\,\text{m s}^{-1}$ along a line midway between the two plates.
The particle is deflected by the field and hits the top plate at point Y.

(i) Calculate the magnitude of the electric force acting on the particle in the field.

electric force = ... N [3]



(ii) By considering the resultant vertical force acting on the particle, show that the acceleration of the particle in the electric and gravitational fields is $14\,m\,s^{-2}$.

[4]

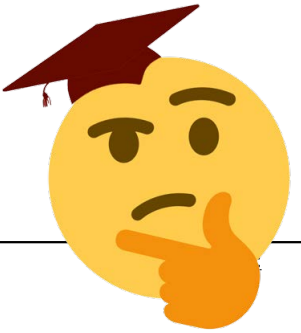
(iii) Determine:

1. the time taken for the particle to move from X to Y

time taken = ... s [2]

2. the distance p of point Y from the left-hand edge of the top plate.

p = ... m [1]



21 – (9702/21_Summer_2020_Q2) – *Kinematics, Dynamics*

(a) State Newton's second law of motion.

.....

..... [1]

(b) A delivery company suggests using a remote-controlled aircraft to drop a parcel into the garden of a customer. When the aircraft is vertically above point P on the ground, it releases the parcel with a velocity that is horizontal and of magnitude $5.4\,m\,s^{-1}$. The path of the parcel is shown in Fig. 2.1.

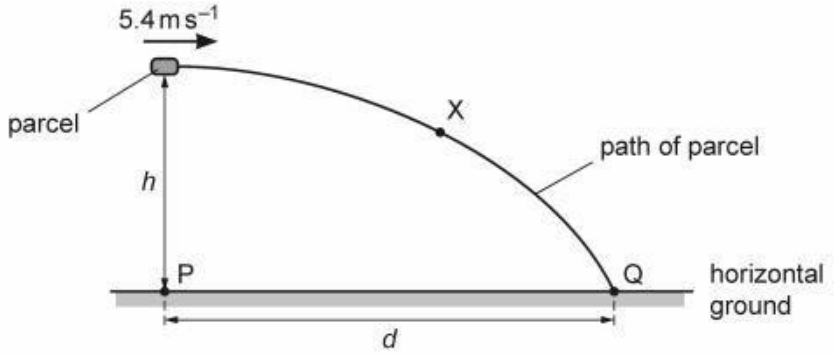


Fig. 2.1 (not to scale)

The parcel takes a time of 0.81 s after its release to reach point Q on the horizontal ground. Assume air resistance is negligible.

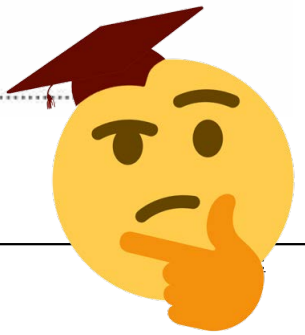
(i) On Fig. 2.1, draw an arrow from point X to show the direction of the acceleration of the parcel when it is at that point. [1]

(ii) Determine the height *h* of the parcel above the ground when it is released.

h = ... m [2]

(iii) Calculate the horizontal distance *d* between points P and Q.

d = ...



(c) Another parcel is accidentally released from rest by a different aircraft when it is hovering at a great height above the ground. Air resistance is now significant.

(i) On Fig. 2.2, draw arrows to show the directions of the forces acting on the parcel as it falls vertically downwards. Label each arrow with the name of the force.

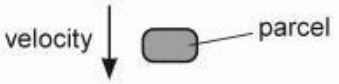


Fig. 2.2

[2]

(ii) By considering the forces acting on the parcel, state and explain the variation, if any, of the acceleration of the parcel as it moves downwards before it reaches constant (terminal) speed.

.....

.....

.....

.....

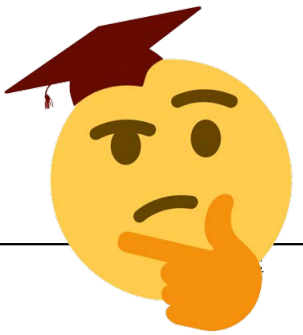
.....

..... [3]

(iii) Describe the energy conversion that occurs when the parcel is falling through the air at constant (terminal) speed.

.....

..... [1]



22 – (9702/22_Summer_2020_Q2) – *Kinematics, Dynamics*

(a) Fig. 2.1 shows the velocity–time graph for an object moving in a straight line.

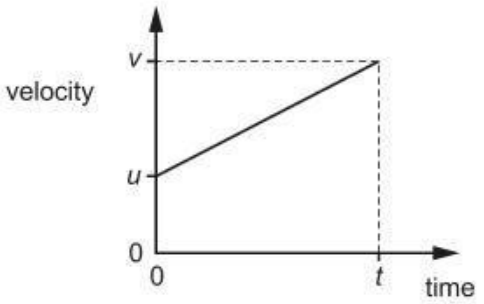


Fig. 2.1

(i) Determine an expression, in terms of u, v and t, for the area under the graph.

area = ... [1]

(ii) State the name of the quantity represented by the area under the graph.

..... [1]

(b) A ball is kicked with a velocity of $15\,\mathrm{m\,s^{-1}}$ at an angle of 60° to horizontal ground. The ball then strikes a vertical wall at the instant when the path of the ball becomes horizontal, as shown in Fig. 2.2.

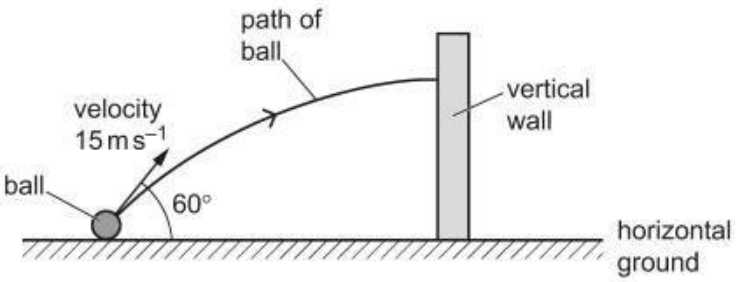
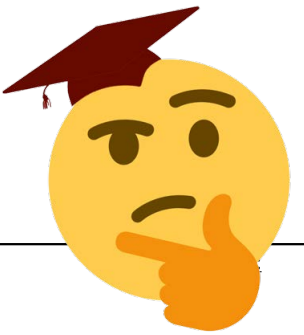


Fig. 2.2 (not to scale)

Assume that air resistance is negligible.



(i) By considering the vertical motion of the ball, calculate the time it takes to reach the wall.

time = ... s [3]

(ii) Explain why the horizontal component of the velocity of the ball remains constant as it moves to the wall.

.....

..... [1]

(iii) Show that the ball strikes the wall with a horizontal velocity of $7.5\,m\,s^{-1}$.

[1]

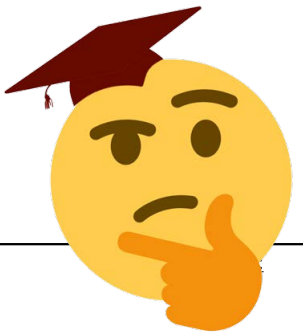
(c) The mass of the ball in **(b)** is 0.40 kg. It is in contact with the wall for a time of 0.12 s and rebounds horizontally with a speed of $4.3\,m\,s^{-1}$.

(i) Use the information from **(b)(iii)** to calculate the change in momentum of the ball due to the collision.

change in momentum = ... $kg\,m\,s^{-1}$ [2]

(ii) Calculate the magnitude of the average force exerted on the ball by the wall.

average force = ... N [1]



23 – (9702/23_Summer_2020_Q2) – *Kinematics, Dynamics*

(a) State Newton's first law of motion.

.....

..... [1]

(b) A skier is pulled in a straight line along horizontal ground by a wire attached to a kite, as shown in Fig. 2.1.

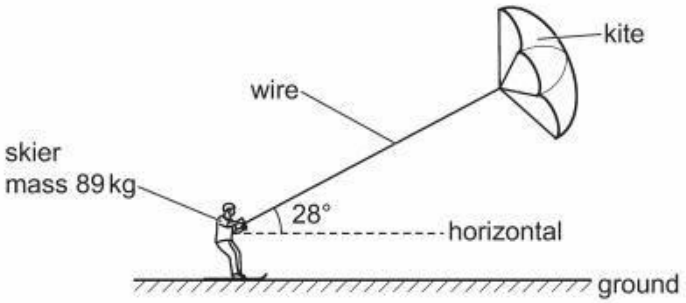


Fig. 2.1 (not to scale)

The mass of the skier is 89 kg. The wire is at an angle of 28° to the horizontal. The variation with time t of the velocity v of the skier is shown in Fig. 2.2.

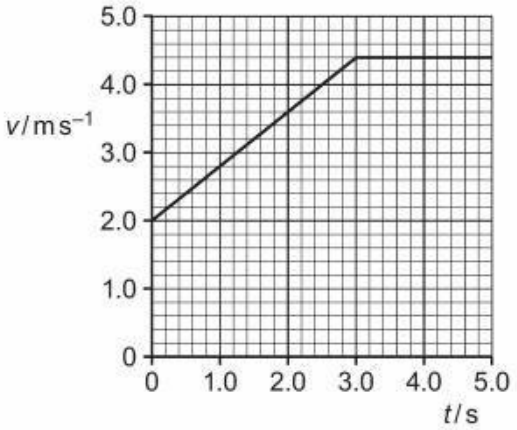
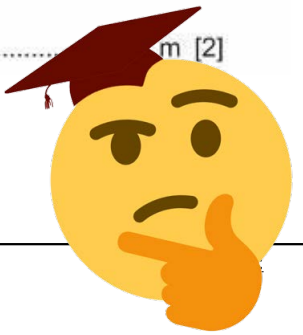


Fig. 2.2

(i) Use Fig. 2.2 to determine the distance moved by the skier from time $t = 0$ to $t = 5.0$ s.

distance = ... m [2]



(ii) Use Fig. 2.2 to show that the acceleration a of the skier is $0.80\,\mathrm{m\,s^{-2}}$ at time $t = 2.0\,\mathrm{s}$.

[2]

(iii) The tension in the wire at time $t = 2.0\,\mathrm{s}$ is $240\,\mathrm{N}$.

Calculate:

1. the horizontal component of the tension force acting on the skier

horizontal component of force = ... N [1]

2. the total resistive force R acting on the skier in the horizontal direction.

R = ... N [2]

(iv) The skier is now lifted upwards by a gust of wind. For a few seconds the skier moves horizontally through the air with the wire at an angle of 45° to the horizontal, as shown in Fig. 2.3.

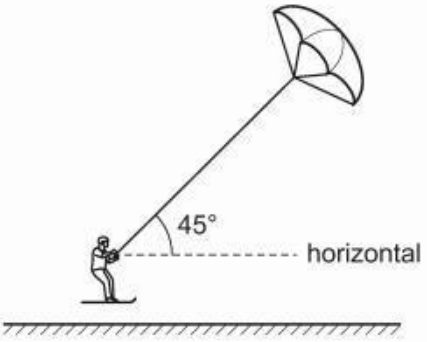
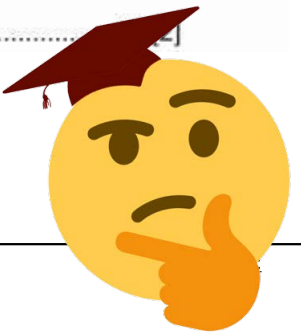


Fig. 2.3 (not to scale)

By considering the vertical components of the forces acting on the skier, determine the new tension in the wire when the skier is moving horizontally through the air.

tension = ... [2]



24 - (9702/22_Winter_2020_Q1) - *Motion In A Circle, Kinematics*

(a) Complete Table 1.1 by putting a tick (✓) in the appropriate column to indicate whether the listed quantities are scalars or vectors.

Table 1.1

quantity	scalar	vector
acceleration		
density		
temperature		
momentum		

[2]

(b) A toy train moves along a straight section of track. Fig. 1.1 shows the variation with time t of the distance d moved by the train.

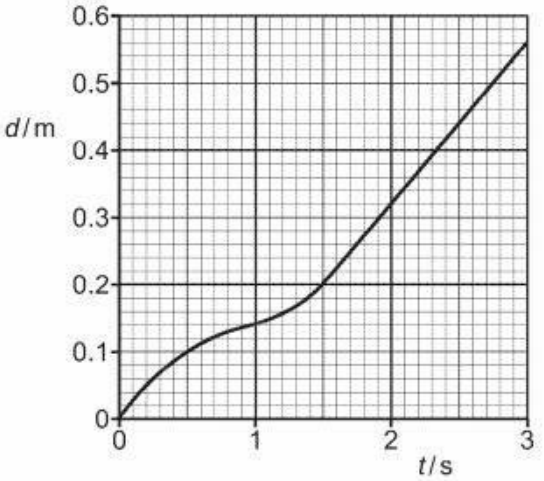
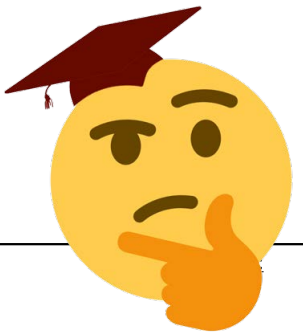


Fig. 1.1

(i) Describe qualitatively the motion of the train between time $t = 0$ and time $t = 1.0$ s.

.....

..... [1]



(ii) Determine the speed of the train at time $t = 2.0\,s$.

speed = ... $m\,s^{-1}$ [2]

(c) The straight section of track in **(b)** is part of the loop of track shown in Fig. 1.2.

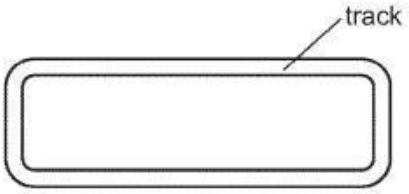


Fig. 1.2

The train completes exactly one lap of the loop.

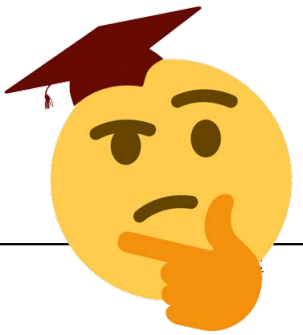
State and explain the average velocity of the train over the one complete lap.

.....

.....

..... [1]

[Total: 6]



25 – (9702/21_Winter_2020_Q2) – *Kinematics, Work, Energy & Power*

A small block is lifted vertically upwards by a toy aircraft, as illustrated in Fig. 2.1.

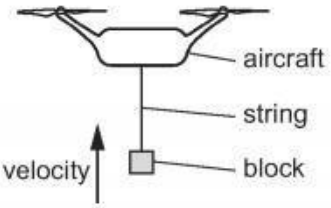


Fig. 2.1

As the block is moving upwards, the string breaks at time t = 0. The block initially continues moving upwards and then falls and hits the ground at time t = 0.90 s. The variation with time t of the velocity v of the block is shown in Fig. 2.2.

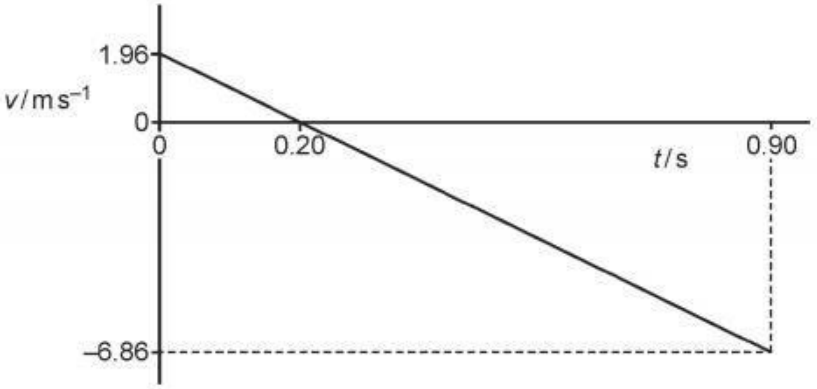


Fig. 2.2

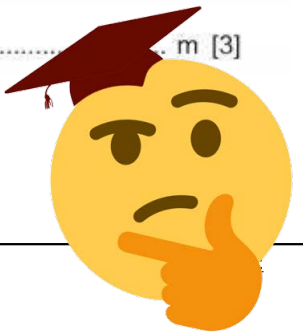
Air resistance is negligible.

(a) State the feature of the graph in Fig. 2.2 that shows the block has a constant acceleration.

..... [1]

(b) Use Fig. 2.2 to determine the height of the block above the ground when the string breaks at time t = 0.

height = ... m [3]



(c) The block has a weight of 0.86 N.

Calculate the difference in gravitational potential energy of the block between time $t = 0$ and time $t = 0.90$ s.

difference in gravitational potential energy = ... J [2]

(d) On Fig. 2.3, sketch a line to show the variation of the distance moved by the block with time t from $t = 0$ to $t = 0.20$ s. Numerical values of distance are not required.

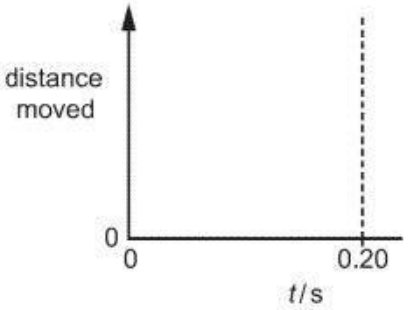


Fig. 2.3

[2]

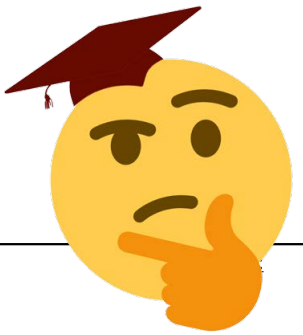
(e) A block of greater mass is now released from the same height with the same upward velocity. Air resistance is still negligible.

State and explain the effect, if any, of the increased mass on the speed with which the block hits the ground.

.....

..... [1]

[Total: 9]



26 – (9702/22_Winter_2020_Q2) – *Kinematics, Dynamics, Forces, Density & Pressure*

(a) A cylinder is suspended from the end of a string. The cylinder is stationary in water with the axis of the cylinder vertical, as shown in Fig. 2.1.

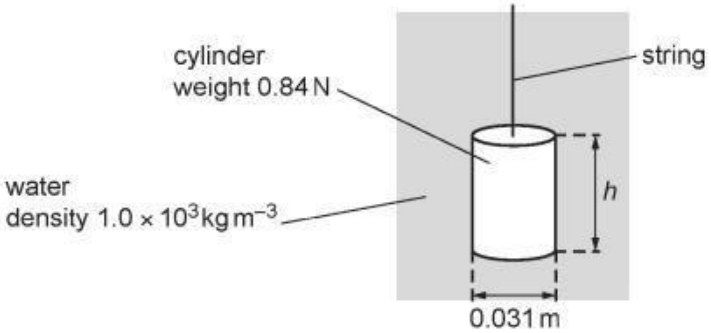


Fig. 2.1 (not to scale)

The cylinder has weight 0.84 N, height h and a circular cross-section of diameter 0.031 m. The density of the water is $1.0 \times 10^3 \text{ kg m}^{-3}$. The difference between the pressures on the top and bottom faces of the cylinder is 520 Pa.

(i) Calculate the height h of the cylinder.

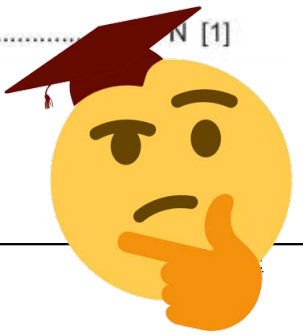
h = ... m [2]

(ii) Show that the upthrust acting on the cylinder is 0.39 N.

[2]

(iii) Calculate the tension T in the string.

T = ... N [1]



(b) The string is now used to move the cylinder in **(a)** vertically upwards through the water. The variation with time t of the velocity v of the cylinder is shown in Fig. 2.2.

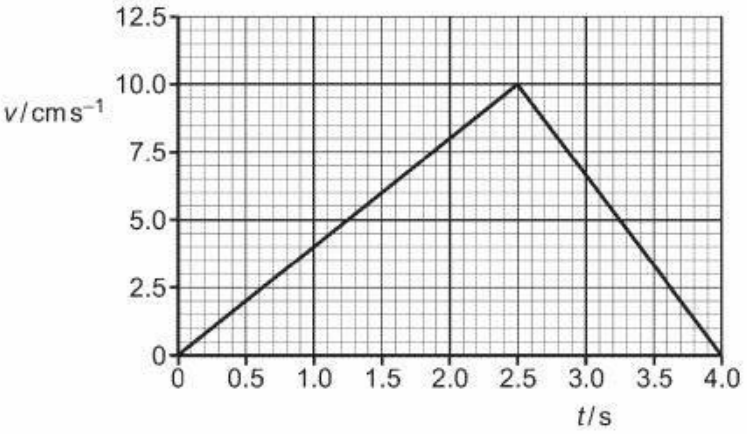


Fig. 2.2

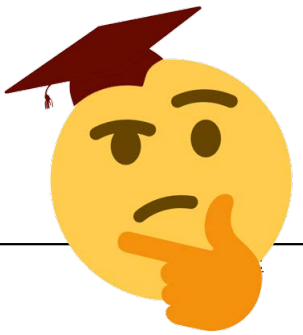
(i) Use Fig. 2.2 to determine the acceleration of the cylinder at time $t = 2.0\,s$.

acceleration = ... $m\,s^{-2}$ [2]

(ii) The top face of the cylinder is at a depth of 0.32 m below the surface of the water at time $t = 0$.

Use Fig. 2.2 to determine the depth of the top face below the surface of the water at time $t = 4.0\,s$.

depth = ... m [2]



(c) The cylinder in **(b)** is released from the string at time $t = 4.0\,\text{s}$. The cylinder falls, from rest, vertically downwards through the water. Assume that the upthrust acting on the cylinder remains constant as it falls.

(i) State the name of the force that acts on the cylinder when it is moving and does not act on the cylinder when it is stationary.

..... [1]

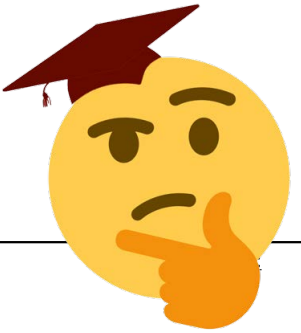
(ii) State and explain the variation, if any, of the acceleration of the cylinder as it falls downwards through the water.

.....

.....

..... [2]

[Total: 12]



27 - (9702/23_Winter_2020_Q3) - *Kinematics, Dynamics*

A ball is fired horizontally with a speed of $41.0\,m\,s^{-1}$ from a stationary cannon at the top of a hill. The ball lands on horizontal ground that is a vertical distance of 57 m below the cannon, as shown in Fig. 3.1.

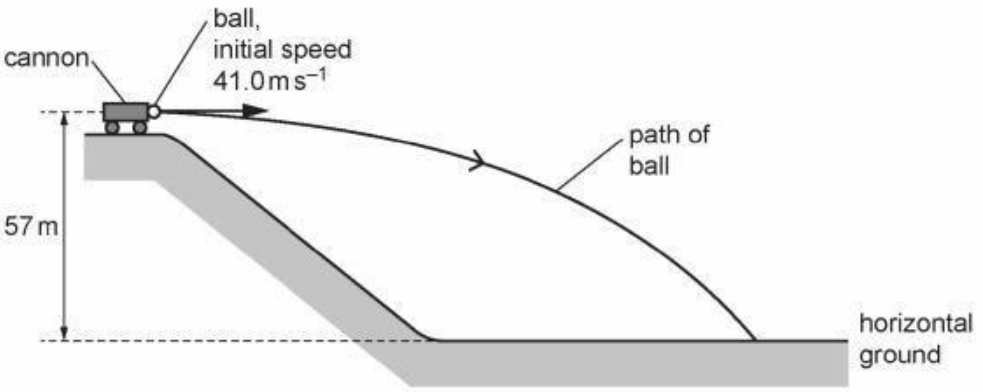


Fig. 3.1 (not to scale)

Assume air resistance is negligible.

(a) Show that the time taken for the ball to reach the ground, after being fired, is 3.4 s.

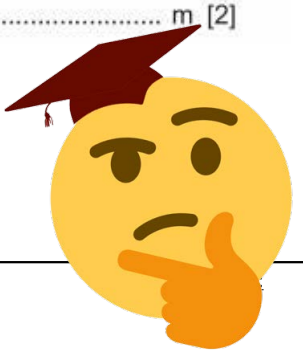
[2]

(b) Calculate the horizontal distance of the ball from the cannon at the point where the ball lands on the ground.

horizontal distance = ... m [1]

(c) Determine the magnitude of the displacement of the ball from the cannon at the point where the ball lands on the ground.

displacement = ... m [2]



(d) The ball leaves the cannon at time $t = 0$.

On Fig. 3.2, sketch a graph to show the variation of the magnitude v of the vertical component of the velocity of the ball with time t from $t = 0$ to $t = 3.4$ s.
Numerical values are not required.

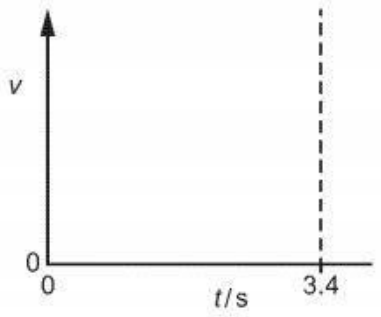


Fig. 3.2

[1]

(e) The cannon recoils horizontally with a speed of $0.340\,\text{m}\,\text{s}^{-1}$ when it fires the ball. The total mass of the ball and the cannon is 1480 kg. Assume that no external horizontal forces act on the ball-cannon system.

Determine, to three significant figures, the mass of the ball.

mass = ... kg [2]

(f) The cannon now fires a ball of smaller mass. Assume that air resistance is still negligible.

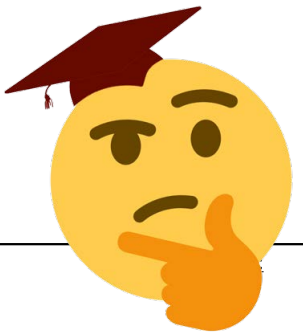
State and explain the change, if any, to the graph in Fig. 3.2 due to the decreased mass of the ball.

.....

.....

..... [2]

[Total: 10]



28 – (9702/22_Summer_2021_Q2) – *Kinematics, Dynamics*

A ball is thrown vertically downwards to the ground, as illustrated in Fig. 2.1.

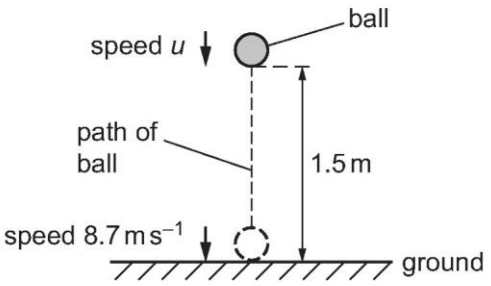


Fig. 2.1

The ball is thrown with speed u from a height of 1.5 m. The ball then hits the ground with speed 8.7 m s^{-1}. Assume that air resistance is negligible.

(a) Calculate speed u.

u = ... m s^{-1} [2]

(b) State how Newton's third law applies to the collision between the ball and the ground.

.....

.....

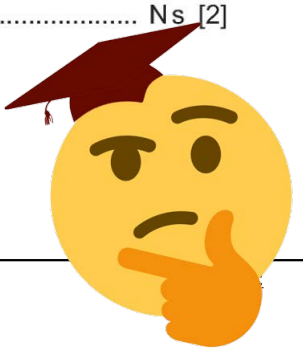
.....

..... [2]

(c) The ball is in contact with the ground for a time of 0.091 s. The ball rebounds vertically and leaves the ground with speed 5.4 m s^{-1}. The mass of the ball is 0.059 kg.

(i) Calculate the magnitude of the change in momentum of the ball during the collision.

change in momentum = ... N s [2]



(ii) Determine the magnitude of the average resultant force that acts on the ball during the collision.

average resultant force = ... N [1]

(iii) Use your answer in **(c)(ii)** to calculate the magnitude of the average force exerted by the ground on the ball during the collision.

average force = ... N [2]

(d) The ball was thrown downwards at time $t = 0$ and hits the ground at time $t = T$.

On Fig. 2.2, sketch a graph to show the variation of the speed of the ball with time t from $t = 0$ to $t = T$. Numerical values are not required.

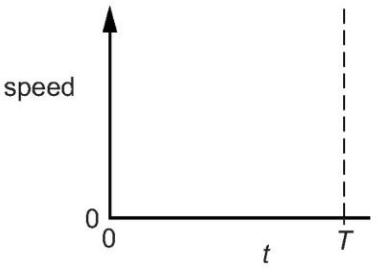


Fig. 2.2

[1]

(e) In practice, air resistance is not negligible.

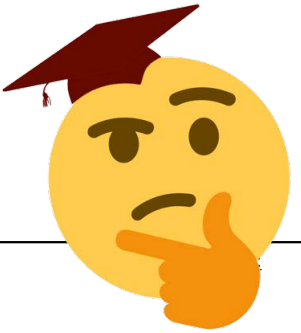
State and explain the variation, if any, with time t of the gradient of the graph in **(d)** when air resistance is not negligible.

.....

.....

.....

..... [2]



29 – (9702/23_Summer_2021_Q2) – *Kinematics*

(a) Define *acceleration*.

.....

..... [1]

(b) A stone falls vertically from the top of a cliff. Fig. 2.1 shows the variation with time t of the velocity v of the stone.

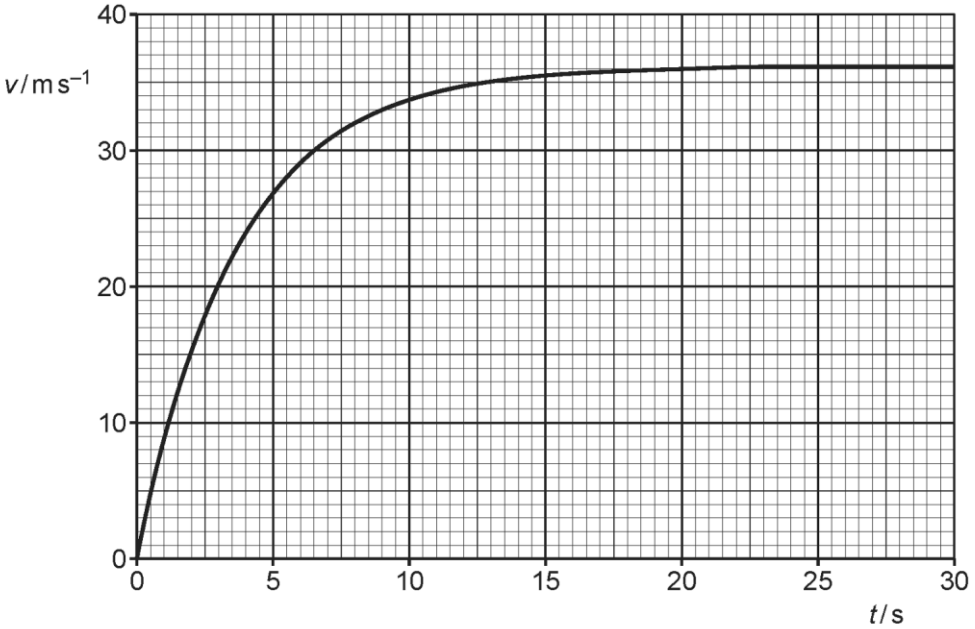


Fig. 2.1

(i) Explain, with reference to forces acting on the stone, the shape of the curve in Fig. 2.1.

.....

.....

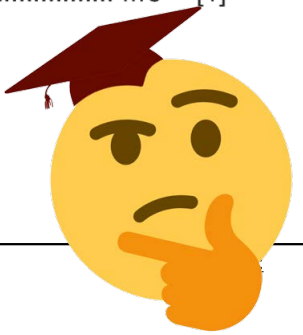
.....

.....

..... [3]

(ii) Use Fig. 2.1 to determine the speed of the stone when the resultant force on it is zero.

speed = ... $m\,s^{-1}$ [1]



(iii) Use Fig. 2.1 to calculate the approximate height through which the stone falls between $t = 0$ and $t = 30\,\text{s}$.

height = ... m [3]

(iv) On Fig. 2.2, sketch the variation with t of the acceleration a of the stone between $t = 0$ and $t = 30\,\text{s}$.

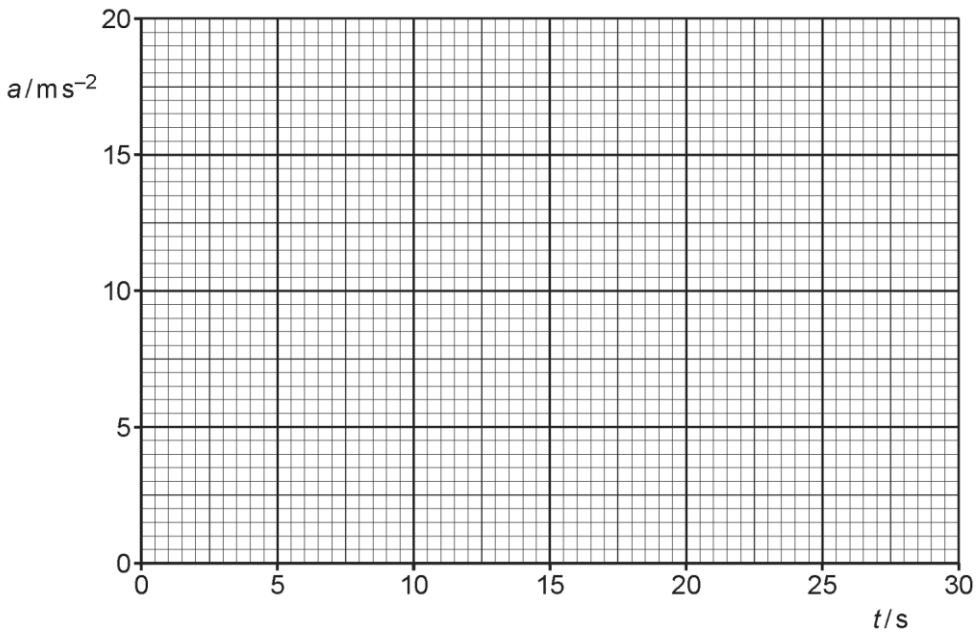
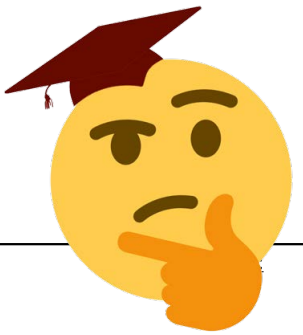


Fig. 2.2

[3]



30 – (9702/21_Winter_2021_Q2) – *Kinematics, Work, Energy & Power*

(a) Define *momentum*.

.....

..... [1]

(b) Two balls X and Y, of equal diameter but different masses 0.24 kg and 0.12 kg respectively, slide towards each other on a frictionless horizontal surface, as shown in Fig. 2.1.

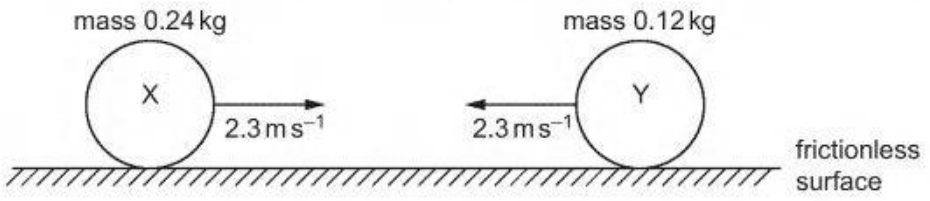


Fig. 2.1

Both balls have initial speed 2.3 m s^{-1} before they collide with each other. Fig. 2.2 shows the variation with time t of the force F_Y exerted on ball Y by ball X during the collision.

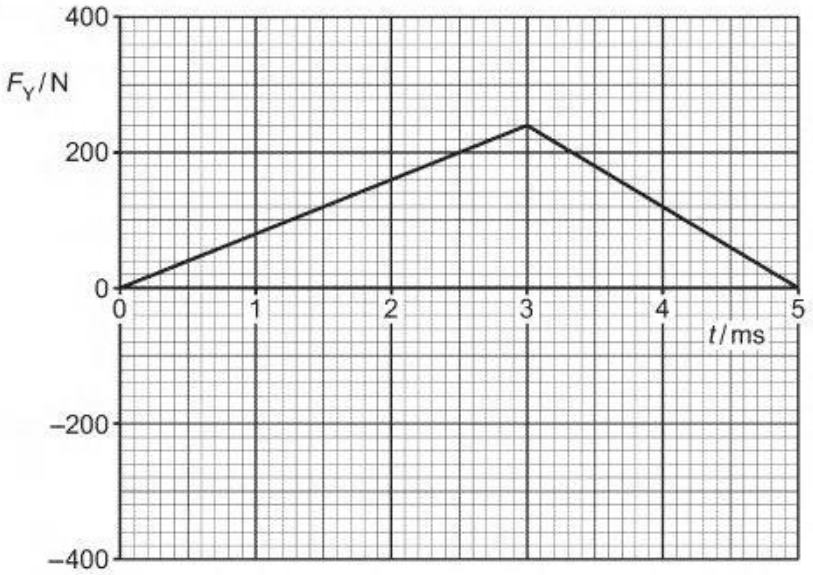
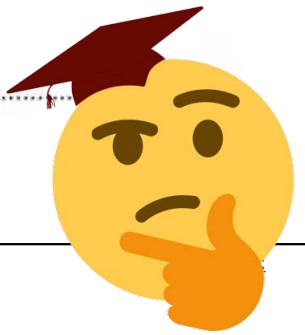


Fig. 2.2

(i) Calculate the kinetic energy of ball X before the collision.

kinetic energy = ...



(ii) The area enclosed by the lines and the time axis in Fig. 2.2 represents the change in momentum of ball Y during the collision.

Determine the magnitude of the change in momentum of ball Y.

change in momentum = ... N s [2]

(iii) Calculate the magnitude of the velocity of ball Y after the collision.

velocity = ... $m\,s^{-1}$ [2]

(c) On Fig. 2.3, sketch the variation with time t of the force F_X exerted on ball X by ball Y during the collision in **(b)**.

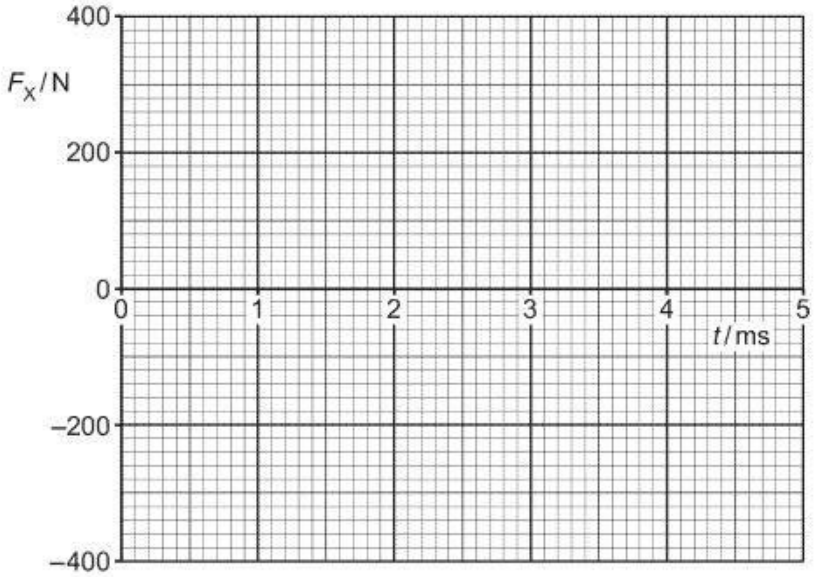
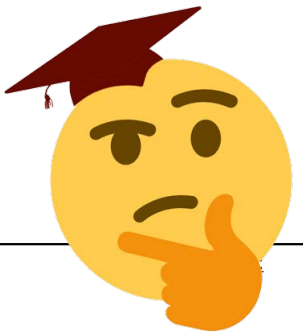


Fig. 2.3

[3]



31 - (9702/23_Winter_2021_Q3) - *Kinematics*

(a) Define *velocity*.

.....

..... [1]

(b) A remote-controlled toy aircraft is flying horizontally in a wind. Fig. 3.1 shows the velocity vectors, to scale, of the wind and of the aircraft in still air.

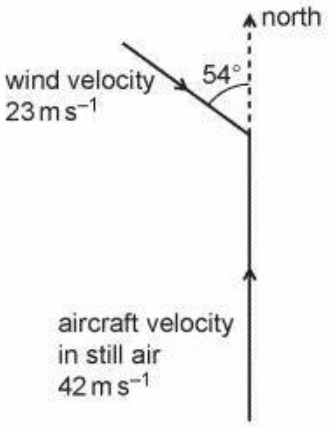
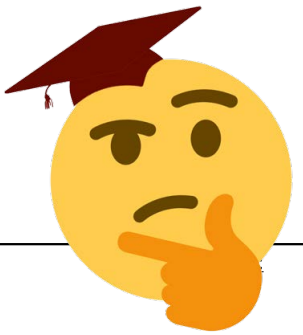


Fig. 3.1

The velocity of the aircraft in still air is $42\,m\,s^{-1}$ to the north. The velocity of the wind is $23\,m\,s^{-1}$ in a direction of 54° east of south.

Determine the magnitude of the resultant velocity of the aircraft.

magnitude of velocity = ... $m\,s^{-1}$ [2]



(c) The engine of the aircraft in **(b)** stops. The aircraft then glides towards the ground with a constant velocity at an angle θ to the horizontal, as illustrated in Fig. 3.2.

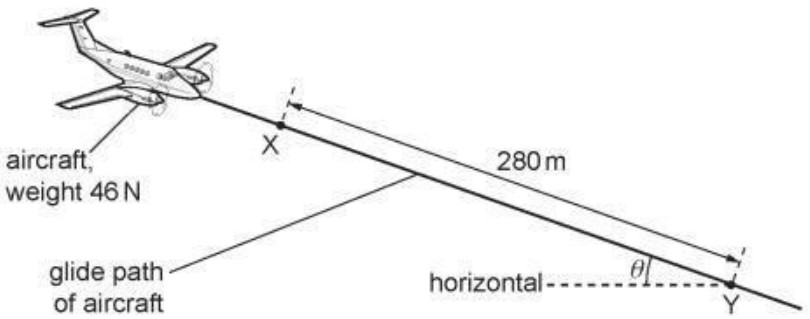


Fig. 3.2 (not to scale)

The aircraft has a weight of 46 N and travels a distance of 280 m from point X to point Y. The change in gravitational potential energy of the aircraft for its movement from X to Y is 6100 J.

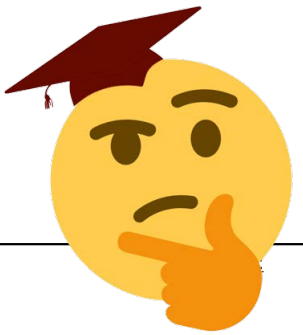
Assume that there is now no wind.

(i) Calculate angle θ.

θ = ... ° [3]

(ii) Calculate the magnitude of the force acting on the aircraft due to air resistance.

force = ... N [2]



(d) The aircraft in **(c)** travels from X to Y in a time of 14 s. Fig. 3.3 shows that, as the aircraft travels from X to Y, it moves directly towards an observer who is standing on the ground.

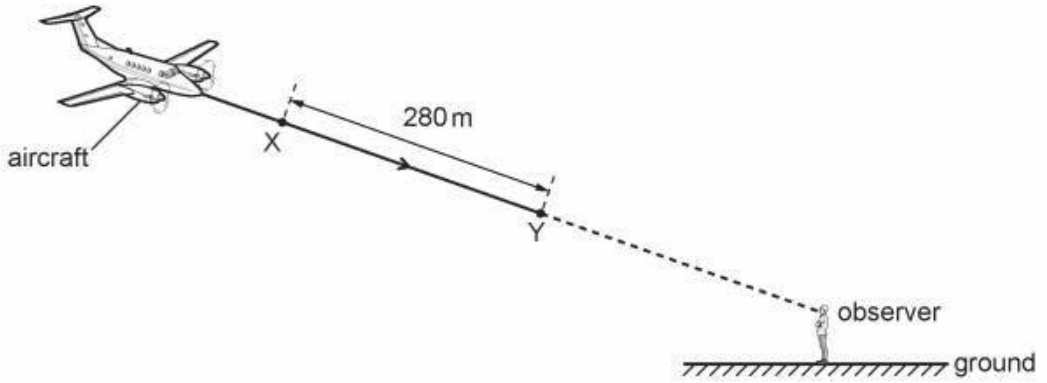
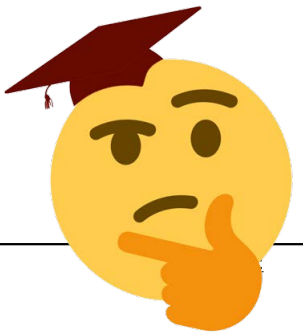


Fig. 3.3 (not to scale)

The aircraft emits sound as it travels from X to Y. The observer hears sound of frequency 450 Hz. The speed of the sound in the air is 340 m s^{-1}.

Calculate the frequency of the sound that is emitted by the aircraft.

frequency = ... Hz [3]



32 - (9702/21_Summer_2022_Q1) - *Kinematics*

(a) Define velocity.

.....

..... [1]

(b) A rock of mass 7.5 kg is projected vertically upwards from the surface of a planet. The rock leaves the surface of the planet with a speed of $4.0\,\mathrm{m\,s^{-1}}$ at time $t = 0$. The variation with time t of the velocity v of the rock is shown in Fig. 1.1.

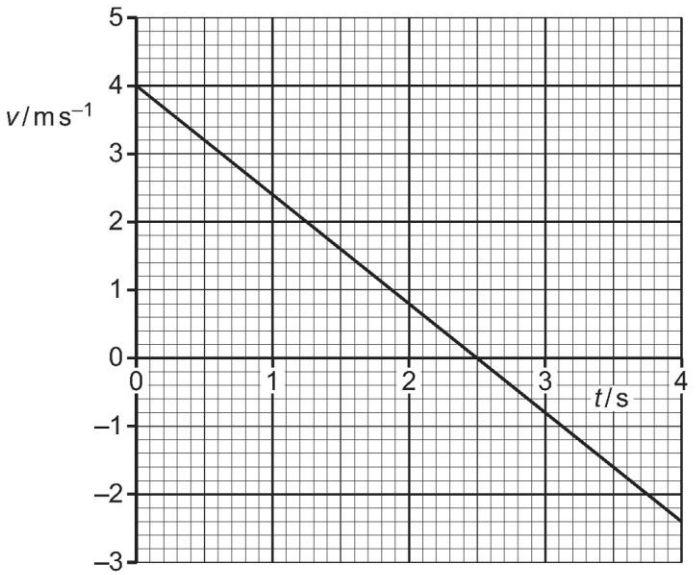
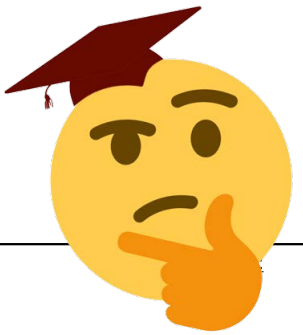


Fig. 1.1

Assume that the planet does not have an atmosphere and that the viscous force acting on the rock is always zero.

(i) Determine the height of the rock above the surface of the planet at time $t = 4.0$ s.

height = ... m [3]



(ii) Determine the change in the momentum of the rock from time $t = 0$ to time $t = 4.0$ s.

change in momentum = ... N s [2]

(iii) Determine the weight W of the rock on this planet.

W = ... N [2]

(c) In practice, the planet in **(b)** does have an atmosphere that causes a viscous force to act on the moving rock.

State and explain the variation, if any, in the resultant force acting on the rock as it moves vertically upwards.

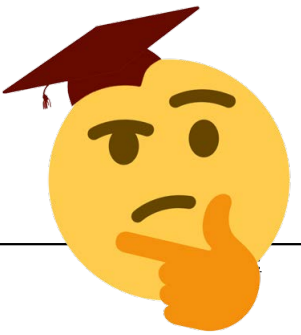
.....

.....

.....

..... [2]

[Total: 10]



33 - (9702/22_Summer_2022_Q2) - *Kinematics*

A sphere is attached by a metal wire to the horizontal surface at the bottom of a river, as shown in Fig. 2.1.

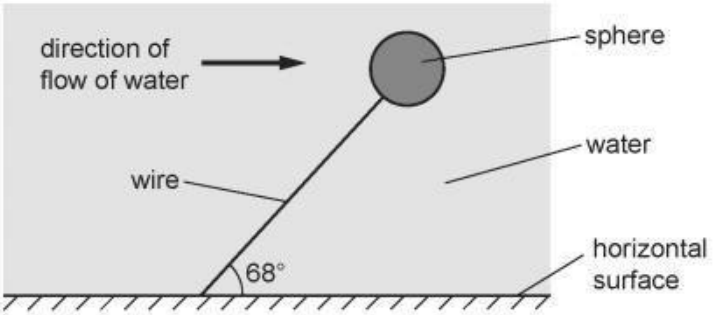


Fig. 2.1 (not to scale)

The sphere is fully submerged and in equilibrium, with the wire at an angle of 68° to the horizontal surface. The weight of the sphere is 32 N. The upthrust acting on the sphere is 280 N. The density of the water is $1.0 \times 10^3\,kg\,m^{-3}$.

Assume that the force on the sphere due to the water flow is in a horizontal direction.

(a) By considering the components of force in the vertical direction, determine the tension in the wire.

tension = ... N [2]

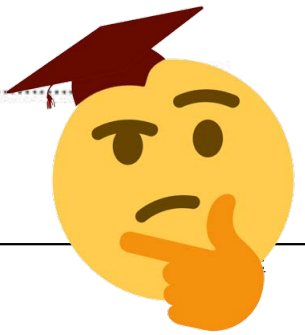
(b) For the sphere, calculate:

(i) the volume

volume = ... m^3 [1]

(ii) the density.

density = ...



(c) The centre of the sphere is initially at a height of 6.2 m above the horizontal surface. The speed of the water then increases, causing the sphere to move to a different position. This movement of the sphere causes its gravitational potential energy to decrease by 77 J.

Calculate the final height of the centre of the sphere above the horizontal surface.

height = ... m [3]

(d) The extension of the wire increases when the sphere changes position as described in **(c)**. The wire obeys Hooke's law.

(i) State a symbol equation that gives the relationship between the tension T in the wire and its extension x. Identify any other symbol that you use.

.....

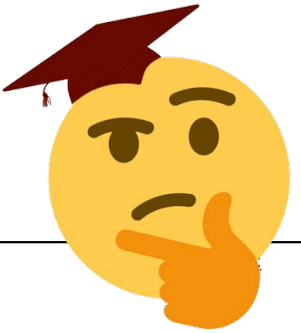
..... [1]

(ii) Before the sphere changed position, the initial elastic potential energy of the wire was 0.65 J. The change in position of the sphere causes the extension of the wire to double.

Calculate the final elastic potential energy of the wire after the sphere has changed position.

final elastic potential energy = ... J [2]

[Total: 11]



34 – (9702/23_Summer_2022_Q2) – *Kinematics*

An archer releases an arrow towards a target at a velocity of $65.0\,m\,s^{-1}$ at an angle of 4.30° above the horizontal, as shown in Fig. 2.1.

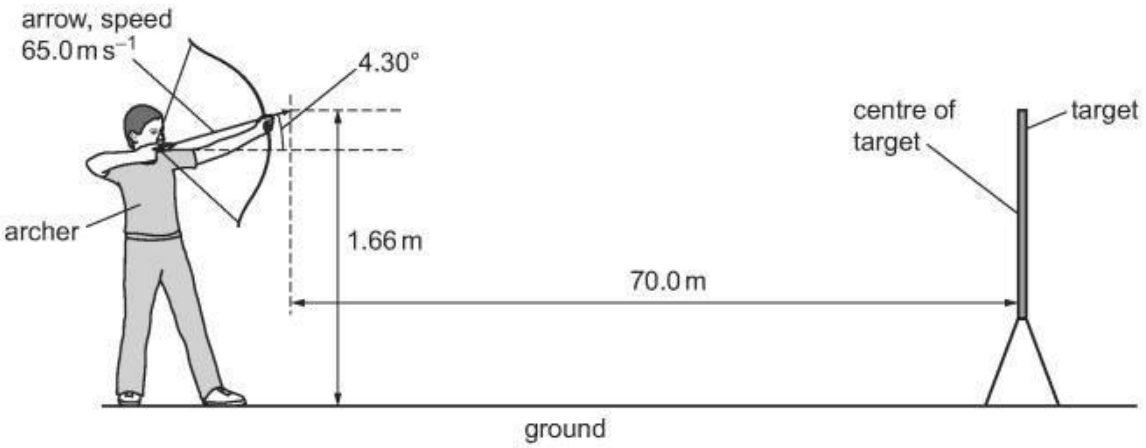


Fig. 2.1 (not to scale)

When released, the tip of the arrow is a horizontal distance of 70.0 m from the target and 1.66 m above the horizontal ground.

The arrow hits the centre of the target.

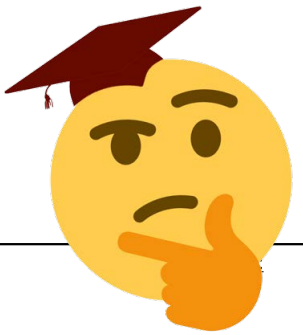
Assume that air resistance is negligible and that all the mass of the arrow is at its tip.

(a) Show that the time taken for the arrow to reach the target is 1.08 s.

[2]

(b) Calculate the height of the centre of the target above the ground.

height above ground = ... m [3]



(c) By considering energy changes, state and explain how the final kinetic energy of the arrow as it hits the target compares with its initial kinetic energy immediately after release. A numerical calculation is not required.

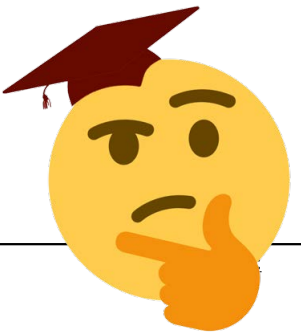
.....

.....

.....

..... [2]

[Total: 7]



35 - (9702/22_Summer_2022_Q3) - *Kinematics*

A man standing on a wall throws a small ball vertically upwards with a velocity of $5.6\,m\,s^{-1}$. The ball leaves his hand when it is at a height of 3.1 m above the ground, as shown in Fig. 3.1.

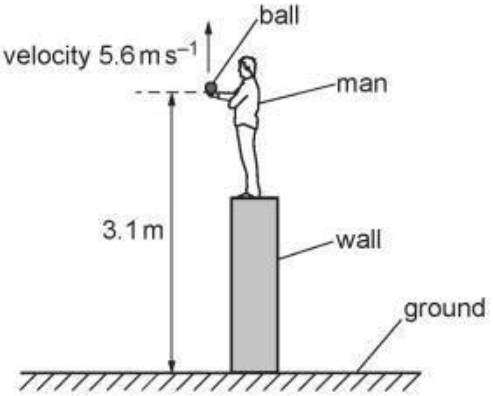


Fig. 3.1 (not to scale)

Assume that air resistance is negligible.

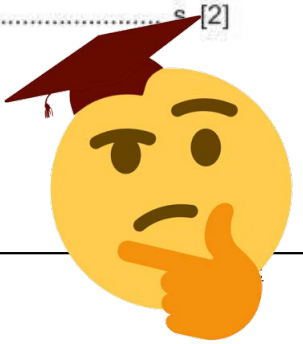
(a) Show that the ball reaches a maximum height above the ground of 4.7 m.

[2]

(b) The man does not catch the ball as it falls.

Calculate the time taken for the ball to fall from its maximum height to the ground.

time taken = ... s [2]



(c) The ball leaves the man's hand at time $t = 0$ and hits the ground at time $t = T$.

On Fig. 3.2, sketch a graph to show the variation of the velocity v of the ball with time t from $t = 0$ to $t = T$. Numerical values of v and t are not required. Assume that v is positive in the upward direction.

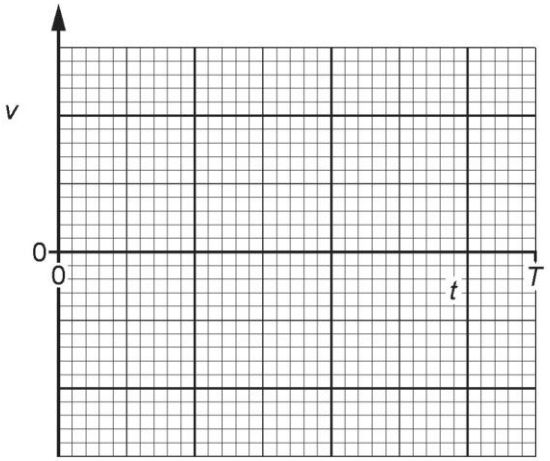


Fig. 3.2

[3]

(d) State what is represented by the gradient of the graph in **(c)**.

..... [1]

(e) The man now throws a second ball with the same velocity and from the same height as the first ball. The mass of the second ball is greater than that of the first ball. Assume that air resistance is still negligible.

For the first and second balls, compare:

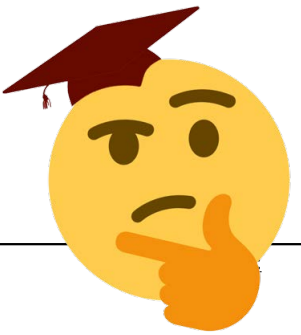
(i) the magnitudes of their accelerations

..... [1]

(ii) the speeds with which they hit the ground.

..... [1]

[Total: 10]



36 – (9702/23_Summer_2022_Q3) – *Kinematics*

(a) Define velocity.

.....

..... [1]

(b) A constant driving force of 2400 N acts on a car of mass 1200 kg. The car accelerates from rest in a straight line along a horizontal road.

Assume that the resistive forces acting on the car are negligible.

(i) Calculate the acceleration of the car.

acceleration = ... $m\,s^{-2}$ [1]

(ii) On Fig. 3.1, sketch a graph showing the variation with time t of the velocity v of the car for the first 20 seconds of its motion.

Label this line A.

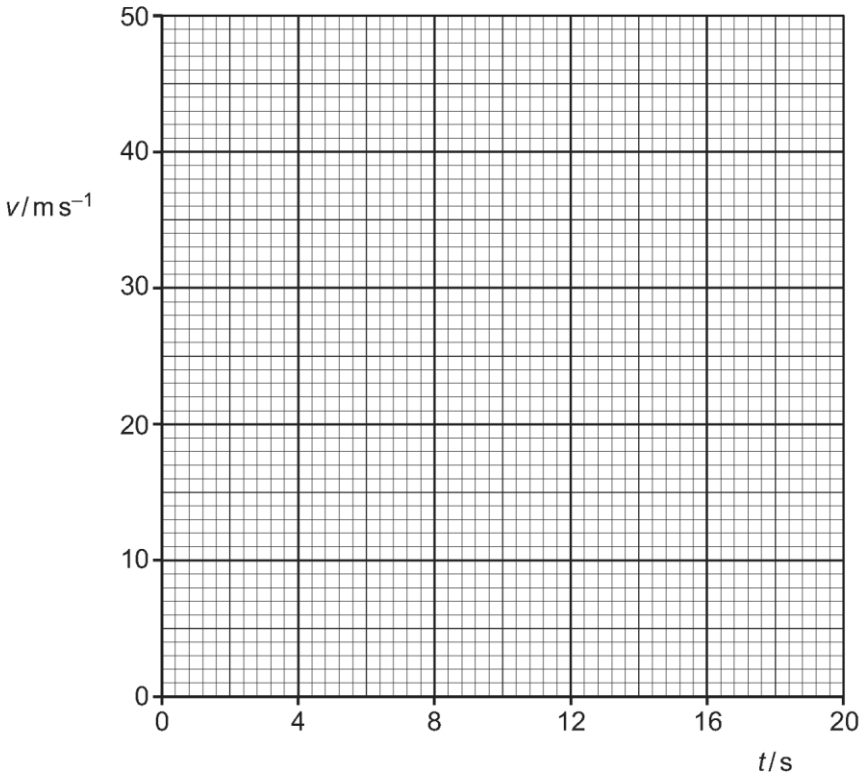
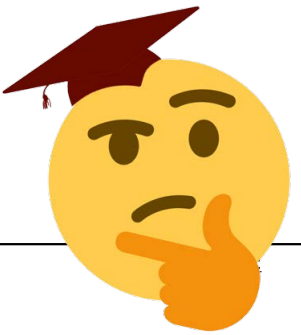


Fig. 3.1

[2]



(c) In reality, a resistive force due to air resistance acts on the car in **(b)**. This resistive force increases with speed until it becomes equal in magnitude to the driving force at time t = 12 s.

(i) On Fig. 3.1, sketch a second line to show the variation with time t of the velocity v of the car for the first 20 seconds of its motion. Label this line B. [3]

(ii) At time t = 20 s, the driving force is increased to 3000 N and remains constant at this value.

Describe how the velocity of the car changes due to this increase in the driving force.

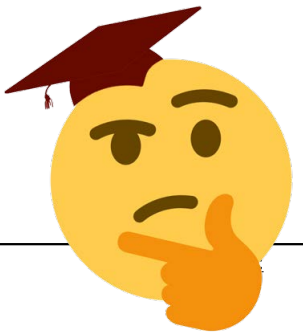
.....

.....

.....

..... [2]

[Total: 9]



37 – (9702/21_Summer_2023_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

A rigid uniform beam of weight W is connected to a fixed support by a hinge, as shown in Fig. 2.1.

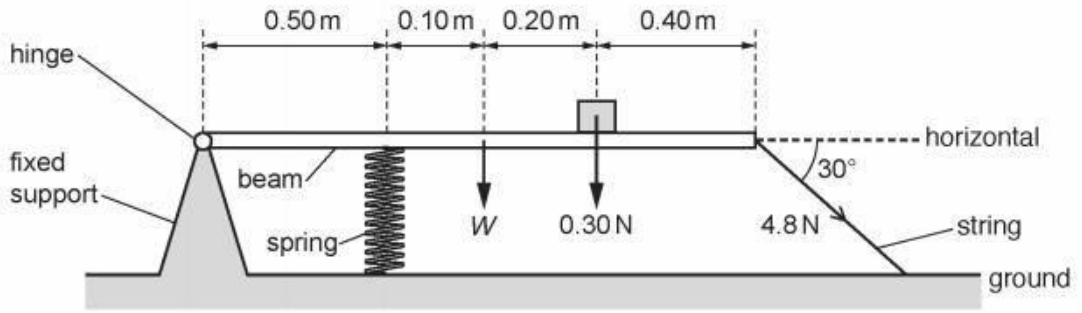


Fig. 2.1 (not to scale)

A compressed spring exerts a total force of 8.2 N vertically upwards on the horizontal beam. A block of weight 0.30 N rests on the beam. The right-hand end of the beam is connected to the ground by a string at an angle of 30° to the horizontal. The tension in the string is 4.8 N. The distances along the beam are shown in Fig. 2.1.

The beam is in equilibrium. Assume that the hinge is frictionless.

(a) **(i)** Show that the vertical component of the tension in the string is 2.4 N.

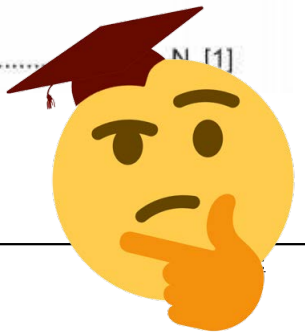
[1]

(ii) By taking moments about the hinge, determine the weight W of the beam.

W = ... N [3]

(iii) Calculate the horizontal component of the force exerted on the beam by the hinge.

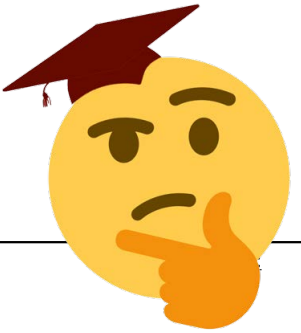
force = ... N [1]



(b) The spring obeys Hooke's law and has an elastic potential energy of 0.32 J.

Calculate the compression of the spring.

compression = ... m [2]



(c) The string is cut so that the spring extends upwards. This causes the beam to rotate and launch the block into the air. The block reaches its maximum height and then falls back to the ground.

Fig. 2.2 shows part of the path of the block in the air shortly before it hits the horizontal ground.

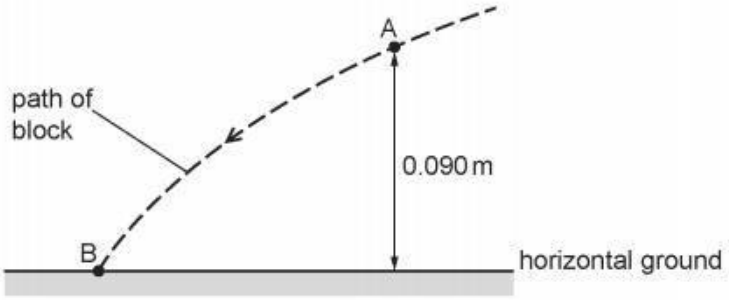


Fig. 2.2 (not to scale)

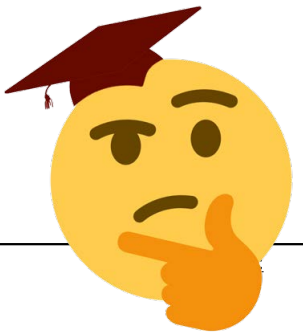
The block is at a height of 0.090 m above the ground when it passes through point A. The block has a kinetic energy of 0.044 J when it hits the ground at point B.
Air resistance is negligible.

(i) Calculate the decrease in the gravitational potential energy of the block for its movement from A to B.

decrease in gravitational potential energy = ... J [2]

(ii) Use your answer in **(c)(i)** and conservation of energy to determine the speed of the block at point A.

speed = ... $m\,s^{-1}$ [3]



(iii) By reference to the force on the block, explain why the horizontal component of the velocity of the block remains constant as it moves from A to B.

.....

..... [1]

(iv) The block passes through point A at time t_A and arrives at point B at time t_B.

On Fig. 2.3, sketch a graph to show the variation of the magnitude of the vertical component v_Y of the velocity of the block with time t from $t = t_A$ to $t = t_B$.
Numerical values of v_Y are not required.

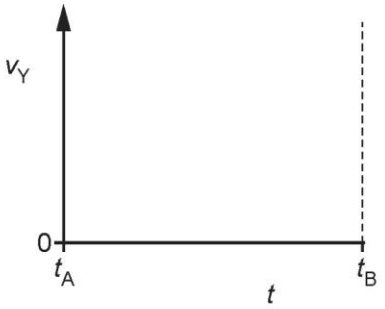


Fig. 2.3

[1]

38 – (9702/22_Summer_2023_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a) State what is meant by the centre of gravity of an object.

.....

..... [1]

(b) Two blocks are on a horizontal beam that is pivoted at its centre of gravity, as shown in Fig. 2.1.

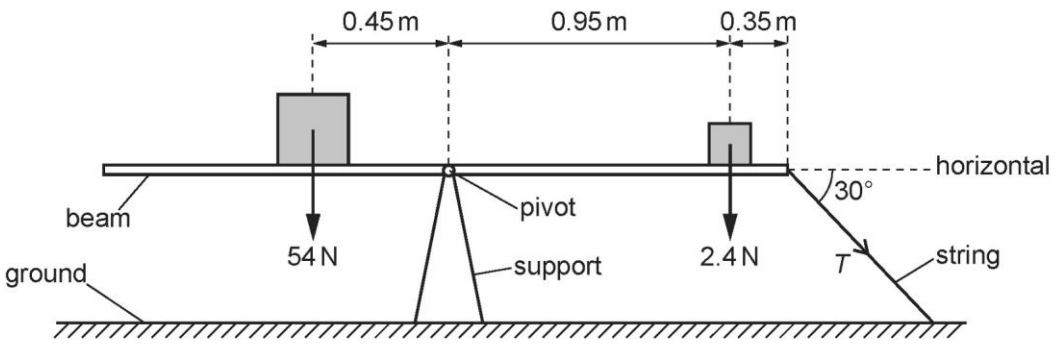


Fig. 2.1 (not to scale)

A large block of weight 54 N is a distance of 0.45 m from the pivot. A small block of weight 2.4 N is a distance of 0.95 m from the pivot and a distance of 0.35 m from the right-hand end of the beam.

The right-hand end of the beam is connected to the ground by a string that is at an angle of 30° to the horizontal. The beam is in equilibrium.

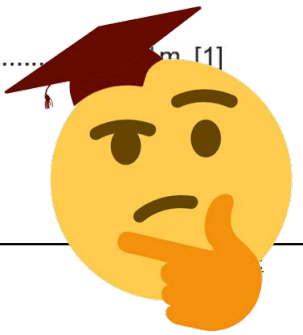
(i) By taking moments about the pivot, calculate the tension T in the string.

T = ... N [3]

(ii) The string is cut so that the beam is no longer in equilibrium.

Calculate the magnitude of the resultant moment about the pivot acting on the beam immediately after the string is cut.

resultant moment = ... m [1]



(c) The beam in **(b)** rotates when the string is cut and the small block of weight 2.4 N is projected through the air. Fig. 2.2 shows the last part of the path of the block before it hits the ground at point Y.

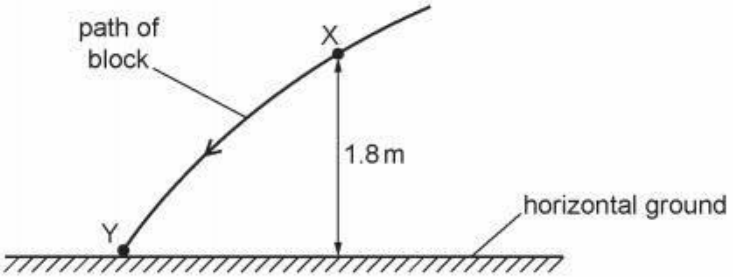


Fig. 2.2 (not to scale)

At point X on the path, the block has a speed of $3.4\,m\,s^{-1}$ and is at a height of 1.8 m above the horizontal ground. Air resistance is negligible.

(i) Calculate the decrease in the gravitational potential energy of the block for its movement from X to Y.

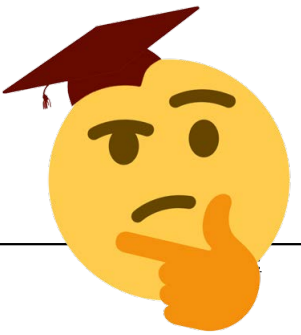
decrease in gravitational potential energy = ... J [2]

(ii) Use your answer to **(c)(i)** and conservation of energy to determine the kinetic energy of the block at Y.

kinetic energy = ... J [3]

(iii) State the variation, if any, in the direction of the acceleration of the block as it moves from X to Y.

..... [1]



(iv) The block passes point X at time t_X and arrives at point Y at time t_Y.

On Fig. 2.3, sketch a graph to show the variation of the magnitude of the horizontal component of the velocity of the block with time from t_X to t_Y.
Numerical values are not required.

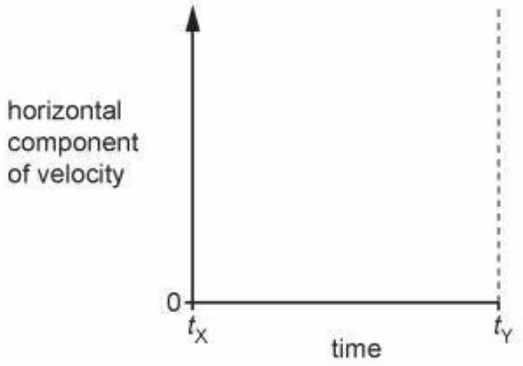


Fig. 2.3

[1]

39 – (9702/22_Summer_2023_Q3) – *Dynamics, Kinematics*

A block is pulled by a force X in a straight line along a rough horizontal surface, as shown in Fig. 3.1.

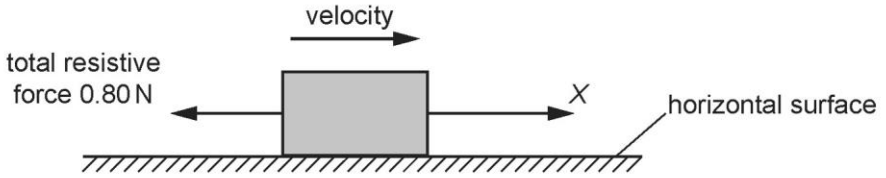


Fig. 3.1

Assume that the total resistive force opposing the motion of the block is 0.80 N at all speeds of the block.

The variation with time t of the magnitude of the force X is shown in Fig. 3.2.

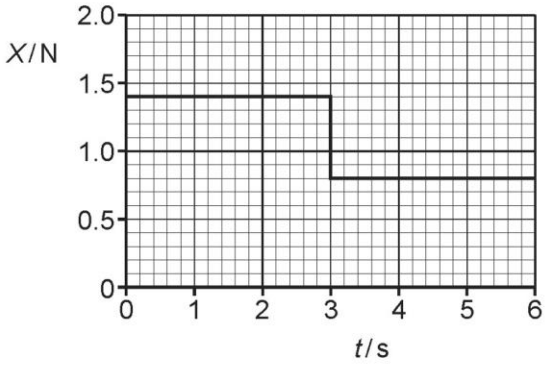


Fig. 3.2

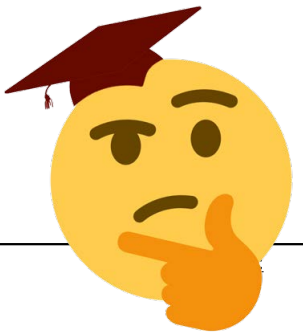
(a) **(i)** Define force.

.....

..... [1]

(ii) Determine the change in momentum of the block from time t = 0 to time t = 3.0 s.

change in momentum = ... kg m s^{-1} [2]



(b) **(i)** Describe and explain the motion of the block between time t = 3.0 s and time t = 6.0 s.

.....

.....

.....

..... [2]

(ii) Force X produces a total power of 2.0 W when moving the block between time t = 3.0 s and time t = 6.0 s.

Calculate the distance moved by the block during this time interval.

distance = ... m [3]

(c) The block is at rest at time t = 0.

On Fig. 3.3, sketch a graph to show the variation of the momentum of the block with time t from t = 0 to t = 6.0 s.
Numerical values of momentum are not required.

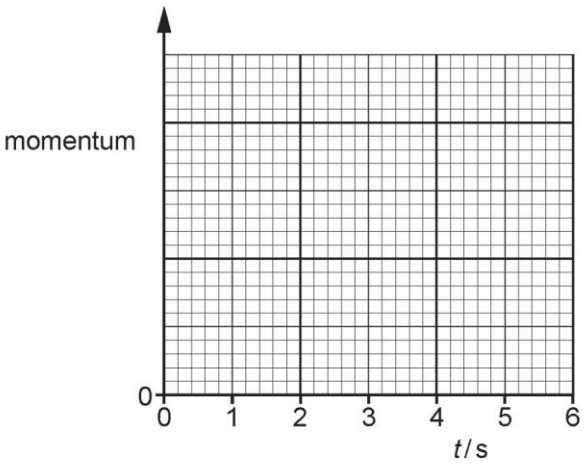
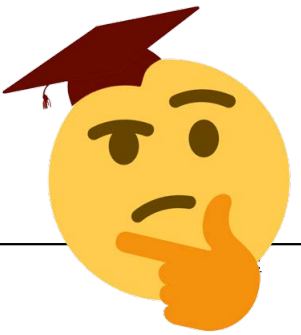


Fig. 3.3

[2]



40 – (9702/23_Summer_2023_Q1) – *Physical Quantities & Units, Kinematics*

A well has a depth of 36 m from ground level to the surface of the water in the well, as shown in Fig. 1.1.

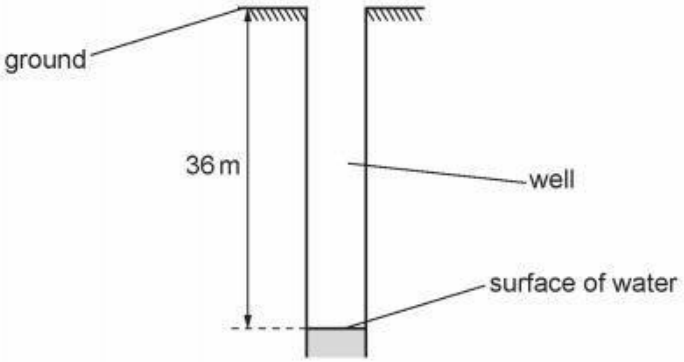


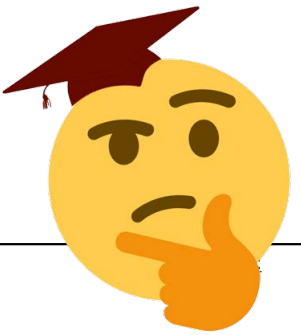
Fig. 1.1 (not to scale)

A student wishes to find the depth of the well. The student plans to drop a stone down the well and record the time taken from releasing the stone to hearing the splash made by the stone as it enters the water.

(a) Assume that air resistance is negligible and that the stone is released from rest.

Calculate the time taken for the stone to fall from ground level to the surface of the water.

time = ... s [2]



(b) The time recorded by the student using a stop-watch is not equal to the time in **(a)**.

Suggest **three** possible reasons, other than the effect of air resistance, for this difference.

1 .....

.....

2 .....

.....

3 .....

.....

[3]

(c) The student repeats the experiment three times and uses the results to calculate the depth of the well. The values are shown in Table 1.1.

Table 1.1

	1st experiment	2nd experiment	3rd experiment
depth/m	54.4	53.9	54.1

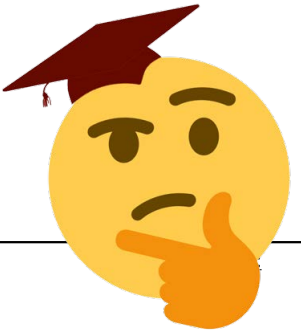
The true depth of the well is 36.0 m. Explain why these results may be described as precise but not accurate.

.....

.....

.....

..... [2]



41 – (9702/21_Winter_2023_Q3) – *Kinematics*

A trolley A moves along a horizontal surface at a constant velocity towards another trolley B which is moving at a lower constant speed in the same direction. Fig. 3.1 shows the trolleys at time $t = 0$.

Fig. 3.1

Table 3.1 shows data for the trolleys.

Table 3.1

trolley	mass / kg	initial speed / m s^{-1}
A	0.25	0.48
B	0.75	0.12

The two trolleys collide elastically and then separate. Resistive forces are negligible.

Fig. 3.2 shows the variation with time t of the velocity v for trolley B.

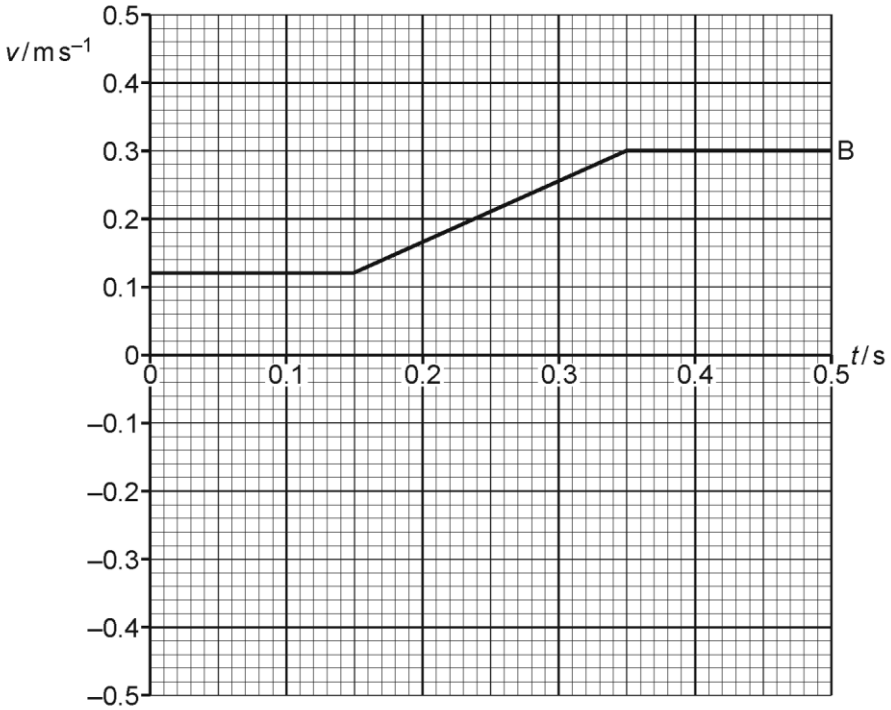
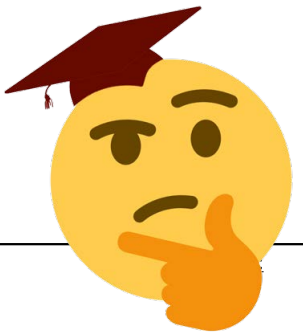


Fig. 3.2



(a) State what is represented by the area under a velocity–time graph.

..... [1]

(b) Use Table 3.1 and Fig. 3.2 to determine:

(i) the acceleration of trolley B during the collision

acceleration of B = ... $m\,s^{-2}$ [2]

(ii) the magnitude and direction of the final velocity of trolley A.

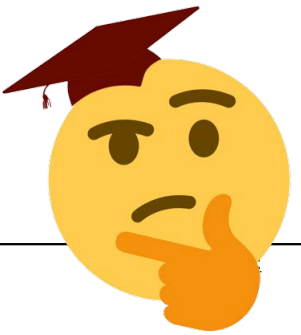
magnitude = ... $m\,s^{-1}$

direction .....

[3]

(c) On Fig. 3.2, sketch the variation of the velocity of trolley A with time t from $t = 0$ to $t = 0.50\,s$.

[3]



42 – (9702/22_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a) In the following list, underline **all** quantities that are SI base quantities.

charge electric current force time [1]

(b) Under certain conditions, the distance s moved in a straight line by an object in time t is given by

$$s = \frac{1}{2}at^2$$

where a is the acceleration of the object.

State **two** conditions under which the above expression applies to the motion of the object.

1 .....

2 .....
[2]

(c) The variation with time t of the velocity v of a car that is moving in a straight line is shown in Fig. 1.1.

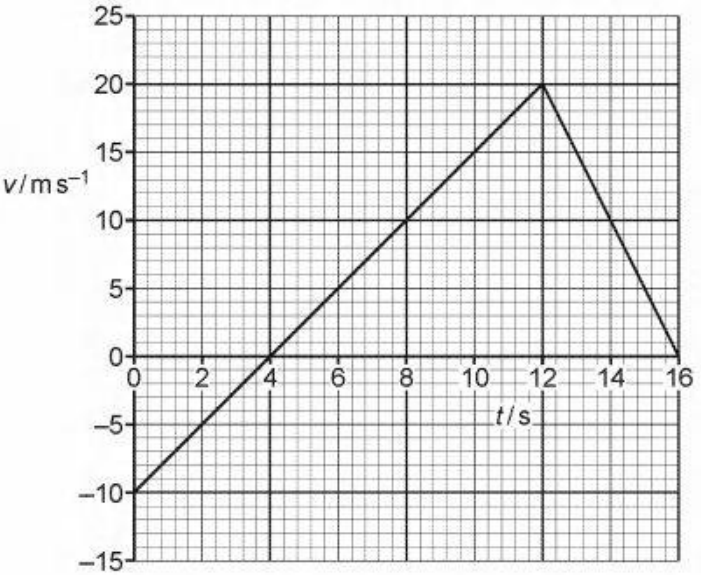


Fig. 1.1

(i) Compare, qualitatively, the acceleration of the car at time t = 8.0 s and at time t = 14.0 s in terms of:

- magnitude

.....

.....

- direction.

.....

.....
[2]

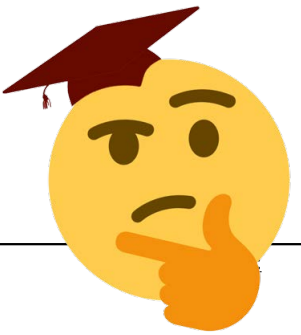
(ii) Determine the magnitude of the acceleration of the car at time t = 4.0 s.

acceleration = ... $m\,s^{-2}$ [2]

(iii) The car is at point X at time t = 0.

Determine the magnitude of the displacement of the car from X at time t = 12.0 s.

displacement = ... m [2]



43 – (9702/23_Winter_2023_Q2) – *Kinematics*

A ball on horizontal ground is kicked towards a vertical wall. Fig. 2.1 shows the path of the ball.

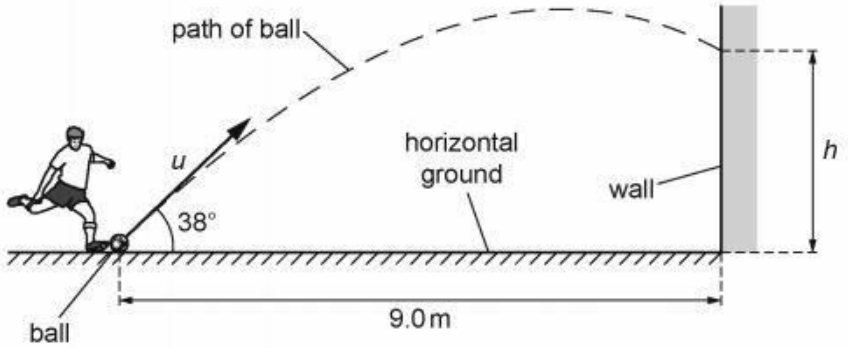


Fig. 2.1 (not to scale)

The ball has an initial velocity u at an angle of 38° to the ground. The ball travels a horizontal distance of 9.0 m before striking the wall at a height h above the ground. The horizontal component u_H of the initial velocity of the ball is $9.5\,m\,s^{-1}$.

Air resistance is negligible.

(a) **(i)** Show that the time t for the ball to reach the wall is 0.95 s.

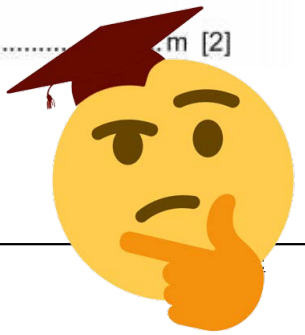
[1]

(ii) Calculate the vertical component u_V of the initial velocity of the ball.

u_V = ... $m\,s^{-1}$ [2]

(iii) Determine h.

h = ... m [2]

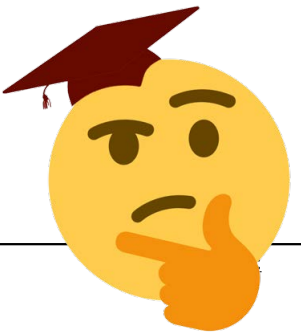


(b) The speed of the ball just after striking the wall is less than its speed just before striking the wall.

State what this indicates about the nature of the collision of the ball with the wall.

.....

..... [1]



1 – (9702/21_Summer_2017_Q2) – *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

(a) State the two conditions for a system to be in equilibrium.

1. .....

.....

2. .....

.....

[2]

(b) A paraglider P of mass 95 kg is pulled by a wire attached to a boat, as shown in Fig. 2.1.

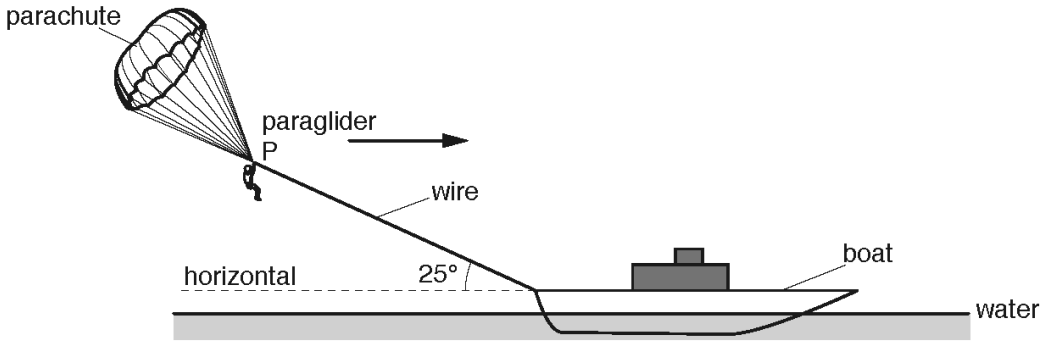


Fig. 2.1

The wire makes an angle of 25° with the horizontal water surface. P moves in a straight line parallel to the surface of the water.

The variation with time t of the velocity v of P is shown in Fig. 2.2.

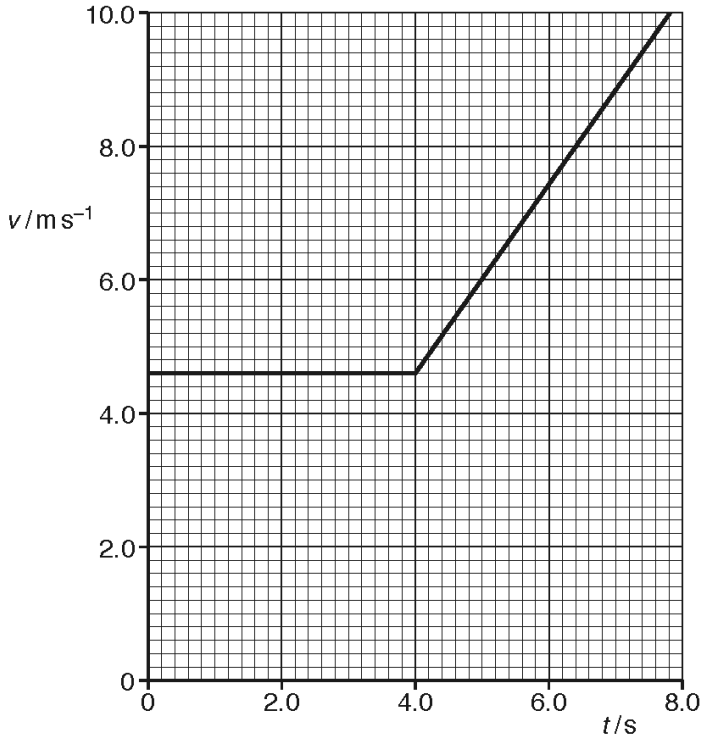
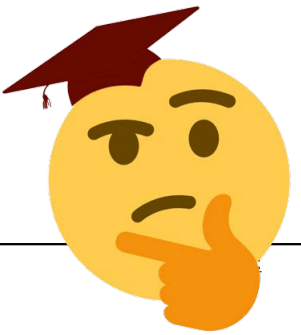


Fig. 2.2



(i) Show that the acceleration of P is $1.4\,\mathrm{m\,s^{-2}}$ at time $t = 5.0\,\mathrm{s}$.

[2]

(ii) Calculate the total distance moved by P from time $t = 0$ to $t = 7.0\,\mathrm{s}$.

distance = ...m [2]

(iii) Calculate the change in kinetic energy of P from time $t = 0$ to $t = 7.0\,\mathrm{s}$.

change in kinetic energy = ...J [2]

(iv) The tension in the wire at time $t = 5.0\,\mathrm{s}$ is $280\,\mathrm{N}$.

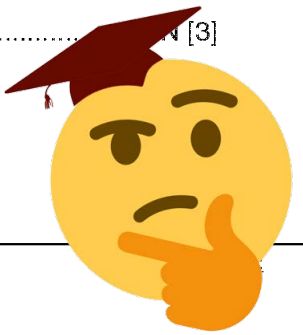
Calculate, for the horizontal motion,

1. the vertical lift force F supporting P,

F = ... N [3]

2. the force R due to air resistance acting on P in the horizontal direction.

R = ... N [3]



2 – (9702/23_Summer_2017_Q2) – *Kinematics, Dynamics*

(a) State Newton's second law of motion.

.....

.....[1]

(b) A constant resultant force F acts on an object A. The variation with time t of the velocity v for the motion of A is shown in Fig. 2.1.

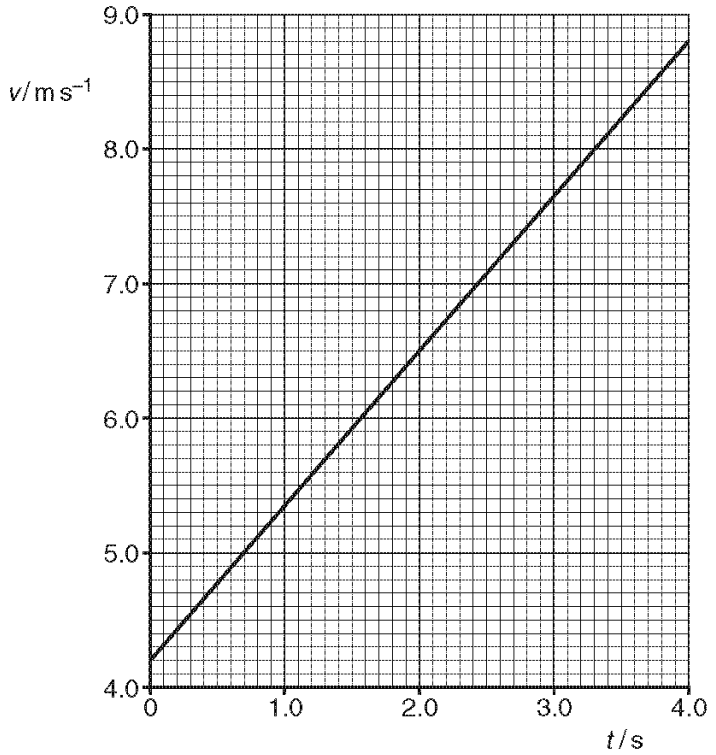


Fig. 2.1

The mass of A is 840 g.

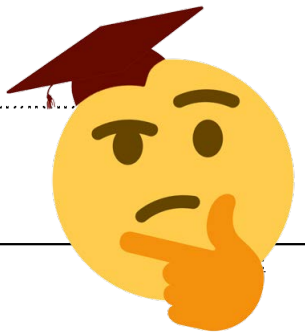
Calculate, for the time $t = 0$ to $t = 4.0$ s,

(i) the change in momentum of A,

change in momentum = ... kg m s^{-1} [2]

(ii) the force F.

F = ...



(c) The force F is removed at $t = 4.0\,\text{s}$. Object A continues at constant velocity before colliding with an object B, as illustrated in Fig. 2.2.

Fig. 2.2

Object B is initially at rest. The mass of B is 730 g.
The objects A and B join together and have a velocity of $4.7\,\text{m}\,\text{s}^{-1}$.

(i) By calculation, show that the changes in momentum of A and of B during the collision are equal and opposite.

[2]

(ii) Explain how the answers obtained in **(i)** support Newton's third law.

.....

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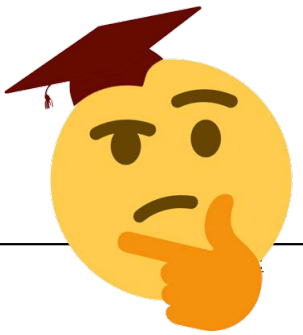
.....

.....[2]

(iii) By reference to the speeds of A and B, explain whether the collision is elastic.

.....

.....[1]



3 – (9702/22_Summer_2017_Q4) – *Dynamics*

(a) State Newton's first law of motion.

.....

.....[1]

(b) An object A of mass 100 g is moving in a straight line with a velocity of $0.60\,m\,s^{-1}$ to the right. An object B of mass 200 g is moving in the same straight line as object A with a velocity of $0.80\,m\,s^{-1}$ to the left, as shown in Fig. 4.1.

Fig. 4.1

Objects A and B collide. Object A then moves with a velocity of $0.40\,m\,s^{-1}$ to the left.

(i) Calculate the magnitude of the velocity of B after the collision.

magnitude of velocity = ...$m\,s^{-1}$ [2]

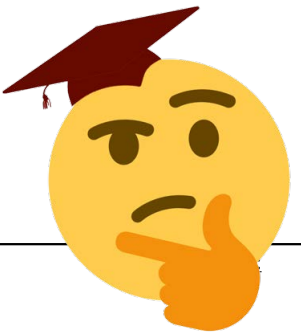
(ii) The collision between A and B is inelastic.

Explain how the collision is inelastic and still obeys the law of conservation of energy.

.....

.....

.....[1]



4 – (9702/21_Winter_2017_Q1) – *Physical Quantities & Units, Kinematics, Dynamics*

(a) The drag force F_D acting on a sphere moving through a fluid is given by the expression

$$F_D = K\rho v^2$$

where K is a constant,
ρ is the density of the fluid
and v is the speed of the sphere.

Determine the SI base units of K.

base units .....[3]

(b) A ball of weight 1.5 N falls vertically from rest in air. The drag force F_D acting on the ball is given by the expression in **(a)**. The ball reaches a constant (terminal) speed of $33\,m\,s^{-1}$.

Assume that the upthrust acting on the ball is negligible and that the density of the air is uniform.

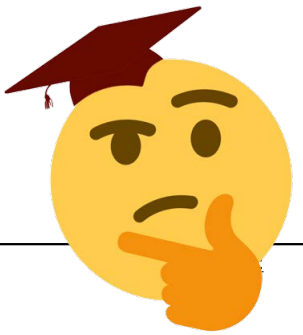
For the instant when the ball is travelling at a speed of $25\,m\,s^{-1}$, determine

(i) the drag force F_D on the ball,

F_D = ... N [2]

(ii) the acceleration of the ball.

acceleration = ... $m\,s^{-2}$ [2]



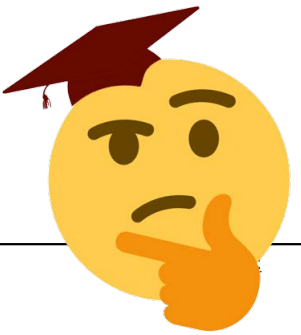
(c) Describe the acceleration of the ball in **(b)** as its speed changes from zero to $33\,m\,s^{-1}$.

.....

.....

.....

.....[3]



5 – (9702/22_Winter_2017_Q3) – *Kinematics, Dynamics, Forces, Density & Pressure*

A spring is attached at one end to a fixed point and hangs vertically with a cube attached to the other end. The cube is initially held so that the spring has zero extension, as shown in Fig. 3.1.

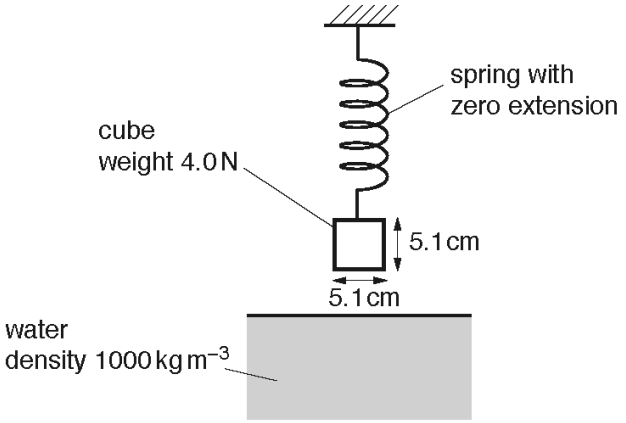


Fig. 3.1

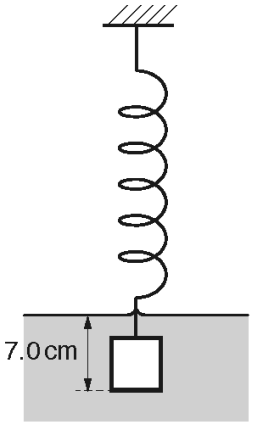


Fig. 3.2

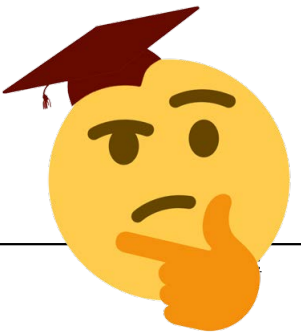
The cube has weight 4.0 N and sides of length 5.1 cm. The cube is released and sinks into water as the spring extends. The cube reaches equilibrium with its base at a depth of 7.0 cm below the water surface, as shown in Fig. 3.2.
The density of the water is 1000 kg m^{-3}.

(a) Calculate the difference in the pressure exerted by the water on the bottom face and on the top face of the cube.

difference in pressure = ... Pa [2]

(b) Use your answer in **(a)** to show that the upthrust on the cube is 1.3 N.

[2]



(c) Calculate the force exerted on the spring by the cube when it is in equilibrium in the water.

force = ... N [1]

(d) The spring obeys Hooke's law and has a spring constant of $30\,N\,m^{-1}$.

Determine the initial height above the water surface of the base of the cube before it was released.

height above surface = ... cm [3]

(e) The cube in the water is released from the spring.

(i) Determine the initial acceleration of the cube.

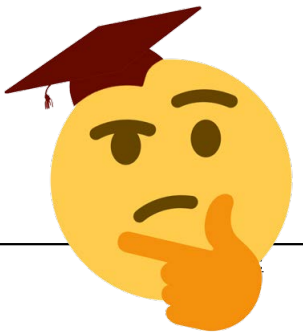
acceleration = ...$m\,s^{-2}$ [2]

(ii) Describe and explain the variation, if any, of the acceleration of the cube as it sinks in the water.

.....

.....

.....[2]



6 – (9702/23_Winter_2017_Q3) – *Dynamics*

(a) State the principle of conservation of momentum.

.....

.....

.....[2]

(b) Ball A moves with speed v along a horizontal frictionless surface towards a stationary ball B, as shown in Fig. 3.1.

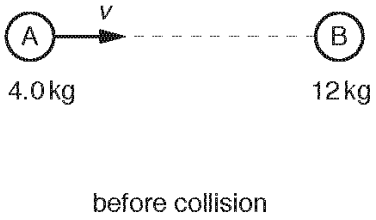


Fig. 3.1

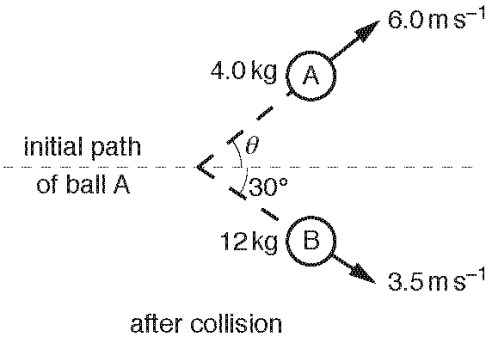
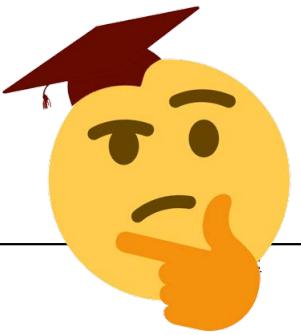


Fig. 3.2 (not to scale)

Ball A has mass 4.0 kg and ball B has mass 12 kg.
The balls collide and then move apart as shown in Fig. 3.2.
Ball A has velocity 6.0 m s^{-1} at an angle of θ to the direction of its initial path.
Ball B has velocity 3.5 m s^{-1} at an angle of 30° to the direction of the initial path of ball A.

(i) By considering the components of momentum at right-angles to the direction of the initial path of ball A, calculate θ.

θ = ... ° [3]



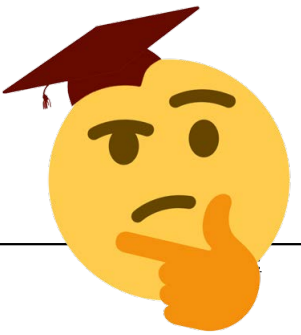
(ii) Use your answer in **(i)** to show that the initial speed v of ball A is $12\,\mathrm{m\,s^{-1}}$.
Explain your working.

[2]

(iii) By calculation of kinetic energies, state and explain whether the collision is elastic or inelastic.

.....

.....[3]



7 – (9702/21_Summer_2018_Q2) – *Dynamics, Kinematics, Work, Energy & Power*

(a) State Newton's first law of motion.

.....

.....[1]

(b) A block of weight 15 N hangs by a wire from a remotely controlled aircraft, as shown in Fig. 2.1.

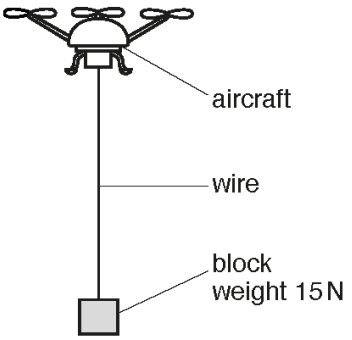


Fig. 2.1

The aircraft is used to move the block only in a vertical direction. The force on the block due to air resistance is negligible.

The variation with time t of the vertical velocity v of the block is shown in Fig. 2.2.
The velocity is taken to be positive in the upward direction.

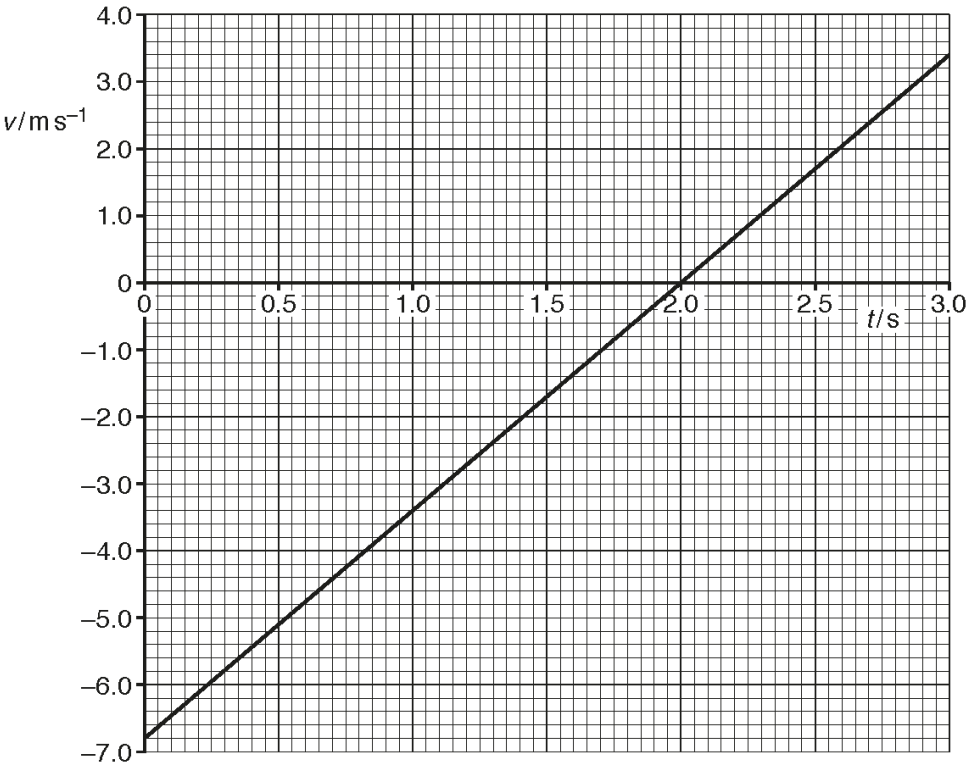
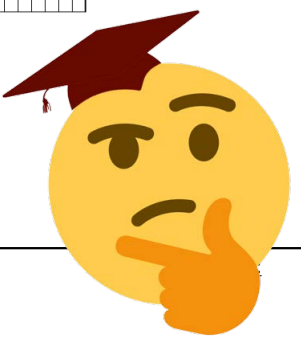


Fig. 2.2



(i) Determine, for the block,

1. the displacement from time $t = 0$ to $t = 3.0\,s$,

magnitude of displacement = ... m

direction of displacement .....

[3]

2. the change in gravitational potential energy from time $t = 0$ to $t = 3.0\,s$.

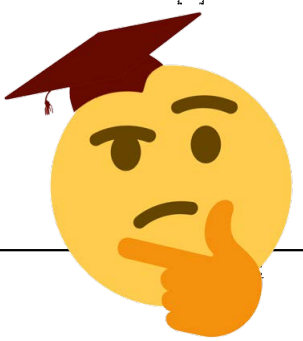
change in gravitational potential energy = ... J [2]

(ii) Calculate the magnitude of the acceleration of the block at time $t = 2.0\,s$.

acceleration = ... $m\,s^{-2}$ [2]

(iii) Use your answer in **(b)(ii)** to show that the tension T in the wire at time $t = 2.0\,s$ is $20\,N$.

[2]



(iv) The wire has a cross-sectional area of $2.8 \times 10^{-5}\,m^2$ and is made from metal of Young modulus 1.7×10^{11} Pa. The wire obeys Hooke's law.

Calculate the strain of the wire at time $t = 2.0$ s.

strain = ... [3]

(v) At some time after $t = 3.0$ s the tension in the wire has a constant value of 15 N.

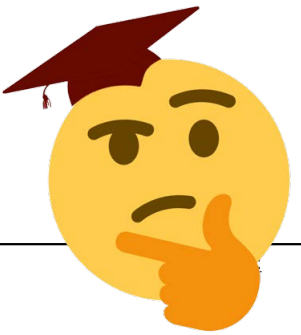
State and explain whether it is possible to deduce that the block is moving vertically after $t = 3.0$ s.

.....

.....

.....

.....[2]



8 – (9702/22_Summer_2018_Q2) – *Kinematics, Dynamics*

(a) State the principle of conservation of momentum.

.....

.....

.....[2]

(b) A stationary firework explodes into three different fragments that move in a horizontal plane, as illustrated in Fig. 2.1.

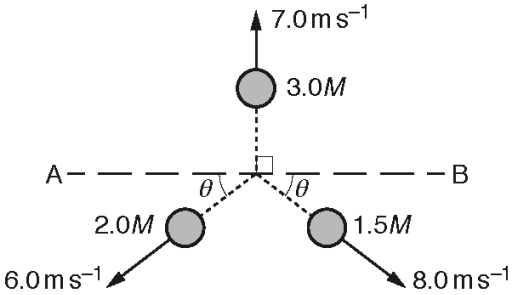


Fig. 2.1

The fragment of mass $3.0M$ has a velocity of $7.0\,\text{m s}^{-1}$ perpendicular to line AB.
The fragment of mass $2.0M$ has a velocity of $6.0\,\text{m s}^{-1}$ at angle θ to line AB.
The fragment of mass $1.5M$ has a velocity of $8.0\,\text{m s}^{-1}$ at angle θ to line AB.

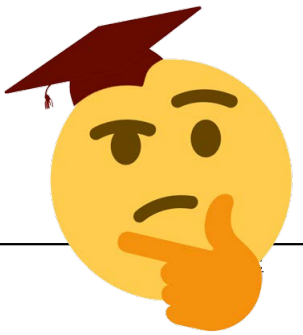
(i) Use the principle of conservation of momentum to determine θ.

θ = ... ° [3]

(ii) Calculate the ratio

$$\frac{\text{kinetic energy of fragment of mass } 2.0M}{\text{kinetic energy of fragment of mass } 1.5M}.$$

ratio = ...[2]



9 – (9702/21_Summer_2018_Q3) – *Kinematics, Dynamics*

(a) State what is meant by the *mass* of a body.

.....

.....[1]

(b) Two blocks travel directly towards each other along a horizontal, frictionless surface. The blocks collide, as illustrated in Fig. 3.1.

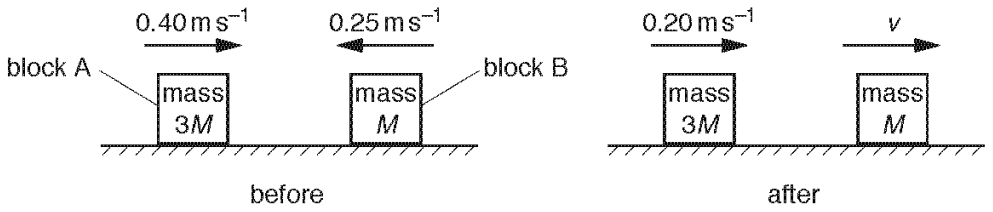


Fig. 3.1

Block A has mass 3*M* and block B has mass *M*.
Before the collision, block A moves to the right with speed $0.40\,m\,s^{-1}$ and block B moves to the left with speed $0.25\,m\,s^{-1}$.
After the collision, block A moves to the right with speed $0.20\,m\,s^{-1}$ and block B moves to the right with speed *v*.

(i) Use Newton's third law to explain why, during the collision, the change in momentum of block A is equal and opposite to the change in momentum of block B.

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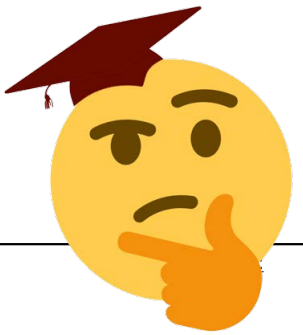
.....

.....[2]

(ii) Determine speed *v*.

v = ... $m\,s^{-1}$ [3]



(iii) Calculate, for the blocks,

1. the relative speed of approach,

relative speed of approach = ... $m\,s^{-1}$

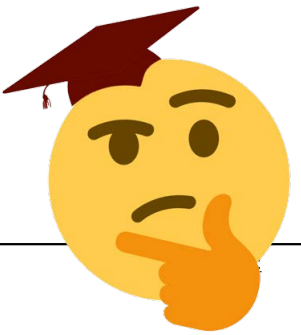
2. the relative speed of separation.

relative speed of separation = ... $m\,s^{-1}$
[2]

(iv) Use your answers in **(b)(iii)** to state and explain whether the collision is elastic or inelastic.

.....

.....[1]



10 – (9702/22_Summer_2018_Q3) – *Kinematics, Dynamics, Waves*

A child on a sledge slides down a steep hill and then travels in a straight line up an ice-covered slope, as illustrated in Fig. 3.1.

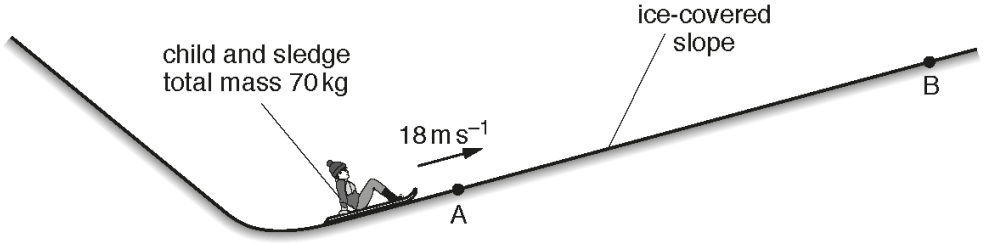


Fig. 3.1 (not to scale)

The sledge passes point A with speed $18\,\mathrm{m\,s^{-1}}$ at time $t = 0$ and then comes to rest at point B. The child applies a brake to the sledge at point B. The brake does not keep the sledge stationary and it immediately slides back down the slope towards A.

The variation with time t of the velocity v of the sledge from $t = 0$ to $t = 24\,\mathrm{s}$ is shown in Fig. 3.2.

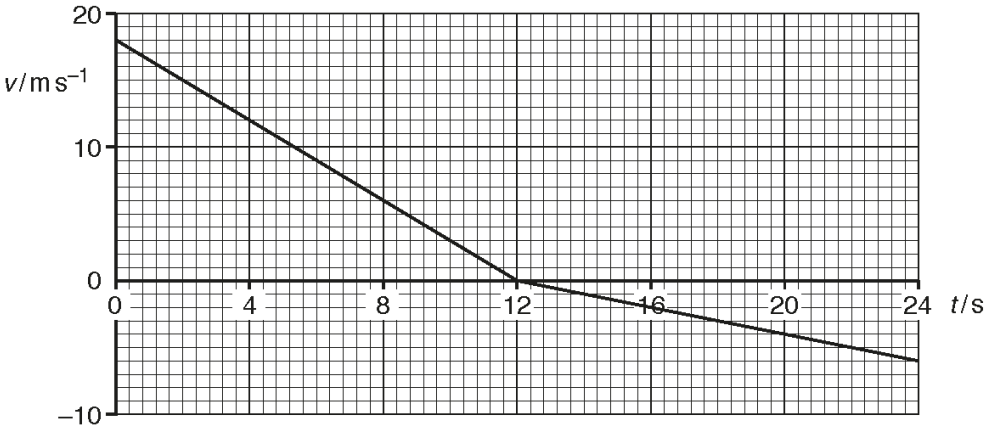
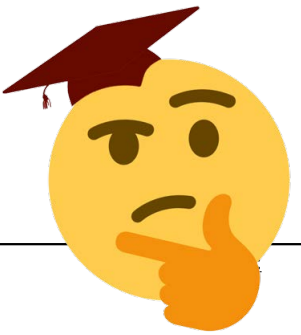


Fig. 3.2

(a) State the time taken for the sledge to travel from A to B.

time = ... s [1]



(b) Determine the displacement of the sledge up the slope from point A at time $t = 24$ s.

displacement = ...m [3]

(c) Show that the acceleration of the sledge as it moves from B back towards A is $0.50\,\text{m}\,\text{s}^{-2}$.

[2]

(d) The child and sledge have a total mass of 70 kg. The component of the total weight of the child and sledge that acts down the slope is 80 N.

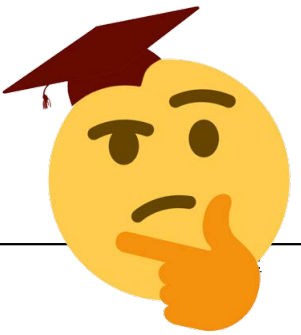
Determine

(i) the frictional force on the sledge as it moves from B towards A,

frictional force = ... N [2]

(ii) the angle θ of the slope to the horizontal.

θ = ... ° [2]



(e) The child on the sledge blows a whistle between $t = 4.0\,\text{s}$ and $t = 8.0\,\text{s}$. The whistle emits sound of frequency 900 Hz. The speed of the sound in the air is $340\,\text{m}\,\text{s}^{-1}$. A man standing at point A hears the sound.

Use Fig. 3.2 to

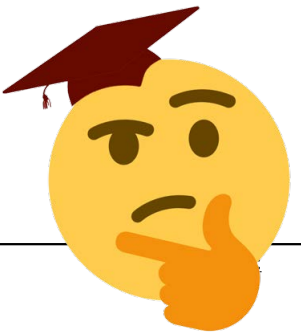
(i) determine the initial frequency of the sound heard by the man,

initial frequency = ... Hz [2]

(ii) describe and explain qualitatively the variation, if any, in the frequency of the sound heard by the man.

.....

.....[1]



11 – (9702/23_Summer_2018_Q3) – *Kinematics, Dynamics, Work, Energy & Power*

A ball is thrown vertically upwards towards a ceiling and then rebounds, as illustrated in Fig. 3.1.

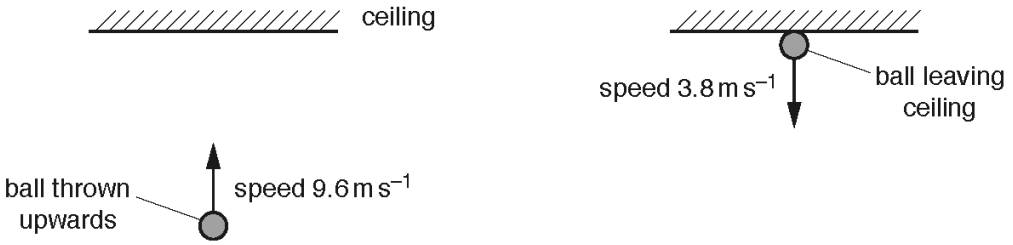


Fig. 3.1

The ball is thrown with speed 9.6 m s^{-1} and takes a time of 0.37 s to reach the ceiling. The ball is then in contact with the ceiling for a further time of 0.085 s until leaving it with a speed of 3.8 m s^{-1}. The mass of the ball is 0.056 kg. Assume that air resistance is negligible.

(a) Show that the ball reaches the ceiling with a speed of 6.0 m s^{-1}.

[1]

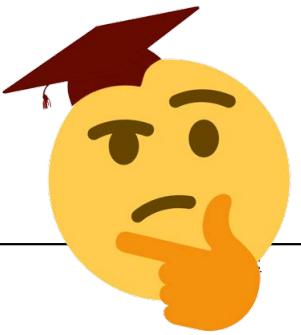
(b) Calculate the height of the ceiling above the point from which the ball was thrown.

height = ... m [2]

(c) Calculate

(i) the increase in gravitational potential energy of the ball for its movement from its initial position to the ceiling,

increase in gravitational potential energy = ... J [2]



(ii) the decrease in kinetic energy of the ball while it is in contact with the ceiling.

decrease in kinetic energy = ... J [2]

(d) State how Newton's third law applies to the collision between the ball and the ceiling.

.....

.....

.....

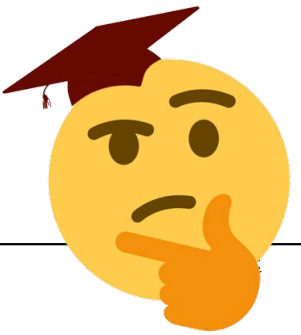
.....[2]

(e) Calculate the change in momentum of the ball during the collision.

change in momentum = ... N s [2]

(f) Determine the magnitude of the average force exerted by the ceiling on the ball during the collision.

average force = ... N [2]



12 – (9702/22_Summer_2018_Q5) – *Forces, Density & Pressure, Dynamics, Work, Energy & Power*

A solid cylinder is lifted out of oil by a wire attached to a motor. Fig. 5.1 shows two different positions X and Y of the cylinder during the lifting process.

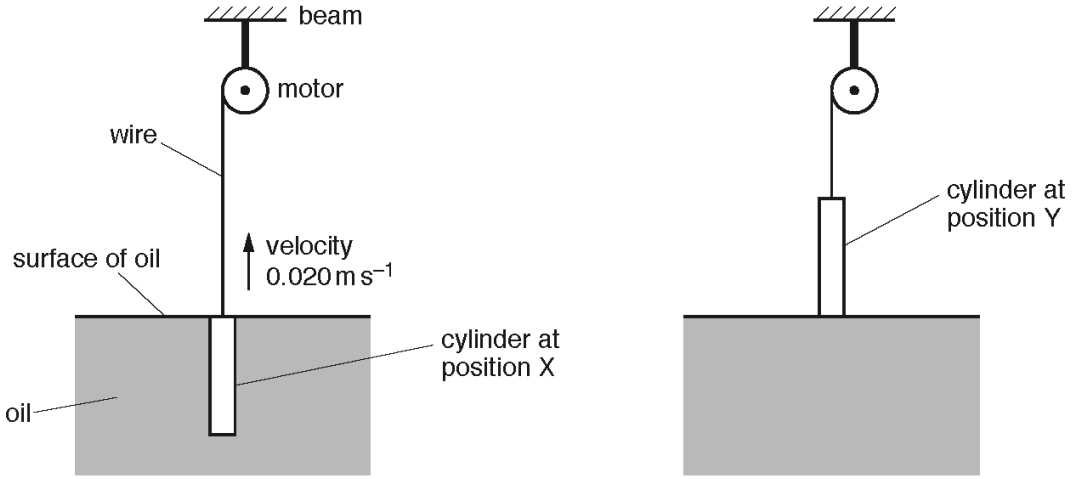


Fig. 5.1

The motor is fixed to an overhead beam.
The cylinder has cross-sectional area $0.018\,m^2$, length 1.2 m and weight 560 N.
The density of the oil is $940\,kg\,m^{-3}$.

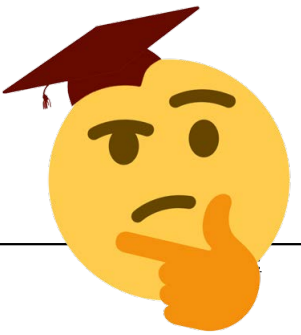
Throughout the lifting process, the cylinder moves vertically upwards with a constant velocity of $0.020\,m\,s^{-1}$. The viscous force of the oil acting on the cylinder is negligible.

(a) Calculate the density of the cylinder.

density = ... $kg\,m^{-3}$ [2]

(b) For the cylinder at position X, show that the upthrust due to the oil is 200 N.

[2]



(c) Calculate, for the moving cylinder at position X,

(i) the tension in the wire,

tension = ... N [1]

(ii) the power output of the motor.

power = ... W [2]

(d) The cylinder is raised with constant velocity from position X to position Y.

(i) State and explain the variation, if any, of the power output of the motor as the cylinder is raised. Numerical values are not required.

.....

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.....

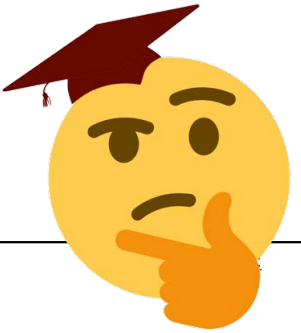
.....

.....[3]

(ii) The rate of energy output of the motor is less than the rate of increase of gravitational potential energy of the cylinder. Without calculation, explain this difference.

.....

.....[1]



13 – (9702/21_Winter_2018_Q2) – *Dynamics*

A wooden block moves along a horizontal frictionless surface, as shown in Fig. 2.1.

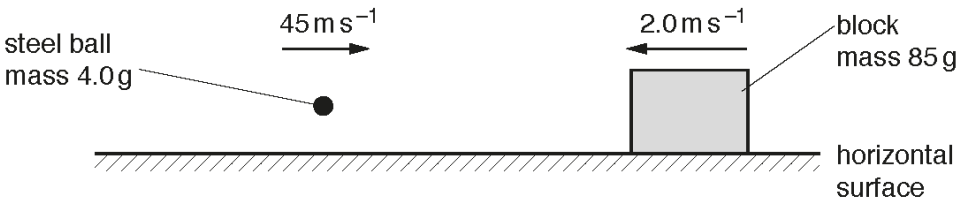


Fig. 2.1

The block has mass 85 g and moves to the left with a velocity of $2.0\,m\,s^{-1}$. A steel ball of mass 4.0 g is fired to the right. The steel ball, moving horizontally with a speed of $45\,m\,s^{-1}$, collides with the block and remains embedded in it. After the collision the block and steel ball both have speed *v*.

(a) Calculate *v*.

v = ... $m\,s^{-1}$ [2]

(b) **(i)** For the block and ball, state

1. the relative speed of approach before collision,

relative speed of approach = ... $m\,s^{-1}$

2. the relative speed of separation after collision.

relative speed of separation = ... $m\,s^{-1}$
[1]

(ii) Use your answers in **(i)** to state and explain whether the collision is elastic or inelastic.

.....

..... [1]

(c) Use Newton's third law to explain the relationship between the rate of change of momentum of the ball and the rate of change of momentum of the block during the collision.

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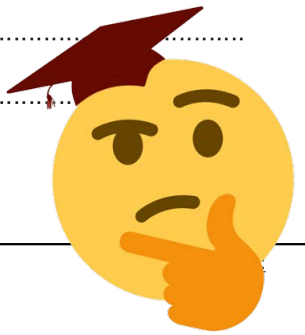


14 – (9702/23_Winter_2018_Q2) – *Dynamics, Work, Energy & Power*

(a) State what is meant by *kinetic energy*.

.....

.....[1]

(b) A cannon fires a shell vertically upwards. The shell leaves the cannon with a speed of $80\,m\,s^{-1}$ and a kinetic energy of 480 J. The shell then rises to a maximum height of 210 m. The effect of air resistance is significant.

(i) Show that the mass of the shell is 0.15 kg.

[2]

(ii) For the movement of the shell from the cannon to its maximum height, calculate

1. the gain in gravitational potential energy,

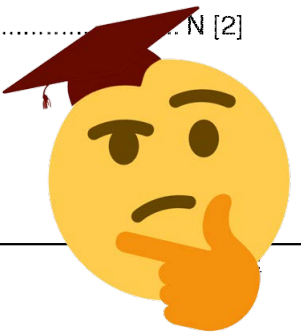
gain in gravitational potential energy = ...J [2]

2. the work done against air resistance.

work done = ...J [1]

(iii) Determine the average force due to the air resistance acting on the shell as it moves from the cannon to its maximum height.

force = ...N [2]



(iv) The shell leaves the cannon at time $t = 0$ and reaches maximum height at time $t = T$.

On Fig. 2.1, sketch the variation with time t of the velocity v of the shell from time $t = 0$ to time $t = T$. Numerical values of v and t are not required.

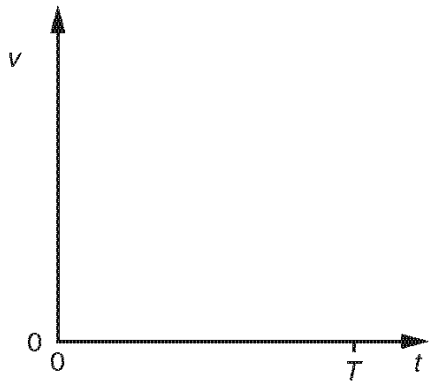


Fig. 2.1

[2]

(v) The force due to the air resistance is a vector quantity.

Compare the force due to the air resistance acting on the shell as it rises with the force due to the air resistance as it falls.

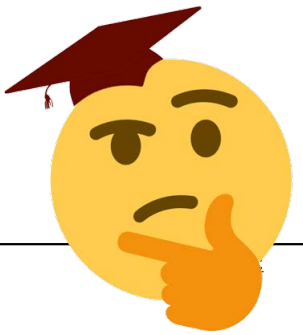
.....

.....

.....

.....

.....[2]



15 - (9702/22_Winter_2018_Q3) - *Dynamics*

(a) State the principle of conservation of momentum.

.....

.....

.....[2]

(b) The propulsion system of a toy car consists of a propeller attached to an electric motor, as illustrated in Fig. 3.1.

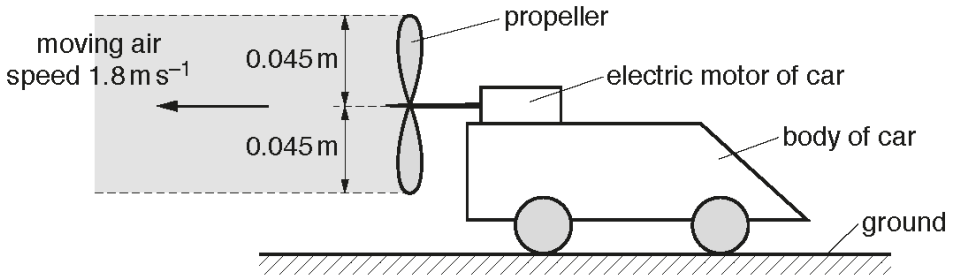


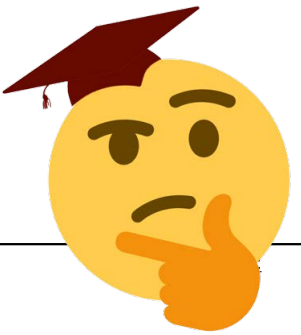
Fig. 3.1

The car is on horizontal ground and is initially held at rest by its brakes. When the motor is switched on, it rotates the propeller so that air is propelled horizontally to the left. The density of the air is $1.3\,kg\,m^{-3}$.

Assume that the air moves with a speed of $1.8\,m\,s^{-1}$ in a uniform cylinder of radius 0.045 m. Also assume that the air to the right of the propeller is stationary.

(i) Show that, in a time interval of 2.0 s, the mass of air propelled to the left is 0.030 kg.

[2]



(ii) Calculate

1. the increase in the momentum of the mass of air in **(b)(i)**,

increase in momentum = ... N s

2. the force exerted on this mass of air by the propeller.

force = ... N
[3]

(iii) Explain how Newton's third law applies to the movement of the air by the propeller.

.....

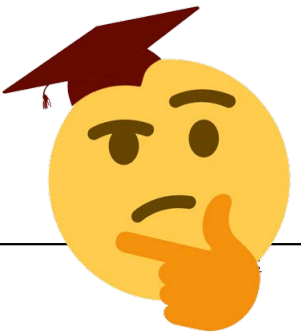
.....

.....[2]

(iv) The total mass of the car is 0.20 kg. The brakes of the car are released and the car begins to move with an initial acceleration of $0.075\,m\,s^{-2}$.

Determine the initial frictional force acting on the car.

frictional force = ... N [2]



16 – (9702/23_Winter_2018_Q3) – *Dynamics*

(a) State Newton's second law of motion.

.....

.....[1]

(b) A toy rocket consists of a container of water and compressed air, as shown in Fig. 3.1.

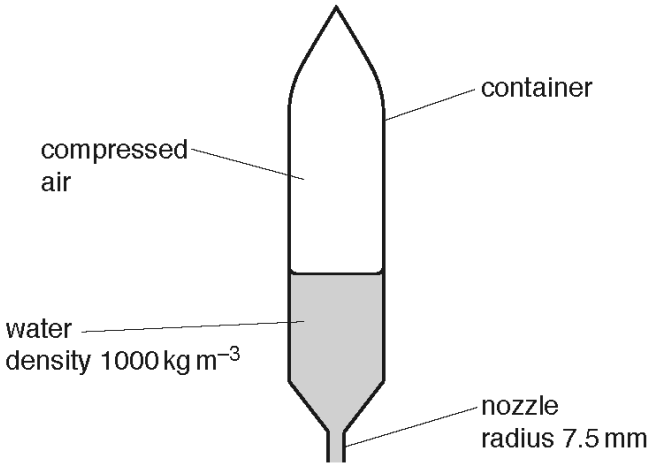


Fig. 3.1

Water is pushed vertically downwards through a nozzle by the compressed air. The rocket moves vertically upwards.

The nozzle has a circular cross-section of radius 7.5 mm. The density of the water is 1000 kg m^{-3}. Assume that the water leaving the nozzle has the shape of a cylinder of radius 7.5 mm and has a constant speed of 13 m s^{-1} relative to the rocket.

(i) Show that the mass of water leaving the nozzle in the first 0.20 s after the rocket launch is 0.46 kg.

[2]

(ii) Calculate

1. the change in the momentum of the mass of water in **(b)(i)** due to leaving the nozzle,

change in momentum = ... N s

2. the force exerted on this mass of water by the rocket.

force = ... N
[3]

(iii) State and explain how Newton's third law applies to the movement of the rocket by the water.

.....

.....

.....[2]

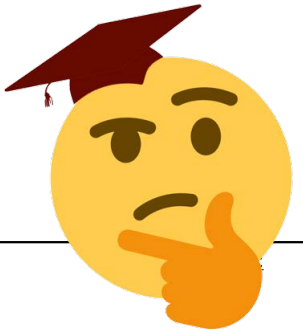
(iv) The container has a mass of 0.40 kg. The initial mass of water before the rocket is launched is 0.70 kg. The mass of the compressed air in the rocket is negligible. Assume that the resistive force on the rocket due to its motion is negligible.

For the rocket at a time of 0.20 s after launching,

1. show that its total mass is 0.64 kg,

2. calculate its acceleration.

acceleration = ... m s^{-2}
[3]



17 – (9702/21_Summer_2019_Q2) – *Dynamics*

A block X slides along a horizontal frictionless surface towards a stationary block Y, as illustrated in Fig. 2.1.

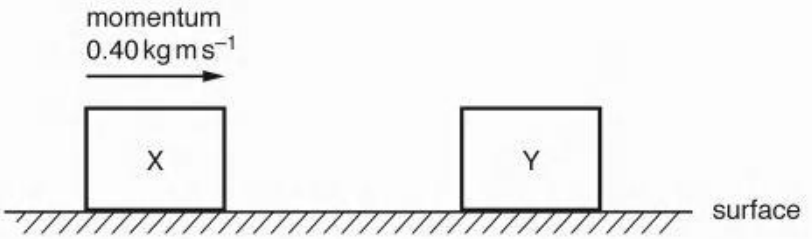


Fig. 2.1

There are no resistive forces acting on block X as it moves towards block Y. At time $t = 0$, block X has momentum $0.40\,\text{kg m s}^{-1}$. A short time later, the blocks collide and then separate.

The variation with time t of the momentum of block Y is shown in Fig. 2.2.

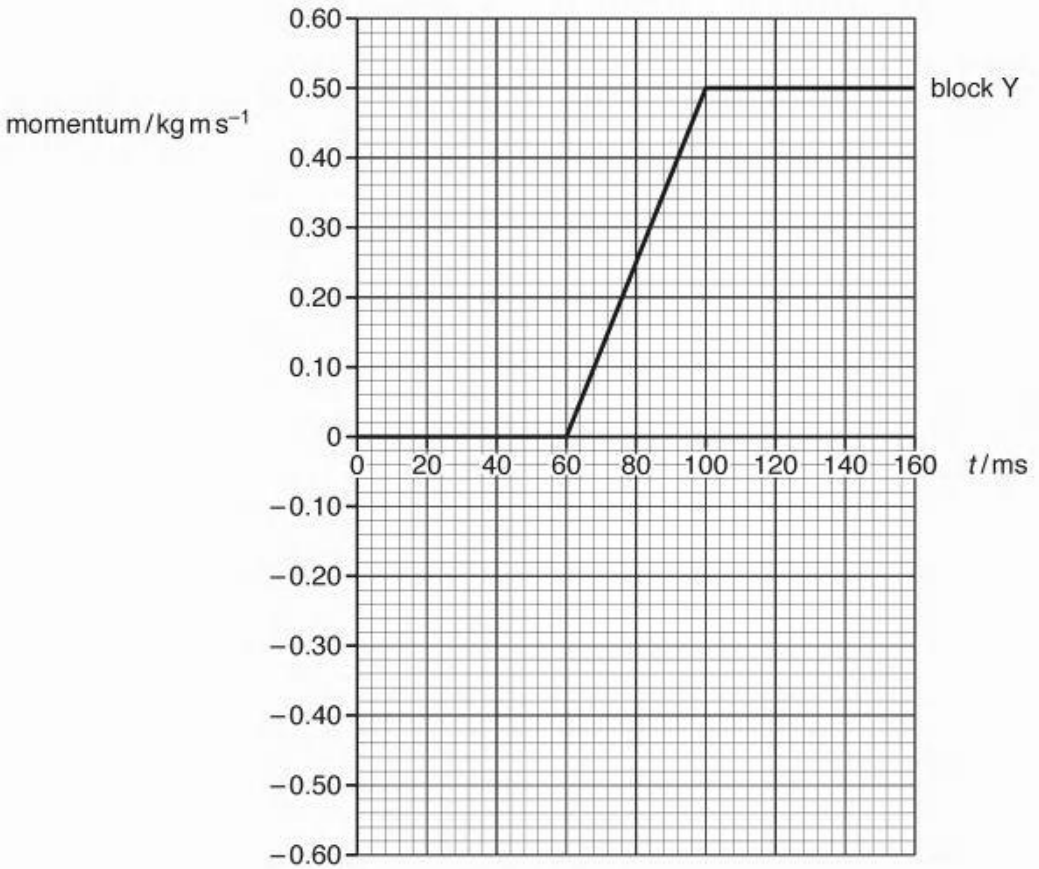
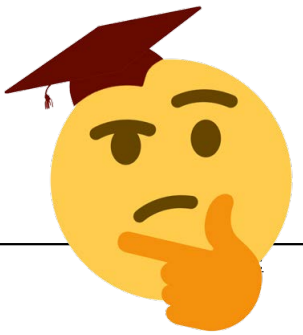


Fig. 2.2



(a) Define *linear momentum*.

.....[1]

(b) Use Fig. 2.2 to:

(i) determine the time interval over which the blocks are in contact with each other

time interval = ... ms [1]

(ii) describe, without calculation, the magnitude of the acceleration of block Y from:

1. time $t = 80$ ms to $t = 100$ ms

.....

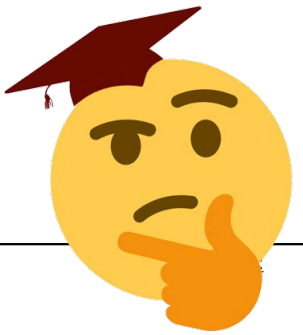
2. time $t = 100$ ms to $t = 120$ ms.

.....
[2]

(c) Use Fig. 2.2 to determine the magnitude of the force exerted by block X on block Y.

force = ... N [2]

(d) On Fig. 2.2, sketch the variation of the momentum of block X with time t from $t = 0$ to $t = 160$ ms. [3]



18 – (9702/22_Summer_2019_Q2) – *Kinematics, Dynamics, Electric Fields*

(a) State Newton's second law of motion.

.....

.....[1]

(b) A car of mass 850 kg tows a trailer in a straight line along a horizontal road, as shown in Fig. 2.1.

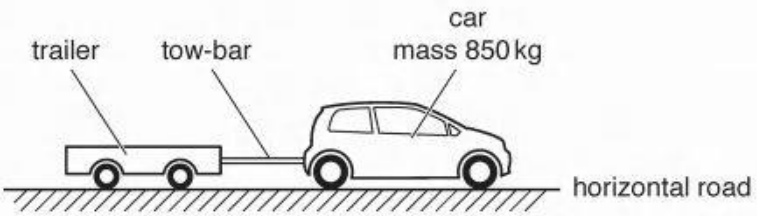


Fig. 2.1

The car and the trailer are connected by a horizontal tow-bar.

The variation with time *t* of the velocity *v* of the car for a part of its journey is shown in Fig. 2.2.

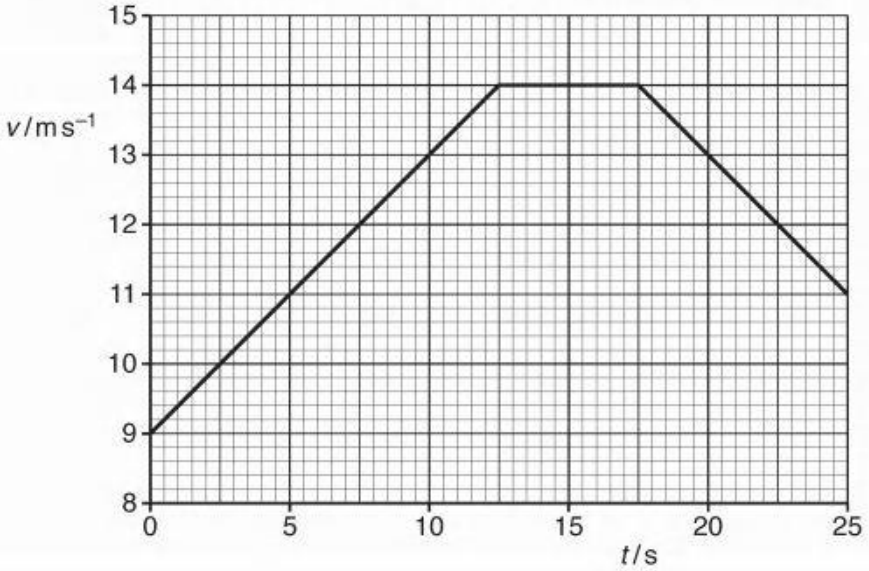


Fig. 2.2

(i) Calculate the distance travelled by the car from time $t = 0$ to $t = 10\,s$.

distance = ... m [2]

(ii) At time $t = 10\,s$, the resistive force acting on the car due to air resistance and friction is 510 N. The tension in the tow-bar is 440 N.

For the car at time $t = 10\,s$:

1. use Fig. 2.2 to calculate the acceleration

acceleration = ... $m\,s^{-2}$ [2]

2. use your answer to calculate the resultant force acting on the car

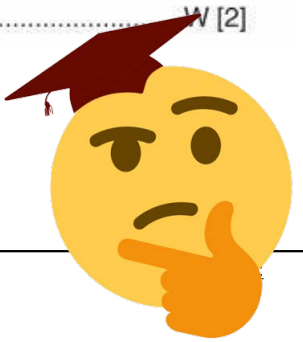
resultant force = ... N [1]

3. show that a horizontal force of 1300 N is exerted on the car by its engine

[1]

4. determine the useful output power of the engine.

output power = ... W [2]



(c) A short time later, the car in **(b)** is travelling at a constant speed and the tension in the tow-bar is 480 N.

The tow-bar is a solid metal rod that obeys Hooke's law. Some data for the tow-bar are listed below.

Young modulus of metal = 2.2×10^{11} Pa

original length of tow-bar = 0.48 m

cross-sectional area of tow-bar = 3.0×10^{-4} m^2

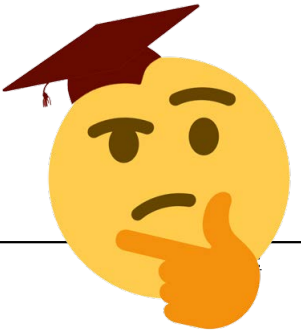
Determine the extension of the tow-bar.

extension = ... m [3]

(d) The driver of the car in **(b)** sees a pedestrian standing directly ahead in the distance. The driver operates the horn of the car from time $t = 15$ s to $t = 17$ s. The frequency of the sound heard by the pedestrian is 480 Hz. The speed of the sound in the air is 340 m s^{-1}.

Use Fig. 2.2 to calculate the frequency of the sound emitted by the horn.

frequency = ... Hz [2]



19 – (9702/23_Summer_2019_Q3) – *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

A cylindrical disc of mass 0.24 kg has a circular cross-sectional area *A*, as shown in Fig. 3.1.

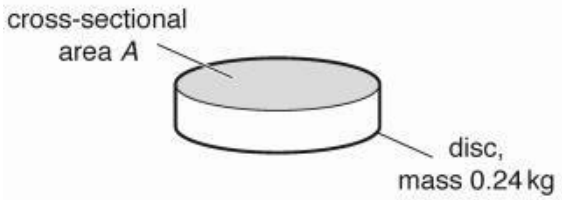


Fig. 3.1

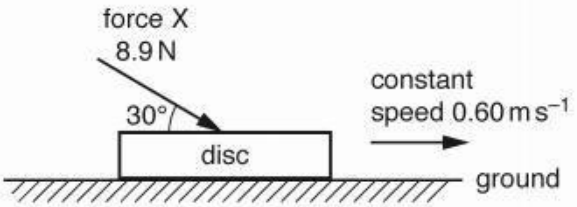


Fig. 3.2

The disc is on horizontal ground, as shown in Fig. 3.2. A force X of magnitude 8.9 N acts on the disc in a direction of 30° to the horizontal. The disc moves at a constant speed of 0.60 m s^{-1} along the ground.

(a) Determine the rate of doing work on the disc by the force X.

rate of doing work = ... W [2]

(b) The force X and the weight of the disc exert a combined pressure on the ground of 3500 Pa.

Calculate the cross-sectional area *A* of the disc.

A = ... m^2 [3]

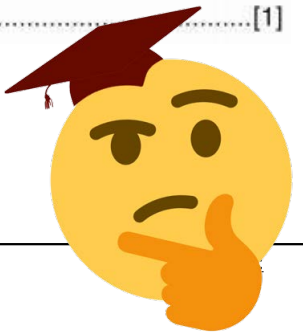
(c) Newton's third law describes how forces exist in pairs. One such pair of forces is the weight of the disc and another force Y. State:

(i) the direction of force Y

.....[1]

(ii) the name of the body on which force Y acts.

.....[1]



20 – (9702/21_Winter_2019_Q2) – *Kinematics, Dynamics, Electric Fields*

A small charged glass bead of weight 5.4×10^{-5} N is initially at rest at point A in a vacuum. The bead then falls through a uniform horizontal electric field as it moves in a straight line to point B, as illustrated in Fig. 2.1.

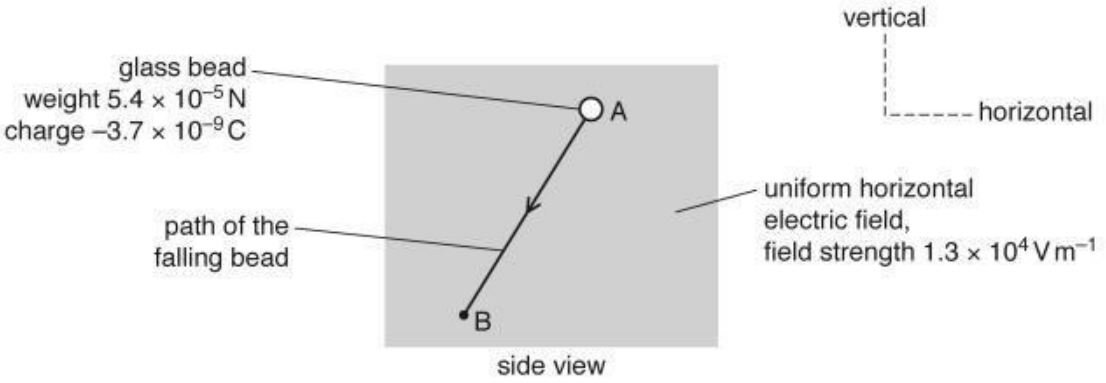


Fig. 2.1 (not to scale)

The electric field strength is 1.3×10^{4} V m^{-1}. The charge on the bead is -3.7×10^{-9} C.

(a) Describe how two metal plates could be used to produce the electric field. Numerical values are not required.

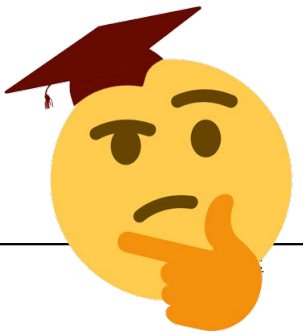
.....

.....

..... [2]

(b) Determine the magnitude of the electric force acting on the bead.

electric force = ... N [2]



(c) Use your answer in **(b)** and the weight of the bead to show that the resultant force acting on it is 7.2×10^{-5} N.

[1]

(d) Explain why the resultant force on the bead of 7.2×10^{-5} N is constant as the bead moves along path AB.

.....

.....

.....

..... [2]

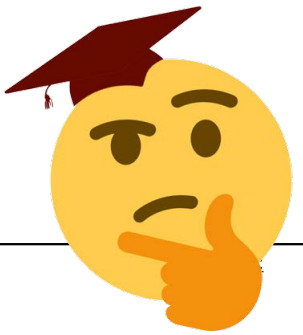
(e) **(i)** Calculate the magnitude of the acceleration of the bead along the path AB.

acceleration = ... $m\,s^{-2}$ [2]

(ii) The path AB has length 0.58 m.

Use your answer in **(i)** to determine the speed of the bead at point B.

speed = ... $m\,s^{-1}$ [2]



21 – (9702/23_Winter_2019_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a) State what is meant by *work done*.

.....

..... [1]

(b) A lift (elevator) of weight 13.0 kN is connected by a cable to a motor, as shown in Fig. 2.1.

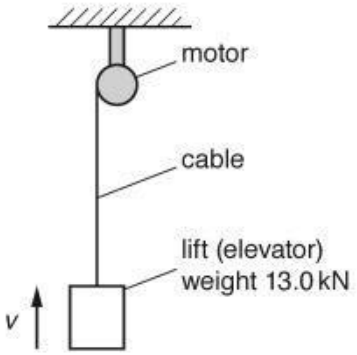


Fig. 2.1

The lift is pulled up a vertical shaft by the cable. A constant frictional force of 2.0 kN acts on the lift when it is moving. The variation with time *t* of the speed *v* of the lift is shown in Fig. 2.2.

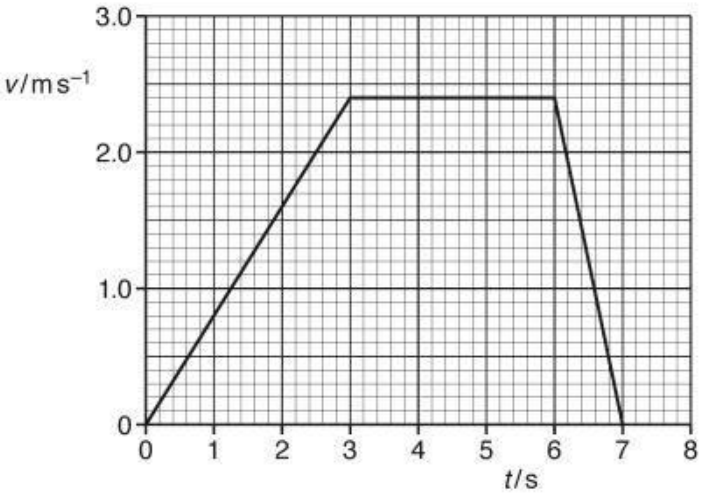
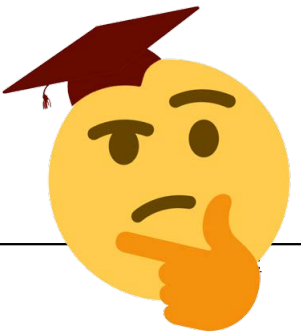


Fig. 2.2



(i) Use Fig. 2.2 to determine:

1. the acceleration of the lift between time $t = 0$ and $t = 3.0\,s$

acceleration = ... $m\,s^{-2}$ [2]

2. the work done by the motor to raise the lift between time $t = 3.0\,s$ and $t = 6.0\,s$.

work done = ... J [2]

(ii) The motor has an efficiency of 67%. The tension in the cable is $1.6 \times 10^4\,N$ at time $t = 2.5\,s$.

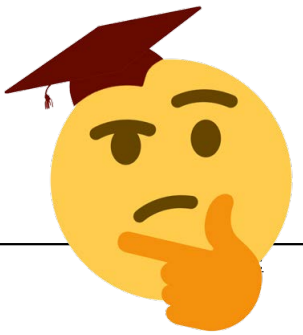
Determine the input power to the motor at this time.

input power = ... W [3]

(iii) State and explain whether the increase in gravitational potential energy of the lift from time $t = 0$ to $t = 7.0\,s$ is less than, the same as, or greater than the work done by the motor. A calculation is not required.

.....

..... [1]



22 – (9702/21_Winter_2019_Q3) – *Waves, Dynamics*

A small remote-controlled model aircraft has two propellers, each of diameter 16 cm. Fig. 3.1 is a side view of the aircraft when hovering.

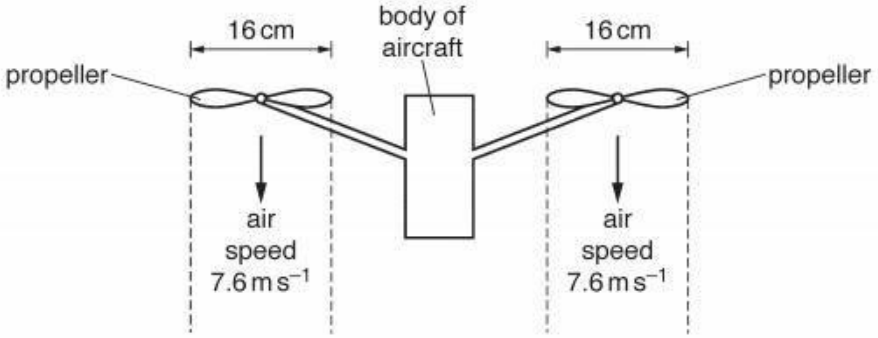


Fig. 3.1

Air is propelled vertically downwards by each propeller so that the aircraft hovers at a fixed position. The density of the air is $1.2\,kg\,m^{-3}$. Assume that the air from each propeller moves with a constant speed of $7.6\,m\,s^{-1}$ in a uniform cylinder of diameter 16 cm. Also assume that the air above each propeller is stationary.

(a) Show that, in a time interval of 3.0 s, the mass of air propelled downwards by **one** propeller is 0.55 kg.

[3]

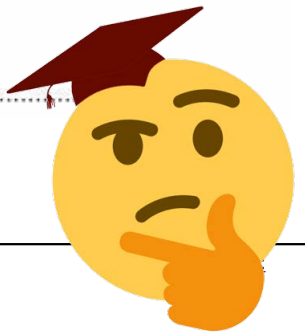
(b) Calculate:

(i) the increase in momentum of the mass of air in **(a)**

increase in momentum = ... N s [1]

(ii) the downward force exerted on this mass of air by the propeller.

force = ...



(c) State:

(i) the upward force acting on **one** propeller

force = ... N [1]

(ii) the name of the law that explains the relationship between the force in **(b)(ii)** and the force in **(c)(i)**.

..... [1]

(d) Determine the mass of the aircraft.

mass = ... kg [1]

(e) In order for the aircraft to hover at a very high altitude (height), the propellers must propel the air downwards with a greater speed than when the aircraft hovers at a low altitude. Suggest the reason for this.

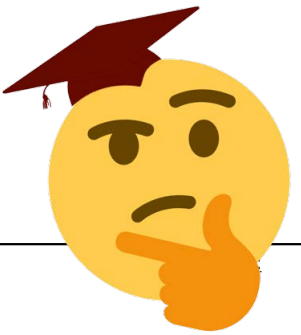
.....

..... [1]

(f) When the aircraft is hovering at a high altitude, an electric fault causes the propellers to stop rotating. The aircraft falls vertically downwards. When the aircraft reaches a constant speed of $22\,m\,s^{-1}$, it emits sound of frequency 3.0 kHz from an alarm. The speed of the sound in the air is $340\,m\,s^{-1}$.

Determine the frequency of the sound heard by a person standing vertically below the falling aircraft.

frequency = ... Hz [2]



23 – (9702/22_Winter_2019_Q3) – *Dynamics*

(a) State Newton's third law of motion.

.....

.....

..... [2]

(b) A block X of mass m_X slides in a straight line along a horizontal frictionless surface, as shown in Fig. 3.1.

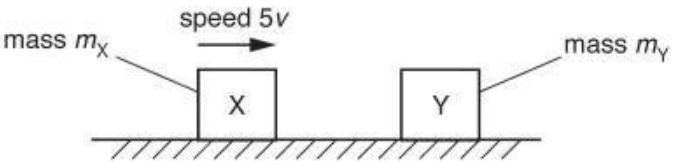


Fig. 3.1

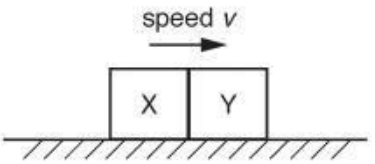


Fig. 3.2

The block X, moving with speed $5v$, collides head-on with a stationary block Y of mass m_Y. The two blocks stick together and then move with common speed v, as shown in Fig. 3.2.

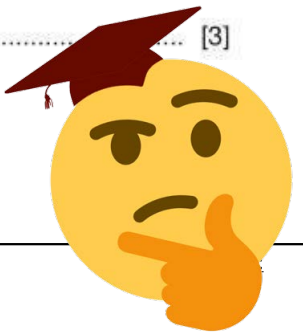
(i) Use conservation of momentum to show that the ratio $\frac{m_Y}{m_X}$ is equal to 4.

[2]

(ii) Calculate the ratio

$$\frac{\text{total kinetic energy of X and Y after collision}}{\text{total kinetic energy of X and Y before collision}}.$$

ratio = ... [3]



(iii) State the value of the ratio in **(ii)** for a perfectly elastic collision.

ratio = ... [1]

(c) The variation with time t of the momentum of block X in **(b)** is shown in Fig. 3.3.

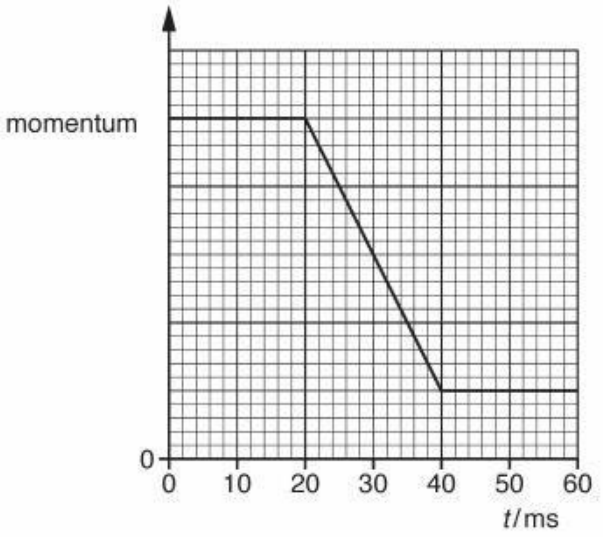


Fig. 3.3

Block X makes contact with block Y at time $t = 20$ ms.

(i) Describe, qualitatively, the magnitude and direction of the resultant force, if any, acting on block X in the time interval:

1. $t = 0$ to $t = 20$ ms

.....

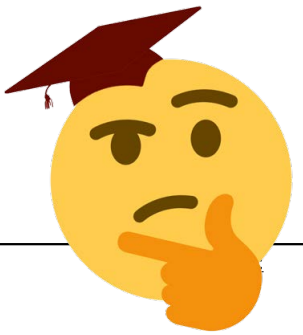
2. $t = 20$ ms to $t = 40$ ms.

.....

.....

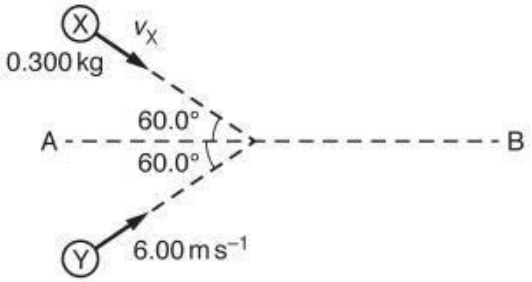
[3]

(ii) On Fig. 3.3, sketch the variation of the momentum of block Y with time t from $t = 0$ to $t = 60$ ms. [3]

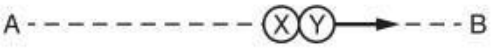


24 – (9702/23_Winter_2019_Q4) – *Dynamics, Deformation Of Solids*

A ball X moves along a horizontal frictionless surface and collides with another ball Y, as illustrated in Fig. 4.1.



BEFORE COLLISION



AFTER COLLISION

Fig. 4.1 (not to scale) **Fig. 4.2** (not to scale)

Ball X has mass 0.300 kg and initial velocity v_X at an angle of 60.0° to line AB.
Ball Y has mass 0.200 kg and initial velocity 6.00 m s^{-1} at an angle of 60.0° to line AB.
The balls stick together during the collision and then travel along line AB, as illustrated in Fig. 4.2.

(a) **(i)** Calculate, to three significant figures, the component of the initial momentum of ball Y that is perpendicular to line AB.

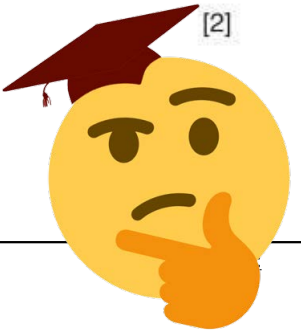
component of momentum = ... kg m s^{-1} [2]

(ii) By considering the component of the initial momentum of each ball perpendicular to line AB, calculate, to three significant figures, v_X.

v_X = ...m s^{-1} [1]

(iii) Show that the speed of the two balls after the collision is 2.4 m s^{-1}.

[2]



(b) The two balls continue moving together along the horizontal frictionless surface towards a spring, as illustrated in Fig. 4.3.

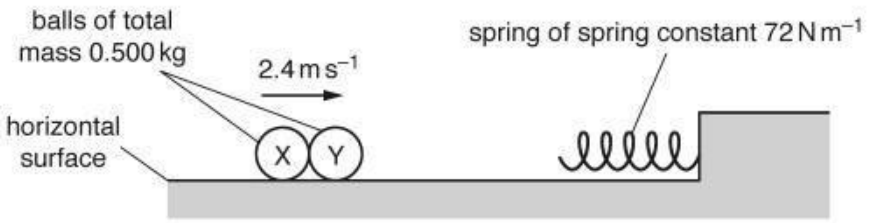


Fig. 4.3

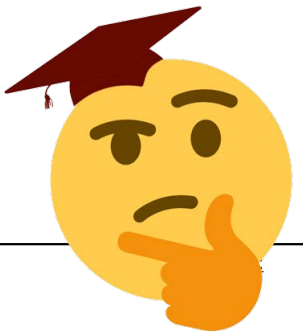
The balls hit the spring and remain stuck together as they decelerate to rest. All the kinetic energy of the balls is converted into elastic potential energy of the spring. The energy E stored in the spring is given by

$$E = \frac{1}{2}kx^2$$

where k is the spring constant of the spring and x is its compression.
The spring obeys Hooke's law and has a spring constant of $72\,\text{N}\,\text{m}^{-1}$.

(i) Determine the maximum compression of the spring caused by the two balls.

maximum compression = ...m [3]

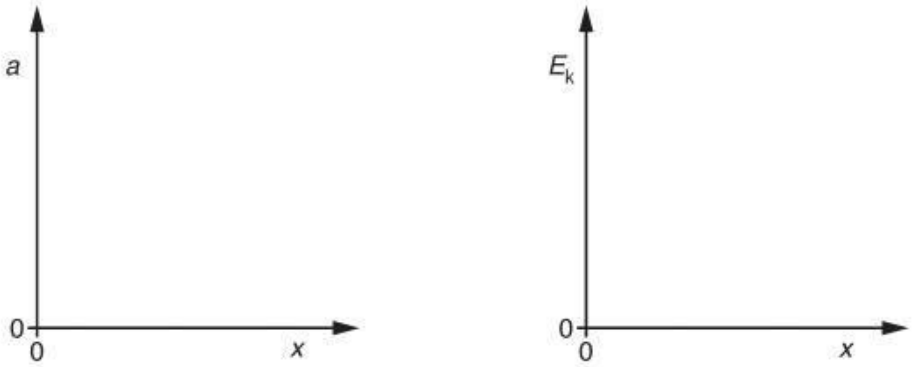


(ii) On Fig. 4.4, sketch graphs to show the variation with compression x of the spring, from zero to maximum compression, of:

1. the magnitude of the deceleration a of the balls

2. the kinetic energy E_k of the balls.

Numerical values are not required.



[3]

Fig. 4.4

25 – (9702/21_Summer_2020_Q2) – *Kinematics, Dynamics*

(a) State Newton's second law of motion.

.....

..... [1]

(b) A delivery company suggests using a remote-controlled aircraft to drop a parcel into the garden of a customer. When the aircraft is vertically above point P on the ground, it releases the parcel with a velocity that is horizontal and of magnitude $5.4\,m\,s^{-1}$. The path of the parcel is shown in Fig. 2.1.

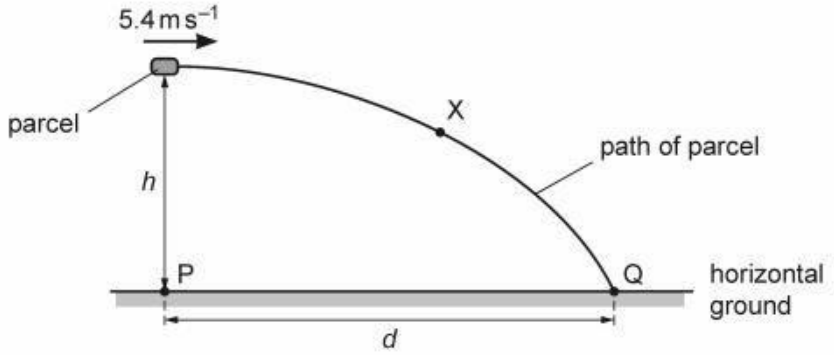


Fig. 2.1 (not to scale)

The parcel takes a time of 0.81 s after its release to reach point Q on the horizontal ground. Assume air resistance is negligible.

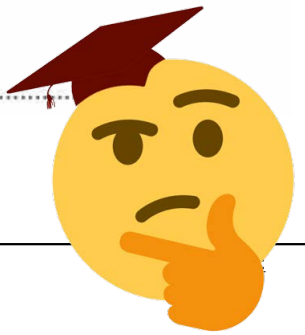
(i) On Fig. 2.1, draw an arrow from point X to show the direction of the acceleration of the parcel when it is at that point. [1]

(ii) Determine the height *h* of the parcel above the ground when it is released.

h = ... m [2]

(iii) Calculate the horizontal distance *d* between points P and Q.

d = ...



(c) Another parcel is accidentally released from rest by a different aircraft when it is hovering at a great height above the ground. Air resistance is now significant.

(i) On Fig. 2.2, draw arrows to show the directions of the forces acting on the parcel as it falls vertically downwards. Label each arrow with the name of the force.

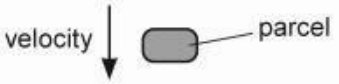


Fig. 2.2

[2]

(ii) By considering the forces acting on the parcel, state and explain the variation, if any, of the acceleration of the parcel as it moves downwards before it reaches constant (terminal) speed.

.....

.....

.....

.....

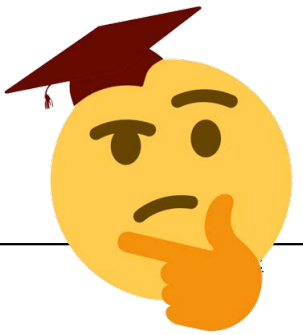
.....

..... [3]

(iii) Describe the energy conversion that occurs when the parcel is falling through the air at constant (terminal) speed.

.....

..... [1]



26 – (9702/22_Summer_2020_Q2) – *Kinematics, Dynamics*

(a) Fig. 2.1 shows the velocity–time graph for an object moving in a straight line.

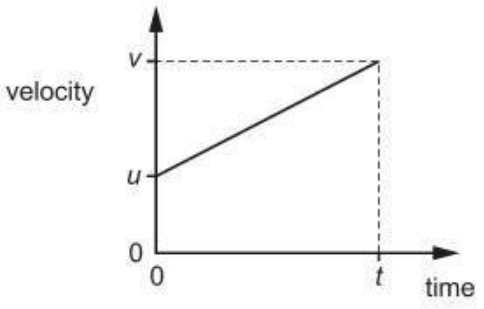


Fig. 2.1

(i) Determine an expression, in terms of u, v and t, for the area under the graph.

area = ... [1]

(ii) State the name of the quantity represented by the area under the graph.

..... [1]

(b) A ball is kicked with a velocity of $15\,\mathrm{m\,s^{-1}}$ at an angle of 60° to horizontal ground. The ball then strikes a vertical wall at the instant when the path of the ball becomes horizontal, as shown in Fig. 2.2.

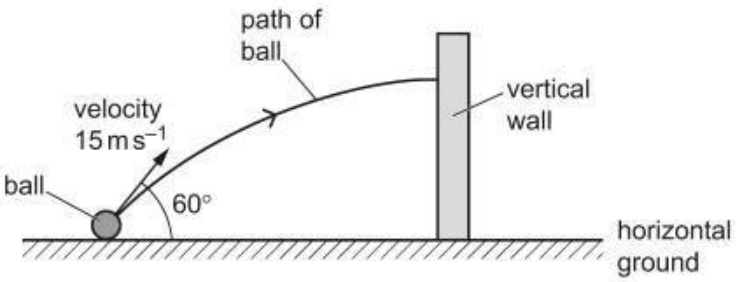
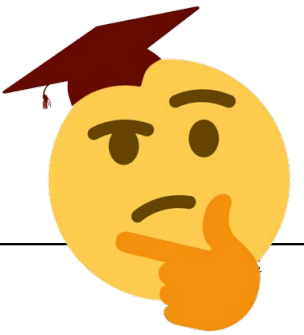


Fig. 2.2 (not to scale)

Assume that air resistance is negligible.



(i) By considering the vertical motion of the ball, calculate the time it takes to reach the wall.

time = ... s [3]

(ii) Explain why the horizontal component of the velocity of the ball remains constant as it moves to the wall.

.....

..... [1]

(iii) Show that the ball strikes the wall with a horizontal velocity of $7.5\,m\,s^{-1}$.

[1]

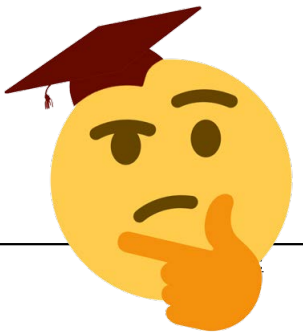
(c) The mass of the ball in **(b)** is 0.40 kg. It is in contact with the wall for a time of 0.12 s and rebounds horizontally with a speed of $4.3\,m\,s^{-1}$.

(i) Use the information from **(b)(iii)** to calculate the change in momentum of the ball due to the collision.

change in momentum = ... $kg\,m\,s^{-1}$ [2]

(ii) Calculate the magnitude of the average force exerted on the ball by the wall.

average force = ... N [1]



27 – (9702/23_Summer_2020_Q2) – *Kinematics, Dynamics*

(a) State Newton's first law of motion.

.....

..... [1]

(b) A skier is pulled in a straight line along horizontal ground by a wire attached to a kite, as shown in Fig. 2.1.

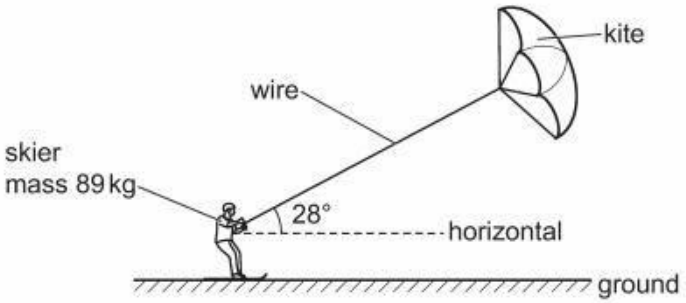


Fig. 2.1 (not to scale)

The mass of the skier is 89 kg. The wire is at an angle of 28° to the horizontal. The variation with time t of the velocity v of the skier is shown in Fig. 2.2.

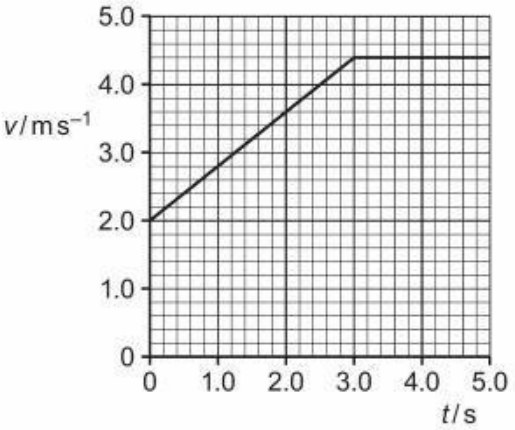
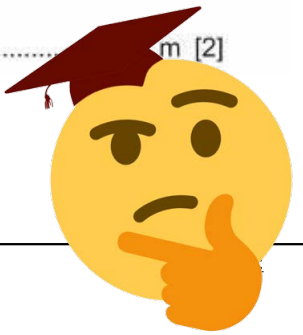


Fig. 2.2

(i) Use Fig. 2.2 to determine the distance moved by the skier from time $t = 0$ to $t = 5.0$ s.

distance = ... m [2]



(ii) Use Fig. 2.2 to show that the acceleration a of the skier is $0.80\,\mathrm{m\,s^{-2}}$ at time $t = 2.0\,\mathrm{s}$.

[2]

(iii) The tension in the wire at time $t = 2.0\,\mathrm{s}$ is $240\,\mathrm{N}$.

Calculate:

1. the horizontal component of the tension force acting on the skier

horizontal component of force = ... N [1]

2. the total resistive force R acting on the skier in the horizontal direction.

R = ... N [2]

(iv) The skier is now lifted upwards by a gust of wind. For a few seconds the skier moves horizontally through the air with the wire at an angle of 45° to the horizontal, as shown in Fig. 2.3.

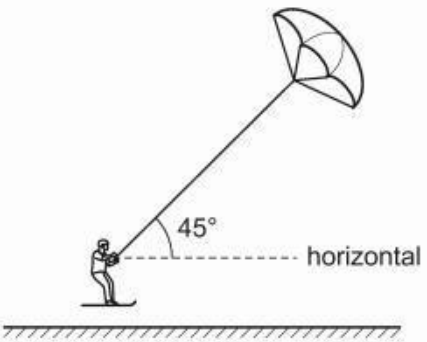
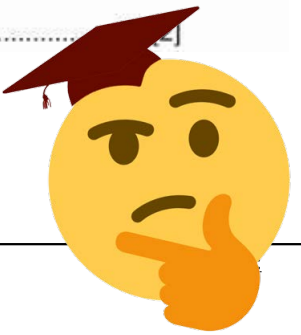


Fig. 2.3 (not to scale)

By considering the vertical components of the forces acting on the skier, determine the new tension in the wire when the skier is moving horizontally through the air.

tension = ... [2]



28 – (9702/22_Winter_2020_Q2) – *Kinematics, Dynamics, Forces, Density & Pressure*

(a) A cylinder is suspended from the end of a string. The cylinder is stationary in water with the axis of the cylinder vertical, as shown in Fig. 2.1.

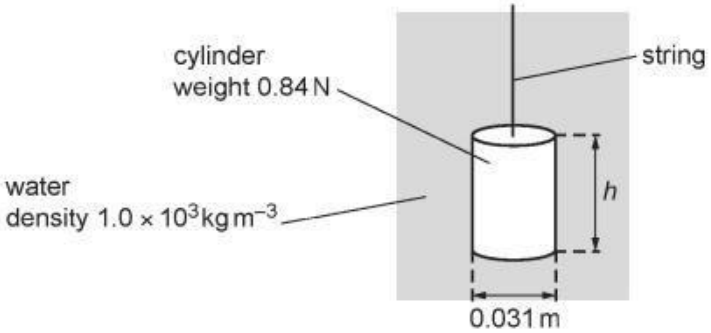


Fig. 2.1 (not to scale)

The cylinder has weight 0.84 N, height h and a circular cross-section of diameter 0.031 m. The density of the water is $1.0 \times 10^3 \text{ kg m}^{-3}$. The difference between the pressures on the top and bottom faces of the cylinder is 520 Pa.

(i) Calculate the height h of the cylinder.

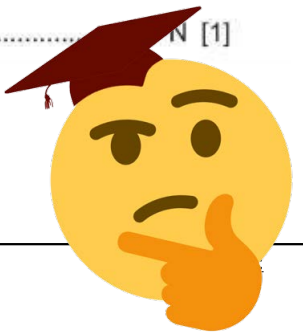
h = ... m [2]

(ii) Show that the upthrust acting on the cylinder is 0.39 N.

[2]

(iii) Calculate the tension T in the string.

T = ... N [1]



(b) The string is now used to move the cylinder in **(a)** vertically upwards through the water. The variation with time t of the velocity v of the cylinder is shown in Fig. 2.2.

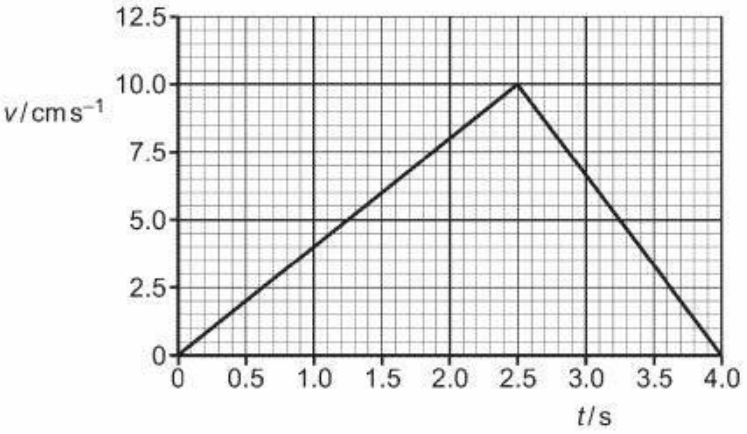


Fig. 2.2

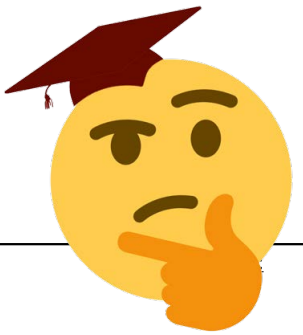
(i) Use Fig. 2.2 to determine the acceleration of the cylinder at time $t = 2.0\,s$.

acceleration = ... $m\,s^{-2}$ [2]

(ii) The top face of the cylinder is at a depth of 0.32 m below the surface of the water at time $t = 0$.

Use Fig. 2.2 to determine the depth of the top face below the surface of the water at time $t = 4.0\,s$.

depth = ... m [2]



(c) The cylinder in **(b)** is released from the string at time $t = 4.0\,\text{s}$. The cylinder falls, from rest, vertically downwards through the water. Assume that the upthrust acting on the cylinder remains constant as it falls.

(i) State the name of the force that acts on the cylinder when it is moving and does not act on the cylinder when it is stationary.

..... [1]

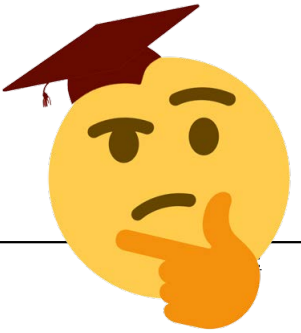
(ii) State and explain the variation, if any, of the acceleration of the cylinder as it falls downwards through the water.

.....

.....

..... [2]

[Total: 12]



29 – (9702/21_Winter_2020_Q3) – *Dynamics*

(a) Define *force*.

.....

..... [1]

(b) A ball falls vertically downwards towards a horizontal floor and then rebounds along its original path, as illustrated in Fig. 3.1.

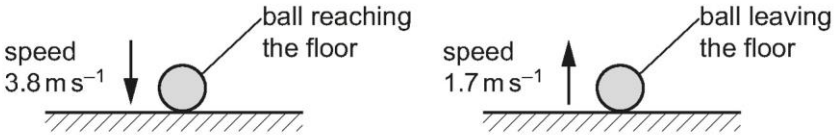


Fig. 3.1

The ball reaches the floor with speed $3.8\,m\,s^{-1}$. The ball is then in contact with the floor for a time of 0.081 s before leaving it with speed $1.7\,m\,s^{-1}$. The mass of the ball is 0.062 kg.

(i) Calculate the loss of kinetic energy of the ball during the collision.

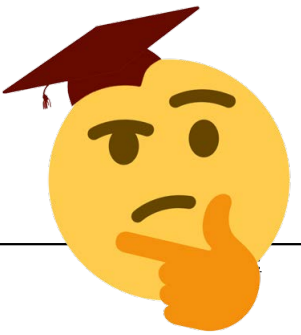
loss of kinetic energy = ... J [2]

(ii) Determine the magnitude of the change in momentum of the ball during the collision.

change in momentum = ... N s [2]

(iii) Show that the magnitude of the average resultant force acting on the ball during the collision is 4.2 N.

[1]



(iv) Use the information in **(iii)** to calculate the magnitude of:

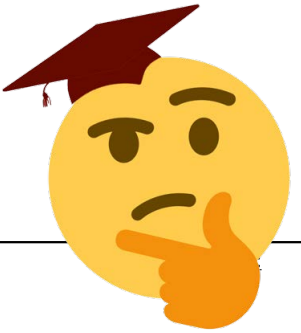
1. the average force of the floor on the ball during the collision

average force = ... N

2. the average force of the ball on the floor during the collision.

average force = ... N
[2]

[Total: 8]



30 – (9702/23_Winter_2020_Q3) – *Kinematics, Dynamics*

A ball is fired horizontally with a speed of $41.0\,m\,s^{-1}$ from a stationary cannon at the top of a hill. The ball lands on horizontal ground that is a vertical distance of 57 m below the cannon, as shown in Fig. 3.1.

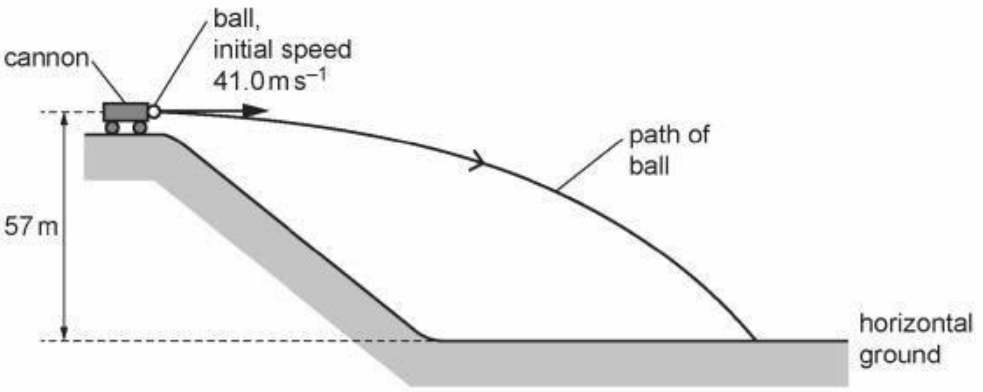


Fig. 3.1 (not to scale)

Assume air resistance is negligible.

(a) Show that the time taken for the ball to reach the ground, after being fired, is 3.4 s.

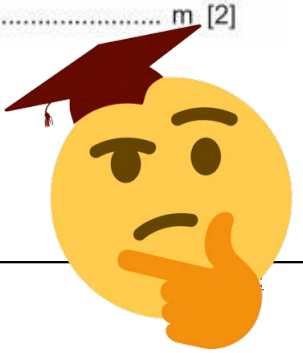
[2]

(b) Calculate the horizontal distance of the ball from the cannon at the point where the ball lands on the ground.

horizontal distance = ... m [1]

(c) Determine the magnitude of the displacement of the ball from the cannon at the point where the ball lands on the ground.

displacement = ... m [2]



(d) The ball leaves the cannon at time $t = 0$.

On Fig. 3.2, sketch a graph to show the variation of the magnitude v of the vertical component of the velocity of the ball with time t from $t = 0$ to $t = 3.4$ s.
Numerical values are not required.

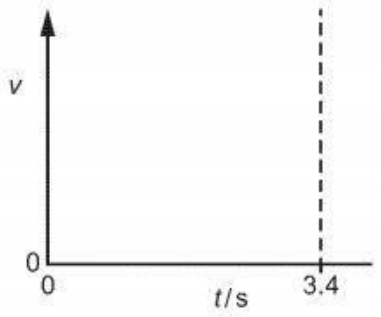


Fig. 3.2

[1]

(e) The cannon recoils horizontally with a speed of $0.340\,\text{m}\,\text{s}^{-1}$ when it fires the ball. The total mass of the ball and the cannon is 1480 kg. Assume that no external horizontal forces act on the ball-cannon system.

Determine, to three significant figures, the mass of the ball.

mass = ... kg [2]

(f) The cannon now fires a ball of smaller mass. Assume that air resistance is still negligible.

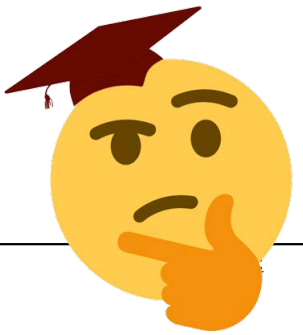
State and explain the change, if any, to the graph in Fig. 3.2 due to the decreased mass of the ball.

.....

.....

..... [2]

[Total: 10]



31 – (9702/22_Summer_2021_Q2) – *Kinematics, Dynamics*

A ball is thrown vertically downwards to the ground, as illustrated in Fig. 2.1.

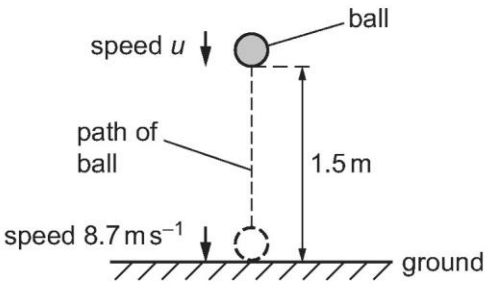


Fig. 2.1

The ball is thrown with speed u from a height of 1.5 m. The ball then hits the ground with speed 8.7 m s^{-1}. Assume that air resistance is negligible.

(a) Calculate speed u.

u = ... m s^{-1} [2]

(b) State how Newton's third law applies to the collision between the ball and the ground.

.....

.....

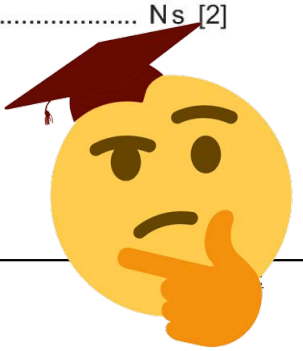
.....

..... [2]

(c) The ball is in contact with the ground for a time of 0.091 s. The ball rebounds vertically and leaves the ground with speed 5.4 m s^{-1}. The mass of the ball is 0.059 kg.

(i) Calculate the magnitude of the change in momentum of the ball during the collision.

change in momentum = ... N s [2]



(ii) Determine the magnitude of the average resultant force that acts on the ball during the collision.

average resultant force = ... N [1]

(iii) Use your answer in **(c)(ii)** to calculate the magnitude of the average force exerted by the ground on the ball during the collision.

average force = ... N [2]

(d) The ball was thrown downwards at time $t = 0$ and hits the ground at time $t = T$.

On Fig. 2.2, sketch a graph to show the variation of the speed of the ball with time t from $t = 0$ to $t = T$. Numerical values are not required.

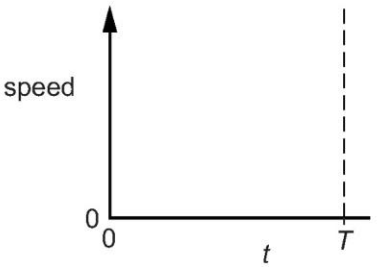


Fig. 2.2

[1]

(e) In practice, air resistance is not negligible.

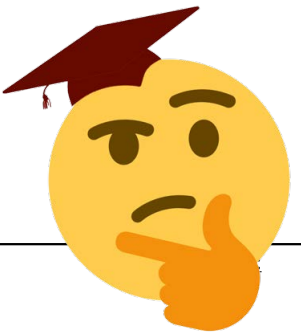
State and explain the variation, if any, with time t of the gradient of the graph in **(d)** when air resistance is not negligible.

.....

.....

.....

..... [2]



32 – (9702/21_Summer_2021_Q3) – *Dynamics, Forces, Density & Pressure*

A pendulum consists of a solid sphere suspended by a string from a fixed point P, as shown in Fig. 3.1.

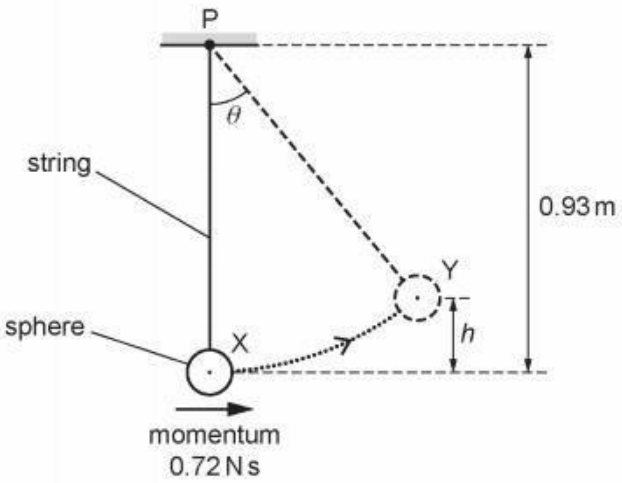


Fig. 3.1 (not to scale)

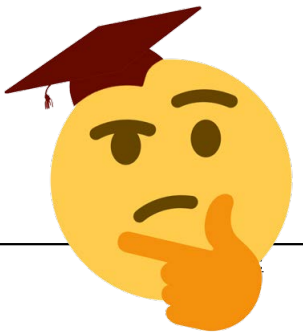
The sphere swings from side to side. At one instant the sphere is at its lowest position X, where it has kinetic energy 0.86 J and momentum 0.72 N s in a horizontal direction. A short time later the sphere is at position Y, where it is momentarily stationary at a maximum vertical height *h* above position X.

The string has a fixed length and negligible weight. Air resistance is also negligible.

(a) On Fig. 3.1, draw a solid line to represent the displacement of the centre of the sphere at position Y from position X. [1]

(b) Show that the mass of the sphere is 0.30 kg.

[3]



(c) Calculate height h.

h = ... m [2]

(d) The distance between point P and the centre of the sphere is 0.93 m. When the sphere is at position Y, the string is at an angle θ to the vertical.

Show that θ is 47°.

[1]

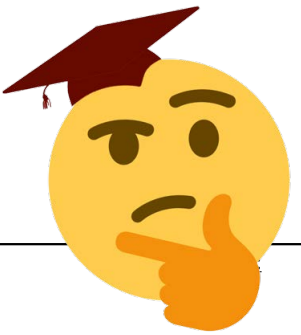
(e) For the sphere at position Y, calculate the moment of its weight about point P.

moment = ... N m [2]

(f) State and explain whether the sphere is in equilibrium when it is stationary at position Y.

.....

..... [1]



33 – (9702/21_Summer_2022_Q2) – *Dynamics*

(a) State what is meant by the centre of gravity of an object.

.....

..... [1]

(b) A non-uniform rod XY is pivoted at point P, as shown in Fig. 2.1.

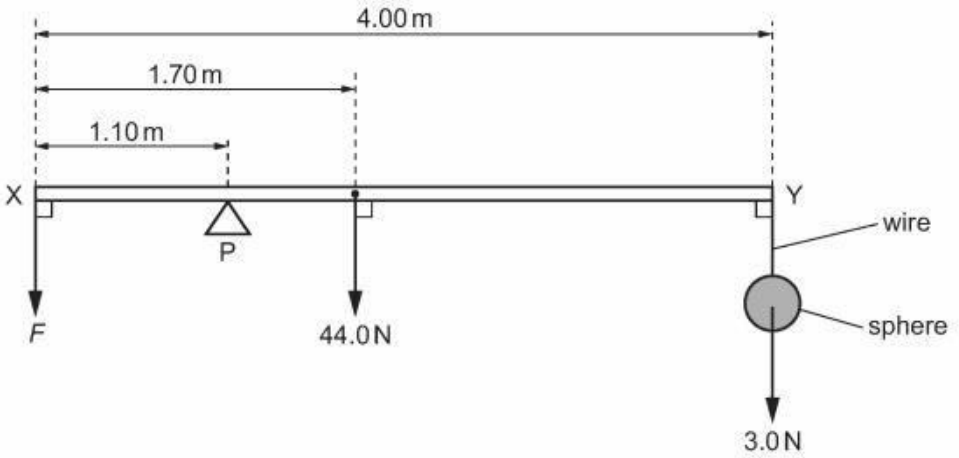


Fig. 2.1 (not to scale)

The rod has length 4.00 m and weight 44.0 N. The centre of gravity of the rod is 1.70 m from end X of the rod. Point P is 1.10 m from end X.

A sphere hangs by a wire from end Y of the rod. The weight of the sphere is 3.0 N. The weight of the wire is negligible.

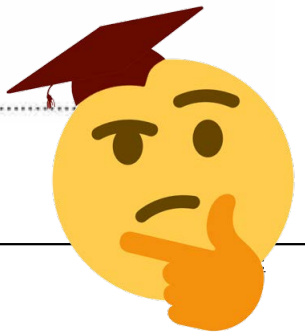
A force *F* is applied vertically downwards at end X so that the horizontal rod is in equilibrium.

(i) By taking moments about P, calculate *F*.

F = ... N [3]

(ii) Calculate the force exerted on the rod by the pivot.

force = ...



(c) The sphere in **(b)** is now immersed in a liquid in a container, as shown in Fig. 2.2.

Fig. 2.2

The density of the liquid is 1100 kg m^{-3}. The upthrust acting on the sphere due to the liquid is 2.5 N. The magnitude of F is unchanged so that the horizontal rod is **not** in equilibrium.

(i) Use Archimedes' principle to determine the radius r of the sphere.

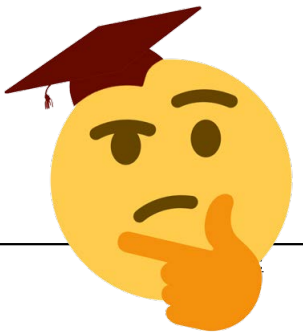
r = ... m [3]

(ii) Calculate the magnitude and direction of the resultant moment of the forces on the rod about P.

magnitude of resultant moment = ... N m

direction of resultant moment .....
[2]

[Total: 10]



34 – (9702/22_Summer_2022_Q4) – *Dynamics*

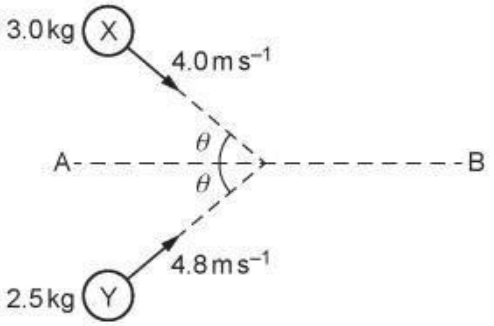
(a) State the principle of conservation of momentum.

.....

.....

..... [2]

(b) Two balls, X and Y, move along a horizontal frictionless surface, as shown from above in Fig. 4.1.



before collision

Fig. 4.1 (not to scale)

after collision

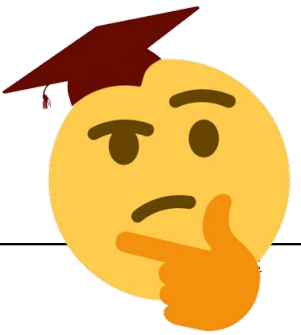
Fig. 4.2 (not to scale)

Ball X has a mass of 3.0 kg and a velocity of $4.0\,m\,s^{-1}$ in a direction at angle θ to a line AB. Ball Y has a mass of 2.5 kg and a velocity of $4.8\,m\,s^{-1}$ in a direction at angle θ to the line AB.

The balls collide and stick together. After colliding, the balls have a velocity of $3.7\,m\,s^{-1}$ along the line AB on the horizontal surface, as shown in Fig. 4.2.

(i) By considering the components of the momenta along the line AB, calculate θ.

θ = ... ° [3]

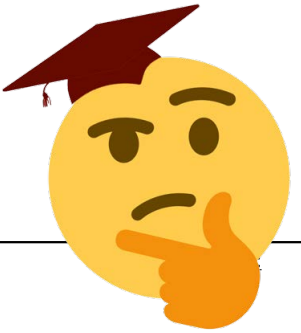


(ii) By calculation of kinetic energies, state and explain whether the collision of the balls is inelastic or perfectly elastic.

.....

..... [2]

[Total: 7]



35 - (9702/23_Winter_2022_Q2) - *Dynamics*

The engine of a toy rocket pushes gases vertically downwards and this results in the rocket accelerating vertically upwards from the ground.

The rocket starts to move from rest at time $t = 0$. The variation with time t of the vertical velocity v of the rocket for the first 0.30 s of the flight is shown in Fig. 2.1.

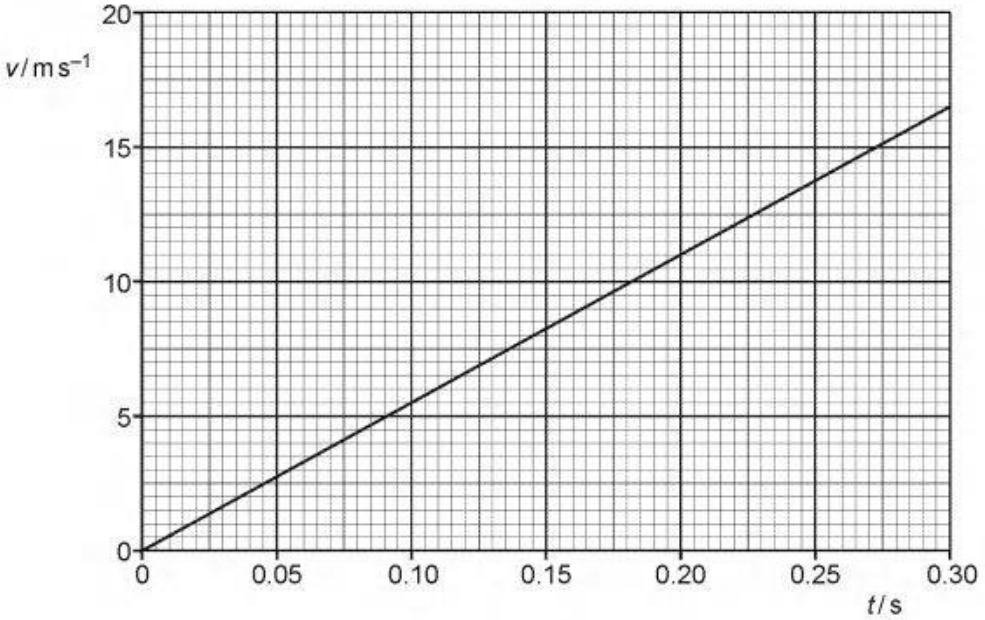


Fig. 2.1

As the rocket moves, the thrust force T provided by the rocket engine is 16 N.
Assume that the mass of the rocket is constant for this part of its flight.

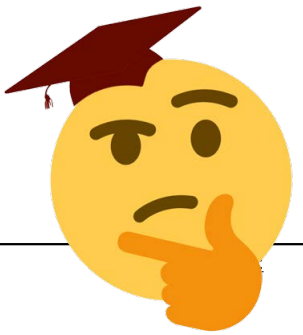
Assume that air resistance is negligible.

(a) For this part of the rocket's flight:

(i) show that the acceleration of the rocket is $55\,\mathrm{m\,s^{-2}}$

[1]

(ii) state an expression for the resultant force F experienced by the rocket in terms of the thrust force T and the weight W of the rocket



(iii) calculate the mass of the rocket.

mass = ... kg [2]

(b) At time t = 0.30 s, a small piece of metal separates from the rocket.

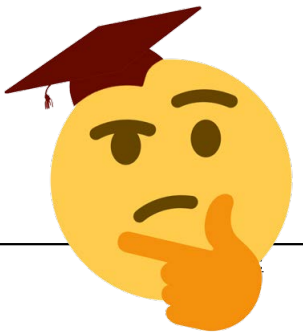
Calculate:

(i) the height of the rocket above the ground at t = 0.30 s

height = ... m [2]

(ii) the speed at which the piece of metal strikes the ground.

speed = ... $m\,s^{-1}$ [3]



36 – (9702/21_Summer_2023_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

A rigid uniform beam of weight W is connected to a fixed support by a hinge, as shown in Fig. 2.1.

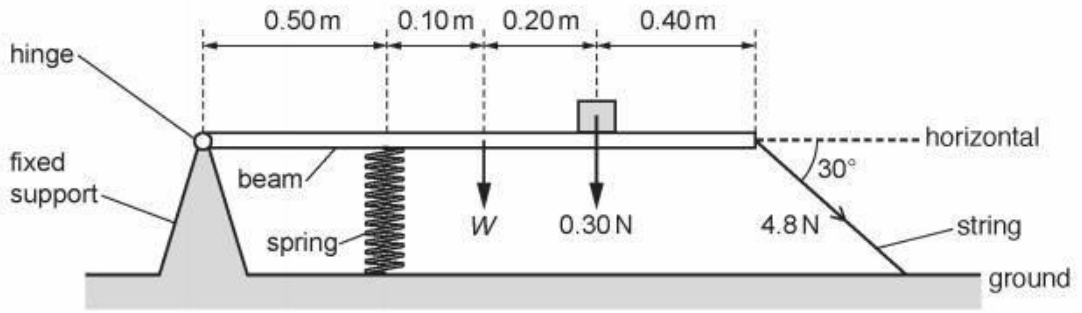


Fig. 2.1 (not to scale)

A compressed spring exerts a total force of 8.2 N vertically upwards on the horizontal beam. A block of weight 0.30 N rests on the beam. The right-hand end of the beam is connected to the ground by a string at an angle of 30° to the horizontal. The tension in the string is 4.8 N. The distances along the beam are shown in Fig. 2.1.

The beam is in equilibrium. Assume that the hinge is frictionless.

(a) **(i)** Show that the vertical component of the tension in the string is 2.4 N.

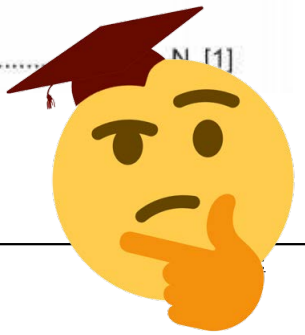
[1]

(ii) By taking moments about the hinge, determine the weight W of the beam.

W = ... N [3]

(iii) Calculate the horizontal component of the force exerted on the beam by the hinge.

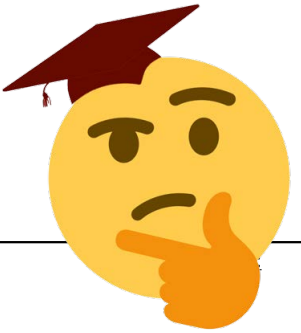
force = ... N [1]



(b) The spring obeys Hooke's law and has an elastic potential energy of 0.32 J.

Calculate the compression of the spring.

compression = ... m [2]



(c) The string is cut so that the spring extends upwards. This causes the beam to rotate and launch the block into the air. The block reaches its maximum height and then falls back to the ground.

Fig. 2.2 shows part of the path of the block in the air shortly before it hits the horizontal ground.

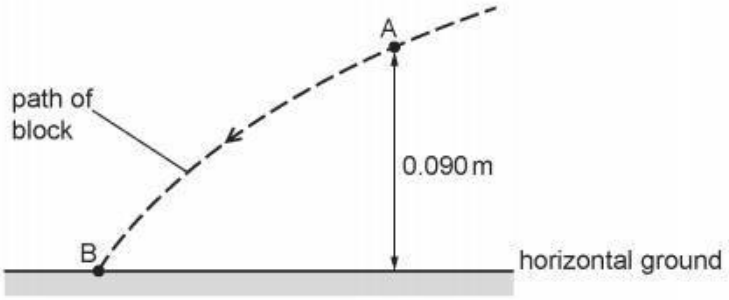


Fig. 2.2 (not to scale)

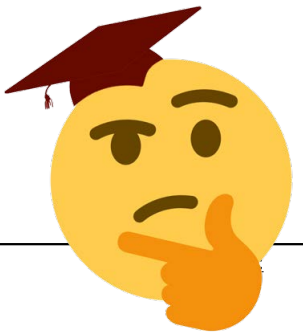
The block is at a height of 0.090 m above the ground when it passes through point A. The block has a kinetic energy of 0.044 J when it hits the ground at point B.
Air resistance is negligible.

(i) Calculate the decrease in the gravitational potential energy of the block for its movement from A to B.

decrease in gravitational potential energy = ... J [2]

(ii) Use your answer in **(c)(i)** and conservation of energy to determine the speed of the block at point A.

speed = ... $m\,s^{-1}$ [3]



(iii) By reference to the force on the block, explain why the horizontal component of the velocity of the block remains constant as it moves from A to B.

.....

..... [1]

(iv) The block passes through point A at time t_A and arrives at point B at time t_B.

On Fig. 2.3, sketch a graph to show the variation of the magnitude of the vertical component v_Y of the velocity of the block with time t from $t = t_A$ to $t = t_B$.
Numerical values of v_Y are not required.

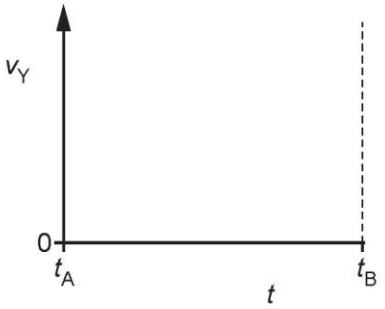


Fig. 2.3

[1]

37 – (9702/21_Summer_2023_Q3) – *Dynamics, Forces, Density & Pressure*

A block is pulled in a straight line along a rough horizontal surface by a varying force X, as shown in Fig. 3.1.

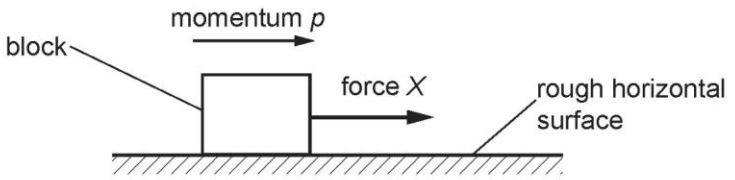


Fig. 3.1

Air resistance is negligible. Assume that the frictional force exerted on the block by the surface is constant and has magnitude 2.0 N.

The variation with time t of the momentum p of the block is shown in Fig. 3.2.

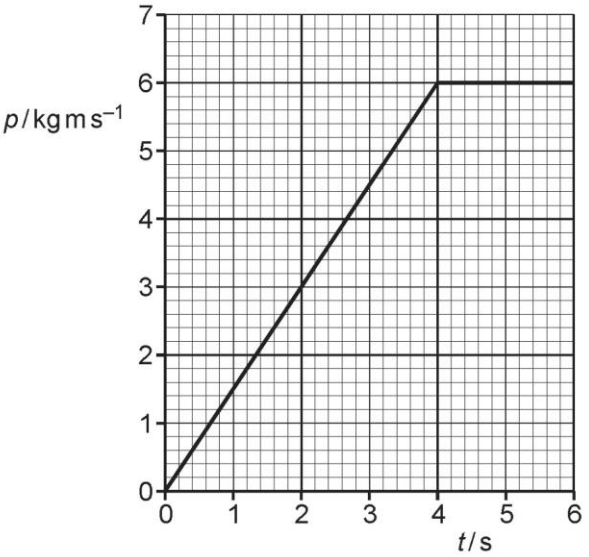
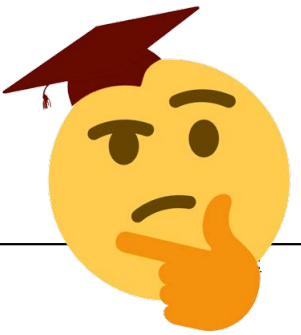


Fig. 3.2

(a) State Newton's second law of motion.

.....

..... [1]



(b) Use Fig. 3.2 to determine, for the block at time t = 2.0 s, the magnitude of:

(i) the resultant force on the block

resultant force = ... N [1]

(ii) the force X.

X = ... N [1]

(c) On Fig. 3.3, sketch a graph to show the variation of force X with time t from t = 0 to t = 6.0 s.

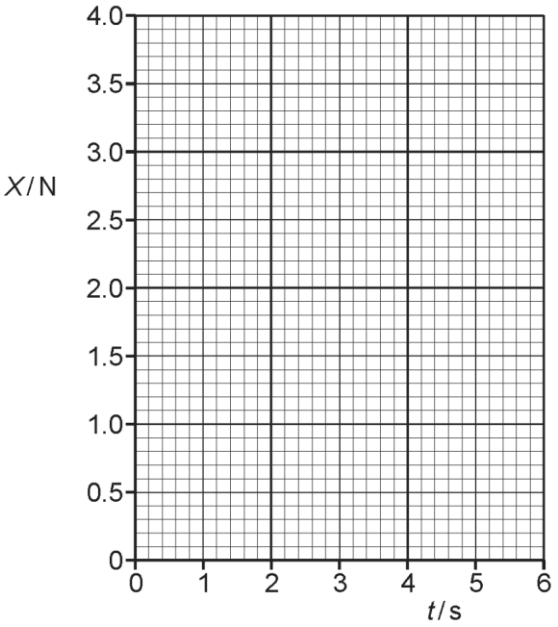
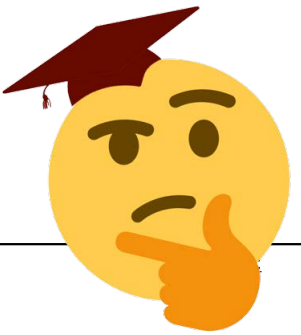


Fig. 3.3

[3]



38 – (9702/22_Summer_2023_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a) State what is meant by the centre of gravity of an object.

.....

..... [1]

(b) Two blocks are on a horizontal beam that is pivoted at its centre of gravity, as shown in Fig. 2.1.

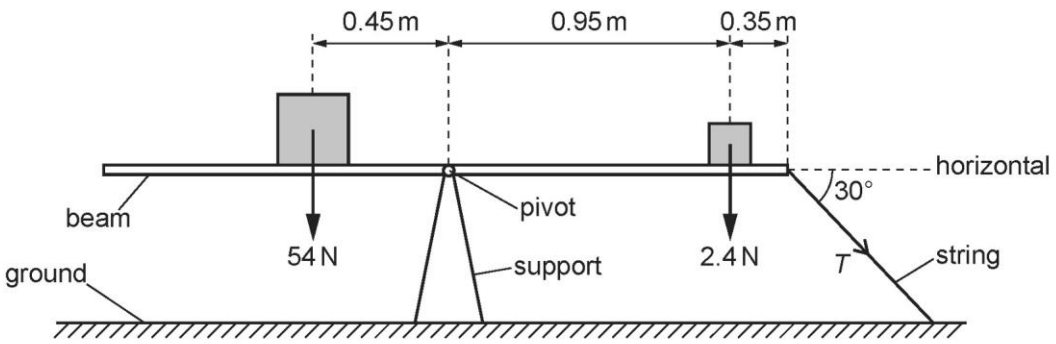


Fig. 2.1 (not to scale)

A large block of weight 54 N is a distance of 0.45 m from the pivot. A small block of weight 2.4 N is a distance of 0.95 m from the pivot and a distance of 0.35 m from the right-hand end of the beam.

The right-hand end of the beam is connected to the ground by a string that is at an angle of 30° to the horizontal. The beam is in equilibrium.

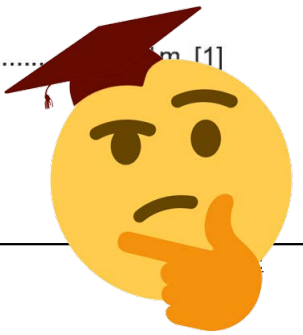
(i) By taking moments about the pivot, calculate the tension T in the string.

T = ... N [3]

(ii) The string is cut so that the beam is no longer in equilibrium.

Calculate the magnitude of the resultant moment about the pivot acting on the beam immediately after the string is cut.

resultant moment = ... m [1]



(c) The beam in **(b)** rotates when the string is cut and the small block of weight 2.4 N is projected through the air. Fig. 2.2 shows the last part of the path of the block before it hits the ground at point Y.

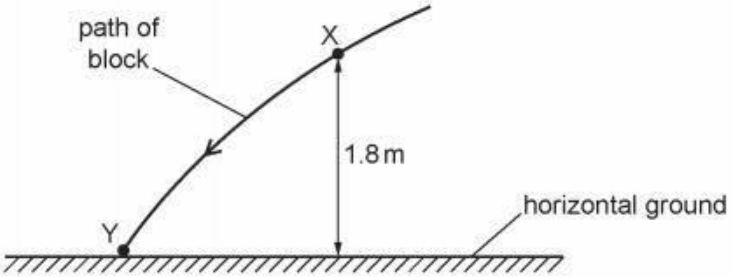


Fig. 2.2 (not to scale)

At point X on the path, the block has a speed of $3.4\,m\,s^{-1}$ and is at a height of 1.8 m above the horizontal ground. Air resistance is negligible.

(i) Calculate the decrease in the gravitational potential energy of the block for its movement from X to Y.

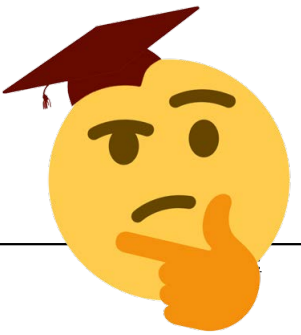
decrease in gravitational potential energy = ... J [2]

(ii) Use your answer to **(c)(i)** and conservation of energy to determine the kinetic energy of the block at Y.

kinetic energy = ... J [3]

(iii) State the variation, if any, in the direction of the acceleration of the block as it moves from X to Y.

..... [1]



(iv) The block passes point X at time t_X and arrives at point Y at time t_Y.

On Fig. 2.3, sketch a graph to show the variation of the magnitude of the horizontal component of the velocity of the block with time from t_X to t_Y.
Numerical values are not required.

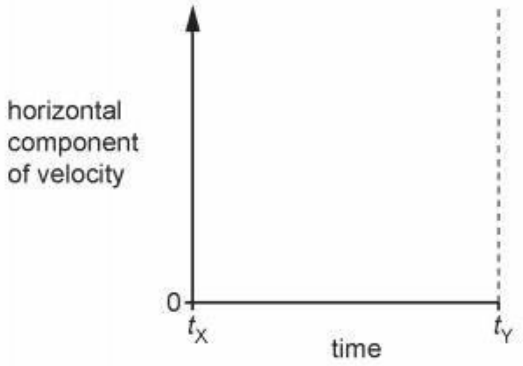


Fig. 2.3

[1]

39 – (9702/22_Summer_2023_Q3) – *Dynamics, Kinematics*

A block is pulled by a force X in a straight line along a rough horizontal surface, as shown in Fig. 3.1.

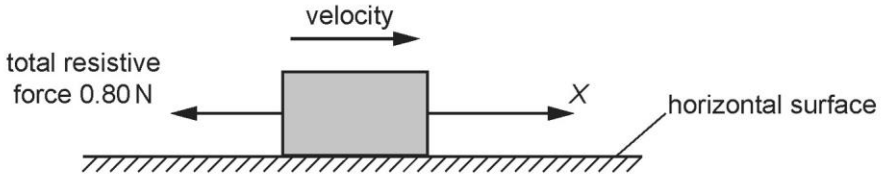


Fig. 3.1

Assume that the total resistive force opposing the motion of the block is 0.80 N at all speeds of the block.

The variation with time t of the magnitude of the force X is shown in Fig. 3.2.

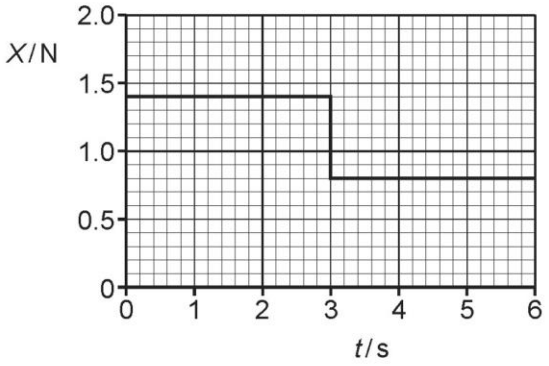


Fig. 3.2

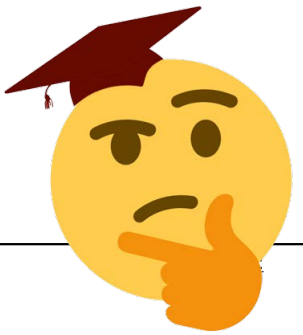
(a) **(i)** Define force.

.....

..... [1]

(ii) Determine the change in momentum of the block from time t = 0 to time t = 3.0 s.

change in momentum = ... kg m s^{-1} [2]



(b) **(i)** Describe and explain the motion of the block between time t = 3.0 s and time t = 6.0 s.

.....

.....

.....

..... [2]

(ii) Force X produces a total power of 2.0 W when moving the block between time t = 3.0 s and time t = 6.0 s.

Calculate the distance moved by the block during this time interval.

distance = ... m [3]

(c) The block is at rest at time t = 0.

On Fig. 3.3, sketch a graph to show the variation of the momentum of the block with time t from t = 0 to t = 6.0 s.
Numerical values of momentum are not required.

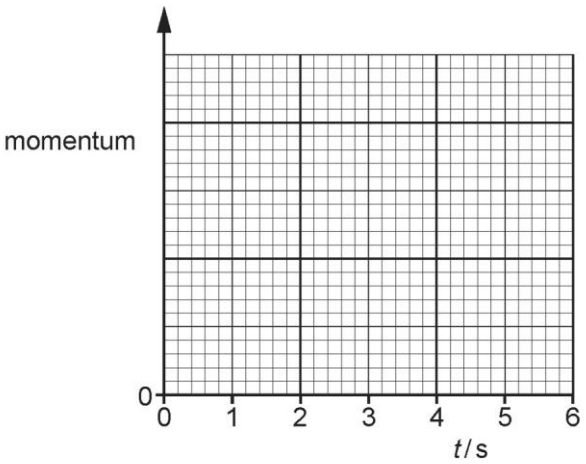
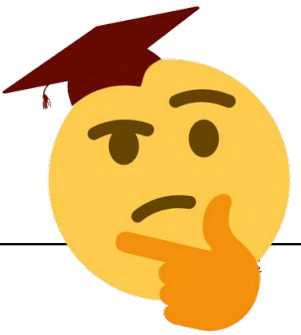


Fig. 3.3

[2]



40 – (9702/22_Summer_2023_Q4) – *Dynamics, Work, Energy & Power*

A spring is suspended from a fixed point at one end. The spring is extended by a vertical force applied to the other end. The variation of the applied force F with the length L of the spring is shown in Fig. 4.1.

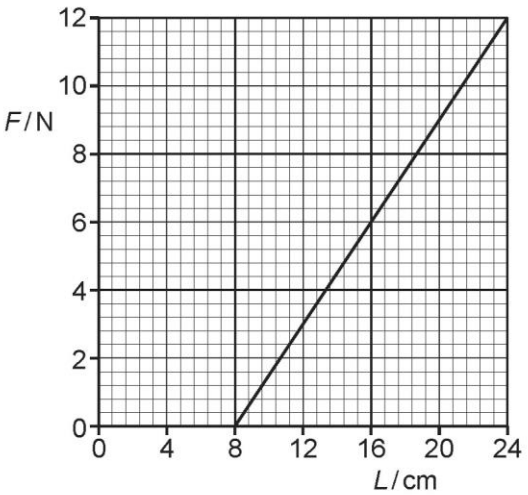


Fig. 4.1

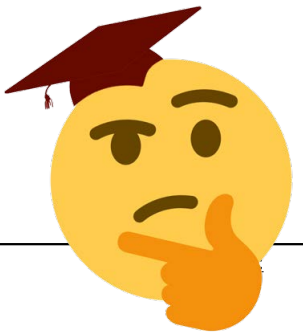
For the spring:

(a) state the name of the law that gives the relationship between the force and the extension

..... [1]

(b) determine the spring constant, in $N\,m^{-1}$

spring constant = ...$N\,m^{-1}$ [2]



(c) determine the elastic potential energy when $F = 6.0\,\text{N}$.

elastic potential energy = ... J [2]

41 – (9702/23_Summer_2023_Q3) – *Dynamics*

(a) State the principle of conservation of momentum.

.....

.....

..... [2]

(b) A firework is initially stationary. It explodes into three fragments A, B and C that move in a horizontal plane, as shown in the view from above in Fig. 3.1.

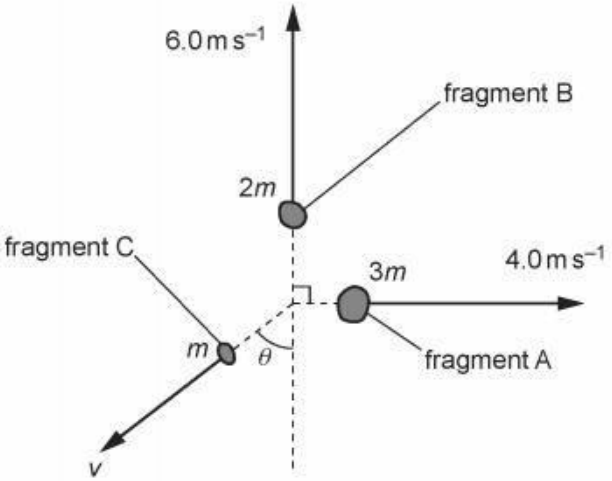


Fig. 3.1

Fragment A has a mass of $3m$ and moves away from the explosion at a speed of $4.0\,\text{m s}^{-1}$.

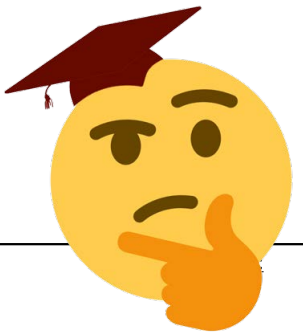
Fragment B has a mass of $2m$ and moves away from the explosion at a speed of $6.0\,\text{m s}^{-1}$ at right angles to the direction of A.

Fragment C has a mass of m and moves away from the explosion at a speed v and at an angle θ as shown in Fig. 3.1.

Calculate:

(i) the angle θ

θ = ...° [3]



(ii) the speed v.

v = ... $m\,s^{-1}$ [2]

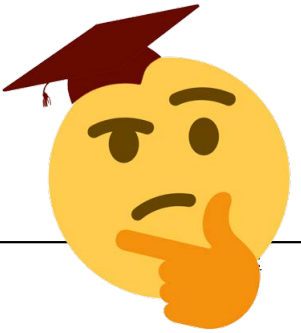
(c) The firework in **(b)** contains a chemical that has mass 5.0 g and has chemical energy per unit mass 700 J kg^{-1}. When the firework explodes, all of the chemical energy is transferred to the kinetic energy of fragments A, B and C.

(i) Show that the total chemical energy in the firework is 3.5 J.

[1]

(ii) Calculate the mass m.

m = ... kg [3]



42 – (9702/23_Summer_2023_Q6) – *Dynamics, Forces, Density & Pressure*

(a) Define the Young modulus.

.....

..... [1]

(b) A uniform wire is suspended from a fixed support. Masses are added to the other end of the wire, as shown in Fig. 6.1.

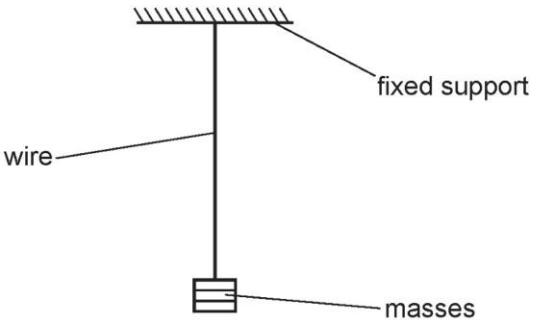


Fig. 6.1 (not to scale)

The variation of the length l of the wire with the force F applied to the wire by the masses is shown in Fig. 6.2.

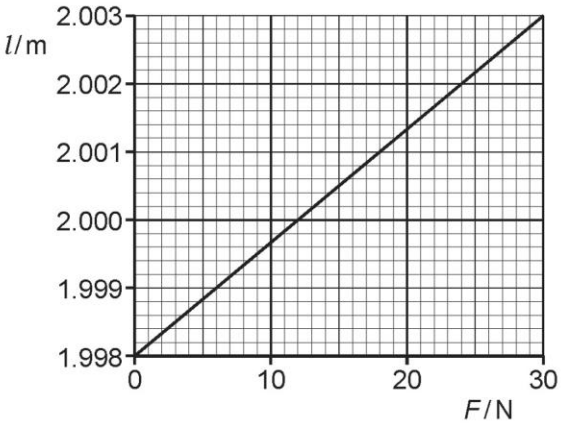
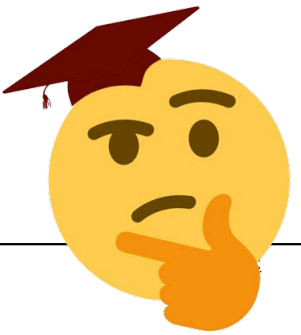


Fig. 6.2

The cross-sectional area of the wire is $0.95\,mm^2$.

(i) Determine the unstretched length of the wire.

unstretched length = ... m [1]



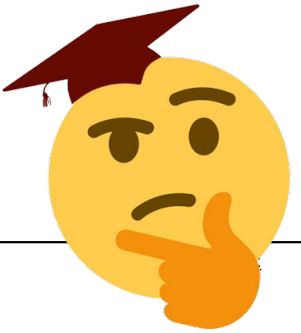
(ii) For an applied force F of 30 N, determine:

- the stress in the wire

stress = ... Pa

- the strain of the wire.

strain = ...
[3]



43 – (9702/21_Winter_2023_Q2) – *Work, Energy & Power, Dynamics*

A hot-air balloon floats just above the ground. The balloon is stationary and is held in place by a vertical rope, as shown in Fig. 2.1.

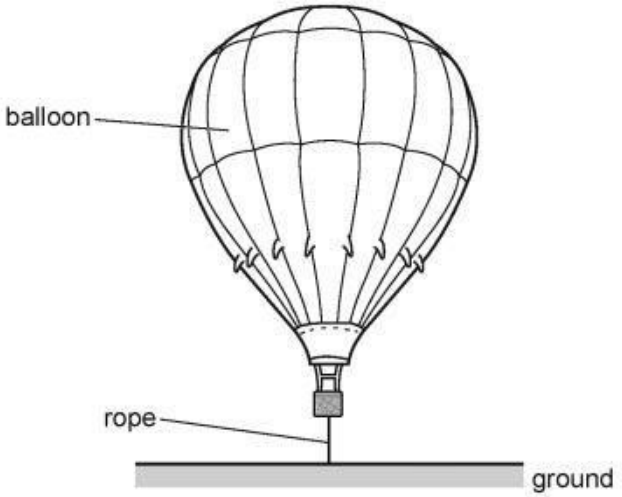


Fig. 2.1

The balloon has a weight W of 3.39×10^4 N. The tension T in the rope is 4.00×10^2 N.
Upthrust U acts on the balloon.
The density of the surrounding air is $1.23\,\text{kg}\,\text{m}^{-3}$.

(a) **(i)** On Fig. 2.1, draw labelled arrows to show the directions of the three forces acting on the balloon. [2]

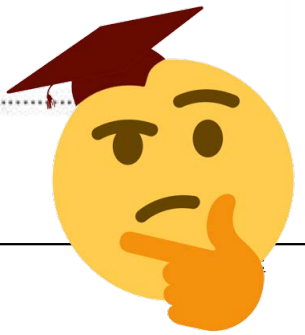
(ii) Calculate the volume, to three significant figures, of the balloon.

volume = ... m^3 [3]

(iii) The balloon is released from the rope.

Calculate the initial acceleration of the balloon.

acceleration = ...



(b) The balloon is stationary at a height of 500 m above the ground. A tennis ball is released from rest and falls vertically from the balloon.

A passenger in the balloon uses the equation $v^2 = u^2 + 2as$ to calculate that the ball will be travelling at a speed of approximately $100\,\mathrm{m\,s^{-1}}$ when it hits the ground.

Explain why the actual speed of the ball will be much lower than $100\,\mathrm{m\,s^{-1}}$ when it hits the ground.

.....

.....

.....

..... [3]

(c) Before the balloon is released, the rope holding the balloon has a strain of 2.4×10^{-5}. The rope has an unstretched length of 2.5 m. The rope obeys Hooke's law.

(i) Show that the extension of the rope is 6.0×10^{-5} m.

[1]

(ii) Calculate the elastic potential energy E_P of the rope.

E_P = ... J [2]

(iii) The rope holding the balloon is replaced with a new one of the same original length and cross-sectional area. The tension is unchanged and the new rope also obeys Hooke's law.

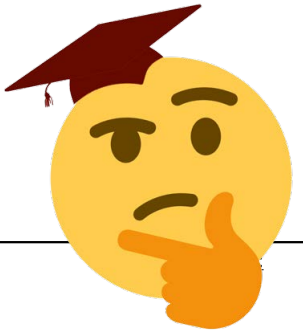
The new rope is made from a material of a lower Young modulus.

State and explain the effect of the lower Young modulus on the elastic potential energy of the rope.

.....

.....

..... [2]



44 - (9702/22_Winter_2023_Q2) - *Dynamics*

A high-altitude balloon is stationary in still air. A solid sphere is suspended from the balloon by a string, as shown in Fig. 2.1.

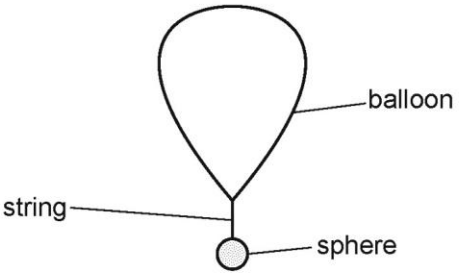


Fig. 2.1 (not to scale)

The volume of the balloon is $7.5\,m^3$. The total weight of the balloon, string and sphere is 65 N. The upthrust acting on the string and sphere is negligible.

(a) Calculate the density of the air surrounding the balloon.

density = ... $kg\,m^{-3}$ [2]

(b) The string breaks, releasing the sphere.

(i) State the magnitude of the acceleration of the sphere immediately after the string breaks.

acceleration = ... $m\,s^{-2}$ [1]

(ii) State and explain the variation, if any, in the magnitude of the acceleration of the sphere when it is moving downwards **before** it reaches terminal (constant) velocity.

.....

.....

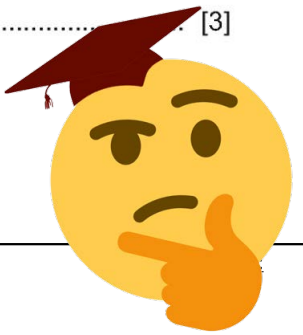
.....

.....

.....

.....

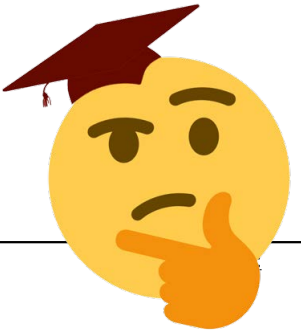
..... [3]



(c) The sphere has a mass of 4.0 kg.

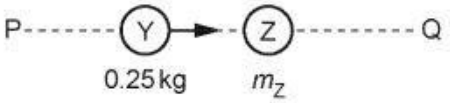
Calculate the total resistive force acting on the sphere at the instant when its acceleration is $1.9\,m\,s^{-2}$.

resistive force = ... N [2]



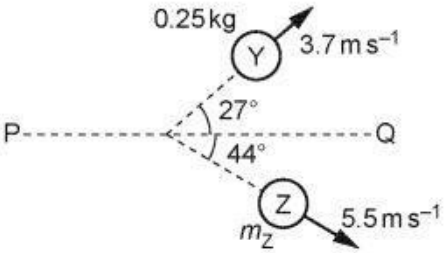
45 - (9702/22_Winter_2023_Q4) - *Dynamics*

(a) A ball Y moves along a horizontal frictionless surface and collides with a ball Z, as illustrated in the views from above in Fig. 4.1 and Fig. 4.2.



BEFORE COLLISION

Fig. 4.1 (not to scale)



AFTER COLLISION

Fig. 4.2 (not to scale)

Ball Y has a mass of 0.25 kg and initially moves along a line PQ.
Ball Z has a mass m_Z and is initially stationary.

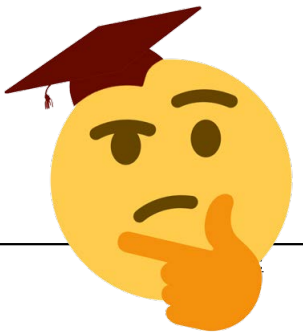
After the collision, ball Y has a final velocity of $3.7\,\text{m s}^{-1}$ at an angle of 27° to line PQ and ball Z has a final velocity of $5.5\,\text{m s}^{-1}$ at an angle of 44° to line PQ.

(i) Calculate the component of the final momentum of ball Y in the direction perpendicular to line PQ.

component of momentum = ... N s [2]

(ii) By considering the component of the final momentum of each ball in the direction perpendicular to line PQ, calculate m_Z.

m_Z = ... kg [1]



(iii) During the collision, the average force exerted on Y by Z is F_Y and the average force exerted on Z by Y is F_Z.

Compare the magnitudes and directions of F_Y and F_Z. Numerical values are not required.

magnitudes: .....

directions: .....

[2]

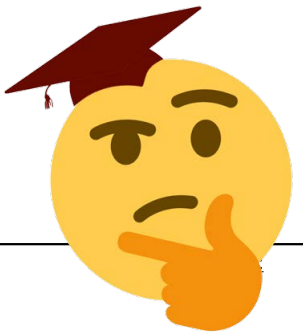
(b) Two blocks, A and B, move directly towards each other along a horizontal frictionless surface, as shown in the view from above in Fig. 4.3.

Fig. 4.3

The blocks collide perfectly elastically. Before the collision, block A has a speed of $4\,m\,s^{-1}$ and block B has a speed of $6\,m\,s^{-1}$. After the collision, block B moves back along its original path with a speed of $2\,m\,s^{-1}$.

Calculate the speed of block A after the collision.

speed = ... $m\,s^{-1}$ [1]



46 – (9702/23_Winter_2023_Q3) – *Dynamics, Work, Energy & Power*

(a) State the conditions for a system to be in equilibrium.

.....

.....

..... [2]

(b) Fig. 3.1 shows an airship in flight. The airship is propelled by identical fans that can be angled to control the motion of the airship.

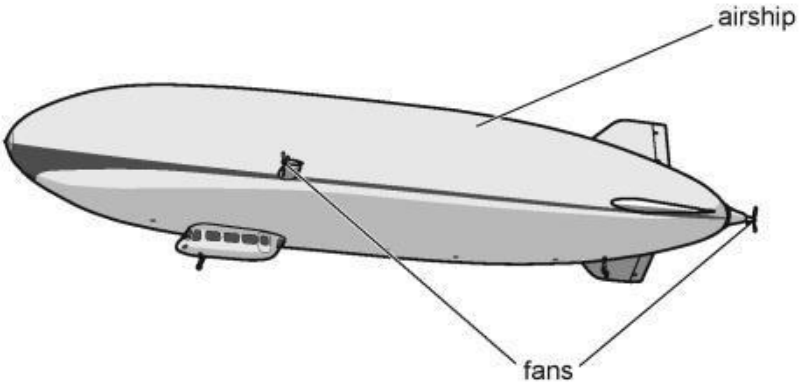


Fig. 3.1

The upthrust on the airship is 93 000 N.
The density of the surrounding air is 1.2 kg m^{-3}.

(i) Calculate the volume of air displaced by the airship.

volume = ... m^3 [1]

(ii) When fully loaded, the weight of the airship is greater than the upthrust.
To maintain horizontal flight, the fans provide a total vertical force of 3.0 × 10^3 N upwards on the airship.

Calculate the mass of the airship.

mass = ... kg [2]

(c) At a certain time, the airship in **(b)** is stationary. The thrust force exerted by a fan on the airship is 2800 N.

To produce this force, a mass of 64 kg of air is propelled through the blades of the fan in a time of 0.50 s. Assume that this air is initially stationary at the entrance to the fan.

Calculate:

(i) the change in momentum Δp of the air propelled through the fan blades in this time

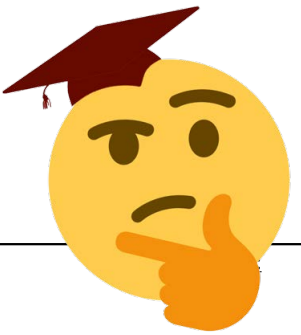
Δp = ... $kg\,m\,s^{-1}$ [2]

(ii) the speed of the air as it leaves the fan

speed = ... $m\,s^{-1}$ [2]

(iii) the total kinetic energy of this air due to its movement through the fan.

kinetic energy = ... J [2]



1 – (9702/21_Summer_2017_Q2) – *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

(a) State the two conditions for a system to be in equilibrium.

1. .....

.....

2. .....

.....

[2]

(b) A paraglider P of mass 95 kg is pulled by a wire attached to a boat, as shown in Fig. 2.1.

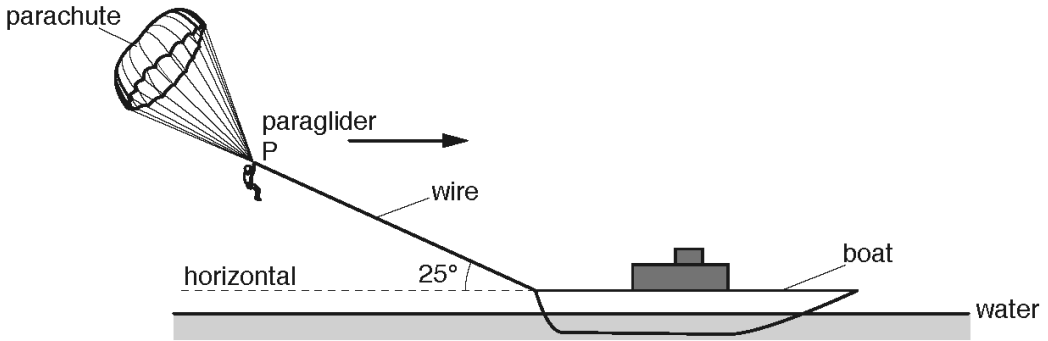


Fig. 2.1

The wire makes an angle of 25° with the horizontal water surface. P moves in a straight line parallel to the surface of the water.

The variation with time t of the velocity v of P is shown in Fig. 2.2.

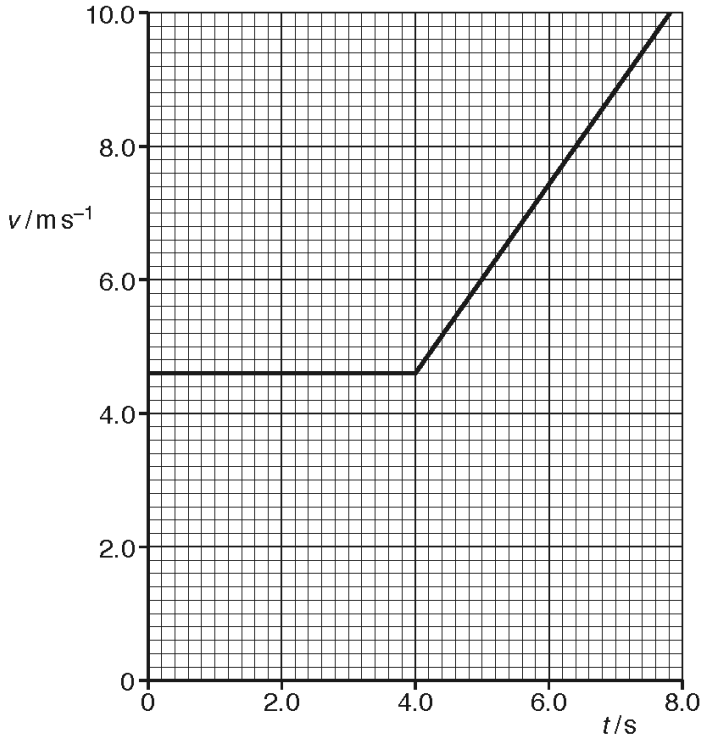
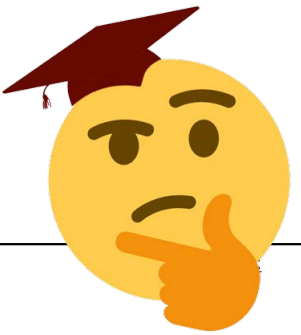


Fig. 2.2



(i) Show that the acceleration of P is $1.4\,\mathrm{m\,s^{-2}}$ at time $t = 5.0\,\mathrm{s}$.

[2]

(ii) Calculate the total distance moved by P from time $t = 0$ to $t = 7.0\,\mathrm{s}$.

distance = ...m [2]

(iii) Calculate the change in kinetic energy of P from time $t = 0$ to $t = 7.0\,\mathrm{s}$.

change in kinetic energy = ...J [2]

(iv) The tension in the wire at time $t = 5.0\,\mathrm{s}$ is 280 N.

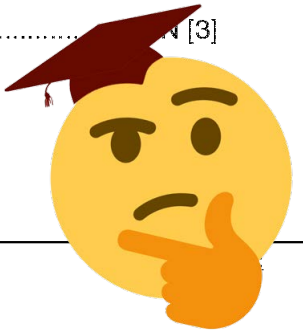
Calculate, for the horizontal motion,

1. the vertical lift force F supporting P,

F = ... N [3]

2. the force R due to air resistance acting on P in the horizontal direction.

R = ... N [3]



2 – (9702/21_Summer_2017_Q3) – *Forces, Density & Pressure*

(a) A cylinder is made from a material of density 2.7 g cm^{-3}. The cylinder has diameter 2.4 cm and length 5.0 cm.

Show that the cylinder has weight 0.60 N.

[3]

(b) The cylinder in **(a)** is hung from the end A of a non-uniform bar AB, as shown in Fig. 3.1.

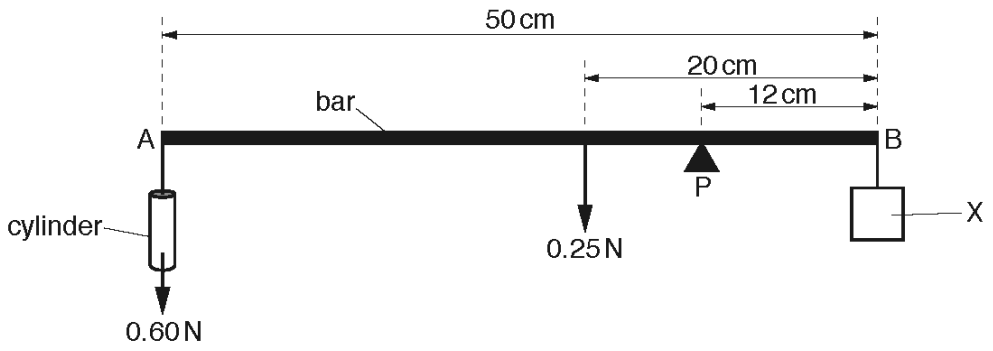


Fig. 3.1

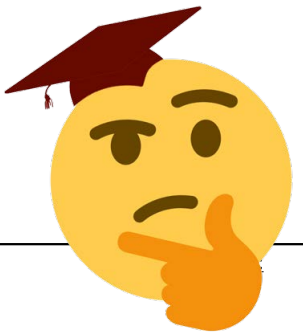
The bar has length 50 cm and has weight 0.25 N. The centre of gravity of the bar is 20 cm from B. The bar is pivoted at P. The pivot is 12 cm from B.

An object X is hung from end B. The weight of X is adjusted until the bar is horizontal and in equilibrium.

(i) Explain what is meant by *centre of gravity*.

.....

.....[1]



(ii) Calculate the weight of X.

weight of X = ... N [3]

(c) The cylinder is now immersed in water, as illustrated in Fig. 3.2.

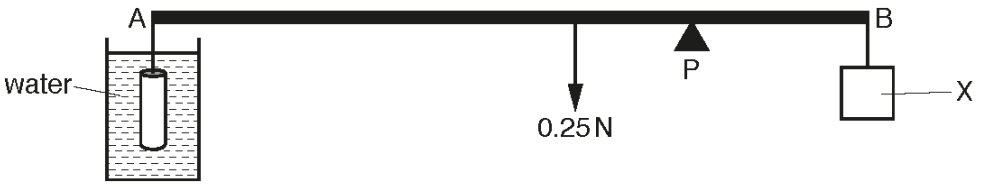


Fig. 3.2

An upthrust acts on the cylinder and the bar is not in equilibrium.

(i) Explain the origin of the upthrust.

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.....

.....

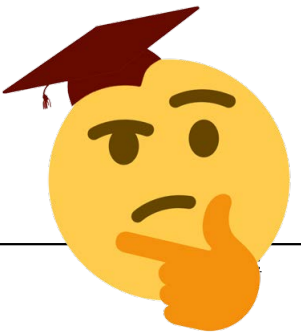
.....[2]

(ii) Explain why the weight of X must be reduced in order to obtain equilibrium for AB.

.....

.....

.....[1]



3 – (9702/22_Winter_2017_Q2) – *Forces, Density & Pressure*

(a) Define the *moment* of a force.

.....

.....[1]

(b) A thin disc of radius r is supported at its centre O by a pin. The disc is supported so that it is vertical. Three forces act in the plane of the disc, as shown in Fig. 2.1.

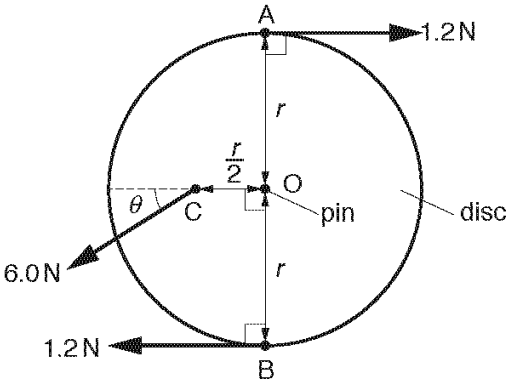


Fig. 2.1

Two horizontal and opposite forces, each of magnitude 1.2 N, act at points A and B on the edge of the disc. A force of 6.0 N, at an angle θ below the horizontal, acts on the midpoint C of a radial line of the disc, as shown in Fig. 2.1. The disc has negligible weight and is in equilibrium.

(i) State an expression, in terms of r, for the torque of the couple due to the forces at A and B acting on the disc.

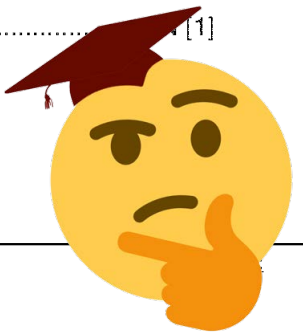
.....[1]

(ii) Friction between the disc and the pin is negligible.
Determine the angle θ.

θ = ... ° [2]

(iii) State the magnitude of the force of the pin on the disc.

force = ... [1]



4 – (9702/23_Winter_2017_Q2) – *Forces, Density & Pressure, Work, Energy & Power*

A liquid of density ρ fills a container to a depth h, as shown in Fig. 2.1.

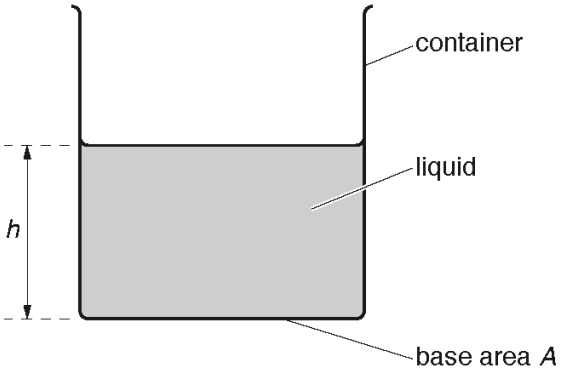


Fig. 2.1

The base of the container has area A.

(a) Derive, from the definitions of pressure and density, the equation

$$p = \rho g h$$

where p is the pressure exerted by the liquid on the base of the container and g is the acceleration of free fall.

[3]

(b) A small solid sphere falls with constant velocity through the liquid.

(i) State

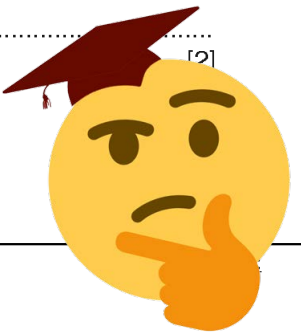
1. the names of the three forces acting on the sphere,

.....

.....

2. a word equation that relates the magnitudes of these forces.

..... [2]



(ii) State and explain the changes in energy that occur as the sphere falls.

.....

.....

.....

.....[2]

(c) The liquid in the container is liquid L. Liquid M is now added to the container. The two liquids do not mix. The total depth of the liquids is 0.17 m.

Fig. 2.2 shows how the pressure p inside the liquids varies with height x above the base of the container.

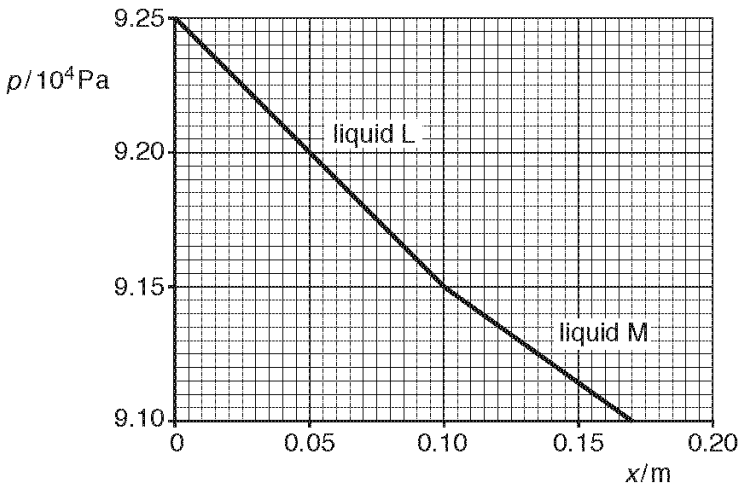


Fig. 2.2

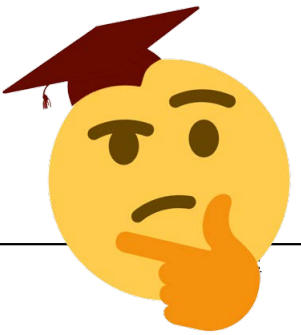
Use Fig. 2.2 to

(i) state the value of atmospheric pressure,

atmospheric pressure = ... Pa [1]

(ii) determine the density of liquid M.

density = ... kg m^{-3} [2]



5 – (9702/22_Winter_2017_Q3) – *Kinematics, Dynamics, Forces, Density & Pressure*

A spring is attached at one end to a fixed point and hangs vertically with a cube attached to the other end. The cube is initially held so that the spring has zero extension, as shown in Fig. 3.1.

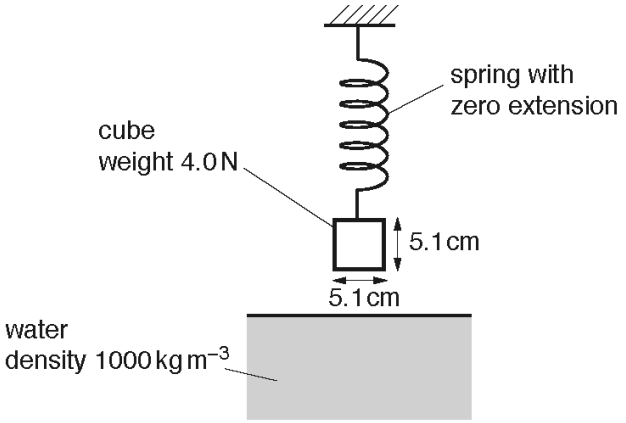


Fig. 3.1

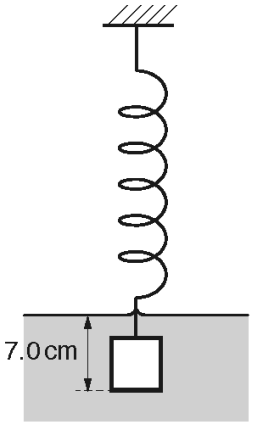


Fig. 3.2

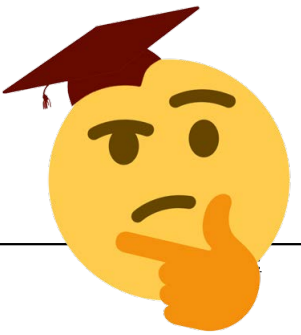
The cube has weight 4.0 N and sides of length 5.1 cm. The cube is released and sinks into water as the spring extends. The cube reaches equilibrium with its base at a depth of 7.0 cm below the water surface, as shown in Fig. 3.2.
The density of the water is 1000 kg m^{-3}.

(a) Calculate the difference in the pressure exerted by the water on the bottom face and on the top face of the cube.

difference in pressure = ... Pa [2]

(b) Use your answer in **(a)** to show that the upthrust on the cube is 1.3 N.

[2]



(c) Calculate the force exerted on the spring by the cube when it is in equilibrium in the water.

force = ... N [1]

(d) The spring obeys Hooke's law and has a spring constant of $30\,N\,m^{-1}$.

Determine the initial height above the water surface of the base of the cube before it was released.

height above surface = ... cm [3]

(e) The cube in the water is released from the spring.

(i) Determine the initial acceleration of the cube.

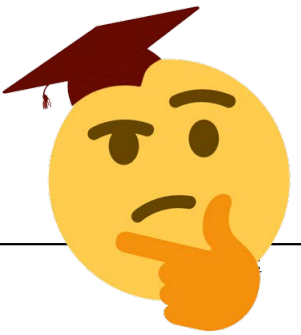
acceleration = ...$m\,s^{-2}$ [2]

(ii) Describe and explain the variation, if any, of the acceleration of the cube as it sinks in the water.

.....

.....

.....[2]



6 – (9702/23_Summer_2018_Q2) – *Forces, Density & Pressure, Work, Energy & Power, Waves*

(a) State what is meant by *work done*.

.....

.....[1]

(b) A diver releases a solid sphere of radius 16 cm from the sea bed. The sphere moves vertically upwards towards the surface of the sea.

The weight of the sphere is 20 N. The upthrust acting on the sphere is 170 N. The upthrust remains constant as the sphere moves upwards.

(i) Calculate the density of the material of the sphere.

density = ... $kg\,m^{-3}$ [2]

(ii) Briefly explain the origin of the upthrust acting on the sphere.

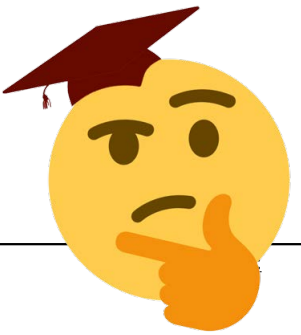
.....

.....

.....[1]

(iii) Calculate the acceleration of the sphere as it is released from rest.

acceleration = ... $m\,s^{-2}$ [2]



(iv) The viscous (drag) force D acting on the sphere is given by

$$D = kr^2v^2$$

where r is the radius of the sphere and v is its speed.
The constant k is equal to $810\,\text{kg}\,\text{m}^{-3}$.

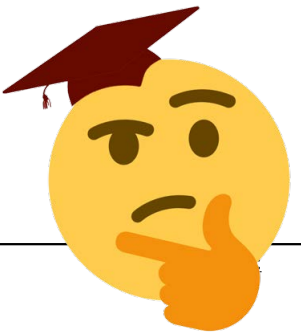
Determine the constant (terminal) speed reached by the sphere.

speed = ... $\text{m}\,\text{s}^{-1}$ [3]

(v) The diver releases a different sphere that moves with a constant speed of $6.30\,\text{m}\,\text{s}^{-1}$ directly towards a stationary ship. The sphere emits sound of frequency 4850 Hz. The ship detects sound of frequency 4870 Hz as the sphere moves towards it.

Determine, to three significant figures, the speed of the sound in the water.

speed = ... $\text{m}\,\text{s}^{-1}$ [2]



7 – (9702/22_Summer_2018_Q5) – *Forces, Density & Pressure, Dynamics, Work, Energy & Power*

A solid cylinder is lifted out of oil by a wire attached to a motor. Fig. 5.1 shows two different positions X and Y of the cylinder during the lifting process.

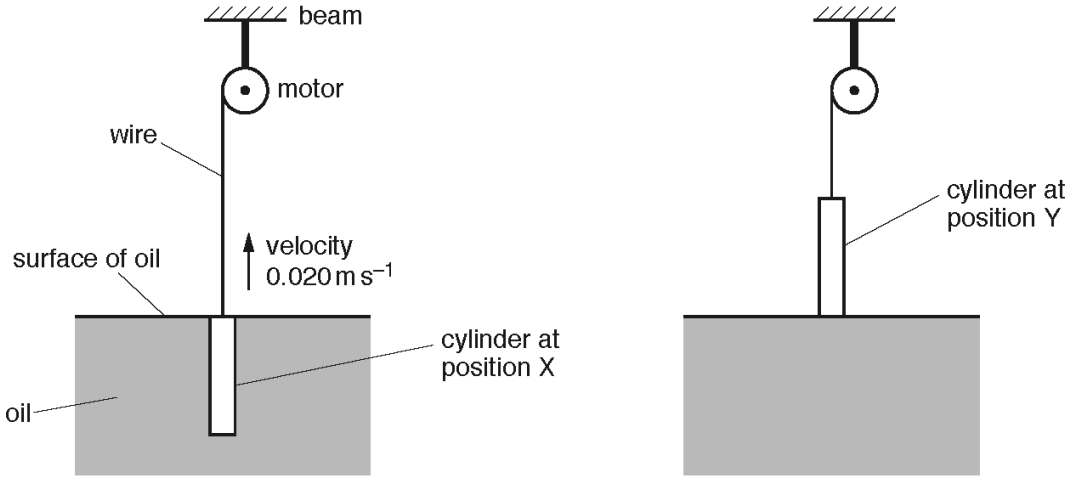


Fig. 5.1

The motor is fixed to an overhead beam.
The cylinder has cross-sectional area $0.018\,m^2$, length 1.2 m and weight 560 N.
The density of the oil is $940\,kg\,m^{-3}$.

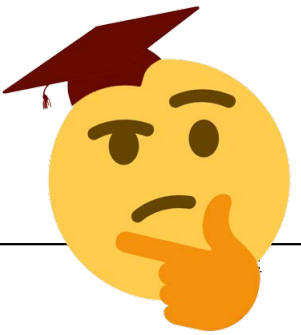
Throughout the lifting process, the cylinder moves vertically upwards with a constant velocity of $0.020\,m\,s^{-1}$. The viscous force of the oil acting on the cylinder is negligible.

(a) Calculate the density of the cylinder.

density = ... $kg\,m^{-3}$ [2]

(b) For the cylinder at position X, show that the upthrust due to the oil is 200 N.

[2]



(c) Calculate, for the moving cylinder at position X,

(i) the tension in the wire,

tension = ... N [1]

(ii) the power output of the motor.

power = ... W [2]

(d) The cylinder is raised with constant velocity from position X to position Y.

(i) State and explain the variation, if any, of the power output of the motor as the cylinder is raised. Numerical values are not required.

.....

.....

.....

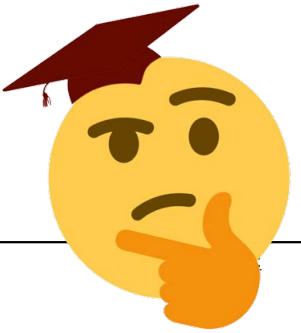
.....

.....[3]

(ii) The rate of energy output of the motor is less than the rate of increase of gravitational potential energy of the cylinder. Without calculation, explain this difference.

.....

.....[1]



8 – (9702/23_Winter_2018_Q1) – *Physical Quantities & Units, Forces, Density & Pressure, Deformation Of Solids*

(a) Mass, length and time are all SI base quantities.

State two other SI base quantities.

1. .....

2. .....

[2]

(b) A wire hangs between two fixed points, as shown in Fig. 1.1.

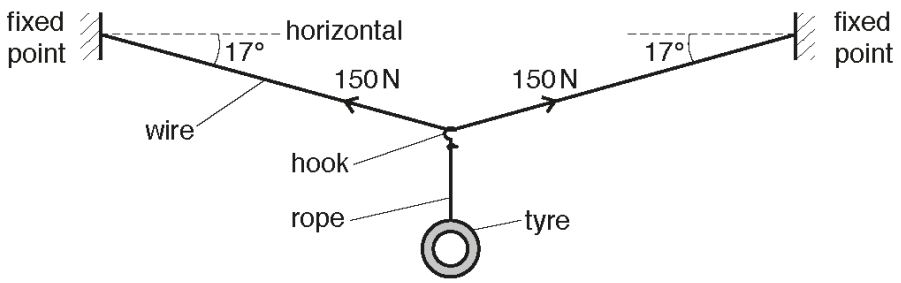


Fig. 1.1 (not to scale)

A child's swing is made by connecting a car tyre to the wire using a rope and a hook. The system is in equilibrium with the wire hanging at an angle of 17° to the horizontal. The tension in the wire is 150 N. Assume that the rope and hook have negligible weight.

(i) Determine the weight of the tyre.

weight = ... N [2]

(ii) The wire has a cross-sectional area of $7.5\,mm^2$ and is made of metal of Young modulus 2.1×10^{11} Pa. The wire obeys Hooke's law.

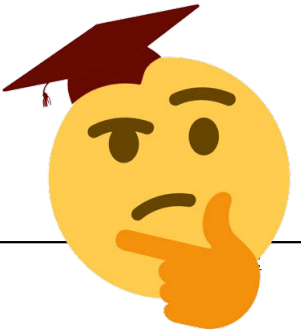
Calculate, for the wire,

1. the stress,

stress = ... Pa [2]

2. the strain.

strain = ... [2]



9 – (9702/22_Winter_2018_Q2) – *Physical Quantities & Units, Forces, Density & Pressure*

(a) The kilogram, metre and second are all SI base units.

State two other SI base units.

1. .....

2. .....
[2]

(b) A uniform beam AB of length 6.0 m is placed on a horizontal surface and then tilted at an angle of 31° to the horizontal, as shown in Fig. 2.1.

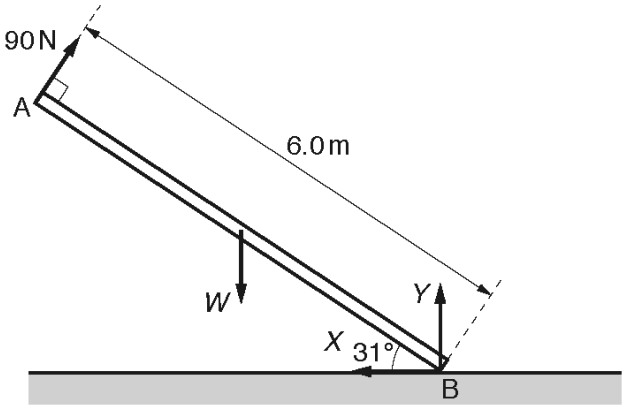


Fig. 2.1 (not to scale)

The beam is held in equilibrium by four forces that all act in the same plane. A force of 90 N acts perpendicular to the beam at end A. The weight *W* of the beam acts at its centre of gravity. A vertical force *Y* and a horizontal force *X* both act at end B of the beam.

(i) State the name of force *X*.

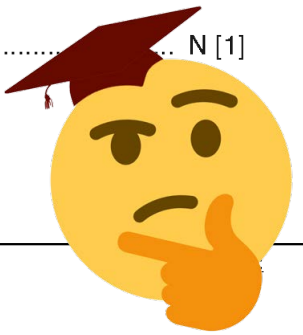
.....[1]

(ii) By taking moments about end B, calculate the weight *W* of the beam.

W = ... N [2]

(iii) Determine the magnitude of force *X*.

magnitude of force *X* = ... N [1]



10 – (9702/22_Summer_2019_Q3) – *Forces, Density & Pressure, Work, Energy & Power*

(a) State what is meant by the *centre of gravity* of a body.

.....

.....[1]

(b) A uniform square sign with sides of length 0.68 m is fixed at its corner points A and B to a wall. The sign is also supported by a wire CD, as shown in Fig. 3.1.

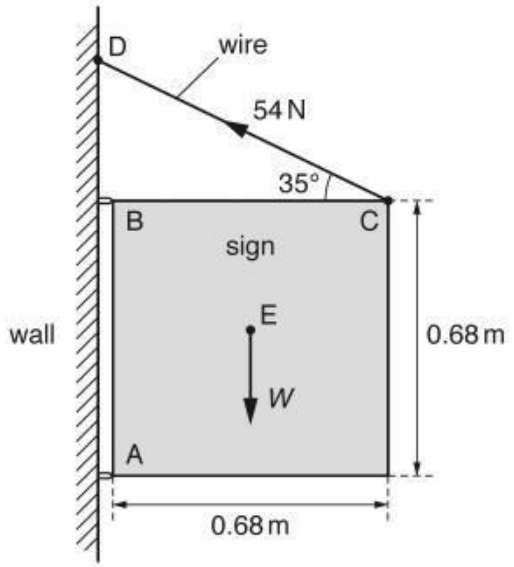


Fig. 3.1 (not to scale)

The sign has weight *W* and centre of gravity at point E. The sign is held in a vertical plane with side BC horizontal. The wire is at an angle of 35° to side BC. The tension in the wire is 54 N.

The force exerted on the sign at B is only in the vertical direction.

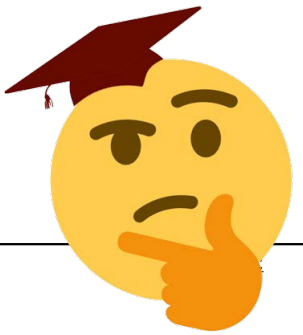
(i) Calculate the vertical component of the tension in the wire.

vertical component of tension = ... N [1]

(ii) Explain why the force on the sign at B does not have a moment about point A.

.....

.....[1]



(iii) By taking moments about point A, show that the weight W of the sign is 150 N.

[2]

(iv) Calculate the total vertical force exerted by the wall on the sign at points A and B.

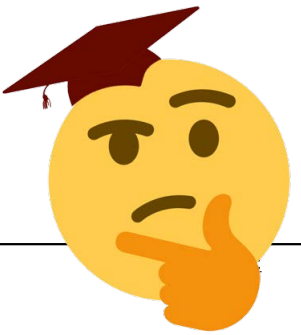
total vertical force = ... N [1]

(c) The sign in **(b)** is held together by nuts and bolts. One of the nuts falls vertically from rest through a distance of 4.8 m to the pavement below. The nut lands on the pavement with a speed of $9.2\,\mathrm{m\,s^{-1}}$.

Determine, for the nut falling from the sign to the pavement, the ratio

$$\frac{\text{change in gravitational potential energy}}{\text{final kinetic energy}}.$$

ratio = ... [4]



11 – (9702/23_Summer_2019_Q3) – *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

A cylindrical disc of mass 0.24 kg has a circular cross-sectional area *A*, as shown in Fig. 3.1.

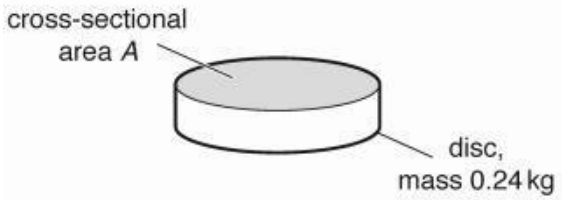


Fig. 3.1

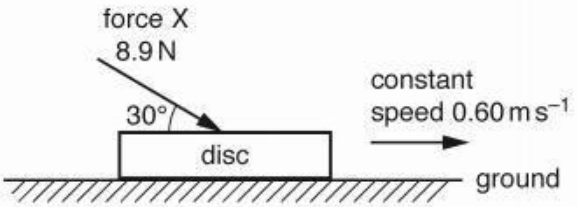


Fig. 3.2

The disc is on horizontal ground, as shown in Fig. 3.2. A force X of magnitude 8.9 N acts on the disc in a direction of 30° to the horizontal. The disc moves at a constant speed of 0.60 m s^{-1} along the ground.

(a) Determine the rate of doing work on the disc by the force X.

rate of doing work = ... W [2]

(b) The force X and the weight of the disc exert a combined pressure on the ground of 3500 Pa.

Calculate the cross-sectional area *A* of the disc.

A = ... m^2 [3]

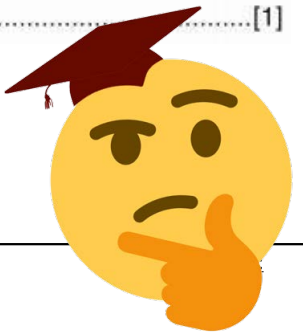
(c) Newton's third law describes how forces exist in pairs. One such pair of forces is the weight of the disc and another force Y. State:

(i) the direction of force Y

.....[1]

(ii) the name of the body on which force Y acts.

.....[1]



12 – (9702/23_Winter_2019_Q1) – *Forces, Density & Pressure*

(a) Determine the SI base units of the moment of a force.

SI base units ..... [1]

(b) A uniform square sheet of card ABCD is freely pivoted by a pin at a point P. The card is held in a vertical plane by an external force in the position shown in Fig. 1.1.

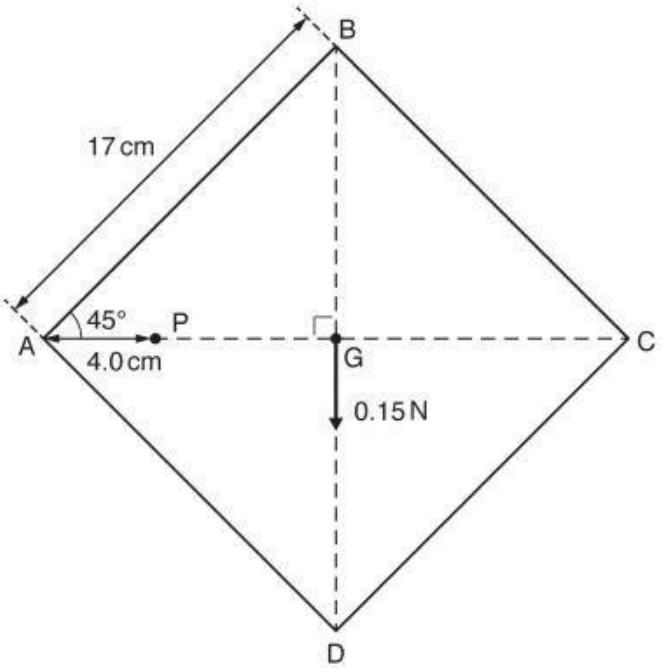
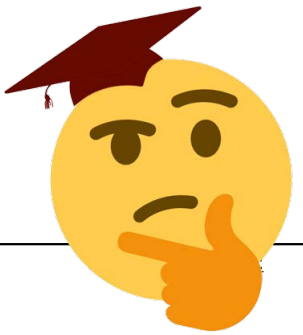


Fig. 1.1 (not to scale)

The card has weight 0.15 N which may be considered to act at the centre of gravity G. Each side of the card has length 17 cm. Point P lies on the horizontal line AC and is 4.0 cm from corner A. Line BD is vertical.

The card is released by removing the external force. The card then swings in a vertical plane until it comes to rest.



(i) Calculate the magnitude of the resultant moment about point P acting on the card immediately after it is released.

moment = ... N m [2]

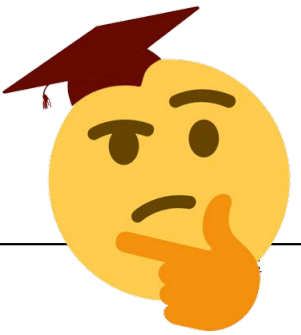
(ii) Explain why, when the card has come to rest, its centre of gravity is vertically below point P.

.....

.....

.....

..... [2]



13 – (9702/22_Winter_2019_Q4) – *Forces, Density & Pressure*

(a) A sphere in a liquid accelerates vertically downwards from rest. For the viscous force acting on the moving sphere, state:

(i) the direction

..... [1]

(ii) the variation, if any, in the magnitude.

..... [1]

(b) A man of weight 750 N stands a distance of 3.6 m from end D of a horizontal uniform beam AD, as shown in Fig. 4.1.

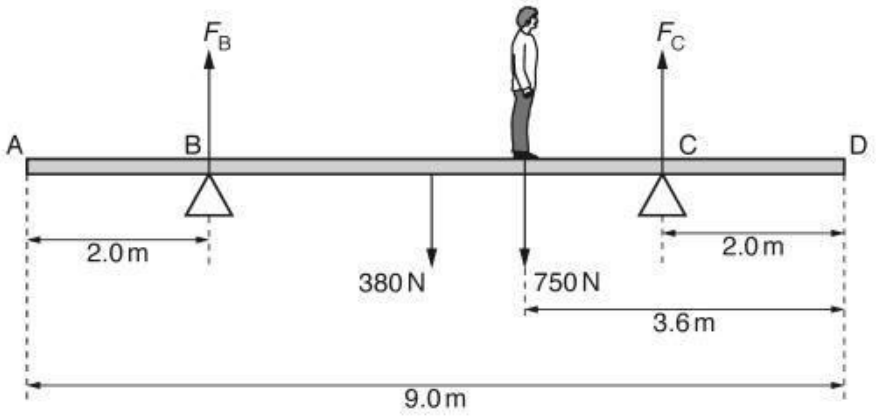


Fig. 4.1 (not to scale)

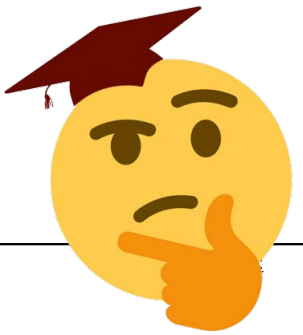
The beam has a weight of 380 N and a length of 9.0 m. The beam is supported by a vertical force F_B at pivot B and a vertical force F_C at pivot C. Pivot B is a distance of 2.0 m from end A and pivot C is a distance of 2.0 m from end D. The beam is in equilibrium.

(i) State the principle of moments.

.....

.....

..... [2]



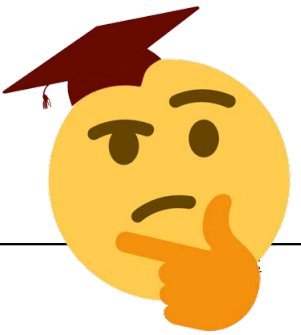
(ii) By using moments about pivot C, calculate F_B.

F_B = ... N [2]

(iii) The man walks towards end D. The beam is about to tip when F_B becomes zero.

Determine the minimum distance x from end D that the man can stand without tipping the beam.

x = ... m [2]



14 – (9702/21_Summer_2020_Q3) – *Forces, Density & Pressure, Work, Energy & Power*

(a) State **two** conditions for an object to be in equilibrium.

1. .....

.....

2. .....

.....

[2]

(b) A sphere of weight 2.4 N is suspended by a wire from a fixed point P. A horizontal string is used to hold the sphere in equilibrium with the wire at an angle of 53° to the horizontal, as shown in Fig. 3.1.

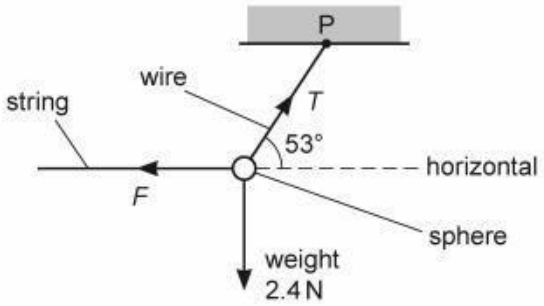


Fig. 3.1 (not to scale)

(i) Calculate:

1. the tension T in the wire

T = ... N

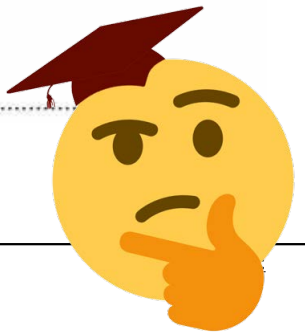
2. the force F exerted by the string on the sphere.

F = ... N

[2]

(ii) The wire has a circular cross-section of diameter 0.50 mm. Determine the stress σ in the wire.

σ = ...



(c) The string is disconnected from the sphere in **(b)**. The sphere then swings from its initial rest position A, as illustrated in Fig. 3.2.

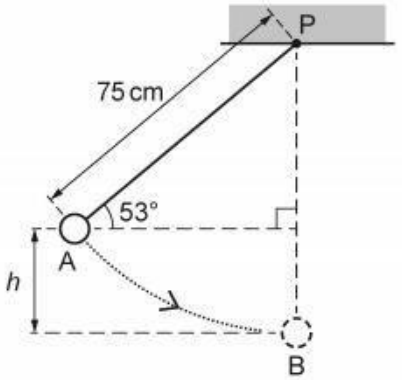


Fig. 3.2 (not to scale)

The sphere reaches maximum speed when it is at the bottom of the swing at position B. The distance between P and the centre of the sphere is 75 cm.
Air resistance is negligible and energy losses at P are negligible.

(i) Show that the vertical distance *h* between A and B is 15 cm.

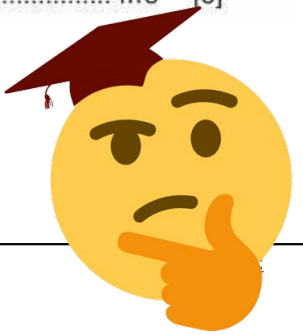
[1]

(ii) Calculate the change in gravitational potential energy of the sphere as it moves from A to B.

change in gravitational potential energy = ... J [2]

(iii) Use your answer in **(c)(ii)** to determine the speed of the sphere at B.
Show your working.

speed = ... $m s^{-1}$ [3]



15 – (9702/23_Summer_2020_Q3) – *Forces, Density & Pressure, Deformation Of Solids*

(a) State the principle of moments.

.....

.....

..... [2]

(b) In a bicycle shop, two wheels hang from a horizontal uniform rod AC, as shown in Fig. 3.1.

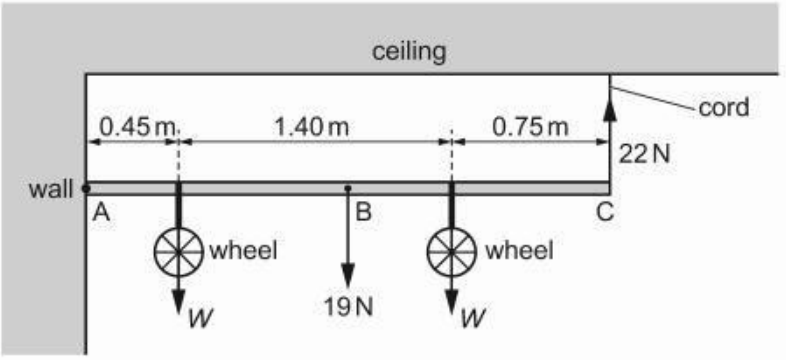


Fig. 3.1 (not to scale)

The rod has weight 19 N and is freely hinged to a wall at end A. The other end C of the rod is attached by a vertical elastic cord to the ceiling. The centre of gravity of the rod is at point B. The weight of each wheel is *W* and the tension in the cord is 22 N.

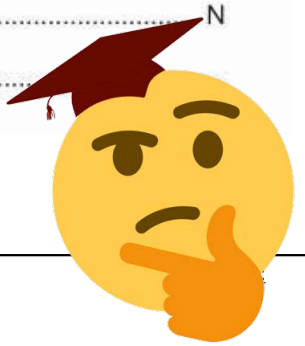
(i) By taking moments about end A, show that the weight *W* of each wheel is 14 N.

[2]

(ii) Determine the magnitude and the direction of the force acting on the rod at end A.

magnitude = ... N

direction .....



(c) The unstretched length of the cord in **(b)** is 0.25 m. The variation with length L of the tension F in the cord is shown in Fig. 3.2.

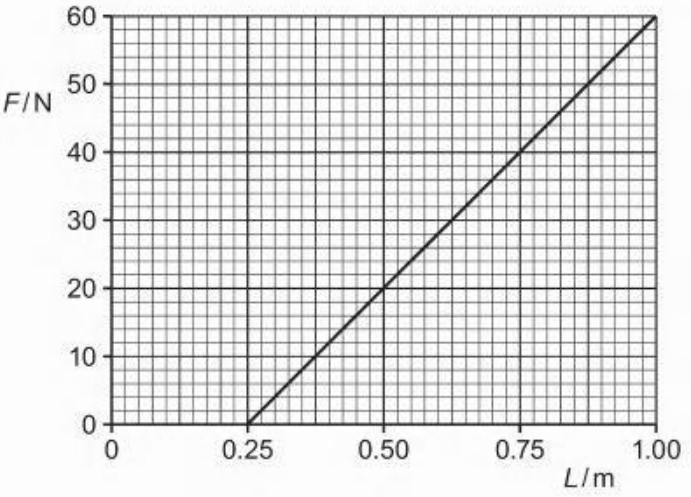


Fig. 3.2

(i) State and explain whether Fig. 3.2 suggests that the cord obeys Hooke's law.

.....

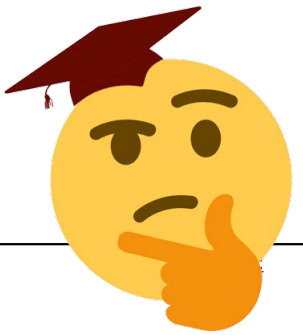
.....

..... [2]

(ii) Calculate the spring constant k of the cord.

k = ... $N\,m^{-1}$ [2]

(iii) On Fig. 3.2, shade the area that represents the work done to extend the cord when the tension is increased from $F = 0$ to $F = 40$ N. [1]



16 – (9702/21_Winter_2020_Q1) – *Forces, Density & Pressure*

(a) **(i)** Define the *moment* of a force about a point.

.....

..... [1]

(ii) Determine the SI base units of the moment of a force.

base units ..... [1]

(b) A uniform rigid rod of length 2.4 m is shown in Fig. 1.1.

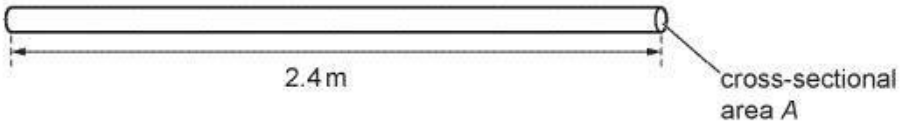
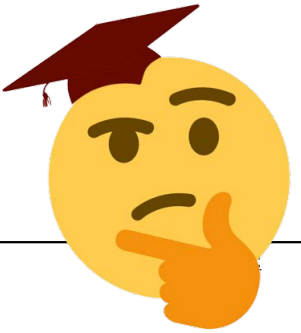


Fig. 1.1

The rod has a weight of 5.2 N and is made of wood of density 790 kg m^{-3}.

Calculate the cross-sectional area A, in mm^2, of the rod.

A = ... mm^2 [3]



(c) A fishing rod AB, made from the rod in **(b)**, is shown in Fig. 1.2.

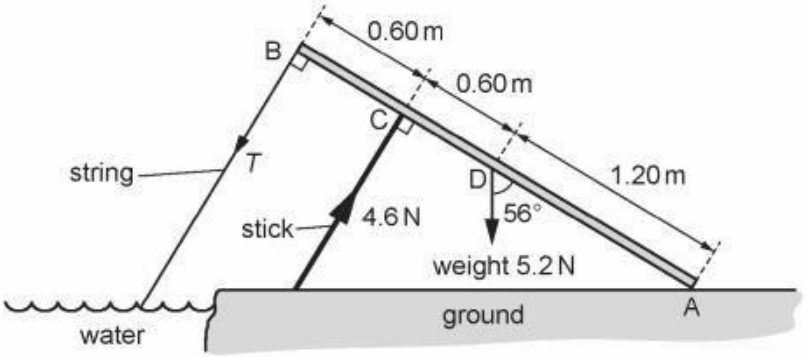


Fig. 1.2 (not to scale)

End A of the rod rests on the ground and a string is attached to the other end B. A support stick exerts a force perpendicular to the rod at point C. The weight of the rod acts at point D.

The tension *T* in the string is in a direction perpendicular to the rod. The rod is in equilibrium and inclined at an angle of 56° to the vertical.

The forces and the distances along the rod of points A, B, C and D are shown in Fig. 1.2.

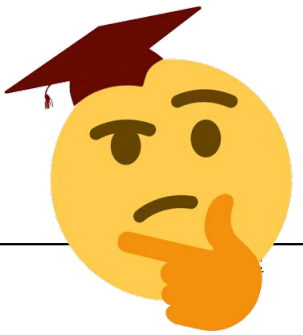
(i) Show that the component of the weight that is perpendicular to the rod is 4.3 N.

[1]

(ii) By taking moments about end A of the rod, calculate the tension *T*.

T = ... N [3]

[Total: 9]



17 – (9702/22_Winter_2020_Q2) – *Kinematics, Dynamics, Forces, Density & Pressure*

(a) A cylinder is suspended from the end of a string. The cylinder is stationary in water with the axis of the cylinder vertical, as shown in Fig. 2.1.

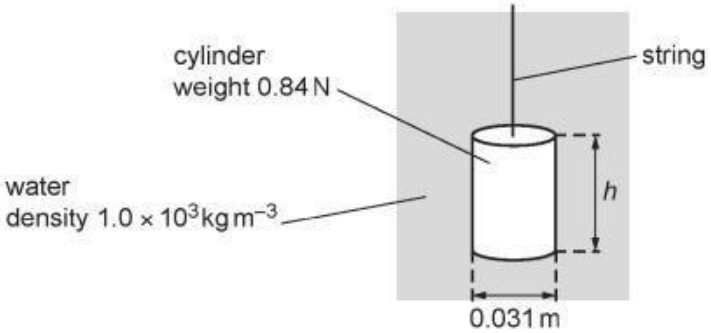


Fig. 2.1 (not to scale)

The cylinder has weight 0.84 N, height h and a circular cross-section of diameter 0.031 m. The density of the water is $1.0 \times 10^3 \text{ kg m}^{-3}$. The difference between the pressures on the top and bottom faces of the cylinder is 520 Pa.

(i) Calculate the height h of the cylinder.

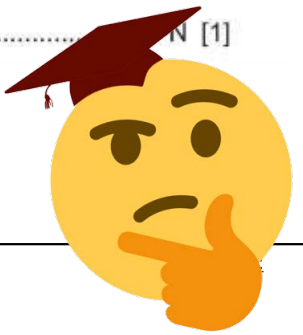
h = ... m [2]

(ii) Show that the upthrust acting on the cylinder is 0.39 N.

[2]

(iii) Calculate the tension T in the string.

T = ... N [1]



(b) The string is now used to move the cylinder in **(a)** vertically upwards through the water. The variation with time t of the velocity v of the cylinder is shown in Fig. 2.2.

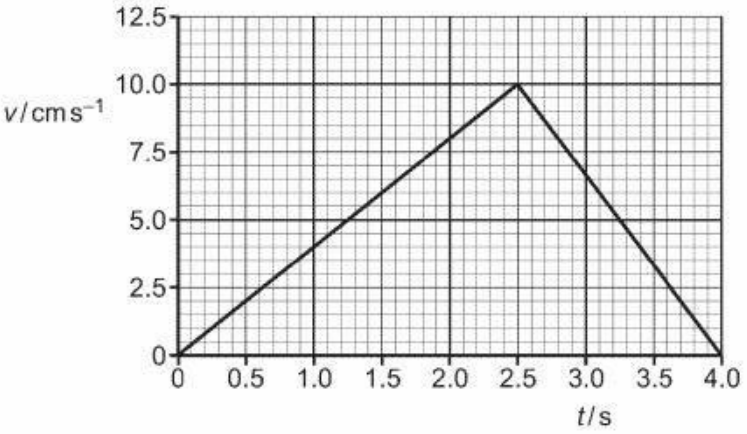


Fig. 2.2

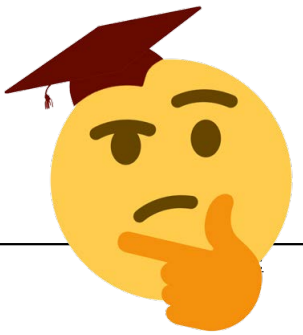
(i) Use Fig. 2.2 to determine the acceleration of the cylinder at time $t = 2.0\,s$.

acceleration = ... $m\,s^{-2}$ [2]

(ii) The top face of the cylinder is at a depth of 0.32 m below the surface of the water at time $t = 0$.

Use Fig. 2.2 to determine the depth of the top face below the surface of the water at time $t = 4.0\,s$.

depth = ... m [2]



(c) The cylinder in **(b)** is released from the string at time $t = 4.0\,\text{s}$. The cylinder falls, from rest, vertically downwards through the water. Assume that the upthrust acting on the cylinder remains constant as it falls.

(i) State the name of the force that acts on the cylinder when it is moving and does not act on the cylinder when it is stationary.

..... [1]

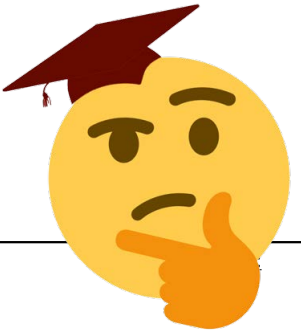
(ii) State and explain the variation, if any, of the acceleration of the cylinder as it falls downwards through the water.

.....

.....

..... [2]

[Total: 12]



18 – (9702/23_Winter_2020_Q2) – *Forces, Density & Pressure*

(a) State what is meant by the *centre of gravity* of a body.

.....

.....

..... [2]

(b) A uniform wooden post AB of weight 45 N stands in equilibrium on hard ground, as shown in Fig. 2.1.

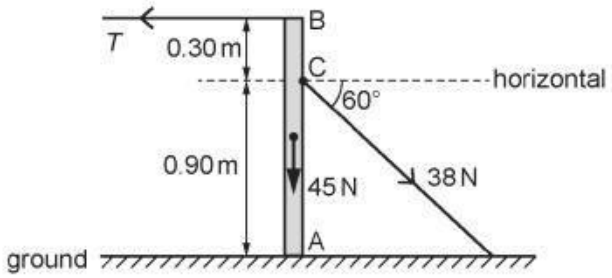


Fig. 2.1 (not to scale)

End A of the vertical post is supported by the ground. A horizontal wire with tension *T* is attached to end B of the post. Another wire, attached to the post at point C, is at an angle of 60° to the horizontal and has tension 38 N. The distances along the post of points A, B and C are shown in Fig. 2.1.

(i) Calculate the horizontal component of the force exerted on the post by the wire connected to point C.

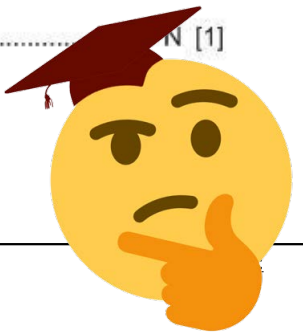
horizontal component of force = ... N [1]

(ii) By considering moments about end A, determine the tension *T*.

T = ... N [2]

(iii) Calculate the vertical component of the force exerted on the post at end A.

force = ... N [1]



19 – (9702/22_Winter_2020_Q4) – *Forces, Density & Pressure*

A rigid plank is used to make a ramp between two different horizontal levels of ground, as shown in Fig. 4.1.

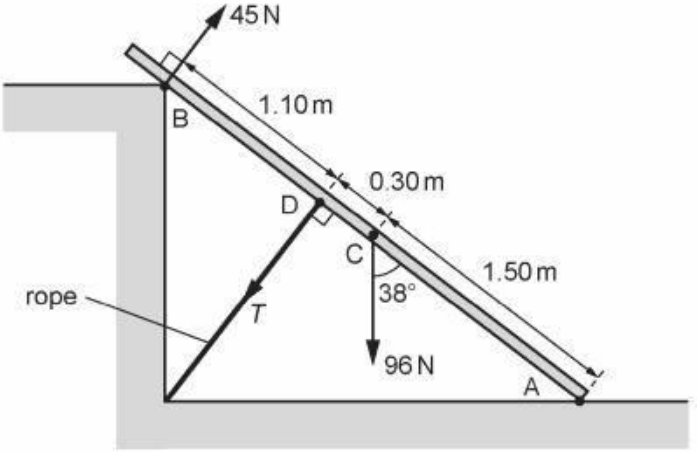


Fig. 4.1 (not to scale)

Point A at one end of the plank rests on the lower level of the ground. A force acts on, and is perpendicular to, the plank at point B. The plank is held in equilibrium by a rope that connects point D on the plank to the ground. The plank has a weight that may be considered to act from its centre of gravity C.

The rope is perpendicular to the plank and has tension *T*. The plank is at an angle of 38° to the vertical.

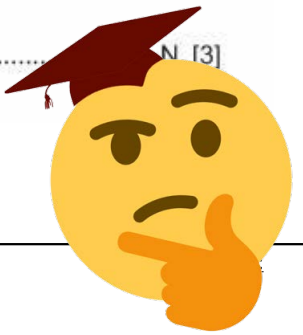
The forces and the distances along the plank of points A, B, C and D are shown in Fig. 4.1.

(a) Show that the component of the weight that is perpendicular to the plank is 59 N.

[1]

(b) By taking moments about end A of the plank, calculate the tension *T*.

T = ... N [3]



20 – (9702/21_Summer_2021_Q1) – *Measurement Techniques, Forces, Density & Pressure*

(a) Define *density*.

.....

..... [1]

(b) Fig. 1.1 shows a solid pyramid with a square base.

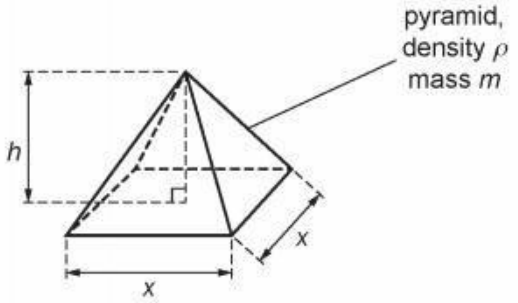


Fig. 1.1

The mass m of the pyramid is given by

$$m = \frac{1}{3}\rho h x^2$$

where ρ is the density of the material of the pyramid,
h is the height, and
x is the length of each side of the base.

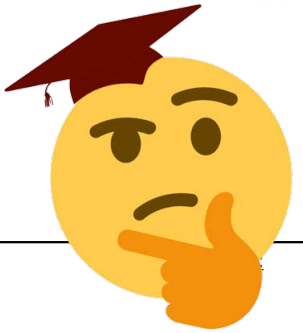
Measurements are taken as shown in Table 1.1.

Table 1.1

quantity	measurement	percentage uncertainty
m	19.5 g	±2%
x	4.0 cm	±5%
h	4.8 cm	±4%

(i) Calculate the absolute uncertainty in length x.

absolute uncertainty = ... cm [1]



(ii) The density ρ is calculated from the measurements in Table 1.1.

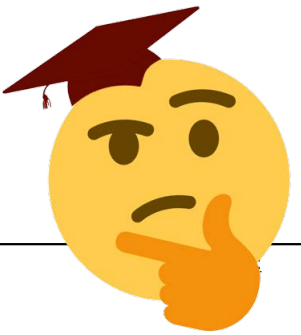
Determine the percentage uncertainty in the calculated value of ρ.

percentage uncertainty = ... % [2]

(c) The square base of the pyramid in **(b)** rests on the horizontal surface of a bench.

Use data from Table 1.1 to calculate the average pressure of the pyramid on the surface of the bench. The uncertainty in your answer is not required.

pressure = ... Pa [3]



21 – (9702/22_Summer_2021_Q1) – *Physical Quantities & Units, Forces, Density & Pressure*

(a) Complete Table 1.1 by stating whether each of the quantities is a vector or a scalar.

Table 1.1

quantity	vector or scalar
acceleration	
electrical resistance	
momentum	

[2]

(b) State the conditions for an object to be in equilibrium.

.....

.....

.....

..... [2]

(c) A floating solid cylinder is attached by a wire to the sea bed, as shown in Fig. 1.1.

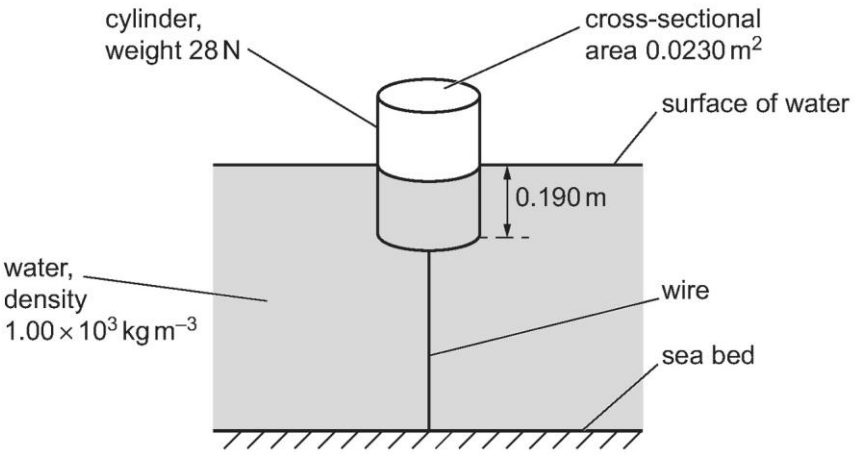
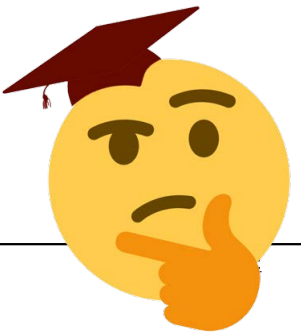


Fig. 1.1 (not to scale)

The density of the water is $1.00 \times 10^3\,kg\,m^{-3}$. The base of the cylinder is at a depth of 0.190 m below the surface of the water. The cylinder has a weight of 28 N and a cross-sectional area of $0.0230\,m^2$.

The wire and the central axis of the cylinder are both vertical. The cylinder is in equilibrium.



(i) Calculate, to three significant figures, the upthrust acting on the cylinder due to the water.

upthrust = ... N [2]

(ii) Show that the tension T in the wire is 15 N.

[1]

(iii) The wire has a cross-sectional area of $3.2\,mm^2$.

Calculate the stress in the wire.

stress = ... Pa [2]

(iv) The surface of the water gradually rises until it is level with the top face of the cylinder.

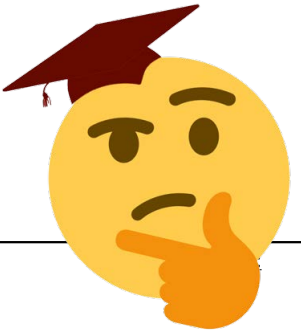
State and explain, qualitatively, the variation of the strain energy stored in the wire as the water surface rises.

.....

.....

.....

..... [2]



22 – (9702/21_Summer_2021_Q3) – *Dynamics, Forces, Density & Pressure*

A pendulum consists of a solid sphere suspended by a string from a fixed point P, as shown in Fig. 3.1.

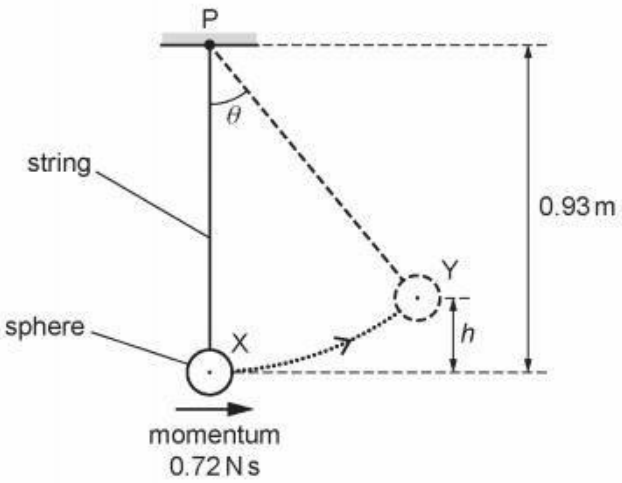


Fig. 3.1 (not to scale)

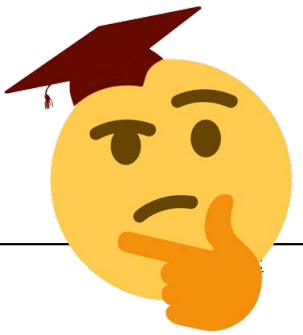
The sphere swings from side to side. At one instant the sphere is at its lowest position X, where it has kinetic energy 0.86 J and momentum 0.72 N s in a horizontal direction. A short time later the sphere is at position Y, where it is momentarily stationary at a maximum vertical height *h* above position X.

The string has a fixed length and negligible weight. Air resistance is also negligible.

(a) On Fig. 3.1, draw a solid line to represent the displacement of the centre of the sphere at position Y from position X. [1]

(b) Show that the mass of the sphere is 0.30 kg.

[3]



(c) Calculate height h.

h = ... m [2]

(d) The distance between point P and the centre of the sphere is 0.93 m. When the sphere is at position Y, the string is at an angle θ to the vertical.

Show that θ is 47°.

[1]

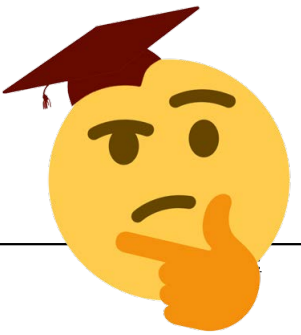
(e) For the sphere at position Y, calculate the moment of its weight about point P.

moment = ... N m [2]

(f) State and explain whether the sphere is in equilibrium when it is stationary at position Y.

.....

..... [1]



23 – (9702/23_Summer_2021_Q3) – *Forces, Density & Pressure*

(a) Define the *moment* of a force about a point.

.....

.....

..... [2]

(b) Fig. 3.1 shows a type of balance that is used for measuring mass.

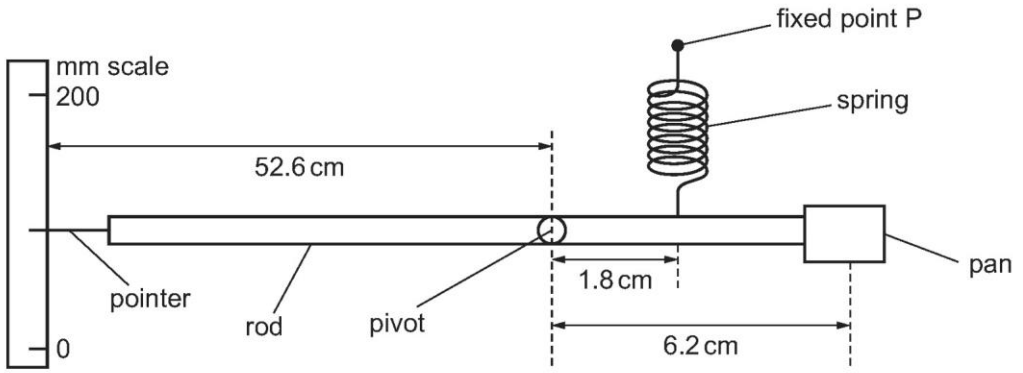


Fig. 3.1 (not to scale)

A rigid rod is pivoted about a point 6.2 cm from the centre of a pan which is attached to one end. The object being measured is placed on the centre of this pan.

A spring, attached to the rod 1.8 cm from the pivot, is attached at its other end to a fixed point P. The spring obeys Hooke's law over the full range of operation of the balance.

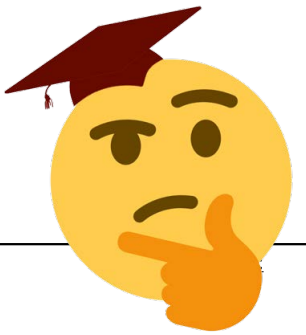
A pointer, on the other side of the pivot, is set against a millimetre scale which is a distance 52.6 cm from the pivot.

When the system is in equilibrium with no mass on the pan, the rod is horizontal and the pointer indicates a reading on the scale of 86 mm.

An object of mass 0.472 kg is now placed on the pan. As a result, the pointer moves to indicate a reading of 123 mm on the scale when the system is again in equilibrium.

(i) Show that the increase in the length of the spring is approximately 1.3 mm.

[2]



(ii) Calculate the magnitude of the moment about the pivot of the weight of the object.

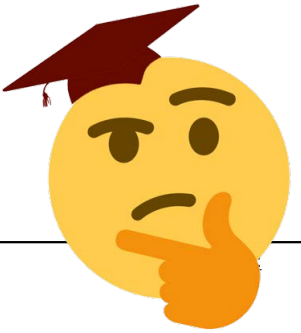
moment = ... N m [2]

(iii) Use your answer in **(b)(ii)** to determine the increase in the tension in the spring due to the 0.472 kg mass.

increase in tension = ... N [2]

(iv) Use the information in **(b)(i)** and your answer in **(b)(iii)** to determine the spring constant *k* of the spring. Give a unit with your answer.

k = ... unit ..... [2]



24 - (9702/21_Winter_2021_Q1) - *Measurement Techniques, Forces, Density & Pressure*

(a) Define *density*.

.....

..... [1]

(b) A smooth pebble, made from uniform rock, has the shape of an elongated sphere as shown in Fig. 1.1.

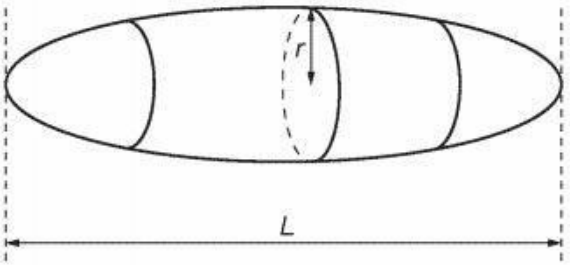


Fig. 1.1

The length of the pebble is L. The cross-section of the pebble, in the plane perpendicular to L, is circular with a maximum radius r.

A student investigating the density of the rock makes measurements to determine the values of L, r and the mass M of the pebble as follows:

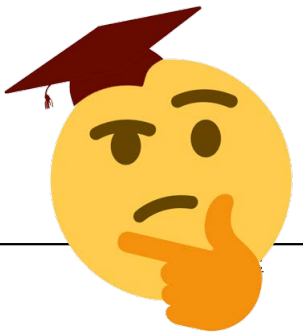
$$L = (0.1242 \pm 0.0001)\,\text{m}$$
$$r = (0.0420 \pm 0.0004)\,\text{m}$$
$$M = (1.072 \pm 0.001)\,\text{kg}.$$

(i) State the name of a measuring instrument suitable for making this measurement of L.

..... [1]

(ii) Determine the percentage uncertainty in the measurement of r.

percentage uncertainty = ... % [1]



(c) The density ρ of the rock from which the pebble in **(b)** is composed is given by

$$\rho = \frac{Mr^n}{kL}$$

where n is an integer and k is a constant, with no units, that is equal to 2.094.

(i) Use SI base units to show that n is equal to –2.

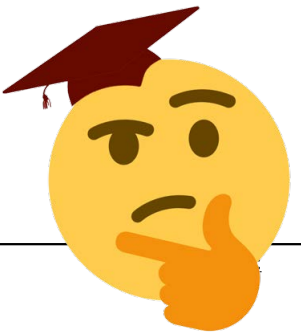
[2]

(ii) Calculate the percentage uncertainty in ρ.

percentage uncertainty = ... % [3]

(iii) Determine ρ with its absolute uncertainty. Give your values to the appropriate number of significant figures.

ρ = (..... ± .....) kg m^{-3} [3]



25 - (9702/23_Winter_2021_Q1) - *Forces, Density & Pressure*

(a) A solid cylinder of weight 24 N is made of material of density 850 kg m^{-3}. The cylinder has a length of 0.18 m, as shown in Fig. 1.1.

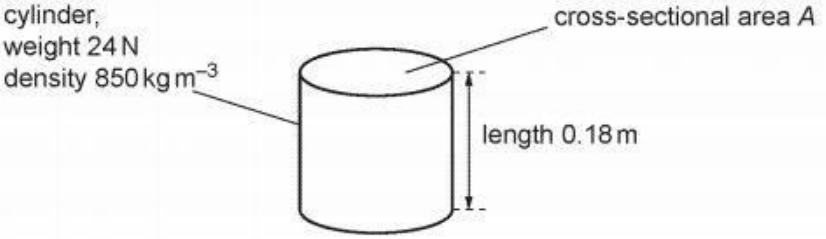


Fig. 1.1

Show that the cross-sectional area A of the cylinder is 0.016 m^2.

[3]

(b) The cylinder in **(a)** is attached by a spring to the bottom of a rigid container of liquid, as shown in Fig. 1.2.

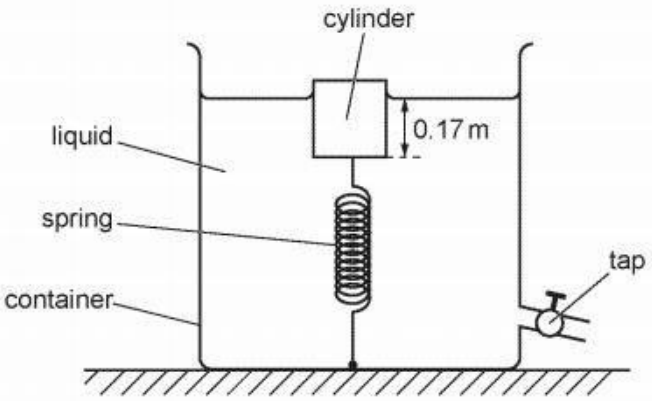
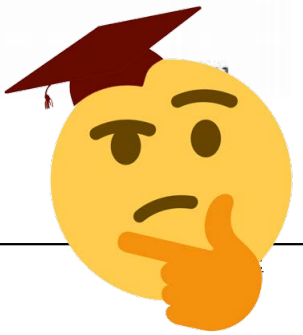


Fig. 1.2 (not to scale)

The cylinder is in equilibrium with its bottom face at a depth of 0.17 m below the surface of the liquid. The tension in the spring is 8.0 N.

(i) Show that the upthrust acting on the cylinder due to the liquid is 32 N.



(ii) Calculate the density of the liquid.

density = ... $kg\,m^{-3}$ [3]

(c) Fig. 1.3 shows the variation of the tension *F* with the length of the spring in **(b)**.

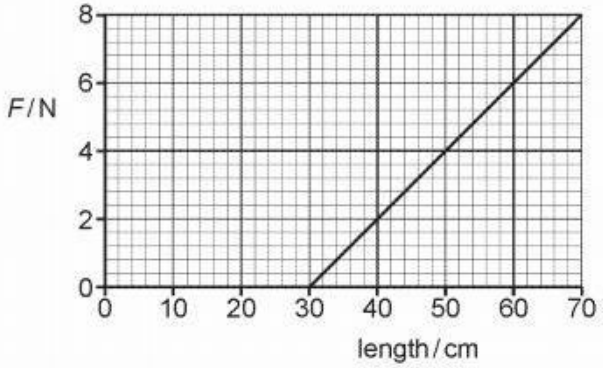


Fig. 1.3

(i) The tap at the bottom of the container is opened so that a fixed amount of liquid flows out of the container. The cylinder moves downwards so that the tension in the spring changes from 8.0 N to 4.0 N.

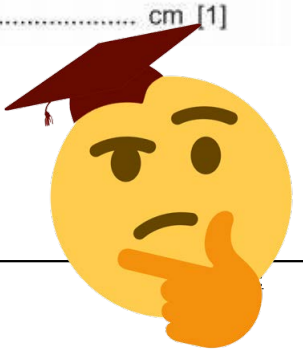
Determine the change in the elastic potential energy of the spring.

change in elastic potential energy = ... J [3]

(ii) More liquid is let out of the container until the upthrust on the cylinder becomes 24 N.

For the upthrust of 24 N, determine the length of the spring.

length = ... cm [1]



26 – (9702/22_Winter_2022_Q2) – *Forces, Density & Pressure*

A spherical balloon is filled with a fixed mass of gas. A small block is connected by a string to the balloon, as shown in Fig. 2.1.

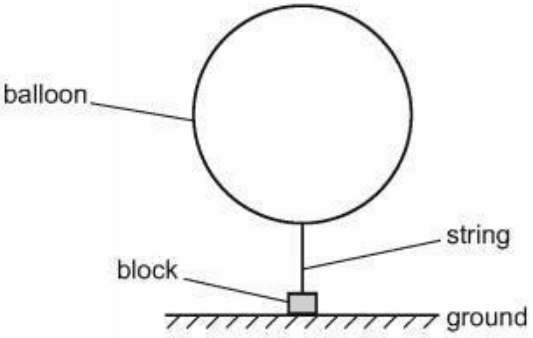


Fig. 2.1 (not to scale)

The block is held on the ground by an external force so that the string is vertical. The density of the air surrounding the balloon is $1.2\,kg\,m^{-3}$. The upthrust acting on the balloon is 0.071 N. The upthrust acting on the string and block is negligible.

(a) By using Archimedes' principle, calculate the radius r of the balloon.

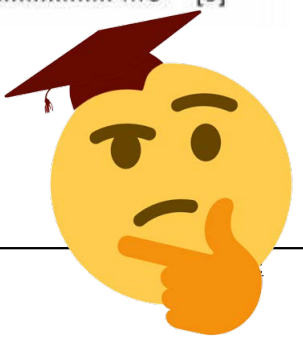
r = ... m [2]

(b) The total weight of the balloon, string and block is 0.053 N.

The external force holding the block on the ground is removed so that the released block is lifted vertically upwards by the balloon.

Calculate the acceleration of the block immediately after it is released.

acceleration = ... $m\,s^{-2}$ [3]



(c) The balloon continues to lift the block. The string breaks as the block is moving vertically upwards with a speed of $1.4\,m\,s^{-1}$. After the string breaks, the detached block briefly continues moving upwards before falling vertically downwards to the ground. The block hits the ground with a speed of $3.6\,m\,s^{-1}$.

Assume that the air resistance on the block is negligible.

(i) By considering the motion of the block after the string breaks, calculate the height of the block above the ground when the string breaks.

height = ... m [2]

(ii) The string breaks at time $t = 0$ and the block hits the ground at time $t = T$.

On Fig. 2.2, sketch a graph to show the variation of the velocity v of the block with time t from $t = 0$ to $t = T$.

Numerical values of t are not required. Assume that v is positive in the upward direction.

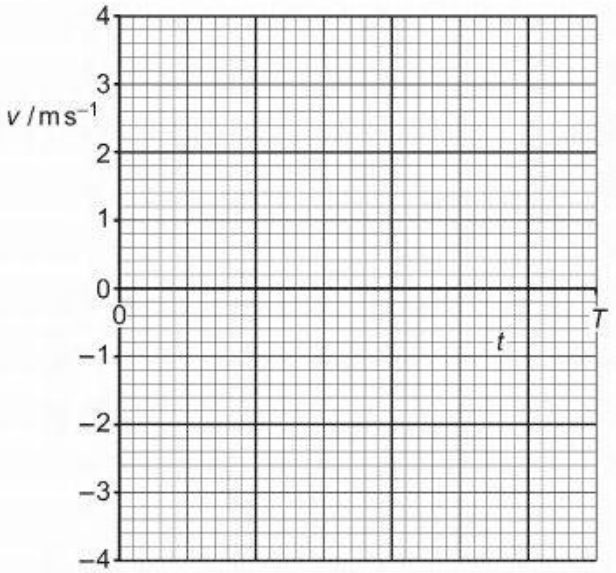
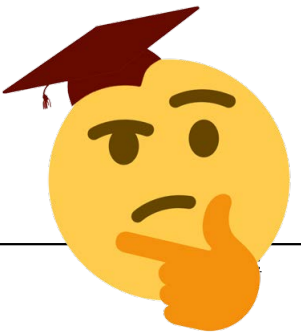


Fig. 2.2

[2]



27 – (9702/22_Winter_2022_Q3) – *Forces, Density & Pressure*

(a) State what is meant by the centre of gravity of an object.

.....

..... [1]

(b) A uniform beam AB is attached by a frictionless hinge to a vertical wall at end A. The beam is held so that it is horizontal by a metal wire CD, as shown in Fig. 3.1.

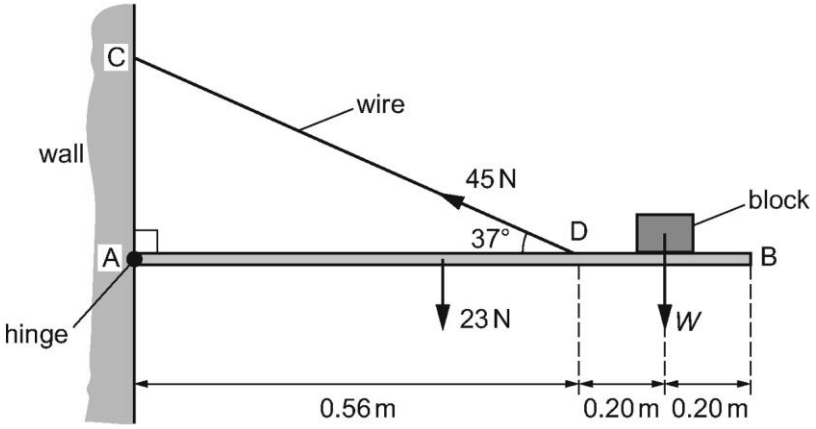


Fig. 3.1 (not to scale)

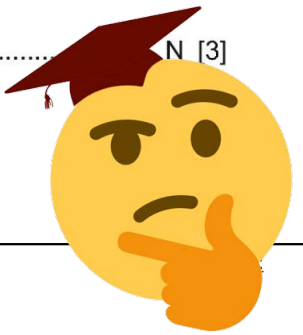
The beam is of length 0.96 m and weight 23 N. A block of weight *W* rests on the beam at a distance of 0.20 m from end B. The wire is attached to the beam at point D which is a distance of 0.40 m from end B. The wire exerts a force on the beam of 45 N at an angle of 37° to the horizontal. The beam is in equilibrium.

(i) Calculate the vertical component of the force exerted by the wire on the beam.

vertical component of the force = ... N [1]

(ii) By taking moments about A, calculate the weight *W* of the block.

W = ... N [3]



(iii) The hinge exerts a force on the beam at end A.

Calculate the horizontal component of this force.

horizontal component of force = ... N [1]

(iv) The block is now placed closer to point D on the beam.

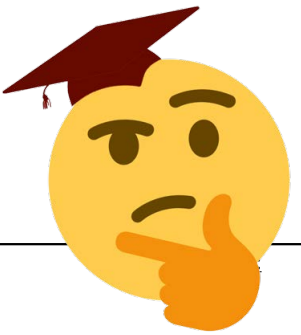
State whether this change will increase, decrease or have no effect on the tension in the wire.

..... [1]

(v) The stress in the wire is 5.3×10^7 Pa. The wire is now replaced by a second wire that has a radius which is three times greater than that of the original wire. The tension in the wire is unchanged.

Calculate the stress in the second wire.

stress = ... Pa [2]



28 – (9702/23_Winter_2022_Q3) – *Forces, Density & Pressure*

(a) State the principle of moments.

.....

.....

..... [2]

(b) A hollow plastic sphere is attached at one end of a bar. The sphere is partially submerged in water and the bar is attached to a fixed vertical support by a pivot P, as shown in Fig. 3.1.

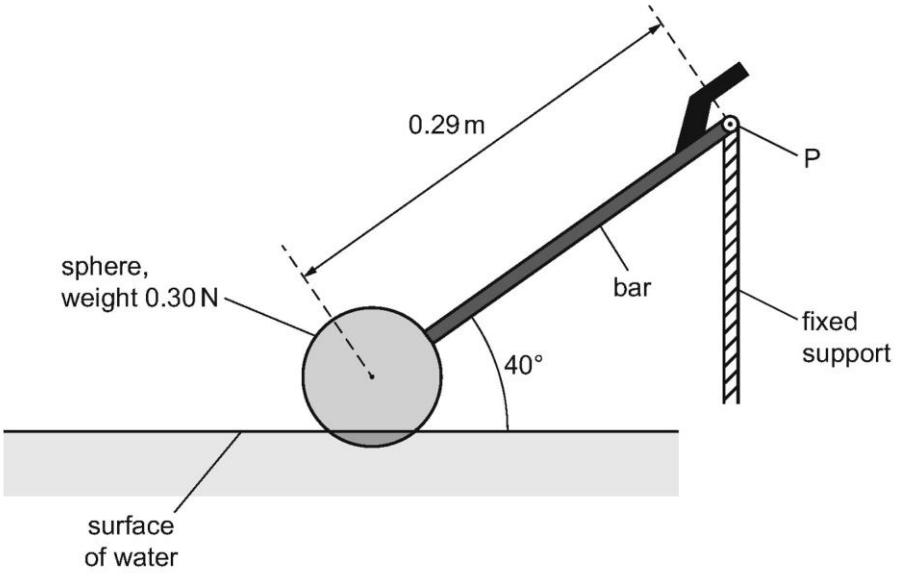
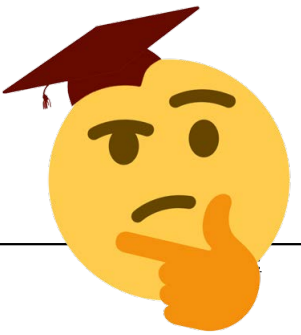


Fig. 3.1 (not to scale)

The sphere has weight 0.30 N. The distance from P to the centre of gravity of the sphere is 0.29 m. Assume that the weight of the bar is negligible.

Calculate the moment of the weight of the sphere about P.

moment = ... N m [2]



(c) The system shown in Fig. 3.1 is part of a mechanism that controls the amount of water in a tank.

Water enters the tank and causes the sphere to rise. This results in the bar becoming horizontal. Fig. 3.2 shows the system in its new position.

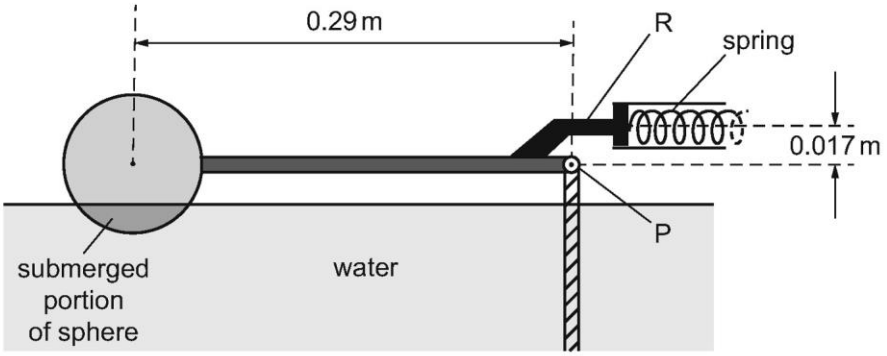


Fig. 3.2 (not to scale)

In this position the rod R exerts a force to compress a horizontal spring that controls the water supply to the tank. R is positioned at a perpendicular distance of 0.017 m above P.

The variation of the force *F* applied to the spring with compression *x* of the spring is shown in Fig. 3.3.

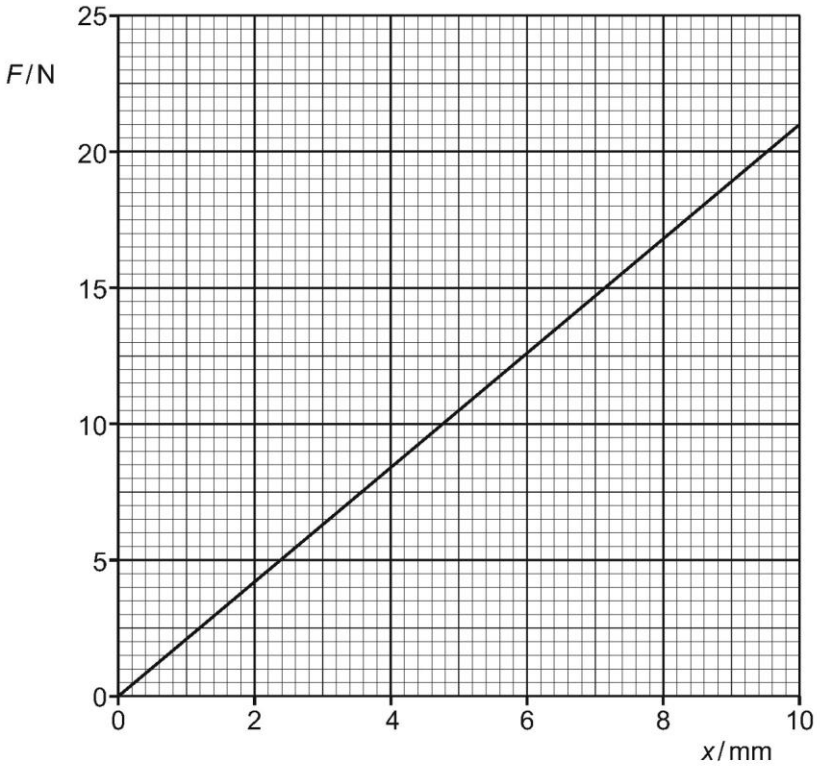


Fig. 3.3

(i) Use Fig. 3.3 to calculate the spring constant k of the spring.

k = ... $N\,m^{-1}$ [2]

(ii) At the position shown in Fig. 3.2, the system is stationary and in equilibrium.

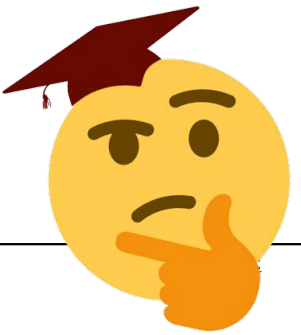
The radius of the sphere is 0.0480 m and 26.0% of the volume of the sphere is submerged.
The density of water is $1.00 \times 10^3\,kg\,m^{-3}$.

Show that the upthrust on the sphere is 1.18 N.

[2]

(iii) By taking moments about P, determine the force exerted on the spring by the rod R.

force = ... N [2]



(iv) Calculate the elastic potential energy E_P of the compressed spring.

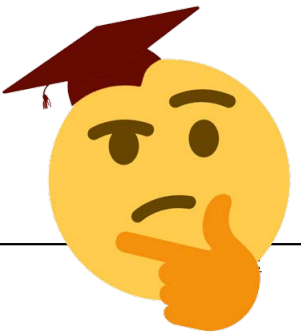
E_P = ... J [2]

(d) When the sphere moves from the position shown in Fig. 3.1 to the position shown in Fig. 3.2, the upthrust on the sphere does work.
Assume that resistive forces are negligible.

Explain why the work done by the upthrust is not equal to the gain in elastic potential energy of the spring.

.....

..... [1]



29 – (9702/21_Summer_2023_Q3) – *Dynamics, Forces, Density & Pressure*

A block is pulled in a straight line along a rough horizontal surface by a varying force X, as shown in Fig. 3.1.

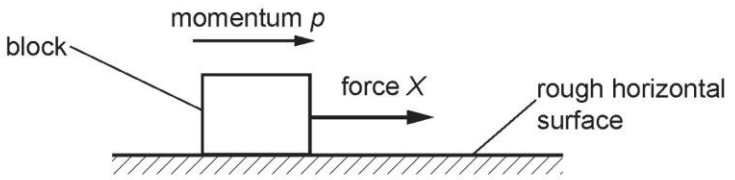


Fig. 3.1

Air resistance is negligible. Assume that the frictional force exerted on the block by the surface is constant and has magnitude 2.0 N.

The variation with time t of the momentum p of the block is shown in Fig. 3.2.

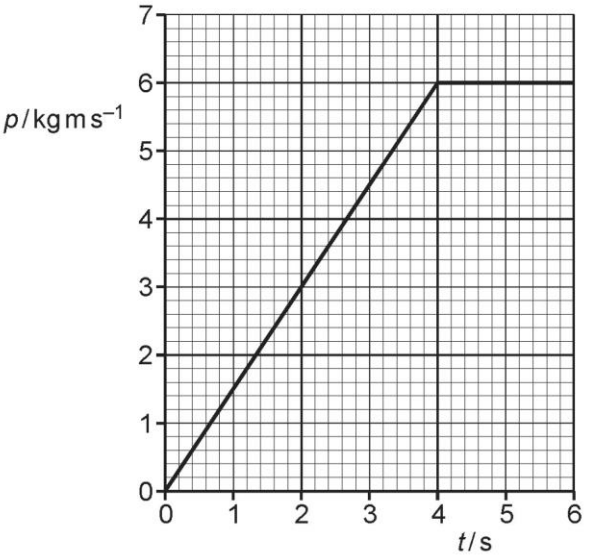
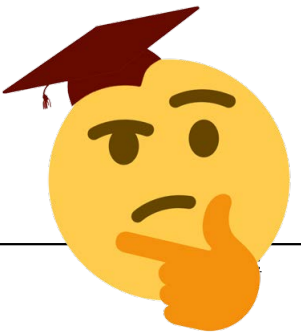


Fig. 3.2

(a) State Newton's second law of motion.

.....

..... [1]



(b) Use Fig. 3.2 to determine, for the block at time t = 2.0 s, the magnitude of:

(i) the resultant force on the block

resultant force = ... N [1]

(ii) the force X.

X = ... N [1]

(c) On Fig. 3.3, sketch a graph to show the variation of force X with time t from t = 0 to t = 6.0 s.

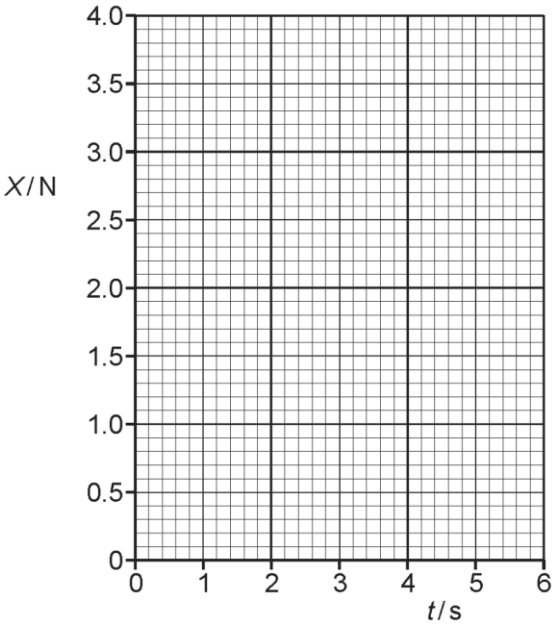
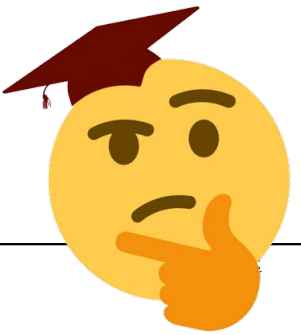


Fig. 3.3

[3]



30 – (9702/21_Summer_2023_Q4) – *Forces, Density & Pressure*

A beaker in air contains a liquid. The base of the beaker is in contact with the liquid and has area A, as shown in Fig. 4.1.

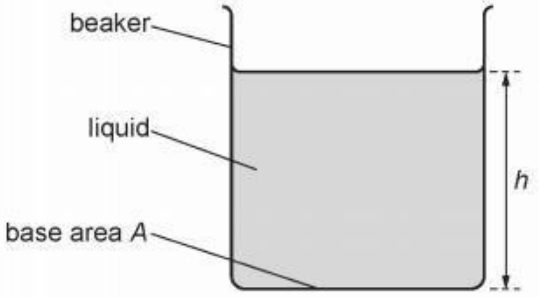


Fig. 4.1

The liquid has density ρ and fills the beaker to a depth h.

(a) By using the definitions of pressure and density, show that

$$p = \rho g h$$

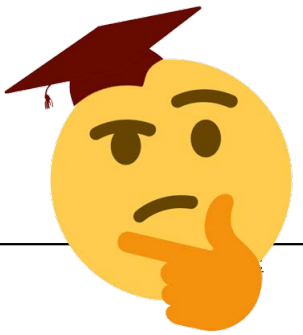
where p is the pressure due to the liquid that is exerted on the base of the beaker and g is the acceleration of free fall.

[3]

(b) Suggest why the equation in **(a)** does not give the total pressure on the base of the beaker.

.....

..... [1]



(c) Fig. 4.2 shows the variation of the total pressure inside the liquid with depth x below the surface.

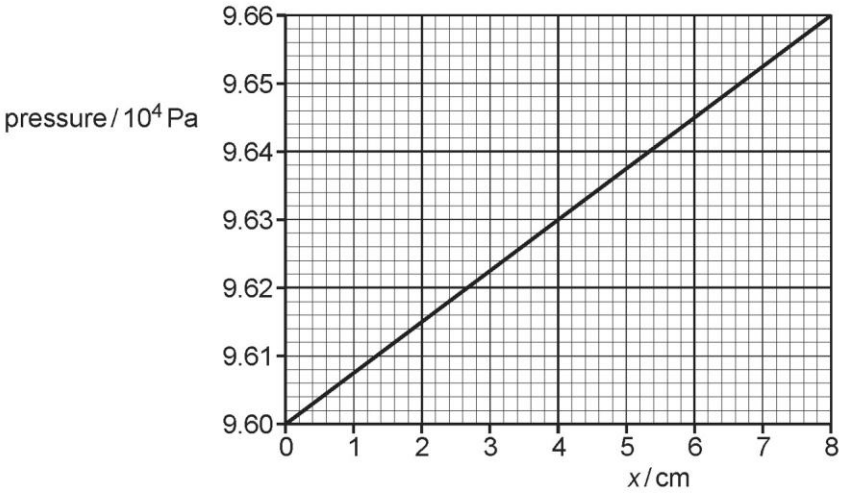
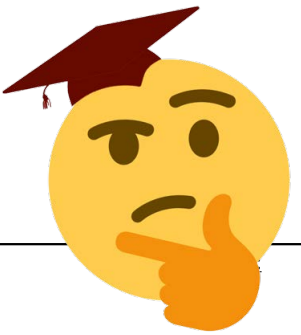


Fig. 4.2

Determine the density of the liquid.

density = ... $kg\,m^{-3}$ [2]



(d) A solid cylinder is held stationary by a wire so that the base of the cylinder is level with the surface of the liquid, as shown in Fig. 4.3.

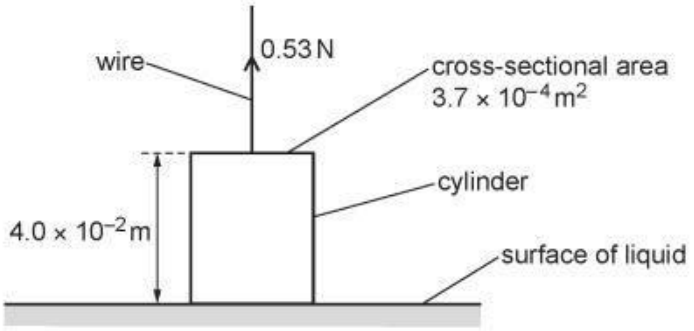


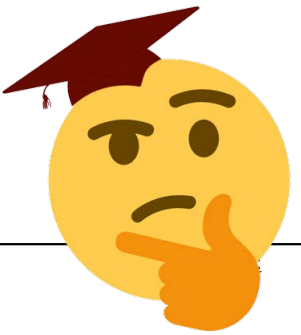
Fig. 4.3 (not to scale)

The cylinder has length 4.0×10^{-2} m and cross-sectional area 3.7×10^{-4} m^2. The tension in the wire is 0.53 N.

The cylinder is now lowered and then held stationary by the wire so that the top of the cylinder is level with the surface of the liquid.

Calculate the new tension in the wire.

tension = ... N [2]



31 – (9702/23_Summer_2023_Q2) – *Forces, Density & Pressure*

A sphere floats in equilibrium on the surface of sea water of density $1050\,kg\,m^{-3}$, as shown in Fig. 2.1.

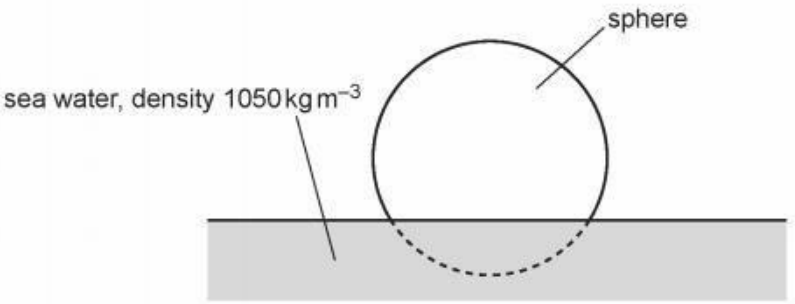


Fig. 2.1

(a) 21% of the volume of the sphere is below the surface of the water.

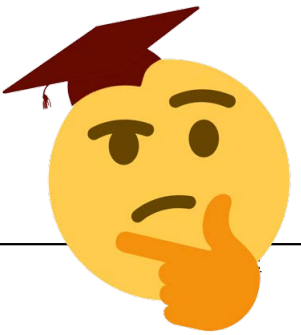
Calculate the density of the sphere.

density = ... $kg\,m^{-3}$ [2]

(b) The sphere is now held so that its entire volume is below the surface of the water. The sphere is then released.

(i) Calculate the initial acceleration of the sphere.

acceleration = ... $m\,s^{-2}$ [3]



(ii) The sphere accelerates upwards but remains entirely below the surface of the water.

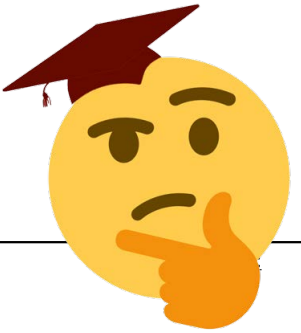
State and explain what happens to the acceleration of the sphere as its velocity begins to increase.

.....

.....

.....

..... [3]



32 – (9702/23_Summer_2023_Q6) – *Dynamics, Forces, Density & Pressure*

(a) Define the Young modulus.

.....

..... [1]

(b) A uniform wire is suspended from a fixed support. Masses are added to the other end of the wire, as shown in Fig. 6.1.

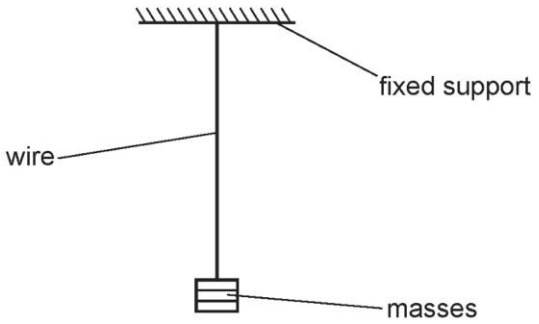


Fig. 6.1 (not to scale)

The variation of the length l of the wire with the force F applied to the wire by the masses is shown in Fig. 6.2.

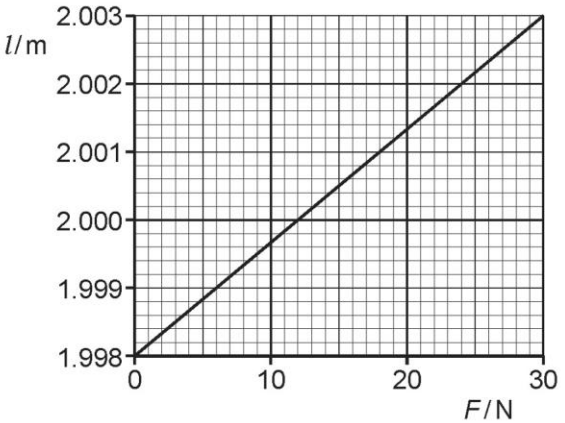
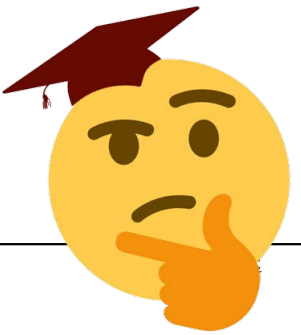


Fig. 6.2

The cross-sectional area of the wire is $0.95\,mm^2$.

(i) Determine the unstretched length of the wire.

unstretched length = ... m [1]



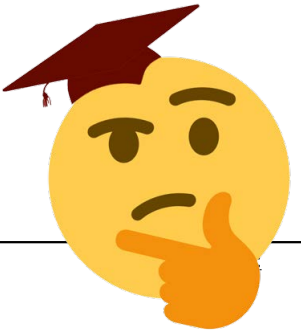
(ii) For an applied force F of 30 N, determine:

- the stress in the wire

stress = ... Pa

- the strain of the wire.

strain = ...
[3]



1 – (9702/21_Summer_2017_Q2) – *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

(a) State the two conditions for a system to be in equilibrium.

1. .....

.....

2. .....

.....

[2]

(b) A paraglider P of mass 95 kg is pulled by a wire attached to a boat, as shown in Fig. 2.1.

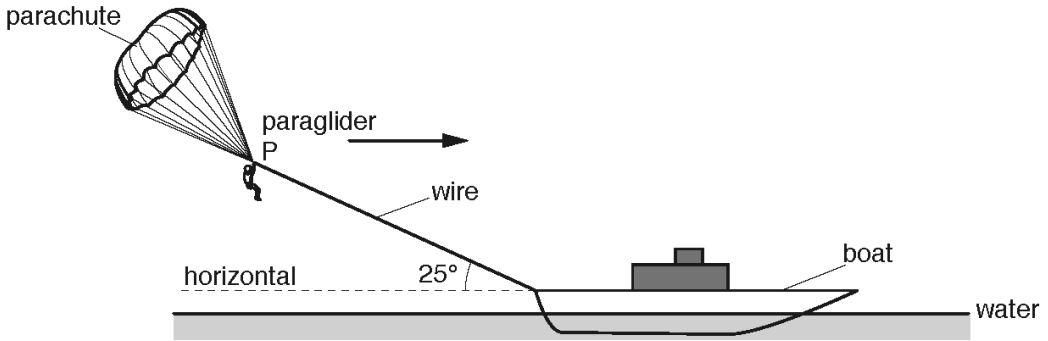


Fig. 2.1

The wire makes an angle of 25° with the horizontal water surface. P moves in a straight line parallel to the surface of the water.

The variation with time t of the velocity v of P is shown in Fig. 2.2.

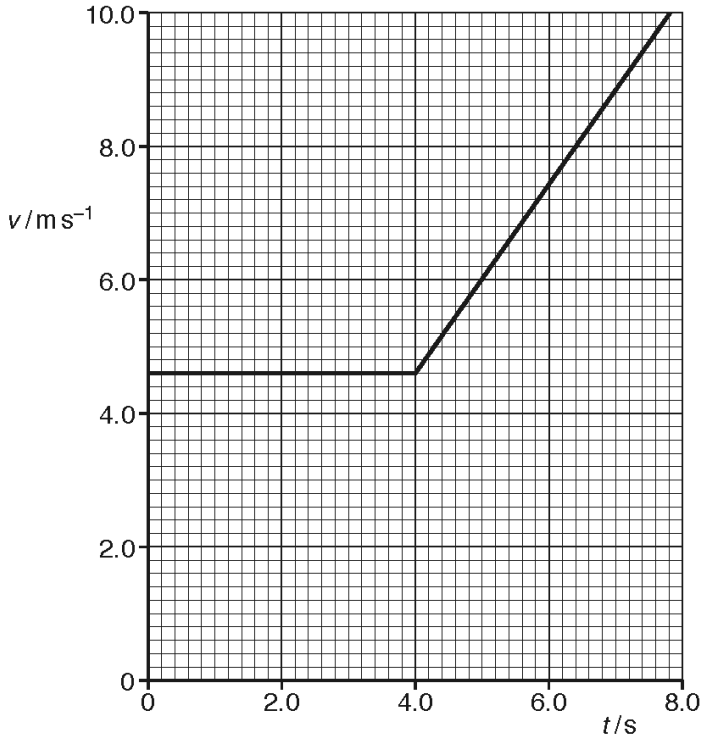
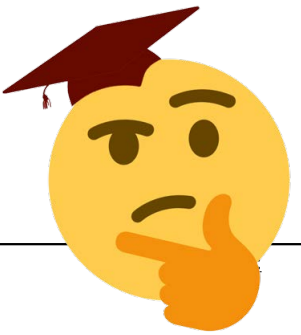


Fig. 2.2



(i) Show that the acceleration of P is $1.4\,\mathrm{m\,s^{-2}}$ at time $t = 5.0\,\mathrm{s}$.

[2]

(ii) Calculate the total distance moved by P from time $t = 0$ to $t = 7.0\,\mathrm{s}$.

distance = ...m [2]

(iii) Calculate the change in kinetic energy of P from time $t = 0$ to $t = 7.0\,\mathrm{s}$.

change in kinetic energy = ...J [2]

(iv) The tension in the wire at time $t = 5.0\,\mathrm{s}$ is $280\,\mathrm{N}$.

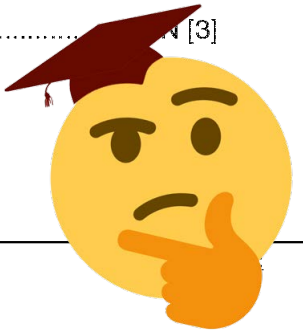
Calculate, for the horizontal motion,

1. the vertical lift force F supporting P,

F = ... N [3]

2. the force R due to air resistance acting on P in the horizontal direction.

R = ... N [3]



2 – (9702/22_Summer_2017_Q2) – *Kinematics, Work, Energy & Power*

(a) Define *velocity*.

.....

.....[1]

(b) A ball of mass 0.45 kg leaves the edge of a table with a horizontal velocity v, as shown in Fig. 2.1.

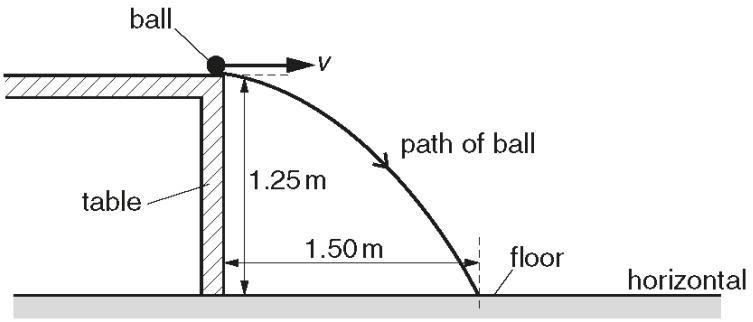


Fig. 2.1

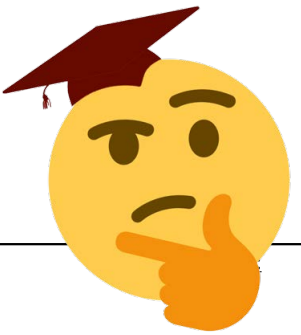
The height of the table is 1.25 m. The ball travels a distance of 1.50 m horizontally before hitting the floor.

Air resistance is negligible.

Calculate, for the ball,

(i) the horizontal velocity v as it leaves the table,

v = ...m s^{-1} [3]



(ii) the velocity just as it hits the floor,

magnitude of velocity = ...m s^{-1}

angle to the horizontal = ... °

[4]

(iii) the kinetic energy just as it hits the floor,

kinetic energy = ... J [2]

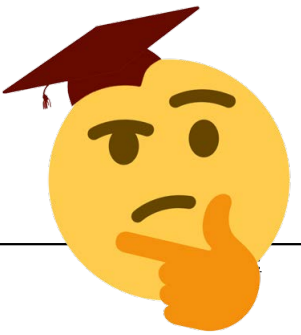
(iv) the loss in gravitational potential energy as it falls from the table to the floor.

loss in potential energy = ... J [2]

(c) Explain why the kinetic energy of the ball in **(b)(iii)** does not equal the loss of gravitational potential energy in **(b)(iv)**.

.....

.....[1]



3 – (9702/23_Winter_2017_Q2) – *Forces, Density & Pressure, Work, Energy & Power*

A liquid of density ρ fills a container to a depth h, as shown in Fig. 2.1.

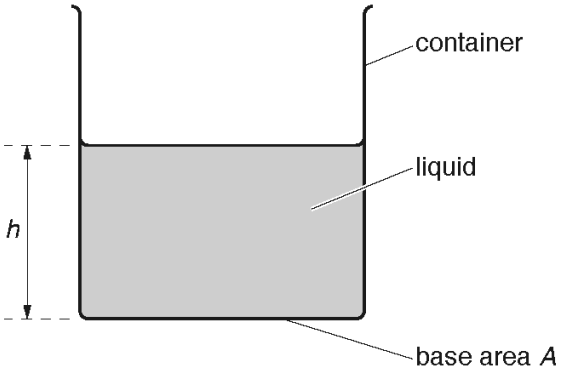


Fig. 2.1

The base of the container has area A.

(a) Derive, from the definitions of pressure and density, the equation

$$p = \rho g h$$

where p is the pressure exerted by the liquid on the base of the container and g is the acceleration of free fall.

[3]

(b) A small solid sphere falls with constant velocity through the liquid.

(i) State

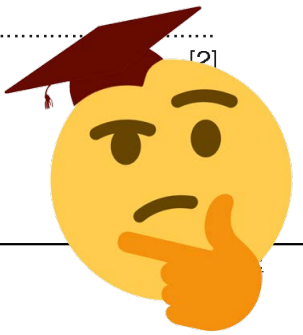
1. the names of the three forces acting on the sphere,

.....

.....

2. a word equation that relates the magnitudes of these forces.

..... [2]



(ii) State and explain the changes in energy that occur as the sphere falls.

.....

.....

.....

.....[2]

(c) The liquid in the container is liquid L. Liquid M is now added to the container. The two liquids do not mix. The total depth of the liquids is 0.17 m.

Fig. 2.2 shows how the pressure p inside the liquids varies with height x above the base of the container.

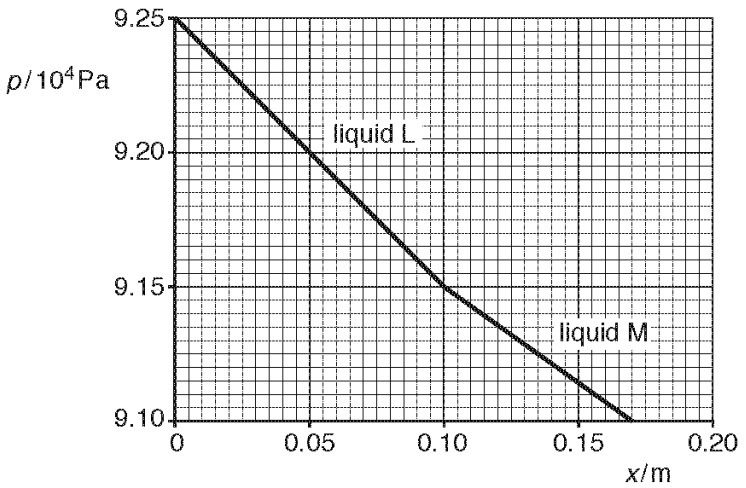


Fig. 2.2

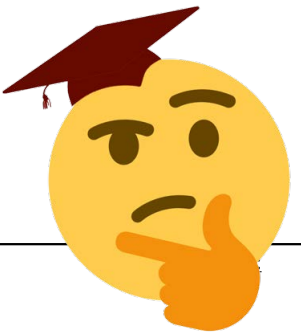
Use Fig. 2.2 to

(i) state the value of atmospheric pressure,

atmospheric pressure = ... Pa [1]

(ii) determine the density of liquid M.

density = ... kg m^{-3} [2]



4 – (9702/21_Summer_2018_Q2) – *Dynamics, Kinematics, Work, Energy & Power*

(a) State Newton's first law of motion.

.....

.....[1]

(b) A block of weight 15 N hangs by a wire from a remotely controlled aircraft, as shown in Fig. 2.1.

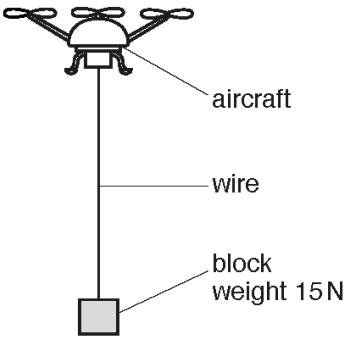


Fig. 2.1

The aircraft is used to move the block only in a vertical direction. The force on the block due to air resistance is negligible.

The variation with time t of the vertical velocity v of the block is shown in Fig. 2.2.
The velocity is taken to be positive in the upward direction.

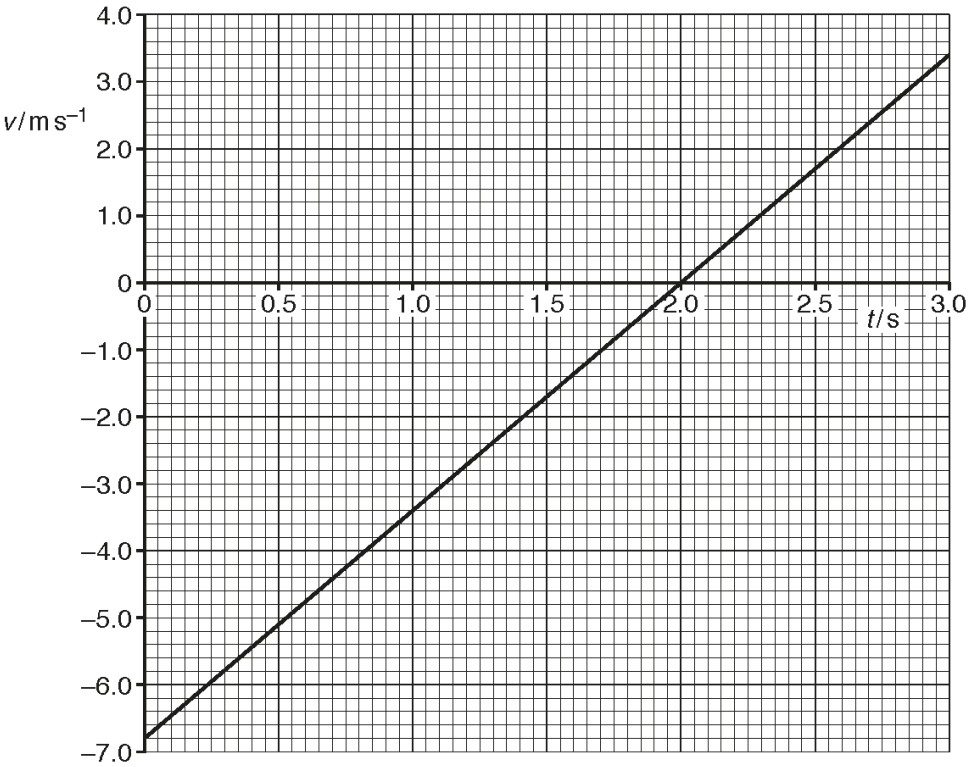
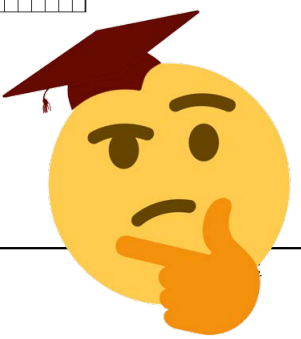


Fig. 2.2



(i) Determine, for the block,

1. the displacement from time $t = 0$ to $t = 3.0\,\text{s}$,

magnitude of displacement = ... m

direction of displacement .....

[3]

2. the change in gravitational potential energy from time $t = 0$ to $t = 3.0\,\text{s}$.

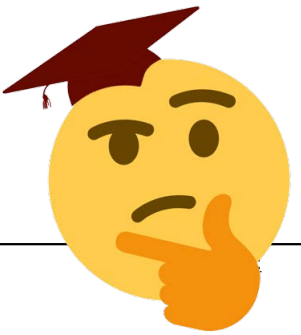
change in gravitational potential energy = ... J [2]

(ii) Calculate the magnitude of the acceleration of the block at time $t = 2.0\,\text{s}$.

acceleration = ... m s^{-2} [2]

(iii) Use your answer in **(b)(ii)** to show that the tension T in the wire at time $t = 2.0\,\text{s}$ is 20 N.

[2]



(iv) The wire has a cross-sectional area of $2.8 \times 10^{-5}\,m^2$ and is made from metal of Young modulus 1.7×10^{11} Pa. The wire obeys Hooke's law.

Calculate the strain of the wire at time $t = 2.0$ s.

strain = ... [3]

(v) At some time after $t = 3.0$ s the tension in the wire has a constant value of 15 N.

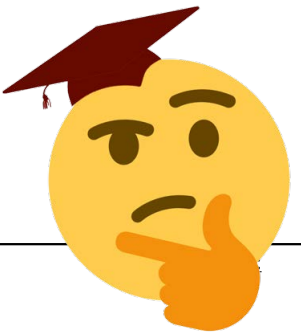
State and explain whether it is possible to deduce that the block is moving vertically after $t = 3.0$ s.

.....

.....

.....

.....[2]



5 – (9702/23_Summer_2018_Q2) – *Forces, Density & Pressure, Work, Energy & Power, Waves*

(a) State what is meant by *work done*.

.....

.....[1]

(b) A diver releases a solid sphere of radius 16 cm from the sea bed. The sphere moves vertically upwards towards the surface of the sea.

The weight of the sphere is 20 N. The upthrust acting on the sphere is 170 N. The upthrust remains constant as the sphere moves upwards.

(i) Calculate the density of the material of the sphere.

density = ... $kg\,m^{-3}$ [2]

(ii) Briefly explain the origin of the upthrust acting on the sphere.

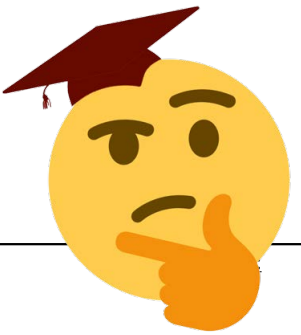
.....

.....

.....[1]

(iii) Calculate the acceleration of the sphere as it is released from rest.

acceleration = ... $m\,s^{-2}$ [2]



(iv) The viscous (drag) force D acting on the sphere is given by

$$D = kr^2v^2$$

where r is the radius of the sphere and v is its speed.
The constant k is equal to $810\,\text{kg}\,\text{m}^{-3}$.

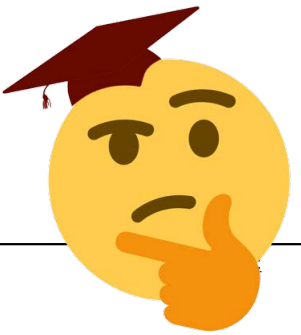
Determine the constant (terminal) speed reached by the sphere.

speed = ... $\text{m}\,\text{s}^{-1}$ [3]

(v) The diver releases a different sphere that moves with a constant speed of $6.30\,\text{m}\,\text{s}^{-1}$ directly towards a stationary ship. The sphere emits sound of frequency 4850 Hz. The ship detects sound of frequency 4870 Hz as the sphere moves towards it.

Determine, to three significant figures, the speed of the sound in the water.

speed = ... $\text{m}\,\text{s}^{-1}$ [2]



6 – (9702/23_Summer_2018_Q3) – *Kinematics, Dynamics, Work, Energy & Power*

A ball is thrown vertically upwards towards a ceiling and then rebounds, as illustrated in Fig. 3.1.

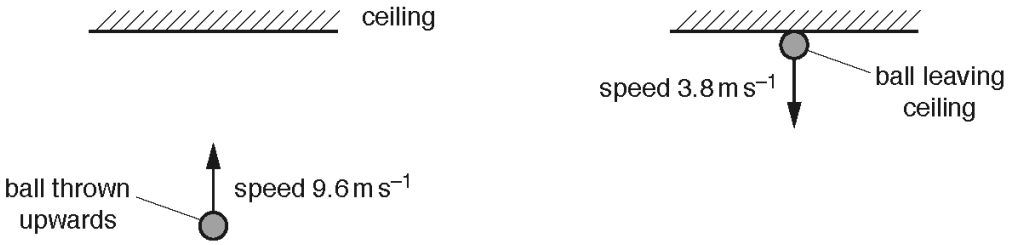


Fig. 3.1

The ball is thrown with speed 9.6 m s^{-1} and takes a time of 0.37 s to reach the ceiling. The ball is then in contact with the ceiling for a further time of 0.085 s until leaving it with a speed of 3.8 m s^{-1}. The mass of the ball is 0.056 kg. Assume that air resistance is negligible.

(a) Show that the ball reaches the ceiling with a speed of 6.0 m s^{-1}.

[1]

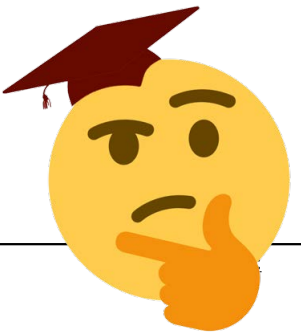
(b) Calculate the height of the ceiling above the point from which the ball was thrown.

height = ... m [2]

(c) Calculate

(i) the increase in gravitational potential energy of the ball for its movement from its initial position to the ceiling,

increase in gravitational potential energy = ... J [2]



(ii) the decrease in kinetic energy of the ball while it is in contact with the ceiling.

decrease in kinetic energy = ... J [2]

(d) State how Newton's third law applies to the collision between the ball and the ceiling.

.....

.....

.....

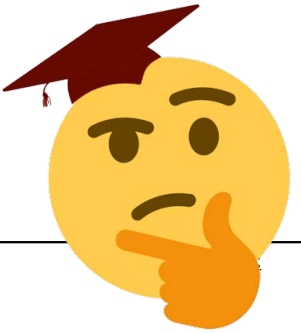
.....[2]

(e) Calculate the change in momentum of the ball during the collision.

change in momentum = ... N s [2]

(f) Determine the magnitude of the average force exerted by the ceiling on the ball during the collision.

average force = ... N [2]



7 – (9702/22_Summer_2018_Q5) – *Forces, Density & Pressure, Dynamics, Work, Energy & Power*

A solid cylinder is lifted out of oil by a wire attached to a motor. Fig. 5.1 shows two different positions X and Y of the cylinder during the lifting process.

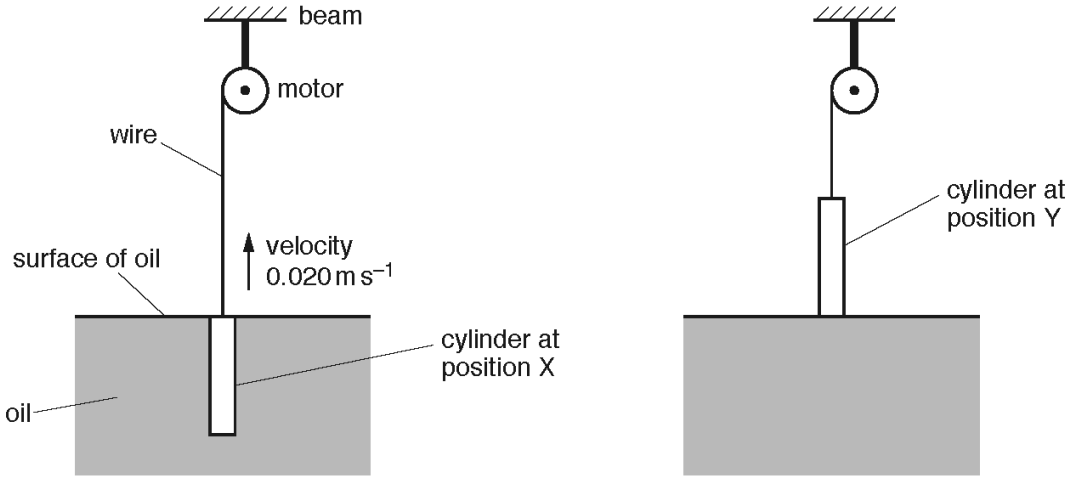


Fig. 5.1

The motor is fixed to an overhead beam.
The cylinder has cross-sectional area $0.018\,m^2$, length $1.2\,m$ and weight $560\,N$.
The density of the oil is $940\,kg\,m^{-3}$.

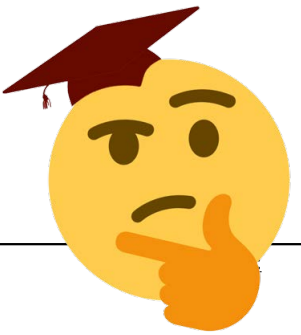
Throughout the lifting process, the cylinder moves vertically upwards with a constant velocity of $0.020\,m\,s^{-1}$. The viscous force of the oil acting on the cylinder is negligible.

(a) Calculate the density of the cylinder.

density = ... $kg\,m^{-3}$ [2]

(b) For the cylinder at position X, show that the upthrust due to the oil is $200\,N$.

[2]



(c) Calculate, for the moving cylinder at position X,

(i) the tension in the wire,

tension = ... N [1]

(ii) the power output of the motor.

power = ... W [2]

(d) The cylinder is raised with constant velocity from position X to position Y.

(i) State and explain the variation, if any, of the power output of the motor as the cylinder is raised. Numerical values are not required.

.....

.....

.....

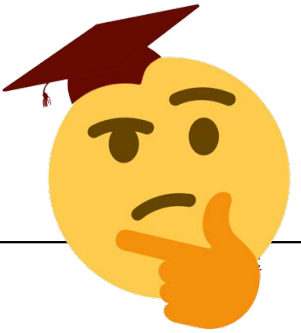
.....

.....[3]

(ii) The rate of energy output of the motor is less than the rate of increase of gravitational potential energy of the cylinder. Without calculation, explain this difference.

.....

.....[1]



8 – (9702/21_Winter_2018_Q1) – *Kinematics, Work, Energy & Power*

(a) Define

(i) *displacement*,

.....

..... [1]

(ii) *acceleration*.

.....

..... [1]

(b) A remote-controlled toy car moves up a ramp and travels across a gap to land on another ramp, as illustrated in Fig. 1.1.

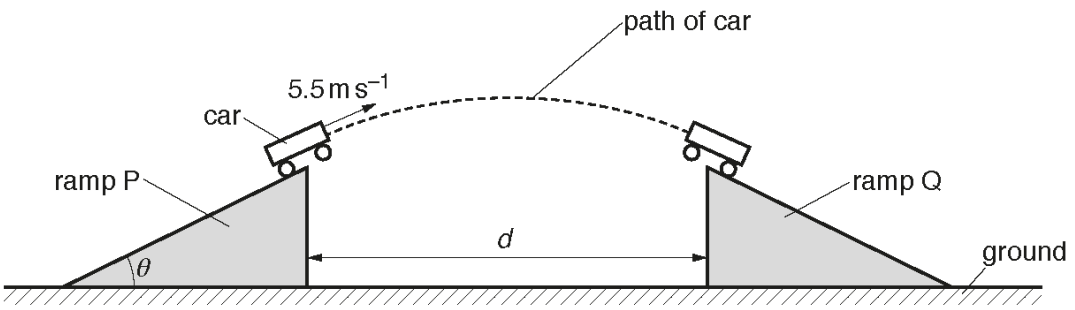


Fig. 1.1

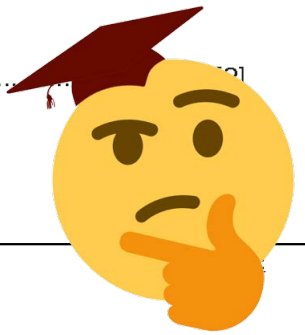
The car leaves ramp P with a velocity of $5.5\,\mathrm{m\,s^{-1}}$ at an angle θ to the horizontal. The horizontal component of the car's velocity as it leaves the ramp is $4.6\,\mathrm{m\,s^{-1}}$. The car lands at the top of ramp Q. The tops of both ramps are at the same height and are distance d apart. Air resistance is negligible.

(i) Show that the car leaves ramp P with a vertical component of velocity of $3.0\,\mathrm{m\,s^{-1}}$.

[1]

(ii) Determine the time taken for the car to travel between the ramps.

time taken = ...



(iii) Calculate the horizontal distance d between the tops of the ramps.

d = ... m [1]

(iv) Calculate the ratio

$$\frac{\text{kinetic energy of the car at its maximum height}}{\text{kinetic energy of the car as it leaves ramp P}}.$$

ratio = ... [3]

(c) Ramp Q is removed. The car again leaves ramp P as in **(b)** and now lands directly on the ground. The car leaves ramp P at time $t = 0$ and lands on the ground at time $t = T$.

On Fig. 1.2, sketch the variation with time t of the vertical component v_y of the car's velocity from $t = 0$ to $t = T$. Numerical values of v_y and t are not required.

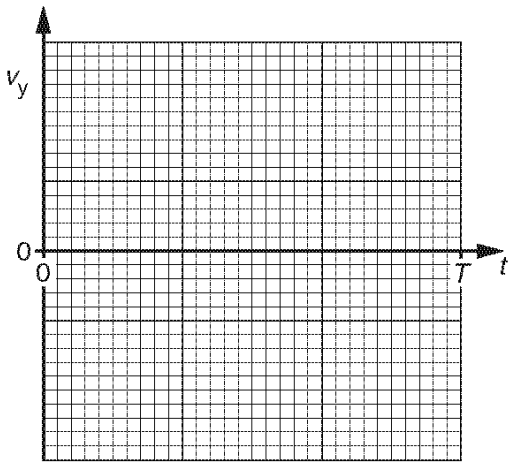
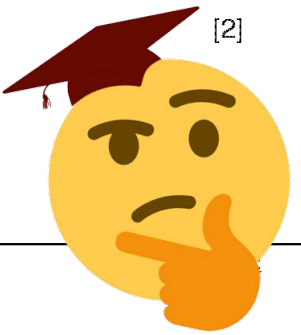


Fig. 1.2

[2]



9 – (9702/22_Winter_2018_Q1) – *Kinematics, Work, Energy & Power*

A golfer strikes a ball so that it leaves horizontal ground with a velocity of $6.0\,\mathrm{m\,s^{-1}}$ at an angle θ to the horizontal, as illustrated in Fig. 1.1.

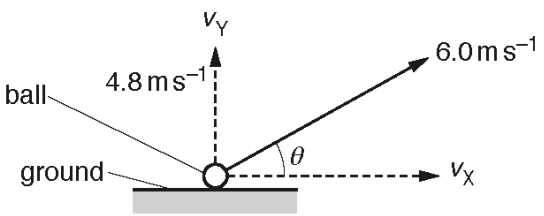


Fig. 1.1 (not to scale)

The magnitude of the initial vertical component v_Y of the velocity is $4.8\,\mathrm{m\,s^{-1}}$.
Assume that air resistance is negligible.

(a) Show that the magnitude of the initial horizontal component v_X of the velocity is $3.6\,\mathrm{m\,s^{-1}}$.

[1]

(b) The ball leaves the ground at time $t = 0$ and reaches its maximum height at $t = 0.49$ s.

On Fig. 1.2, sketch separate lines to show the variation with time t, until the ball returns to the ground, of

(i) the vertical component v_Y of the velocity (label this line Y), [2]

(ii) the horizontal component v_X of the velocity (label this line X). [2]

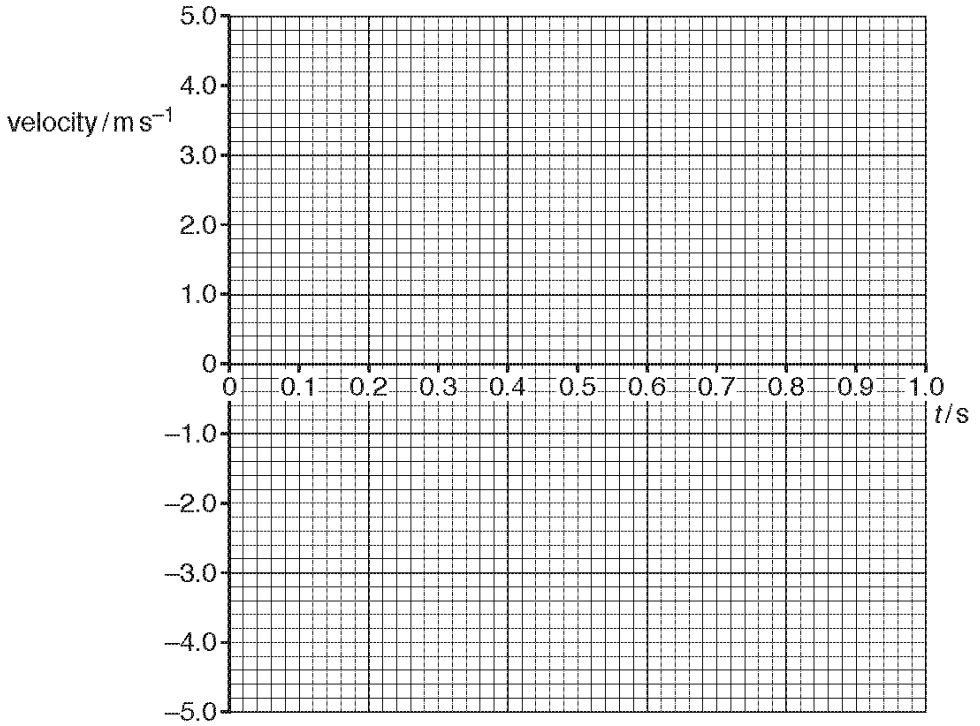
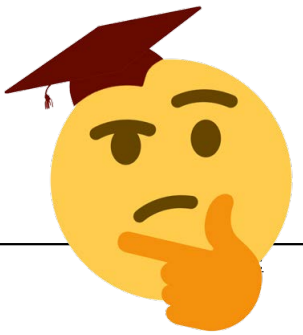


Fig. 1.2

(c) Calculate the maximum height reached by the ball.

maximum height = ... m [2]



(d) For the movement of the ball from the ground to its maximum height, determine the ratio

$$\frac{\text{kinetic energy at maximum height}}{\text{change in gravitational potential energy}}.$$

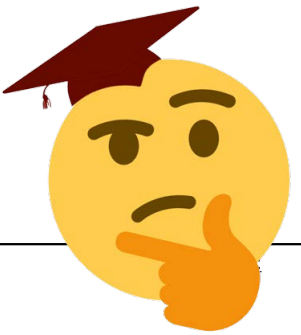
ratio = ...[4]

(e) In practice, significant air resistance acts on the ball. Explain why the actual time taken for the ball to reach maximum height is less than the time calculated when air resistance is assumed to be negligible.

.....

.....

.....[1]



10 – (9702/23_Winter_2018_Q2) – *Dynamics, Work, Energy & Power*

(a) State what is meant by *kinetic energy*.

.....

.....[1]

(b) A cannon fires a shell vertically upwards. The shell leaves the cannon with a speed of $80\,m\,s^{-1}$ and a kinetic energy of 480 J. The shell then rises to a maximum height of 210 m. The effect of air resistance is significant.

(i) Show that the mass of the shell is 0.15 kg.

[2]

(ii) For the movement of the shell from the cannon to its maximum height, calculate

1. the gain in gravitational potential energy,

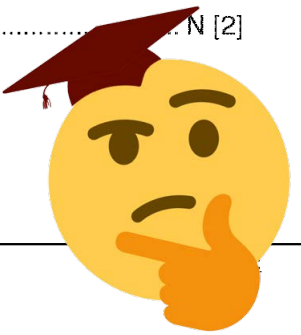
gain in gravitational potential energy = ...J [2]

2. the work done against air resistance.

work done = ...J [1]

(iii) Determine the average force due to the air resistance acting on the shell as it moves from the cannon to its maximum height.

force = ...N [2]



(iv) The shell leaves the cannon at time $t = 0$ and reaches maximum height at time $t = T$.

On Fig. 2.1, sketch the variation with time t of the velocity v of the shell from time $t = 0$ to time $t = T$. Numerical values of v and t are not required.

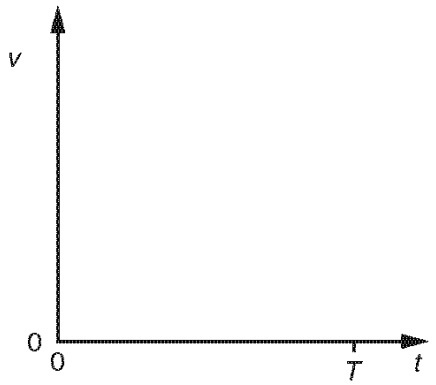


Fig. 2.1

[2]

(v) The force due to the air resistance is a vector quantity.

Compare the force due to the air resistance acting on the shell as it rises with the force due to the air resistance as it falls.

.....

.....

.....

.....

.....[2]

11 – (9702/21_Winter_2018_Q3) – *Work, Energy & Power*

(a) **(i)** Define *power*.

.....

..... [1]

(ii) State what is meant by *gravitational potential energy*.

.....

..... [1]

(b) An aircraft of mass 1200 kg climbs upwards with a constant velocity of $45\,m\,s^{-1}$, as shown in Fig. 3.1.

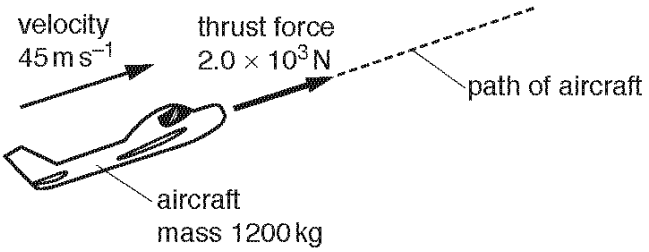
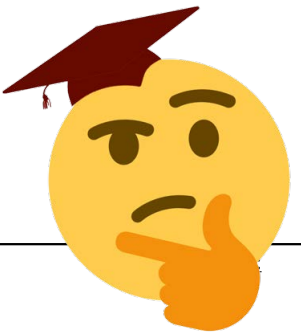


Fig. 3.1 (not to scale)

The aircraft's engine produces a thrust force of 2.0×10^3 N to move the aircraft through the air. The rate of increase in height of the aircraft is $3.3\,m\,s^{-1}$.

(i) Calculate the power produced by the thrust force.

power = ... W [2]



(ii) Determine, for a time interval of 3.0 minutes,

1. the work done by the thrust force to move the aircraft,

work done = ... J [2]

2. the increase in gravitational potential energy of the aircraft,

increase in gravitational potential energy = ... J [2]

3. the work done against air resistance.

work done = ... J [1]

(iii) Use your answer in **(b)(ii) part 3** to calculate the force due to air resistance acting on the aircraft.

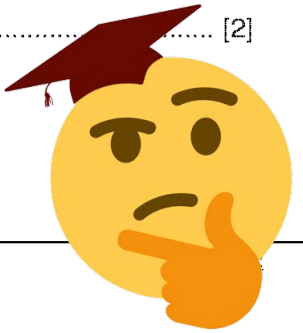
force = ... N [1]

(iv) With reference to the motion of the aircraft, state and explain whether the aircraft is in equilibrium.

.....

.....

..... [2]



12 – (9702/23_Summer_2019_Q2) – *Work, Energy & Power*

(a) A resultant force F moves an object of mass m through distance s in a straight line. The force gives the object an acceleration a so that its speed changes from initial speed u to final speed v.

(i) State an expression for:

1. the work W done by the force, in terms of a, m and s

$W =$ ..... [1]

2. the distance s, in terms of a, u and v.

$s =$ ..... [1]

(ii) Use your answers in **(i)** to show that the kinetic energy of the object is given by

$$\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times (\text{speed})^2.$$

Explain your working.

[2]

(b) A ball of mass 0.040 kg is projected into the air from horizontal ground, as illustrated in Fig. 2.1.

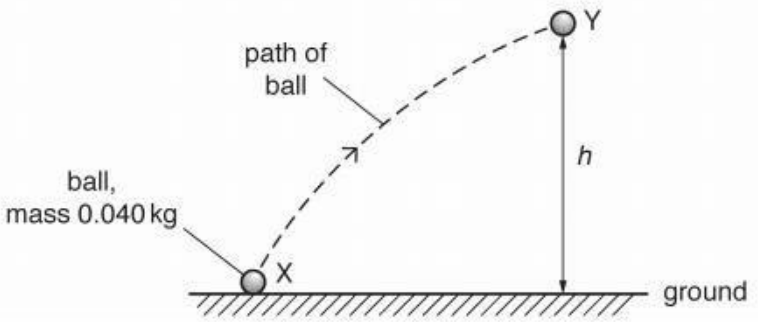
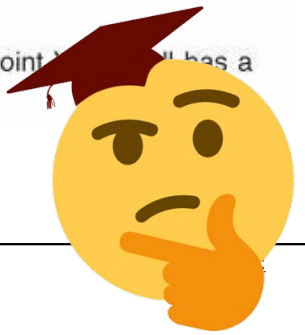


Fig. 2.1

The ball is launched from a point X with a kinetic energy of 4.5 J. At point Y the ball has a speed of 9.5 m s^{-1}. Air resistance is negligible.



(i) For the movement of the ball from X to Y, draw a solid line on Fig. 2.1 to show:

1. the distance moved (label this line D)

2. the displacement (label this line S).

[2]

(ii) By consideration of energy transfer, determine the height *h* of point Y above the ground.

h = ... m [3]

(iii) On Fig. 2.2, sketch the variation of the kinetic energy of the ball with its vertical height above the ground for the movement of the ball from X to Y.
Numerical values are not required.

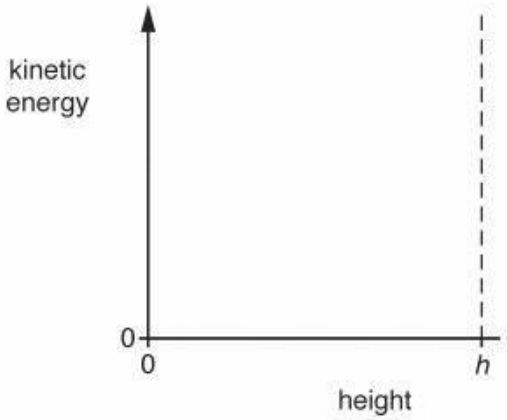
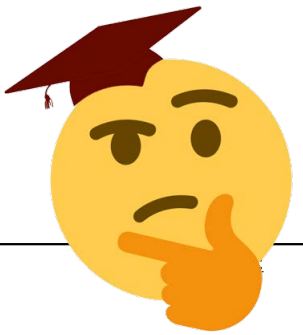


Fig. 2.2

[2]



13 – (9702/21_Summer_2019_Q3) – *Deformation Of Solids, Work, Energy & Power*

The variation with extension x of the force F acting on a spring is shown in Fig. 3.1.

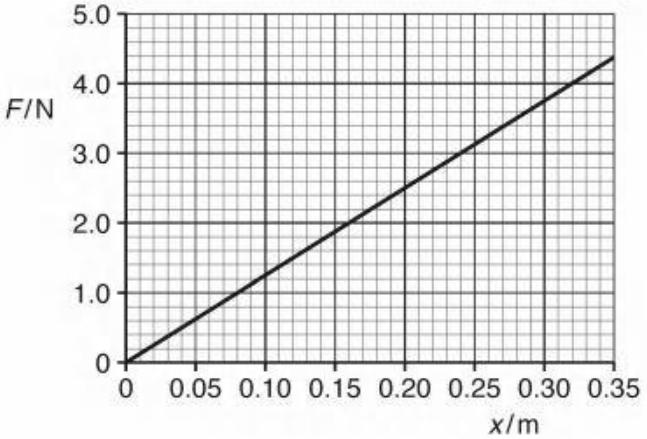


Fig. 3.1

The spring of unstretched length 0.40 m has one end attached to a fixed point, as shown in Fig. 3.2.

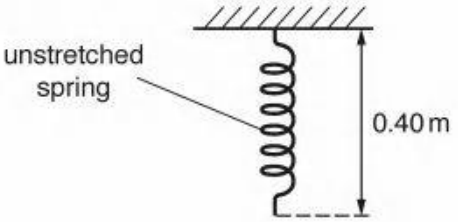


Fig. 3.2

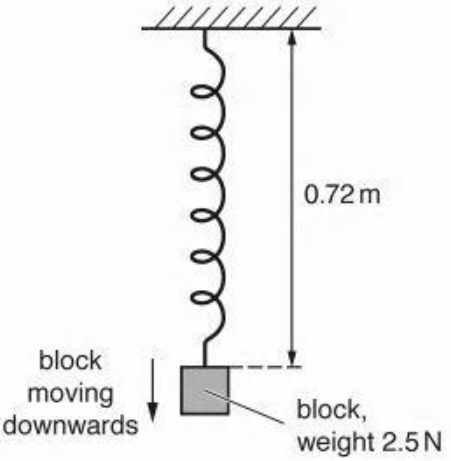


Fig. 3.3

A block of weight 2.5 N is then attached to the spring. The block is then released and begins to move downwards. At one instant, as the block is continuing to move downwards, the spring has a length of 0.72 m, as shown in Fig. 3.3.

Assume that the air resistance and the mass of the spring are both negligible.

(a) For the change in length of the spring from 0.40 m to 0.72 m:

(i) use Fig. 3.1 to show that the increase in elastic potential energy of the spring is 0.64 J

[2]

(ii) calculate the decrease in gravitational potential energy of the block of weight 2.5 N.

decrease in potential energy = ... J [2]

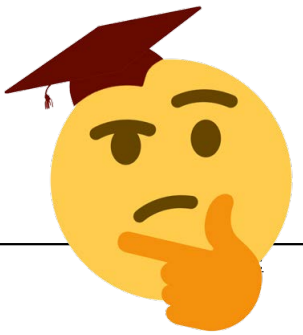
(b) Use the information in **(a)(i)** and your answer in **(a)(ii)** to determine, for the instant when the length of the spring is 0.72 m:

(i) the kinetic energy of the block

kinetic energy = ... J [1]

(ii) the speed of the block.

speed = ... $m\,s^{-1}$ [2]



14 – (9702/22_Summer_2019_Q3) – *Forces, Density & Pressure, Work, Energy & Power*

(a) State what is meant by the *centre of gravity* of a body.

.....

.....[1]

(b) A uniform square sign with sides of length 0.68 m is fixed at its corner points A and B to a wall. The sign is also supported by a wire CD, as shown in Fig. 3.1.

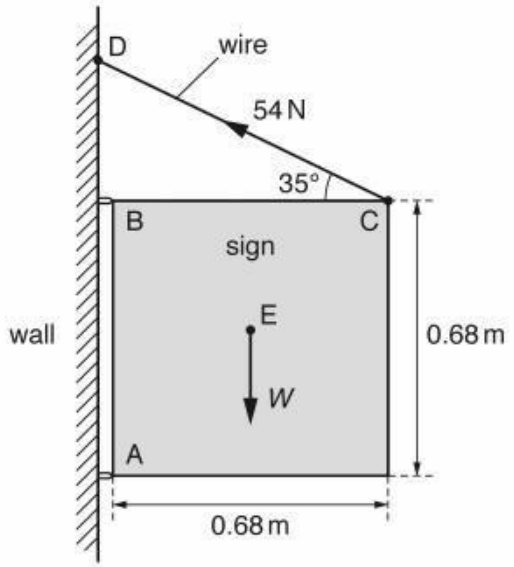


Fig. 3.1 (not to scale)

The sign has weight *W* and centre of gravity at point E. The sign is held in a vertical plane with side BC horizontal. The wire is at an angle of 35° to side BC. The tension in the wire is 54 N.

The force exerted on the sign at B is only in the vertical direction.

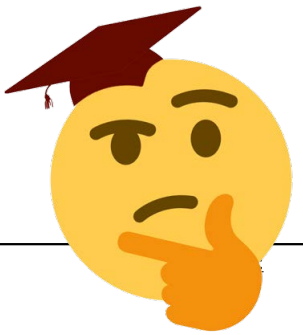
(i) Calculate the vertical component of the tension in the wire.

vertical component of tension = ... N [1]

(ii) Explain why the force on the sign at B does not have a moment about point A.

.....

.....[1]



(iii) By taking moments about point A, show that the weight W of the sign is 150 N.

[2]

(iv) Calculate the total vertical force exerted by the wall on the sign at points A and B.

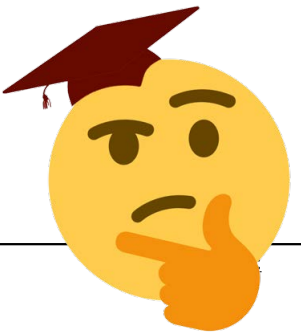
total vertical force = ... N [1]

(c) The sign in **(b)** is held together by nuts and bolts. One of the nuts falls vertically from rest through a distance of 4.8 m to the pavement below. The nut lands on the pavement with a speed of $9.2\,\mathrm{m\,s^{-1}}$.

Determine, for the nut falling from the sign to the pavement, the ratio

$$\frac{\text{change in gravitational potential energy}}{\text{final kinetic energy}}.$$

ratio = ... [4]



15 – (9702/23_Summer_2019_Q3) – *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

A cylindrical disc of mass 0.24 kg has a circular cross-sectional area *A*, as shown in Fig. 3.1.

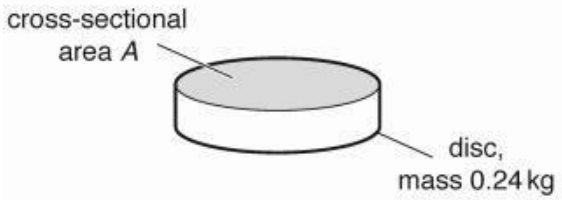


Fig. 3.1

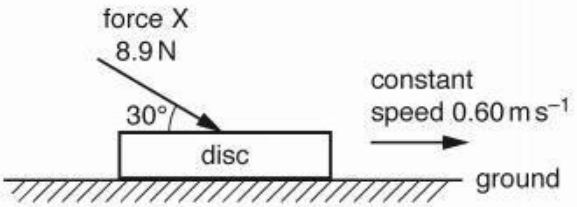


Fig. 3.2

The disc is on horizontal ground, as shown in Fig. 3.2. A force X of magnitude 8.9 N acts on the disc in a direction of 30° to the horizontal. The disc moves at a constant speed of 0.60 m s^{-1} along the ground.

(a) Determine the rate of doing work on the disc by the force X.

rate of doing work = ... W [2]

(b) The force X and the weight of the disc exert a combined pressure on the ground of 3500 Pa.

Calculate the cross-sectional area *A* of the disc.

A = ... m^2 [3]

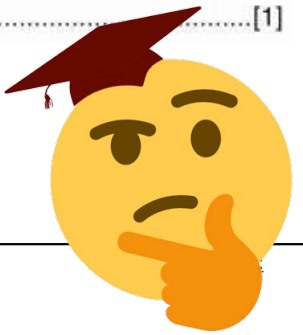
(c) Newton's third law describes how forces exist in pairs. One such pair of forces is the weight of the disc and another force Y. State:

(i) the direction of force Y

.....[1]

(ii) the name of the body on which force Y acts.

.....[1]



16 – (9702/23_Winter_2019_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a) State what is meant by *work done*.

.....

..... [1]

(b) A lift (elevator) of weight 13.0 kN is connected by a cable to a motor, as shown in Fig. 2.1.

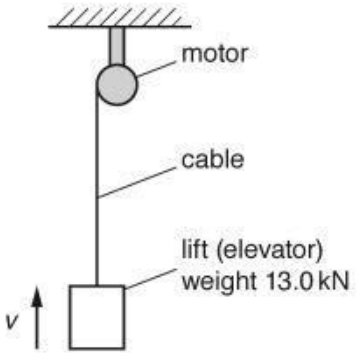


Fig. 2.1

The lift is pulled up a vertical shaft by the cable. A constant frictional force of 2.0 kN acts on the lift when it is moving. The variation with time *t* of the speed *v* of the lift is shown in Fig. 2.2.

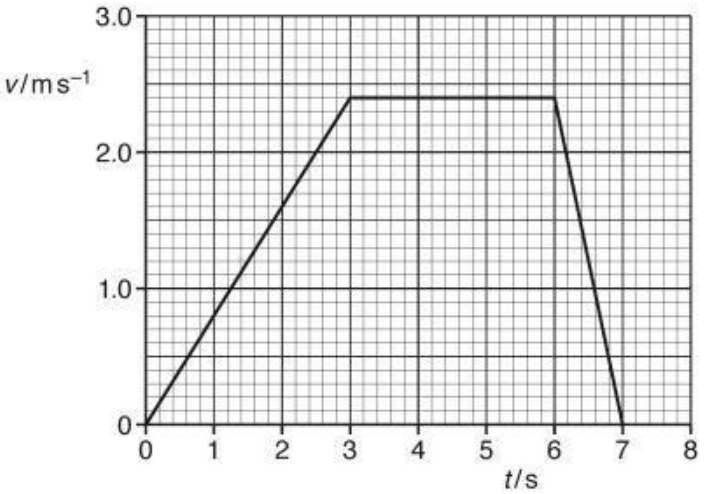


Fig. 2.2

(i) Use Fig. 2.2 to determine:

1. the acceleration of the lift between time $t = 0$ and $t = 3.0\,s$

acceleration = ... $m\,s^{-2}$ [2]

2. the work done by the motor to raise the lift between time $t = 3.0\,s$ and $t = 6.0\,s$.

work done = ... J [2]

(ii) The motor has an efficiency of 67%. The tension in the cable is $1.6 \times 10^4\,N$ at time $t = 2.5\,s$.

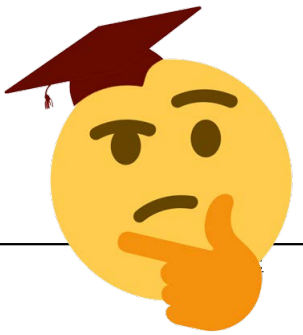
Determine the input power to the motor at this time.

input power = ... W [3]

(iii) State and explain whether the increase in gravitational potential energy of the lift from time $t = 0$ to $t = 7.0\,s$ is less than, the same as, or greater than the work done by the motor. A calculation is not required.

.....

..... [1]



17 – (9702/21_Winter_2019_Q4) – *Work, Energy & Power, Deformation Of Solids*

The variation with extension x of the force F applied to a spring is shown in Fig. 4.1.

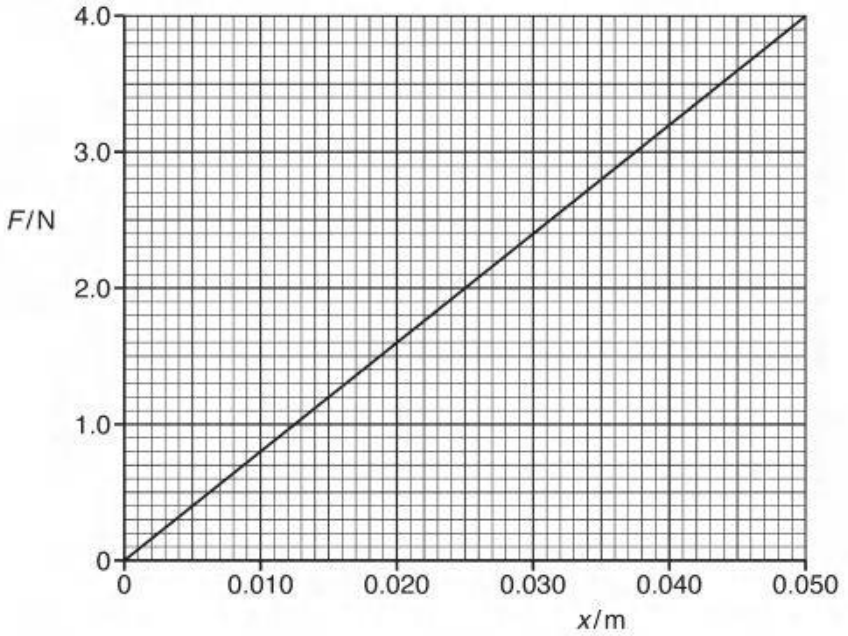


Fig. 4.1

The spring has an unstretched length of 0.080 m and is suspended vertically from a fixed point, as shown in Fig. 4.2.

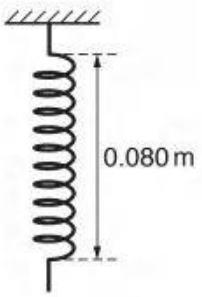


Fig. 4.2

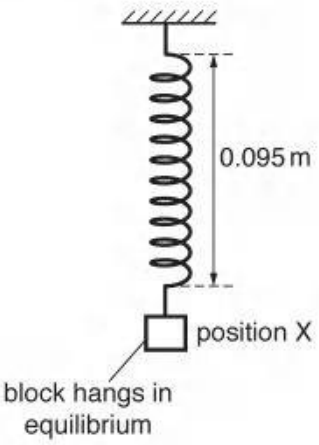


Fig. 4.3

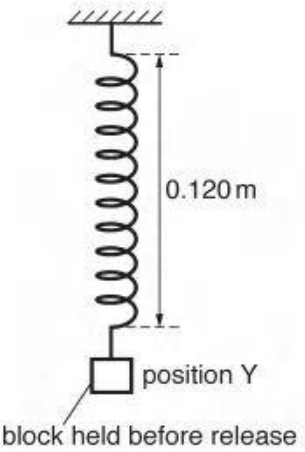
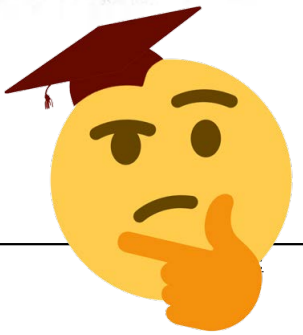


Fig. 4.4

A block is attached to the lower end of the spring. The block hangs in equilibrium at position X when the length of the spring is 0.095 m, as shown in Fig. 4.3.

The block is then pulled vertically downwards and held at position Y so that the length of the spring is 0.120 m, as shown in Fig. 4.4. The block is then released and moves vertically upwards from position Y back towards position X.



(a) Use Fig. 4.1 to determine the spring constant of the spring.

spring constant = ... $N\,m^{-1}$ [2]

(b) Use Fig. 4.1 to show that the decrease in elastic potential energy of the spring is 0.055 J when the block moves from position Y to position X.

[2]

(c) The block has a mass of 0.122 kg. Calculate the increase in gravitational potential energy of the block for its movement from position Y to position X.

increase in gravitational potential energy = ... J [2]

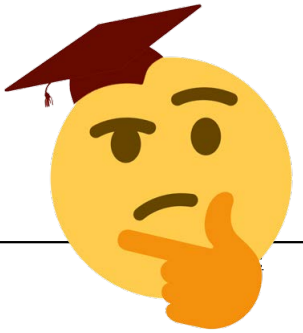
(d) Use the decrease in elastic potential energy stated in **(b)** and your answer in **(c)** to determine, for the block, as it moves through position X:

(i) its kinetic energy

kinetic energy = ... J [1]

(ii) its speed.

speed = ... $m\,s^{-1}$ [2]



18 – (9702/21_Summer_2020_Q3) – *Forces, Density & Pressure, Work, Energy & Power*

(a) State **two** conditions for an object to be in equilibrium.

1. .....

.....

2. .....

.....

[2]

(b) A sphere of weight 2.4 N is suspended by a wire from a fixed point P. A horizontal string is used to hold the sphere in equilibrium with the wire at an angle of 53° to the horizontal, as shown in Fig. 3.1.

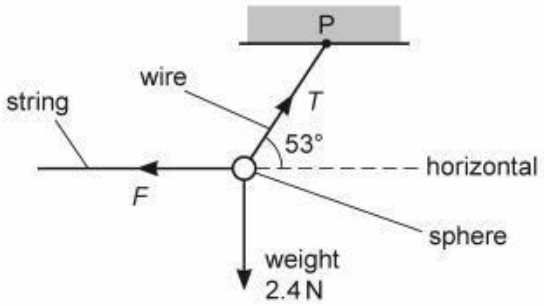


Fig. 3.1 (not to scale)

(i) Calculate:

1. the tension T in the wire

T = ... N

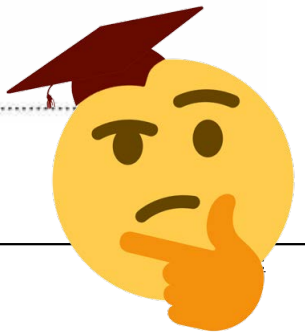
2. the force F exerted by the string on the sphere.

F = ... N

[2]

(ii) The wire has a circular cross-section of diameter 0.50 mm. Determine the stress σ in the wire.

σ = ...



(c) The string is disconnected from the sphere in **(b)**. The sphere then swings from its initial rest position A, as illustrated in Fig. 3.2.

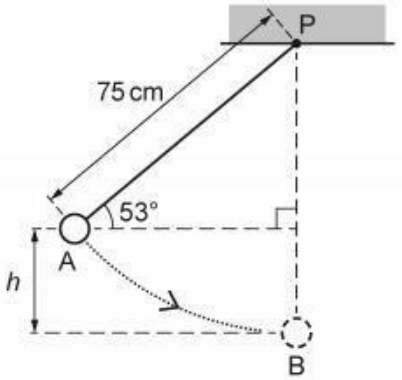


Fig. 3.2 (not to scale)

The sphere reaches maximum speed when it is at the bottom of the swing at position B. The distance between P and the centre of the sphere is 75 cm.
Air resistance is negligible and energy losses at P are negligible.

(i) Show that the vertical distance *h* between A and B is 15 cm.

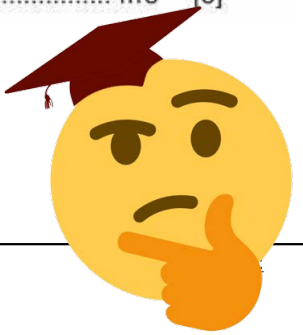
[1]

(ii) Calculate the change in gravitational potential energy of the sphere as it moves from A to B.

change in gravitational potential energy = ... J [2]

(iii) Use your answer in **(c)(ii)** to determine the speed of the sphere at B.
Show your working.

speed = ... $m s^{-1}$ [3]



19 – (9702/22_Summer_2020_Q3) – *Work, Energy & Power*

(a) Explain what is meant by *work done*.

.....

..... [1]

(b) A ball of mass 0.42 kg is dropped from the top of a building. The ball falls from rest through a vertical distance of 78 m to the ground. Air resistance is significant so that the ball reaches constant (terminal) velocity before hitting the ground. The ball hits the ground with a speed of $23\,m\,s^{-1}$.

(i) Calculate, for the ball falling from the top of the building to the ground:

1. the decrease in gravitational potential energy

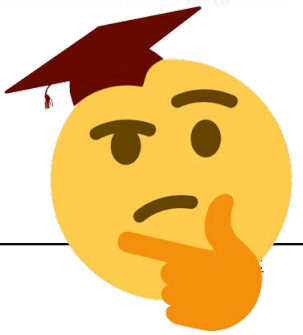
decrease in gravitational potential energy = ... J [2]

2. the increase in kinetic energy.

increase in kinetic energy = ... J [2]

(ii) Use your answers in **(b)(i)** to determine the average resistive force acting on the ball as it falls from the top of the building to the ground.

average resistive force = ... N [2]



(c) The ball in **(b)** is dropped at time $t = 0$ and hits the ground at time $t = T$. The acceleration of free fall is g.

On Fig. 3.1, sketch a line to show the variation of the acceleration a of the ball with time t from time $t = 0$ to $t = T$.

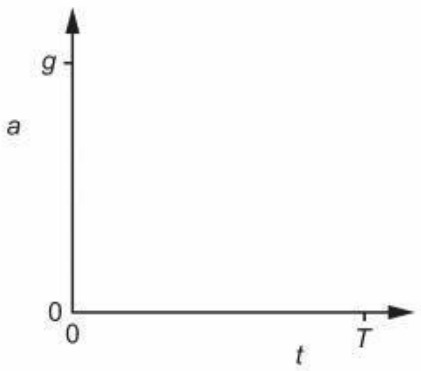


Fig. 3.1

[2]

20 – (9702/21_Winter_2020_Q2) – *Kinematics, Work, Energy & Power*

A small block is lifted vertically upwards by a toy aircraft, as illustrated in Fig. 2.1.

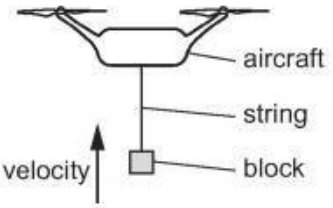


Fig. 2.1

As the block is moving upwards, the string breaks at time t = 0. The block initially continues moving upwards and then falls and hits the ground at time t = 0.90 s. The variation with time t of the velocity v of the block is shown in Fig. 2.2.

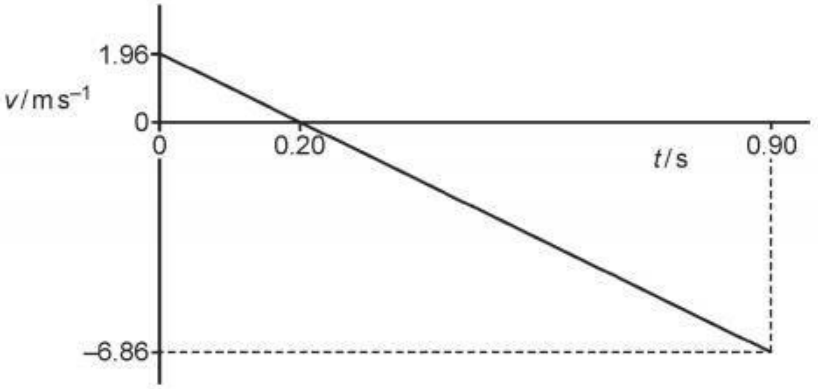


Fig. 2.2

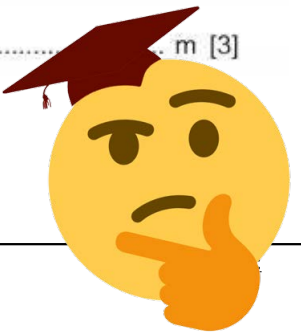
Air resistance is negligible.

(a) State the feature of the graph in Fig. 2.2 that shows the block has a constant acceleration.

..... [1]

(b) Use Fig. 2.2 to determine the height of the block above the ground when the string breaks at time t = 0.

height = ... m [3]



(c) The block has a weight of 0.86 N.

Calculate the difference in gravitational potential energy of the block between time $t = 0$ and time $t = 0.90$ s.

difference in gravitational potential energy = ... J [2]

(d) On Fig. 2.3, sketch a line to show the variation of the distance moved by the block with time t from $t = 0$ to $t = 0.20$ s. Numerical values of distance are not required.

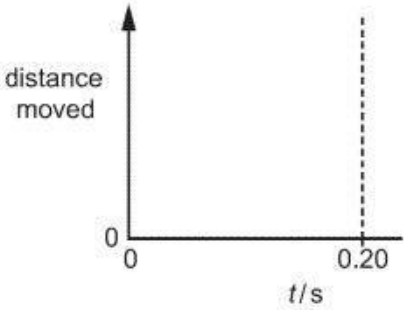


Fig. 2.3

[2]

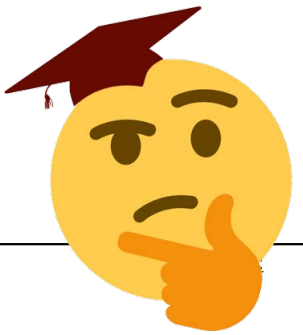
(e) A block of greater mass is now released from the same height with the same upward velocity. Air resistance is still negligible.

State and explain the effect, if any, of the increased mass on the speed with which the block hits the ground.

.....

..... [1]

[Total: 9]



21 – (9702/22_Winter_2020_Q3) – *Work, Energy & Power, Deformation Of Solids*

(a) A spring is fixed at one end and is compressed by applying a force to the other end. The variation of the force F acting on the spring with its compression x is shown in Fig. 3.1.

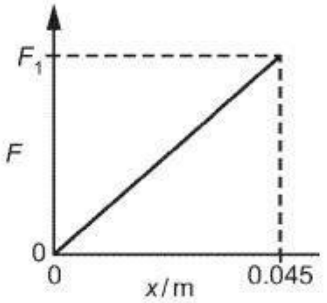


Fig. 3.1

A compression of 0.045 m is produced when a force F_1 acts on the spring. The spring has a spring constant of 800 N m^{-1}.

(i) Determine F_1.

F_1 = ... N [2]

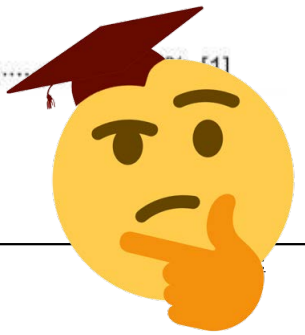
(ii) Use Fig. 3.1 to show that, for a compression of 0.045 m, the elastic potential energy of the spring is 0.81 J.

[2]

(b) A child's toy uses the spring in **(a)** to launch a ball of mass 0.020 kg vertically into the air. The ball is initially held against one end of the spring which has a compression of 0.045 m. The spring is then released to launch the ball. The kinetic energy of the ball as it leaves the toy is 0.72 J.

(i) The toy converts the elastic potential energy of the spring into the kinetic energy of the ball. Use the information in **(a)(ii)** to calculate the percentage efficiency of this conversion.

efficiency = ... % [1]



(ii) Determine the initial momentum of the ball as it leaves the toy.

momentum = ... N s [3]

(c) The ball in **(b)** leaves the toy at point A and moves vertically upwards through the air. Point B is the position of the ball when it is at maximum height *h* above point A, as illustrated in Fig. 3.2.

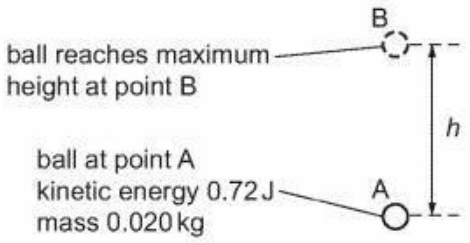


Fig. 3.2 (not to scale)

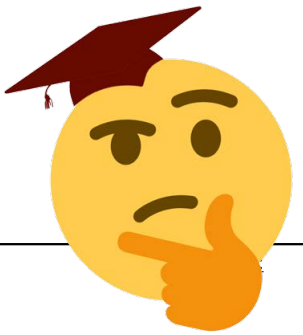
The gravitational potential energy of the ball increases by 0.60 J as it moves from A to B.

(i) Calculate *h*.

h = ... m [2]

(ii) Determine the average force due to air resistance acting on the ball for its movement from A to B.

average force = ... N [2]



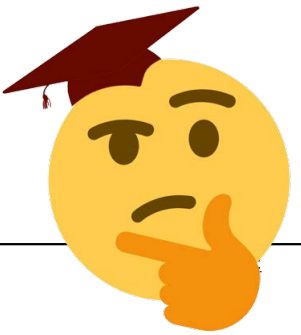
(iii) When there is air resistance, the ball takes time *T* to move from A to B.

State and explain whether the time taken for the ball to move from A to its maximum height will be more than, less than or equal to time *T* if there is **no** air resistance.

.....

..... [1]

[Total: 13]



22 – (9702/23_Winter_2020_Q4) – *Work, Energy & Power, Deformation Of Solids*

(a) State Hooke's law.

.....

..... [1]

(b) A spring is fixed at one end. A compressive force F is applied to the other end. The variation of the force F with the compression x of the spring is shown in Fig. 4.1.

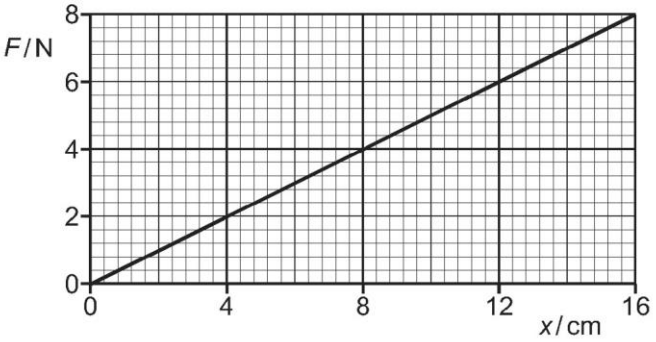


Fig. 4.1

Show that the elastic potential energy of the spring is 0.64 J when its compression is 16.0 cm.

[2]

(c) The spring in **(b)** is used to project a toy car along a track from point X to point Y, as illustrated in Fig. 4.2.

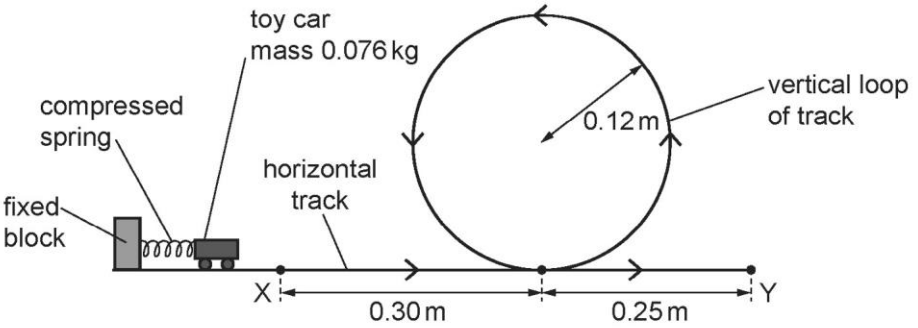
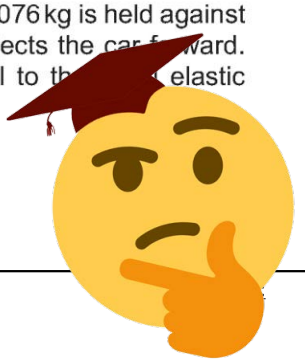


Fig. 4.2 (not to scale)

The spring is initially given a compression of 16.0 cm. The car of mass 0.076 kg is held against one end of the compressed spring. When the spring is released it projects the car forward. The car leaves the spring at point X with kinetic energy that is equal to the elastic potential energy of the compressed spring.



The car follows the track around a vertical loop of radius 0.12 m and then passes point Y. Assume that friction and air resistance are negligible.

Calculate:

(i) the speed of the car at X

speed = ... $m\,s^{-1}$ [2]

(ii) the kinetic energy of the car when it is at the top of the loop

kinetic energy = ... J [3]

(iii) the speed of the car at Y.

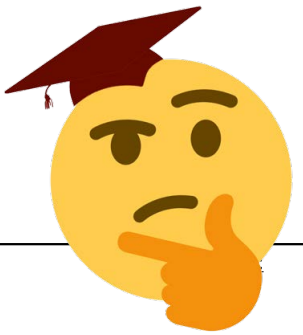
speed = ... $m\,s^{-1}$ [1]

(d) In practice, a resistive force due to friction and air resistance acts on the car so that its kinetic energy at Y is 0.23 J less than its kinetic energy at X.

Determine the average resistive force acting on the car for its movement from X to Y.

average resistive force = ... N [3]

[Total: 12]



23 – (9702/21_Summer_2021_Q2) – *Work, Energy & Power*

A person uses a trolley to move suitcases at an airport. The total mass of the trolley and suitcases is 72 kg.

(a) The person pushes the trolley and suitcases along a horizontal surface with a constant speed of $1.4\,m\,s^{-1}$ and then releases the trolley. The released trolley moves in a straight line and comes to rest. Assume that a constant total resistive force of 18 N opposes the motion of the trolley and suitcases.

(i) Calculate the power required to overcome the total resistive force on the trolley and suitcases when they move with a constant speed of $1.4\,m\,s^{-1}$.

power = ... W [2]

(ii) Calculate the time taken for the trolley to come to rest after it is released.

time = ... s [3]

(b) At another place in the airport, the trolley and suitcases are on a slope, as shown in Fig. 2.1.

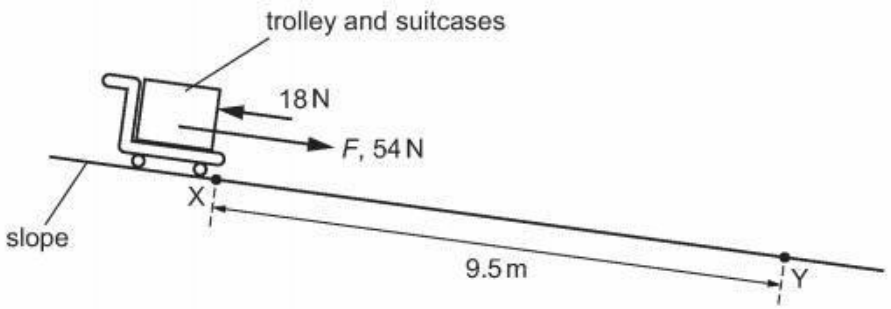
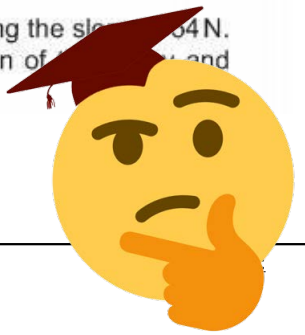


Fig. 2.1 (not to scale)

The person releases the trolley from rest at point X. The trolley moves down the slope in a straight line towards point Y. The distance along the slope between points X and Y is 9.5 m.

The component *F* of the weight of the trolley and suitcases that acts along the sl[illegible] 54 N. Assume that a constant total resistive force of 18 N opposes the motion of [illegible] and suitcases.



(i) Calculate the speed of the trolley at point Y.

speed = ... $m\,s^{-1}$ [3]

(ii) Calculate the work done by *F* for the movement of the trolley from X to Y.

work done = ... J [1]

(iii) The trolley is released at point X at time $t = 0$.

On Fig. 2.2, sketch a graph to show the variation with time *t* of the work done by *F* for the movement of the trolley from X to Y.
Numerical values of the work done and *t* are not required.

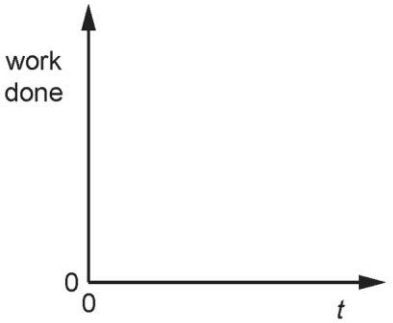


Fig. 2.2

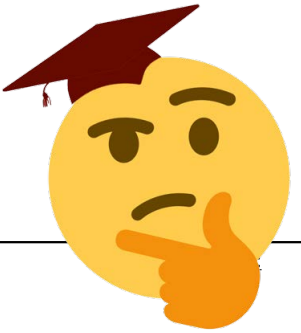
[2]

(c) The angle of the slope in **(b)** is constant. The frictional forces acting on the wheels of the moving trolley are also constant.

Explain why, in practice, it is incorrect to assume that the total resistive force opposing the motion of the trolley and suitcases is constant as the trolley moves between X and Y.

.....

..... [1]



24 – (9702/22_Summer_2021_Q3) – *Work, Energy & Power*

A child of weight 330 N is at point X at the top of a slide. The slide is at the edge of a swimming pool, as shown in Fig. 3.1.

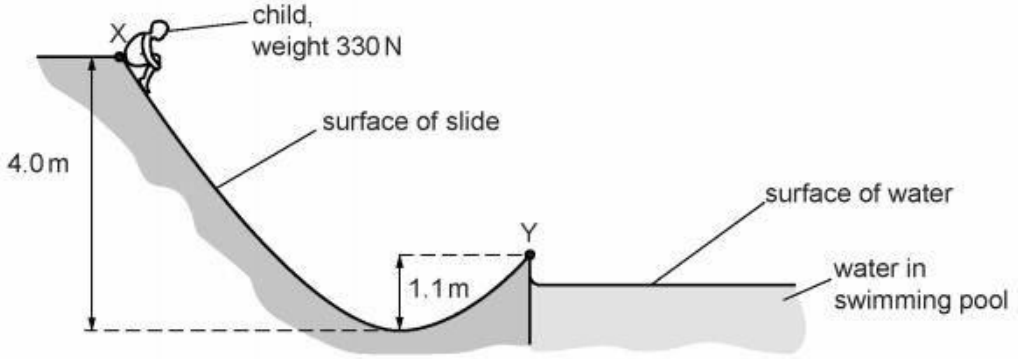


Fig. 3.1 (not to scale)

The child moves from rest to the lowest point of the slide that is a vertical distance of 4.0 m below X. The child continues moving towards point Y which is at the end of the slide and a vertical distance of 1.1 m above the lowest point. The kinetic energy of the child at Y is 540 J.

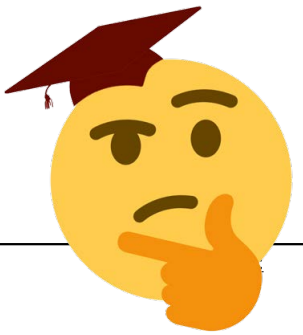
(a) Calculate the difference in the gravitational potential energy of the child at points X and Y.

difference in gravitational potential energy = ... J [2]

(b) An average frictional force of 52 N acts on the child when moving from X to Y.

By considering changes of energy, determine the distance moved by the child from X to Y.

distance moved = ... m [2]



(c) The child leaves the slide at point Y with a velocity that is at an angle of 41° to the horizontal. The path of the child through the air is shown in Fig. 3.2.

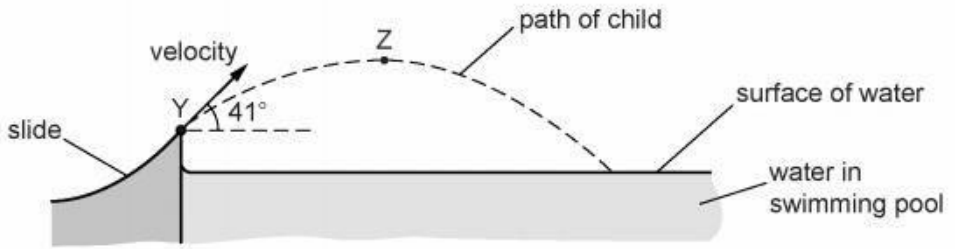


Fig. 3.2 (not to scale)

Point Z is the highest point on the path of the child through the air.
Assume that air resistance is negligible.

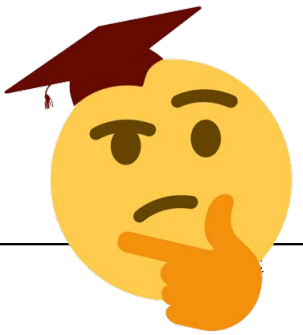
Calculate the speed of the child at:

(i) point Y

speed = ... $m\,s^{-1}$ [2]

(ii) point Z.

speed = ... $m\,s^{-1}$ [2]



25 – (9702/21_Winter_2021_Q2) – *Kinematics, Work, Energy & Power*

(a) Define *momentum*.

.....

..... [1]

(b) Two balls X and Y, of equal diameter but different masses 0.24 kg and 0.12 kg respectively, slide towards each other on a frictionless horizontal surface, as shown in Fig. 2.1.

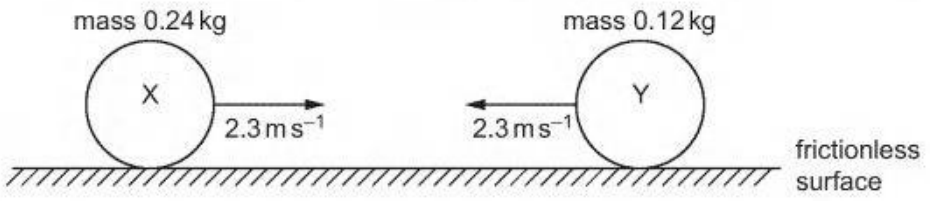


Fig. 2.1

Both balls have initial speed 2.3 m s^{-1} before they collide with each other. Fig. 2.2 shows the variation with time t of the force F_Y exerted on ball Y by ball X during the collision.

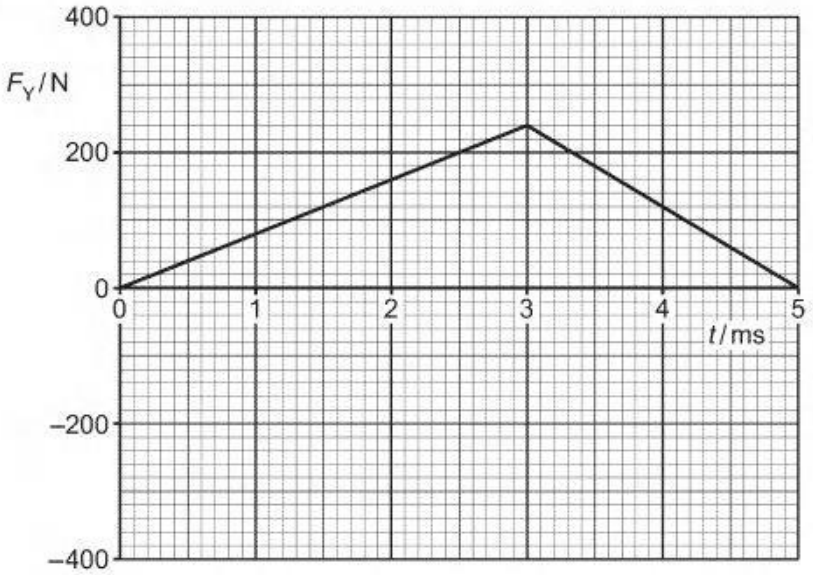
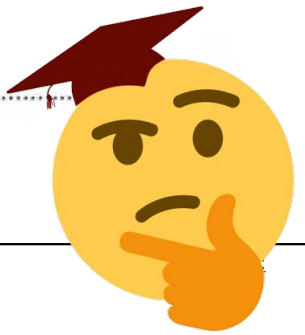


Fig. 2.2

(i) Calculate the kinetic energy of ball X before the collision.

kinetic energy = ...



(ii) The area enclosed by the lines and the time axis in Fig. 2.2 represents the change in momentum of ball Y during the collision.

Determine the magnitude of the change in momentum of ball Y.

change in momentum = ... N s [2]

(iii) Calculate the magnitude of the velocity of ball Y after the collision.

velocity = ... m s^{-1} [2]

(c) On Fig. 2.3, sketch the variation with time t of the force F_X exerted on ball X by ball Y during the collision in **(b)**.

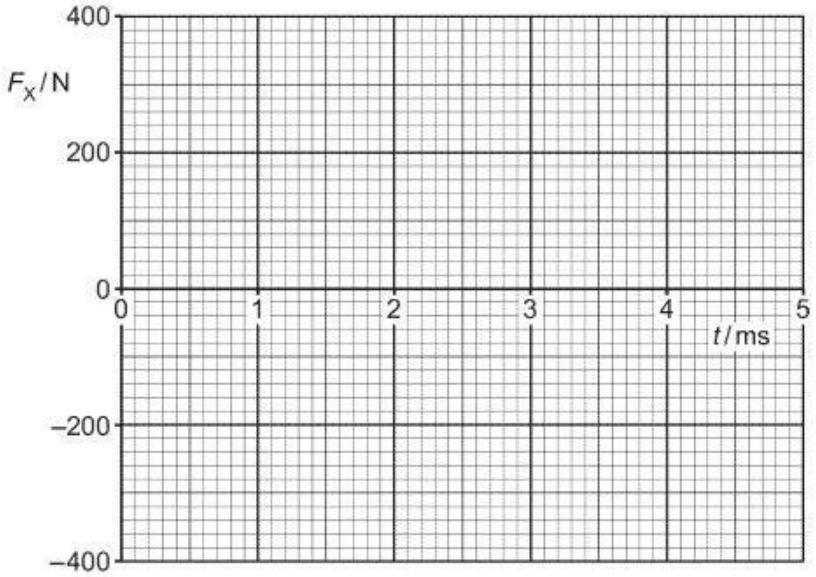
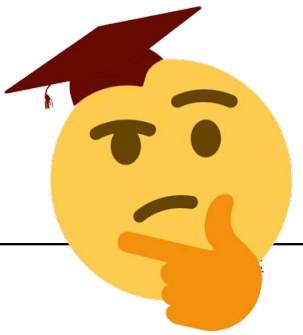


Fig. 2.3

[3]



26 – (9702/23_Winter_2021_Q2) – *Work, Energy & Power*

(a) State what is meant by *work done*.

.....

..... [1]

(b) Use your answer in **(a)** to show that the SI base units of energy are $kg\,m^2\,s^{-2}$.

[1]

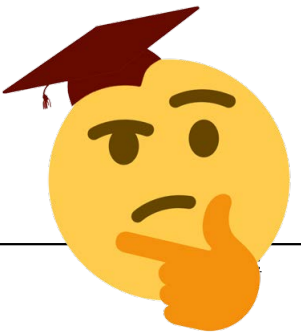
(c) A metal rod is heated at one end so that thermal energy flows to the other end.
The thermal energy E that flows through the rod in time t is given by

$$E = \frac{cA(T_1 - T_2)t}{L}$$

where A is the cross-sectional area of the rod,
T_1 and T_2 are the temperatures of the ends of the rod,
L is the length of the rod,
and c is a constant.

Determine the SI base units of c.

SI base units ..... [3]



27 - (9702/21_Winter_2021_Q3) - *Work, Energy & Power*

(a) A uniform metal bar, initially unstretched, has sides of length w, x and y, as shown in Fig. 3.1.

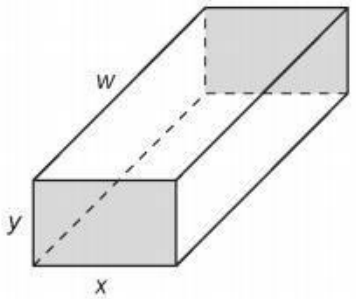


Fig. 3.1

The bar is now stretched by a tensile force F applied to the shaded ends. The changes in the lengths x and y are negligible. The bar now has sides of length x, y and z, as shown in Fig. 3.2.

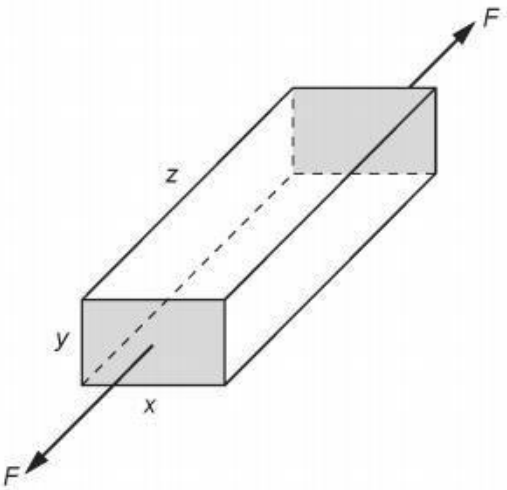


Fig. 3.2

Determine expressions, in terms of some or all of F, w, x, y and z, for:

(i) the stress σ applied to the bar by the tensile force

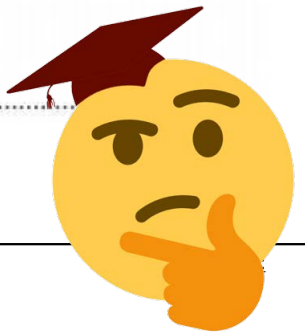
σ = ... [1]

(ii) the strain ε in the bar due to the tensile force

ε = ... [1]

(iii) the Young modulus E of the metal from which the bar is made.

E = ...



(b) A copper wire is stretched by a tensile force that gradually increases from 0 to 280 N. The variation with extension of the tensile force is shown in Fig. 3.3.

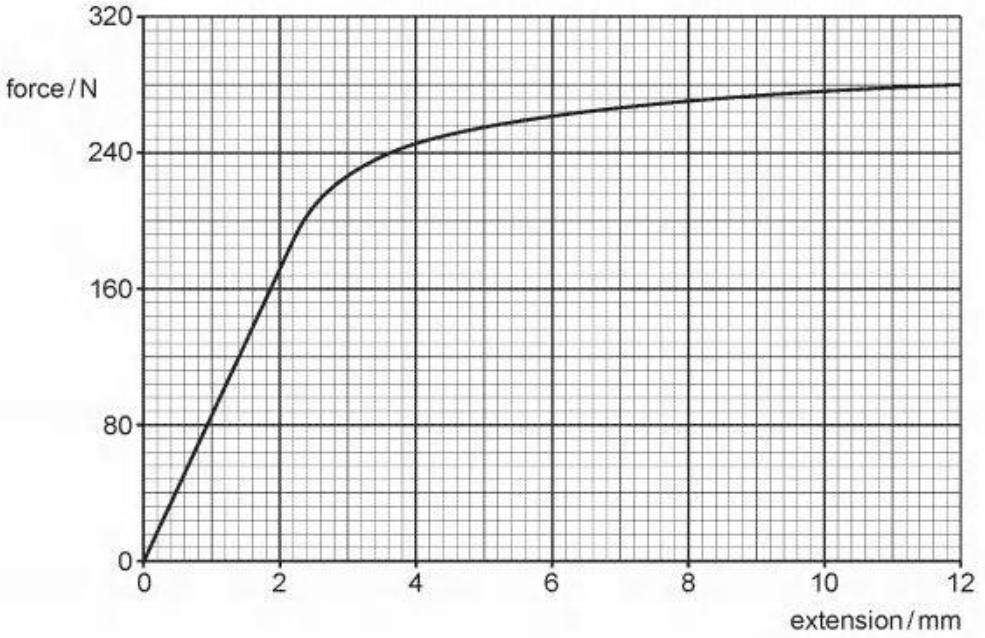


Fig. 3.3

(i) State the maximum extension of the wire for which it obeys Hooke's law.

extension = ... mm [1]

(ii) Use Fig. 3.3 to determine the strain energy in the wire when the tensile force is 120 N.

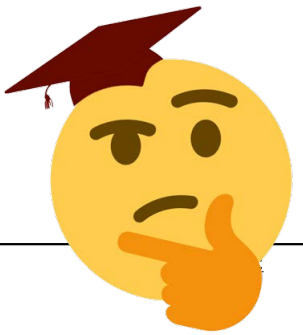
strain energy = ... J [3]

(iii) Explain why the work done in stretching the wire to an extension of 12 mm is not equal to the energy recovered when the tensile force is removed.

.....

.....

..... [2]



28 – (9702/22_Winter_2021_Q3) – *Work, Energy & Power*

(a) Define *power*.

.....

..... [1]

(b) A car of mass 1700 kg moves in a straight line along a slope that is at an angle θ to the horizontal, as shown in Fig. 3.1.

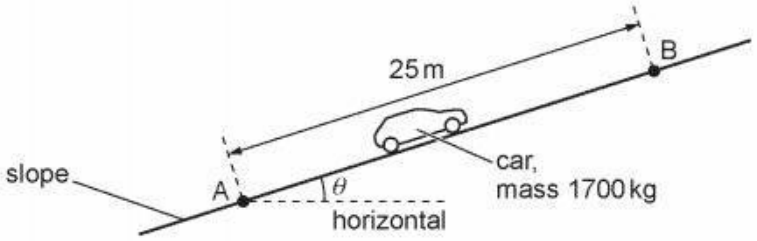


Fig. 3.1 (not to scale)

The car moves at constant velocity for a distance of 25 m from point A to point B.
Air resistance and friction provide a total resistive force of 440 N that opposes the motion of the car.

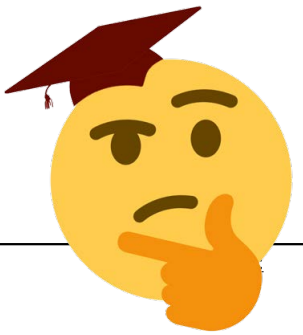
For the movement of the car from A to B:

(i) state the change in the kinetic energy

change in kinetic energy = ... J [1]

(ii) calculate the work done against the total resistive force.

work done = ... J [1]



(c) The movement of the car in **(b)** from A to B causes its gravitational potential energy to increase by 4.8×10^4 J.

Calculate:

(i) the increase in vertical height h of the car for its movement from A to B

h = ... m [2]

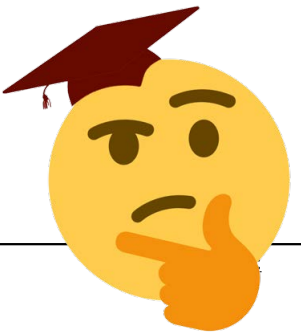
(ii) angle θ.

θ = ... ° [1]

(d) The engine of the car in **(b)** produces an output power of 1.7×10^4 W to move the car along the slope.

Calculate the time taken for the car to move from A to B.

time = ... s [2]



29 – (9702/21_Summer_2022_Q3) – *Work, Energy & Power*

(a) **(i)** Define power.

.....

..... [1]

(ii) A force F takes time t to move an object through a displacement x at constant velocity v in the direction of the force. The work done by the force is W.

Use the definition of power to show that the power P transferred by the force is given by

$$P = Fv.$$

[2]

(b) A block is pulled up a slope by a wire attached to a motor, as shown in Fig. 3.1.

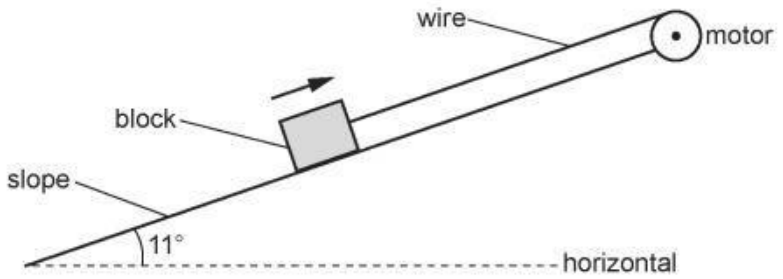


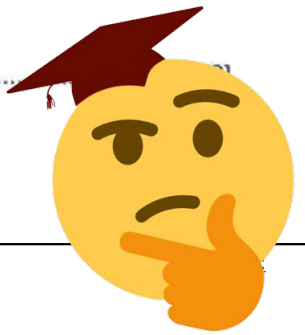
Fig. 3.1 (not to scale)

The useful power output of the motor is 56 W. The block has a weight of 430 N and travels with constant velocity along the slope at an angle of 11° to the horizontal.

Assume that there are no resistive forces opposing the motion of the block.

(i) Calculate the tension T in the wire.

T = ...



(ii) Calculate the speed of the block.

speed = ... $m\,s^{-1}$ [1]

(iii) The rate of increase of gravitational potential energy of the block is equal to the useful power output of the motor. One of the reasons for this is that there is no work done against resistive forces.

By considering the motion of the block, state another reason for this.

.....

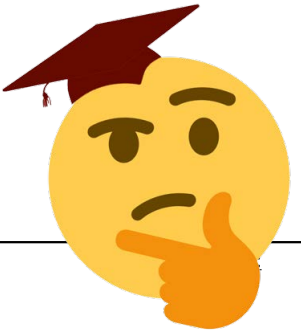
..... [1]

(iv) The motor has an efficiency of 80%.

Calculate the time taken for an input energy of 1.2 kJ to be supplied to the motor.

time taken = ... s [2]

[Total: 9]



30 – (9702/23_Summer_2022_Q4) – *Work, Energy & Power*

(a) A mass m moves a vertical distance Δh in a uniform gravitational field and gains gravitational potential energy ΔE_P. The acceleration of free fall is g.

Use the concept of work done to show that

$$\Delta E_P = mg\Delta h.$$

[2]

(b) A 0.60 kg mass is attached to a string which is wrapped around the wheel of a generator, as shown in Fig. 4.1.

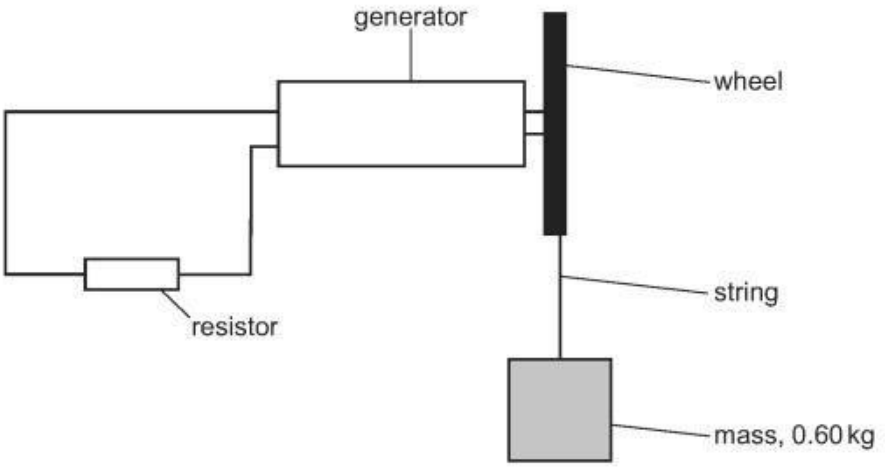
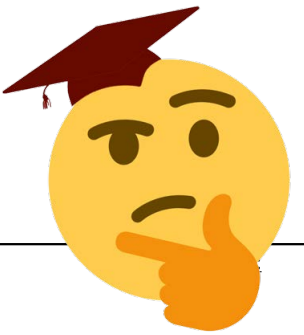


Fig. 4.1

The mass is held stationary above the floor. When released, the mass initially accelerates and then falls at a steady speed and spins the wheel. The generator causes a current in a resistor. Air resistance is negligible.

State the main energy change when the mass is falling at a steady speed.

..... energy to ..... energy. [1]



(c) When falling at a steady speed, the mass in **(b)** falls through a vertical distance of 1.4 m in a time of 4.0 s. This causes a current of 90 mA in the resistor. The resistance of the resistor is 47 Ω.

Calculate:

(i) the rate of work done by the falling mass

rate of work done = ... W [2]

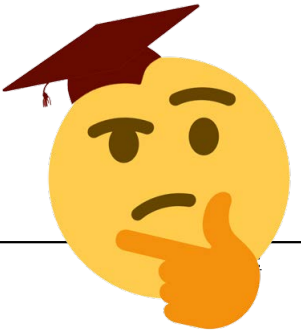
(ii) the power dissipated in the resistor

power = ... W [2]

(iii) the efficiency of the generator.

efficiency = ... [2]

[Total: 9]



31 - (9702/22_Winter_2022_Q1) - *Work, Energy & Power*

(a) State what is meant by work done.

.....

..... [1]

(b) Use the answer to **(a)** to determine the SI base units of power.

SI base units ..... [2]

(c) The maximum useful output power P of a car travelling on a horizontal road is given by

$$P = v^3 b$$

where v is the maximum speed of the car and b is a constant.

For the car,

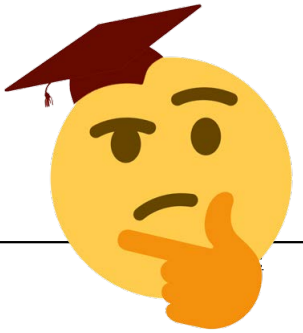
$P = 84\,\text{kW} \pm 5\%$
and $b = 0.56 \pm 7\%$ in SI units.

(i) Calculate the value of v.

v = ... m s^{-1} [2]

(ii) Determine the absolute uncertainty in the value of v.

absolute uncertainty = ... m s^{-1} [2]



32 – (9702/21_Winter_2022_Q3) – *Work, Energy & Power*

(a) **(i)** Define power.

.....

..... [1]

(ii) Mechanical power P can be calculated using the formula $P = Fv$.

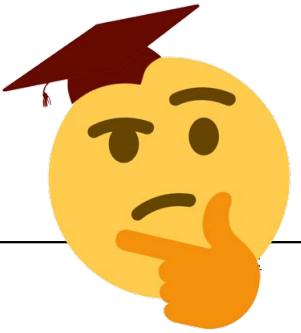
Use the concept of work and the definition of power to show how this formula is derived.

[2]

(b) The engine of a lorry provides 130 kW of power to the lorry's wheels when it is travelling at a constant speed of $25\,\mathrm{m\,s^{-1}}$ along a straight horizontal road.

Show that the resistive force opposing the forward motion of the lorry is 5200 N.

[1]



(c) The lorry in **(b)** travels up a straight section of road that is inclined at an angle θ to the horizontal, as shown in Fig. 3.1.

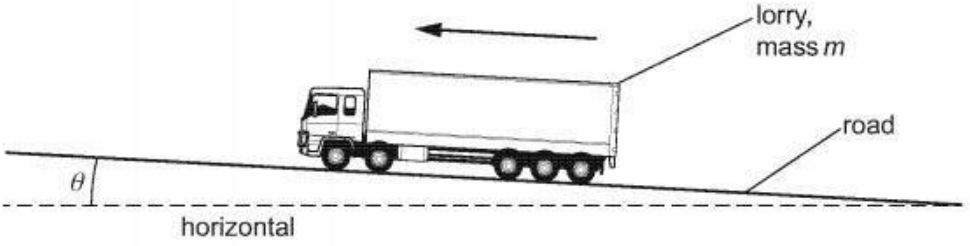


Fig. 3.1 (not to scale)

The lorry has mass m and the acceleration of free fall is g.

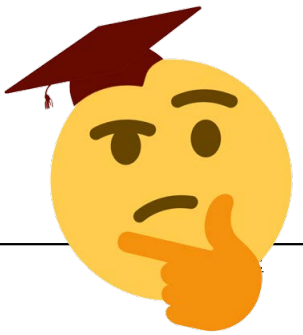
(i) Determine an expression, in terms of m, g and θ, for the component of the weight of the lorry that acts parallel to the surface of the road.

[1]

(ii) The total resistive force remains unchanged at 5200 N and the engine now provides greater power to maintain the speed of 25 m s^{-1}. The total mass m of the lorry is 36 000 kg. The angle θ is 1.4°.

Determine the power, in kW, now provided by the engine.

power = ... kW [3]



33 – (9702/21_Summer_2023_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

A rigid uniform beam of weight W is connected to a fixed support by a hinge, as shown in Fig. 2.1.

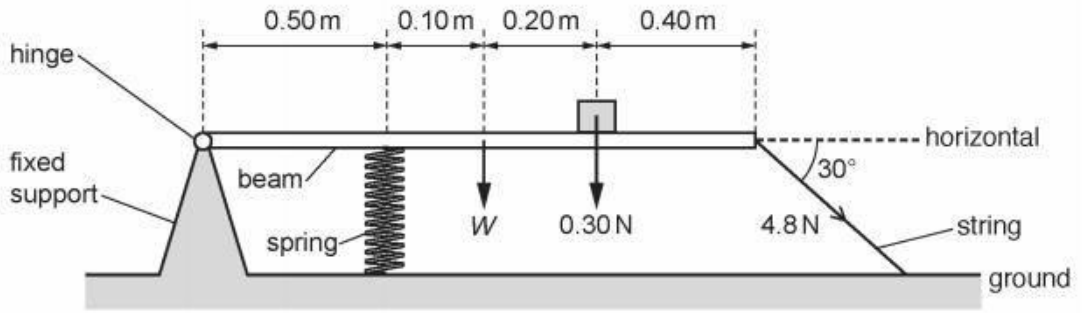


Fig. 2.1 (not to scale)

A compressed spring exerts a total force of 8.2 N vertically upwards on the horizontal beam. A block of weight 0.30 N rests on the beam. The right-hand end of the beam is connected to the ground by a string at an angle of 30° to the horizontal. The tension in the string is 4.8 N. The distances along the beam are shown in Fig. 2.1.

The beam is in equilibrium. Assume that the hinge is frictionless.

(a) **(i)** Show that the vertical component of the tension in the string is 2.4 N.

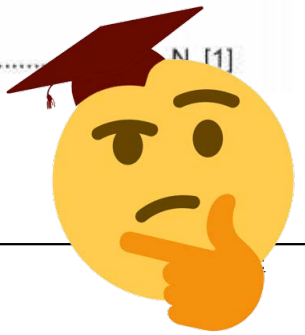
[1]

(ii) By taking moments about the hinge, determine the weight W of the beam.

W = ... N [3]

(iii) Calculate the horizontal component of the force exerted on the beam by the hinge.

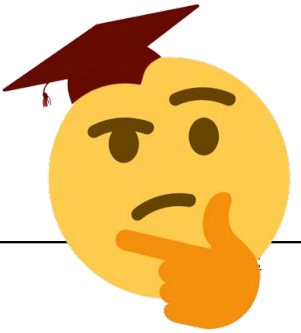
force = ... N [1]



(b) The spring obeys Hooke's law and has an elastic potential energy of 0.32 J.

Calculate the compression of the spring.

compression = ... m [2]



(c) The string is cut so that the spring extends upwards. This causes the beam to rotate and launch the block into the air. The block reaches its maximum height and then falls back to the ground.

Fig. 2.2 shows part of the path of the block in the air shortly before it hits the horizontal ground.

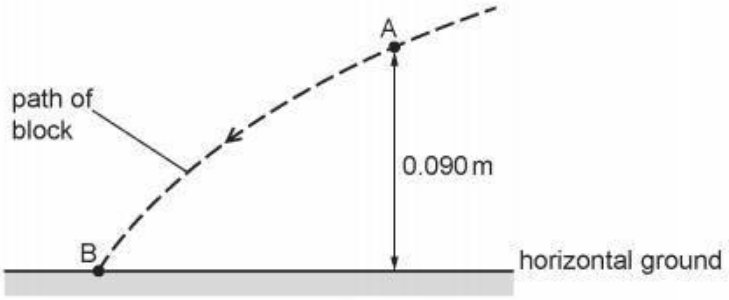


Fig. 2.2 (not to scale)

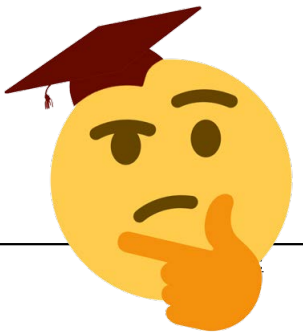
The block is at a height of 0.090 m above the ground when it passes through point A. The block has a kinetic energy of 0.044 J when it hits the ground at point B.
Air resistance is negligible.

(i) Calculate the decrease in the gravitational potential energy of the block for its movement from A to B.

decrease in gravitational potential energy = ... J [2]

(ii) Use your answer in **(c)(i)** and conservation of energy to determine the speed of the block at point A.

speed = ... $m\,s^{-1}$ [3]



(iii) By reference to the force on the block, explain why the horizontal component of the velocity of the block remains constant as it moves from A to B.

.....

..... [1]

(iv) The block passes through point A at time t_A and arrives at point B at time t_B.

On Fig. 2.3, sketch a graph to show the variation of the magnitude of the vertical component v_Y of the velocity of the block with time t from $t = t_A$ to $t = t_B$.
Numerical values of v_Y are not required.

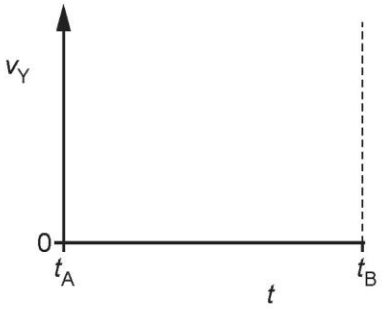


Fig. 2.3

[1]

34 – (9702/22_Summer_2023_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a) State what is meant by the centre of gravity of an object.

.....

..... [1]

(b) Two blocks are on a horizontal beam that is pivoted at its centre of gravity, as shown in Fig. 2.1.

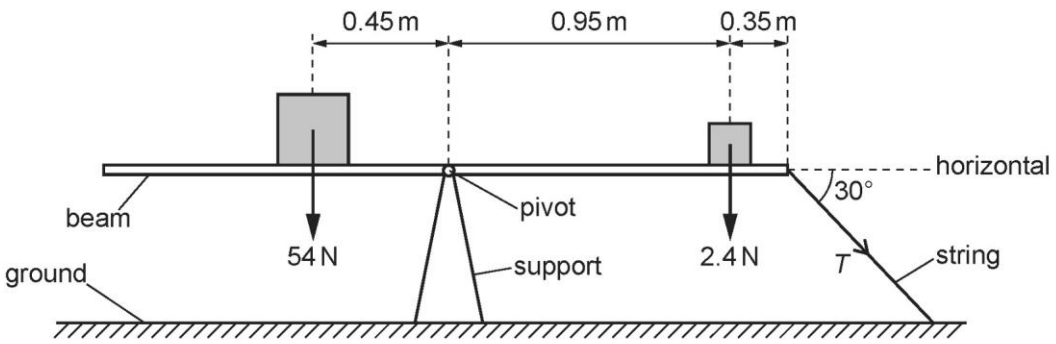


Fig. 2.1 (not to scale)

A large block of weight 54 N is a distance of 0.45 m from the pivot. A small block of weight 2.4 N is a distance of 0.95 m from the pivot and a distance of 0.35 m from the right-hand end of the beam.

The right-hand end of the beam is connected to the ground by a string that is at an angle of 30° to the horizontal. The beam is in equilibrium.

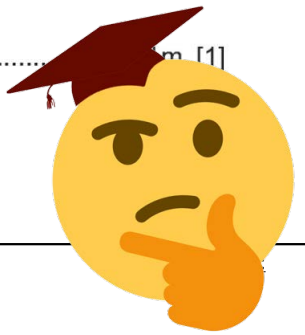
(i) By taking moments about the pivot, calculate the tension *T* in the string.

T = ... N [3]

(ii) The string is cut so that the beam is no longer in equilibrium.

Calculate the magnitude of the resultant moment about the pivot acting on the beam immediately after the string is cut.

resultant moment = ... m [1]



(c) The beam in **(b)** rotates when the string is cut and the small block of weight 2.4 N is projected through the air. Fig. 2.2 shows the last part of the path of the block before it hits the ground at point Y.

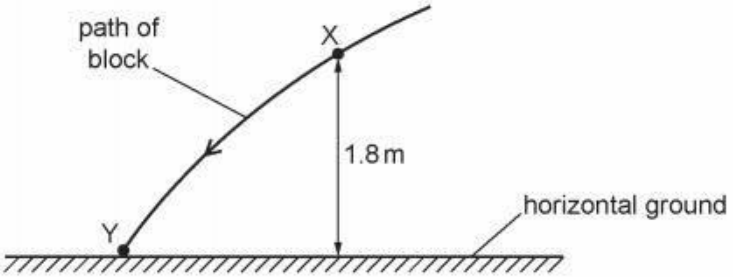


Fig. 2.2 (not to scale)

At point X on the path, the block has a speed of $3.4\,m\,s^{-1}$ and is at a height of 1.8 m above the horizontal ground. Air resistance is negligible.

(i) Calculate the decrease in the gravitational potential energy of the block for its movement from X to Y.

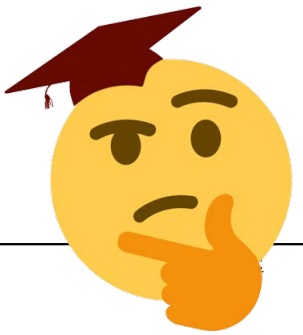
decrease in gravitational potential energy = ... J [2]

(ii) Use your answer to **(c)(i)** and conservation of energy to determine the kinetic energy of the block at Y.

kinetic energy = ... J [3]

(iii) State the variation, if any, in the direction of the acceleration of the block as it moves from X to Y.

..... [1]



(iv) The block passes point X at time t_X and arrives at point Y at time t_Y.

On Fig. 2.3, sketch a graph to show the variation of the magnitude of the horizontal component of the velocity of the block with time from t_X to t_Y.
Numerical values are not required.

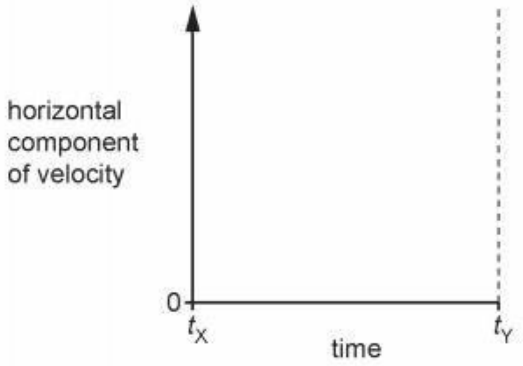


Fig. 2.3

[1]

35 – (9702/22_Summer_2023_Q4) – *Dynamics, Work, Energy & Power*

A spring is suspended from a fixed point at one end. The spring is extended by a vertical force applied to the other end. The variation of the applied force F with the length L of the spring is shown in Fig. 4.1.

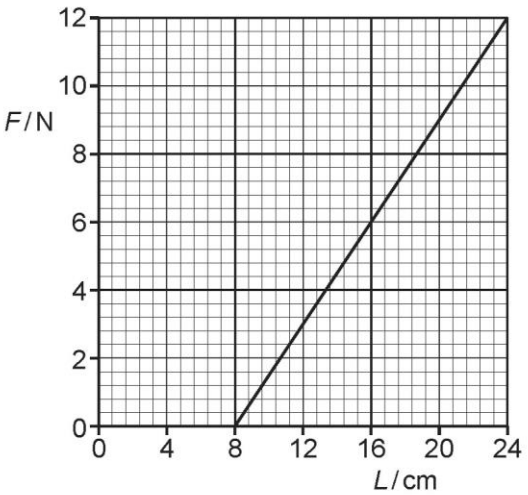


Fig. 4.1

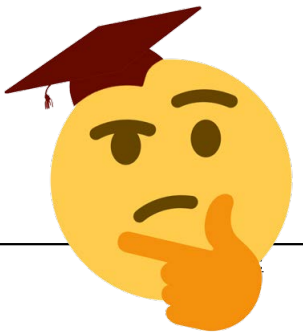
For the spring:

(a) state the name of the law that gives the relationship between the force and the extension

..... [1]

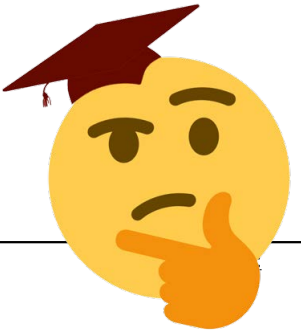
(b) determine the spring constant, in $N\,m^{-1}$

spring constant = ...$N\,m^{-1}$ [2]



(c) determine the elastic potential energy when $F = 6.0\,\text{N}$.

elastic potential energy = ... J [2]



36 – (9702/21_Winter_2023_Q2) – *Work, Energy & Power, Dynamics*

A hot-air balloon floats just above the ground. The balloon is stationary and is held in place by a vertical rope, as shown in Fig. 2.1.

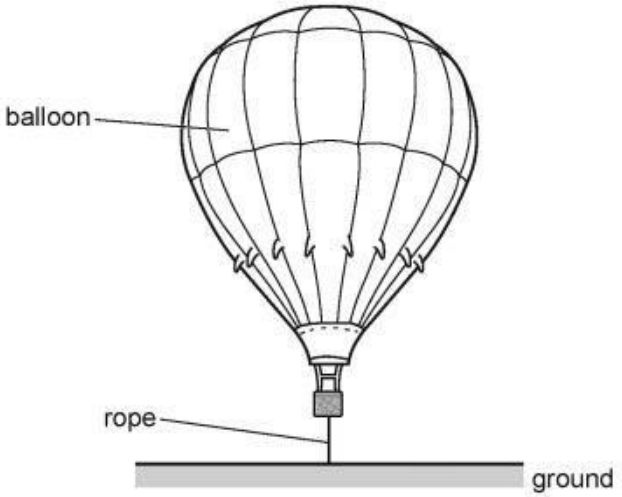


Fig. 2.1

The balloon has a weight W of 3.39×10^4 N. The tension T in the rope is 4.00×10^2 N.
Upthrust U acts on the balloon.
The density of the surrounding air is $1.23\,\text{kg}\,\text{m}^{-3}$.

(a) **(i)** On Fig. 2.1, draw labelled arrows to show the directions of the three forces acting on the balloon. [2]

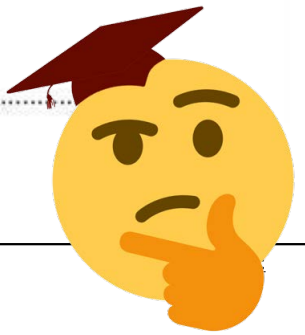
(ii) Calculate the volume, to three significant figures, of the balloon.

volume = ... m^3 [3]

(iii) The balloon is released from the rope.

Calculate the initial acceleration of the balloon.

acceleration = ...



(b) The balloon is stationary at a height of 500 m above the ground. A tennis ball is released from rest and falls vertically from the balloon.

A passenger in the balloon uses the equation $v^2 = u^2 + 2as$ to calculate that the ball will be travelling at a speed of approximately $100\,m\,s^{-1}$ when it hits the ground.

Explain why the actual speed of the ball will be much lower than $100\,m\,s^{-1}$ when it hits the ground.

.....

.....

.....

..... [3]

(c) Before the balloon is released, the rope holding the balloon has a strain of 2.4×10^{-5}. The rope has an unstretched length of 2.5 m. The rope obeys Hooke's law.

(i) Show that the extension of the rope is 6.0×10^{-5} m.

[1]

(ii) Calculate the elastic potential energy E_P of the rope.

E_P = ... J [2]

(iii) The rope holding the balloon is replaced with a new one of the same original length and cross-sectional area. The tension is unchanged and the new rope also obeys Hooke's law.

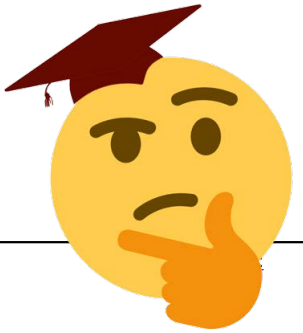
The new rope is made from a material of a lower Young modulus.

State and explain the effect of the lower Young modulus on the elastic potential energy of the rope.

.....

.....

..... [2]



37 - (9702/22_Winter_2023_Q3) - *Work, Energy & Power, Deformation Of Solids*

A vertical rod is fixed to the horizontal surface of a table, as shown in Fig. 3.1.

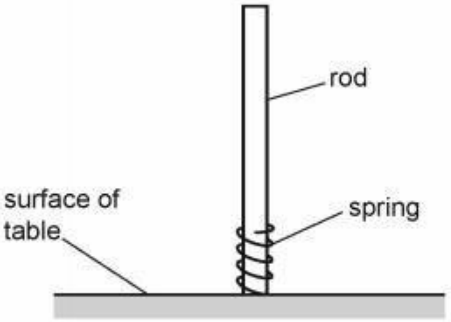


Fig. 3.1 (not to scale)

A spring of mass 7.5 g is able to slide along the full length of the rod.

The spring is first pushed against the surface of the table so that it has an initial compression of 2.1 cm. The spring is then suddenly released so that it leaves the surface of the table with a kinetic energy of 0.048 J and then moves up the rod.

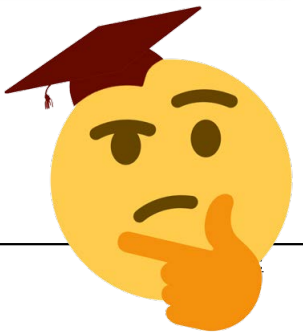
Assume that the spring obeys Hooke's law and that the initial elastic potential energy of the compressed spring is equal to the kinetic energy of the spring as it leaves the surface of the table. Air resistance is negligible.

(a) By using the initial elastic potential energy of the compressed spring, calculate its spring constant.

spring constant = ... $N\,m^{-1}$ [2]

(b) Calculate the speed of the spring as it leaves the surface of the table.

speed = ... $m\,s^{-1}$ [2]



(c) The spring rises to its maximum height up the rod from the surface of the table. This causes the gravitational potential energy of the spring to increase by 0.039 J.

(i) Calculate, for this movement of the spring, the increase in height of the spring after leaving the surface of the table.

increase in height = ... m [2]

(ii) Calculate the average frictional force exerted by the rod on the spring as it rises.

average frictional force = ... N [2]

(d) The rod is replaced by another rod that exerts negligible frictional force on the moving spring. The initial compression x of the spring is now varied in order to vary the maximum increase in height Δh of the spring after leaving the surface of the table. Assume that the spring obeys Hooke's law for all compressions.

On Fig. 3.2, sketch a graph to show the variation with x of Δh. Numerical values are not required.

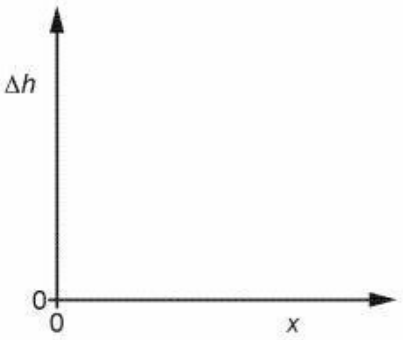
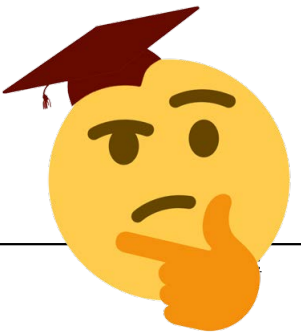


Fig. 3.2

[2]



38 – (9702/23_Winter_2023_Q3) – *Dynamics, Work, Energy & Power*

(a) State the conditions for a system to be in equilibrium.

.....

.....

..... [2]

(b) Fig. 3.1 shows an airship in flight. The airship is propelled by identical fans that can be angled to control the motion of the airship.

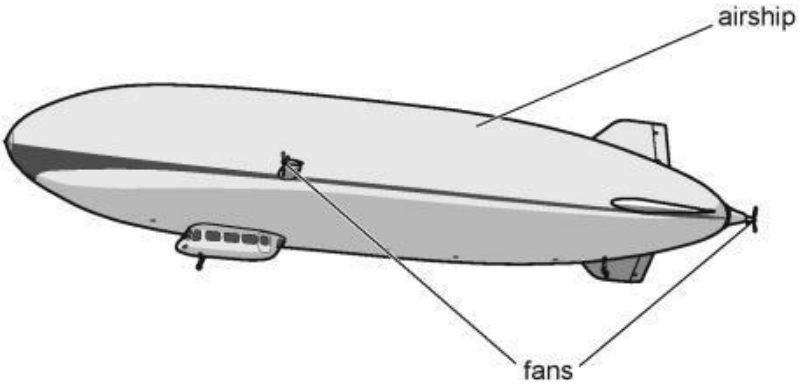


Fig. 3.1

The upthrust on the airship is 93 000 N.
The density of the surrounding air is 1.2 kg m^{-3}.

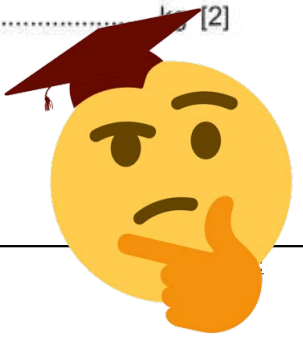
(i) Calculate the volume of air displaced by the airship.

volume = ... m^3 [1]

(ii) When fully loaded, the weight of the airship is greater than the upthrust.
To maintain horizontal flight, the fans provide a total vertical force of 3.0 × 10^3 N upwards on the airship.

Calculate the mass of the airship.

mass = ... kg [2]



(c) At a certain time, the airship in **(b)** is stationary. The thrust force exerted by a fan on the airship is 2800 N.

To produce this force, a mass of 64 kg of air is propelled through the blades of the fan in a time of 0.50 s. Assume that this air is initially stationary at the entrance to the fan.

Calculate:

(i) the change in momentum Δp of the air propelled through the fan blades in this time

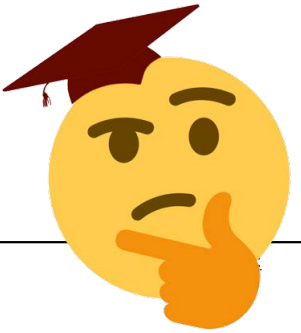
Δp = ... kg m s^{-1} [2]

(ii) the speed of the air as it leaves the fan

speed = ... m s^{-1} [2]

(iii) the total kinetic energy of this air due to its movement through the fan.

kinetic energy = ... J [2]



1 – (9702/22_Winter_2020_Q1) – *Motion In A Circle, Kinematics*

(a) Complete Table 1.1 by putting a tick (✓) in the appropriate column to indicate whether the listed quantities are scalars or vectors.

Table 1.1

quantity	scalar	vector
acceleration		
density		
temperature		
momentum		

[2]

(b) A toy train moves along a straight section of track. Fig. 1.1 shows the variation with time t of the distance d moved by the train.

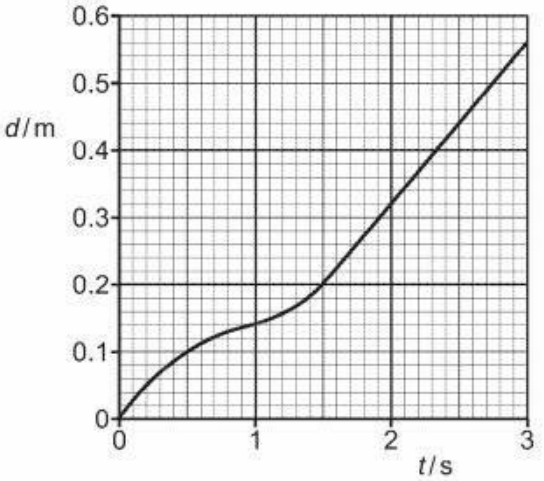
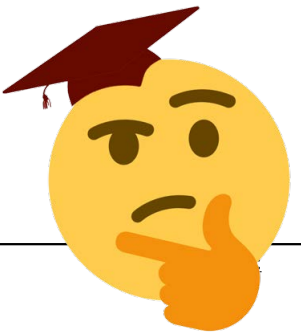


Fig. 1.1

(i) Describe qualitatively the motion of the train between time $t = 0$ and time $t = 1.0$ s.

.....

..... [1]



(ii) Determine the speed of the train at time $t = 2.0\,s$.

speed = ... $m\,s^{-1}$ [2]

(c) The straight section of track in **(b)** is part of the loop of track shown in Fig. 1.2.

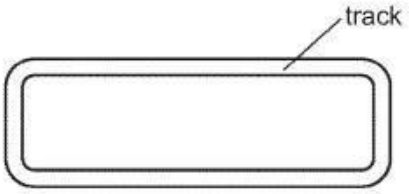


Fig. 1.2

The train completes exactly one lap of the loop.

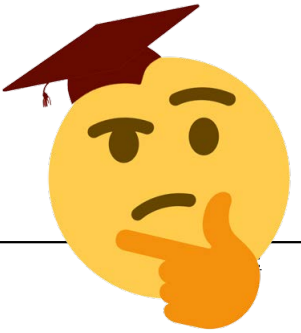
State and explain the average velocity of the train over the one complete lap.

.....

.....

..... [1]

[Total: 6]



1 – (9702/22_Summer_2017_Q3) – *Deformation Of Solids*

The Young modulus of the material of a wire can be determined using the apparatus shown in Fig. 3.1.

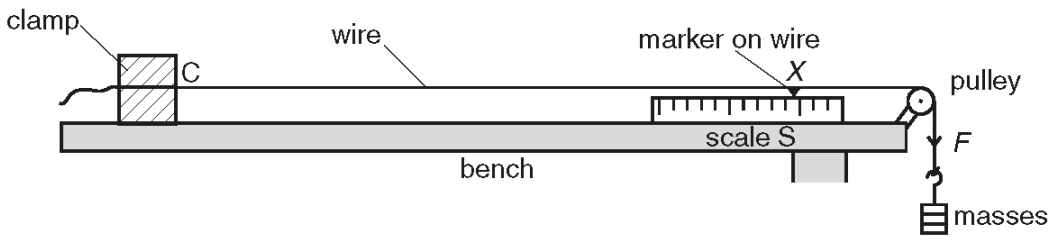


Fig. 3.1

One end of the wire is clamped at C and a marker is attached to the wire above a scale S. A force to extend the wire is applied by attaching masses to the other end of the wire.

The reading X of the marker on the scale S is determined for different forces F applied to the end of the wire. The variation with X of F is shown in Fig. 3.2.

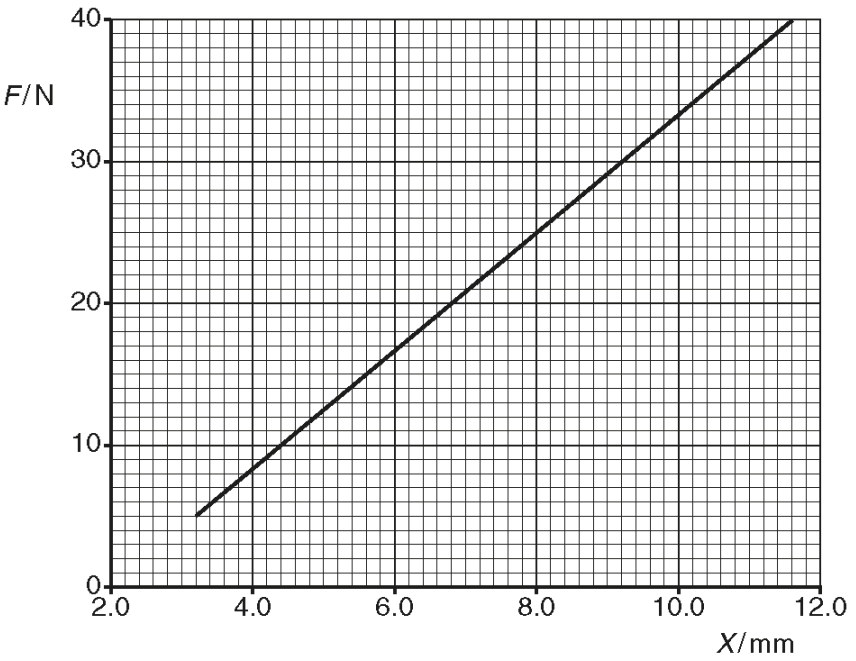


Fig. 3.2

(a) The length of the wire from C to the marker for $F = 0$ is 3.50 m. The diameter of the wire is 0.38 mm.

Use the gradient of the line in Fig. 3.2 to determine the Young modulus E of the material of the wire in TPa.

E = ... TPa [3]

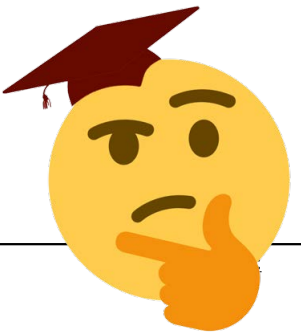
(b) The experiment is repeated with a thicker wire of the same material and length.

State how the range of the force F must be changed to obtain the same range of scale readings as in Fig. 3.2.

.....

.....

.....[1]



2 – (9702/23_Summer_2017_Q4) – *Deformation Of Solids*

A spring is supported so that it hangs vertically, as shown in Fig. 4.1.

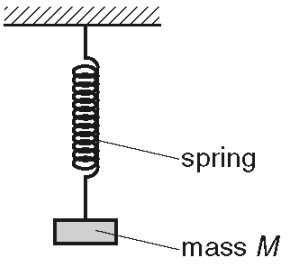


Fig. 4.1

Different masses are attached to the lower end of the spring. The extension x of the spring is measured for each mass M. The variation with x of M is shown in Fig. 4.2.

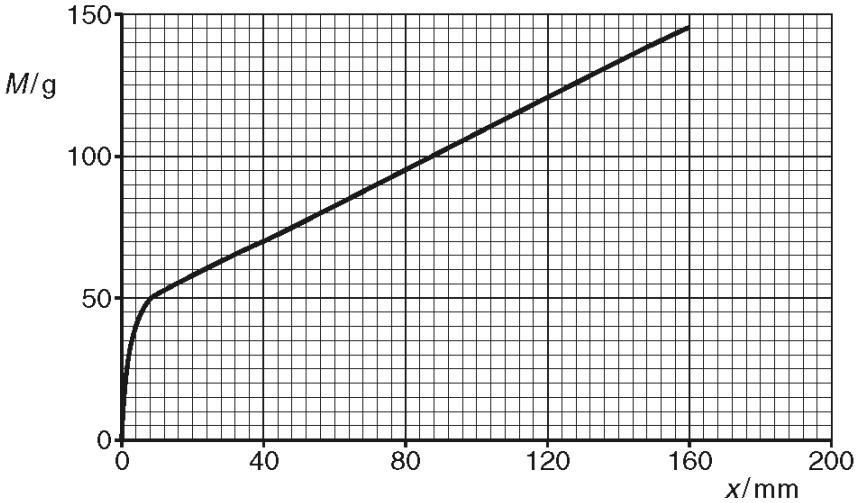


Fig. 4.2

(a) State and explain whether the spring obeys Hooke's law.

.....

.....[1]

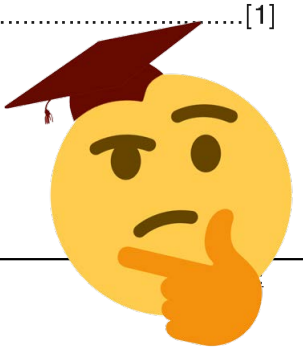
(b) State the form of energy stored in the spring due to the addition of the masses.

.....[1]

(c) Describe how to determine whether the extension of the spring is elastic.

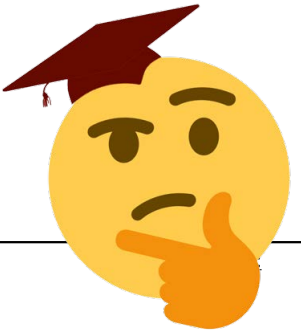
.....

.....[1]



(d) Calculate the work done on the spring as it is extended from $x = 40.0$ mm to $x = 160$ mm.

work done = ... J [3]



3 – (9702/21_Winter_2017_Q4) – *Deformation Of Solids*

(a) Define *strain*.

.....

.....[1]

(b) A wire is designed to ensure that its strain does not exceed 4.0×10^{-4} when a force of 8.0 kN is applied. The Young modulus of the metal of the wire is 2.1×10^{11} Pa. It may be assumed that the wire obeys Hooke's law.

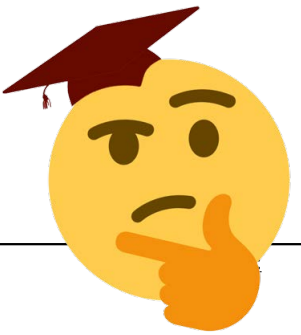
For a force of 8.0 kN, calculate, for the wire,

(i) the maximum stress,

maximum stress = ... Pa [2]

(ii) the minimum cross-sectional area.

minimum cross-sectional area = ... m^2 [2]



4 – (9702/23_Summer_2018_Q4) – *Deformation Of Solids*

(a) Define the *Young modulus* of a material.

.....

.....[1]

(b) A metal rod is compressed, as shown in Fig. 4.1.

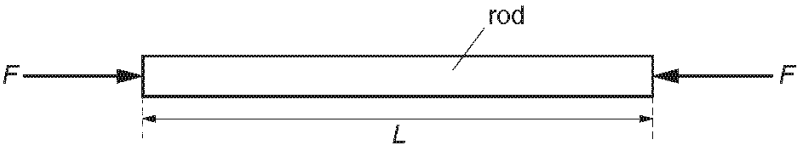


Fig. 4.1

The variation with compressive force *F* of the length *L* of the rod is shown in Fig. 4.2.

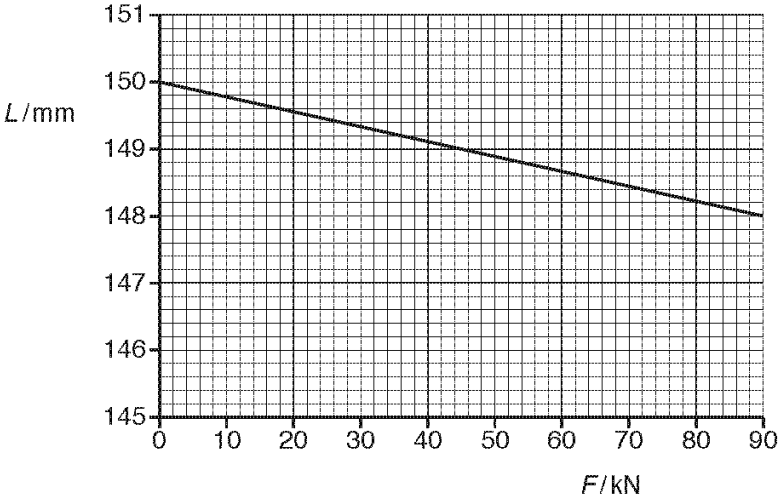
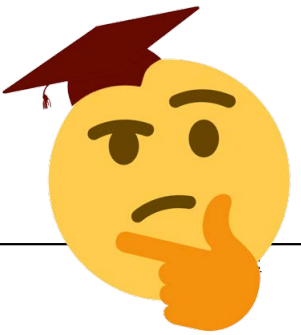


Fig. 4.2

Use Fig. 4.2 to

(i) determine the spring constant *k* of the rod,

k = ... $N\,m^{-1}$ [2]

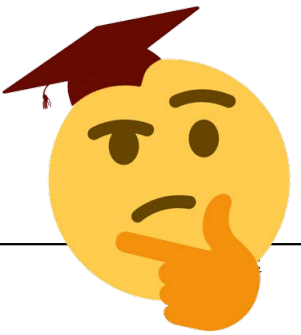


(ii) determine the strain energy stored in the rod for $F = 90\,\text{kN}$.

strain energy = ... J [3]

(c) The rod in **(b)** has cross-sectional area A and is made of metal of Young modulus E. It is now replaced by a new rod of the same original length. The new rod has cross-sectional area $A/3$ and is made of metal of Young modulus $2E$. The compression of the new rod obeys Hooke's law.

On Fig. 4.2, sketch the variation with F of the length L for the new rod from $F = 0$ to $F = 90\,\text{kN}$. [2]



5 – (9702/23_Winter_2018_Q1) – *Physical Quantities & Units, Forces, Density & Pressure, Deformation Of Solids*

(a) Mass, length and time are all SI base quantities.

State two other SI base quantities.

1. .....

2. .....

[2]

(b) A wire hangs between two fixed points, as shown in Fig. 1.1.

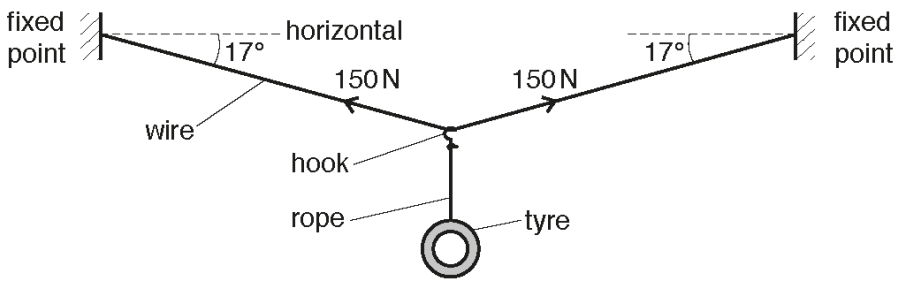


Fig. 1.1 (not to scale)

A child's swing is made by connecting a car tyre to the wire using a rope and a hook. The system is in equilibrium with the wire hanging at an angle of 17° to the horizontal. The tension in the wire is 150 N. Assume that the rope and hook have negligible weight.

(i) Determine the weight of the tyre.

weight = ... N [2]

(ii) The wire has a cross-sectional area of $7.5\,mm^2$ and is made of metal of Young modulus 2.1×10^{11} Pa. The wire obeys Hooke's law.

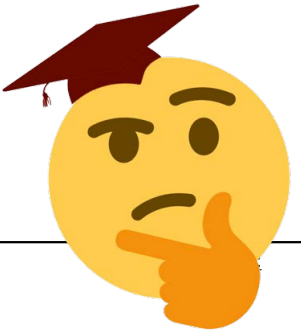
Calculate, for the wire,

1. the stress,

stress = ... Pa [2]

2. the strain.

strain = ... [2]



6 – (9702/21_Summer_2019_Q3) – *Deformation Of Solids, Work, Energy & Power*

The variation with extension x of the force F acting on a spring is shown in Fig. 3.1.

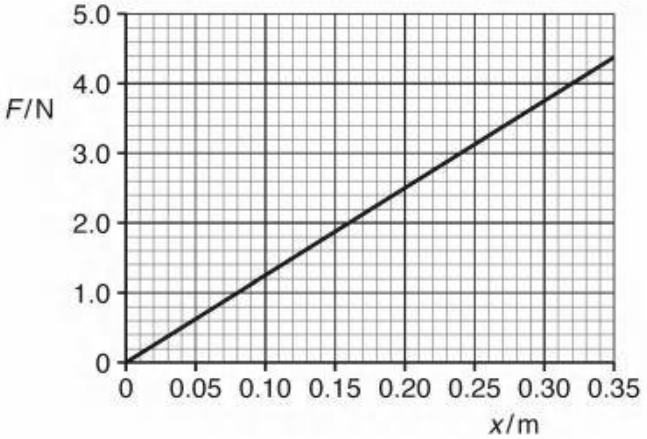


Fig. 3.1

The spring of unstretched length 0.40 m has one end attached to a fixed point, as shown in Fig. 3.2.

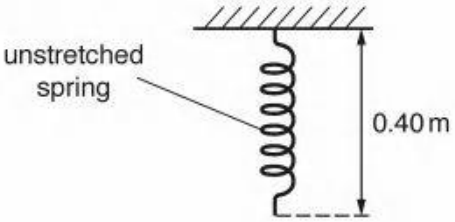


Fig. 3.2

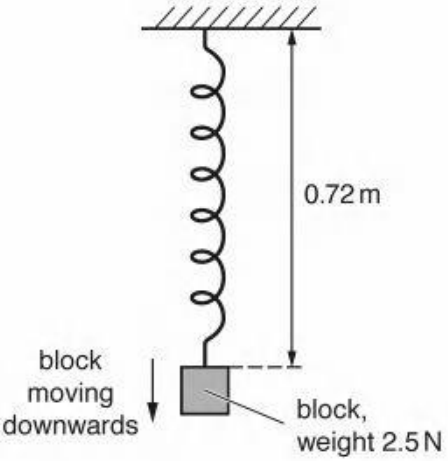
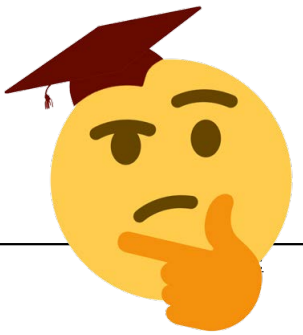


Fig. 3.3

A block of weight 2.5 N is then attached to the spring. The block is then released and begins to move downwards. At one instant, as the block is continuing to move downwards, the spring has a length of 0.72 m, as shown in Fig. 3.3.

Assume that the air resistance and the mass of the spring are both negligible.



(a) For the change in length of the spring from 0.40 m to 0.72 m:

(i) use Fig. 3.1 to show that the increase in elastic potential energy of the spring is 0.64 J

[2]

(ii) calculate the decrease in gravitational potential energy of the block of weight 2.5 N.

decrease in potential energy = ... J [2]

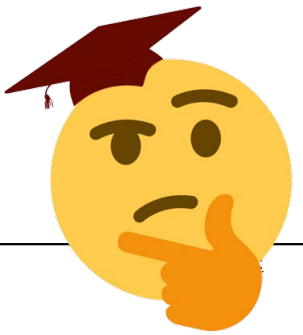
(b) Use the information in **(a)(i)** and your answer in **(a)(ii)** to determine, for the instant when the length of the spring is 0.72 m:

(i) the kinetic energy of the block

kinetic energy = ... J [1]

(ii) the speed of the block.

speed = ... $m\,s^{-1}$ [2]



7 – (9702/21_Winter_2019_Q4) – *Work, Energy & Power, Deformation Of Solids*

The variation with extension x of the force F applied to a spring is shown in Fig. 4.1.

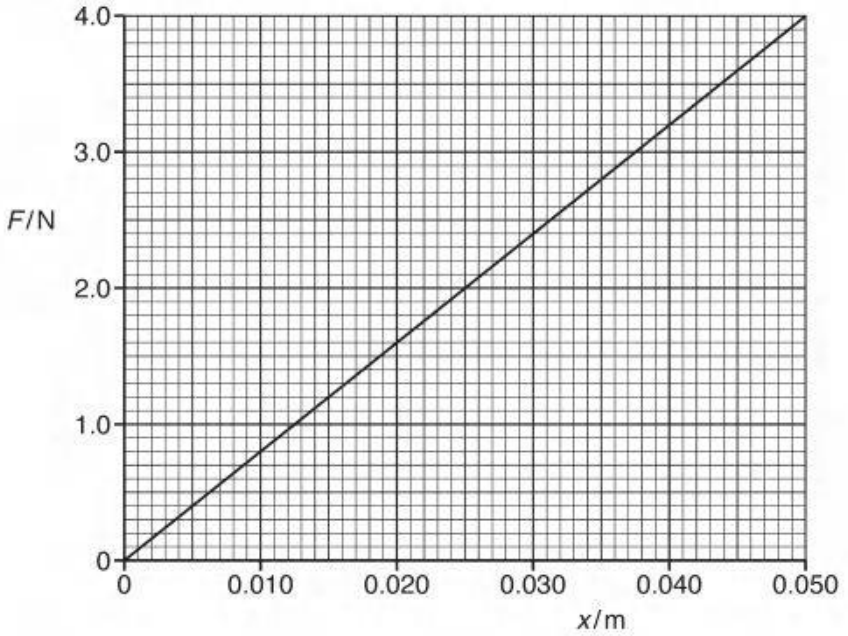


Fig. 4.1

The spring has an unstretched length of 0.080 m and is suspended vertically from a fixed point, as shown in Fig. 4.2.

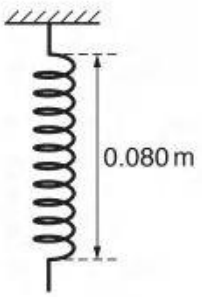


Fig. 4.2

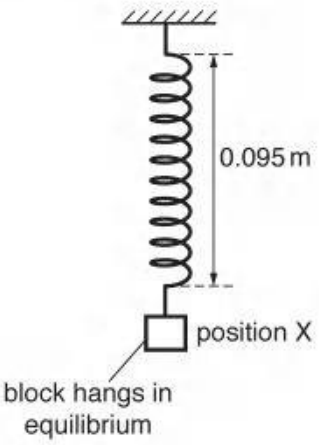


Fig. 4.3

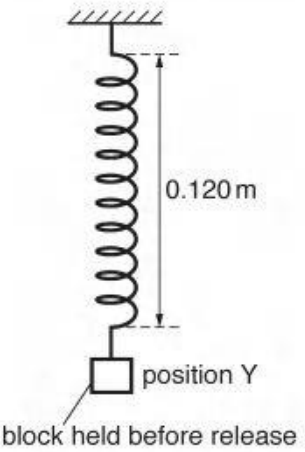
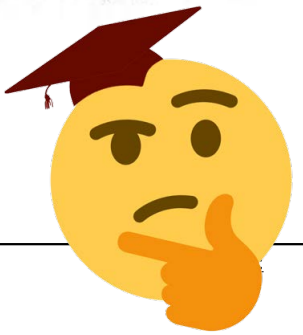


Fig. 4.4

A block is attached to the lower end of the spring. The block hangs in equilibrium at position X when the length of the spring is 0.095 m, as shown in Fig. 4.3.

The block is then pulled vertically downwards and held at position Y so that the length of the spring is 0.120 m, as shown in Fig. 4.4. The block is then released and moves vertically upwards from position Y back towards position X.



(a) Use Fig. 4.1 to determine the spring constant of the spring.

spring constant = ... $N\,m^{-1}$ [2]

(b) Use Fig. 4.1 to show that the decrease in elastic potential energy of the spring is 0.055 J when the block moves from position Y to position X.

[2]

(c) The block has a mass of 0.122 kg. Calculate the increase in gravitational potential energy of the block for its movement from position Y to position X.

increase in gravitational potential energy = ... J [2]

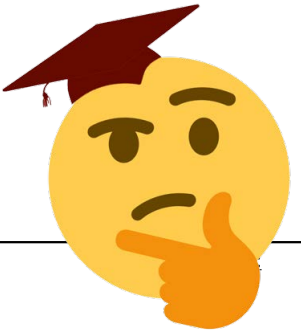
(d) Use the decrease in elastic potential energy stated in **(b)** and your answer in **(c)** to determine, for the block, as it moves through position X:

(i) its kinetic energy

kinetic energy = ... J [1]

(ii) its speed.

speed = ... $m\,s^{-1}$ [2]



8 – (9702/23_Winter_2019_Q4) – *Dynamics, Deformation Of Solids*

A ball X moves along a horizontal frictionless surface and collides with another ball Y, as illustrated in Fig. 4.1.

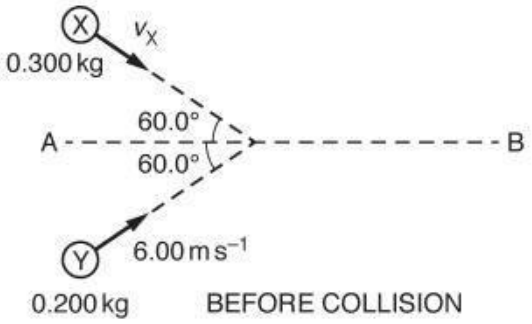


Fig. 4.1 (not to scale)

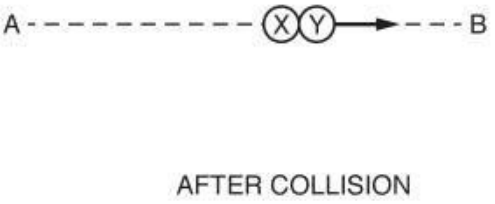


Fig. 4.2 (not to scale)

Ball X has mass 0.300 kg and initial velocity v_X at an angle of 60.0° to line AB.
Ball Y has mass 0.200 kg and initial velocity 6.00 m s^{-1} at an angle of 60.0° to line AB.
The balls stick together during the collision and then travel along line AB, as illustrated in Fig. 4.2.

(a) **(i)** Calculate, to three significant figures, the component of the initial momentum of ball Y that is perpendicular to line AB.

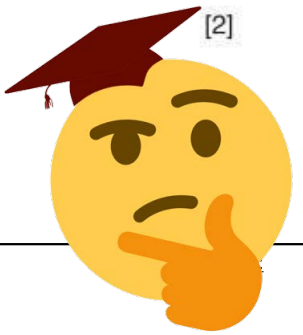
component of momentum = ... kg m s^{-1} [2]

(ii) By considering the component of the initial momentum of each ball perpendicular to line AB, calculate, to three significant figures, v_X.

v_X = ...m s^{-1} [1]

(iii) Show that the speed of the two balls after the collision is 2.4 m s^{-1}.

[2]



(b) The two balls continue moving together along the horizontal frictionless surface towards a spring, as illustrated in Fig. 4.3.

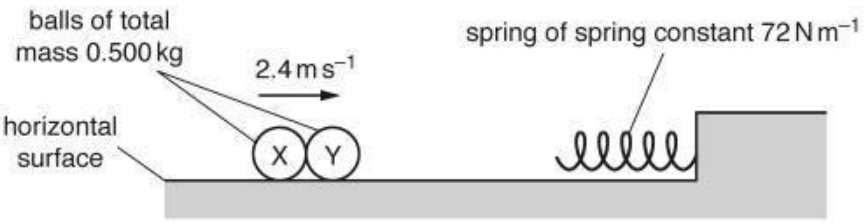


Fig. 4.3

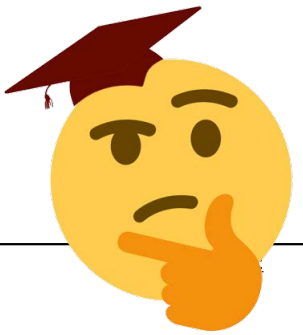
The balls hit the spring and remain stuck together as they decelerate to rest. All the kinetic energy of the balls is converted into elastic potential energy of the spring. The energy E stored in the spring is given by

$$E = \frac{1}{2}kx^2$$

where k is the spring constant of the spring and x is its compression.
The spring obeys Hooke's law and has a spring constant of $72\,\text{N}\,\text{m}^{-1}$.

(i) Determine the maximum compression of the spring caused by the two balls.

maximum compression = ...m [3]

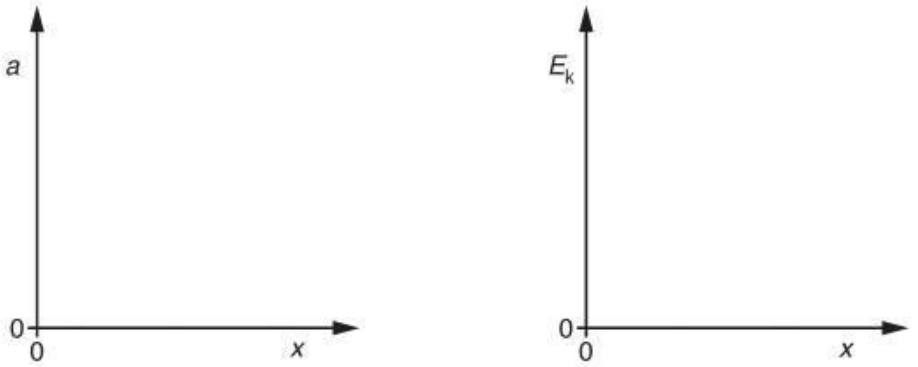


(ii) On Fig. 4.4, sketch graphs to show the variation with compression x of the spring, from zero to maximum compression, of:

1. the magnitude of the deceleration a of the balls

2. the kinetic energy E_k of the balls.

Numerical values are not required.



[3]

Fig. 4.4

9 – (9702/23_Summer_2020_Q3) – *Forces, Density & Pressure, Deformation Of Solids*

(a) State the principle of moments.

.....

.....

..... [2]

(b) In a bicycle shop, two wheels hang from a horizontal uniform rod AC, as shown in Fig. 3.1.

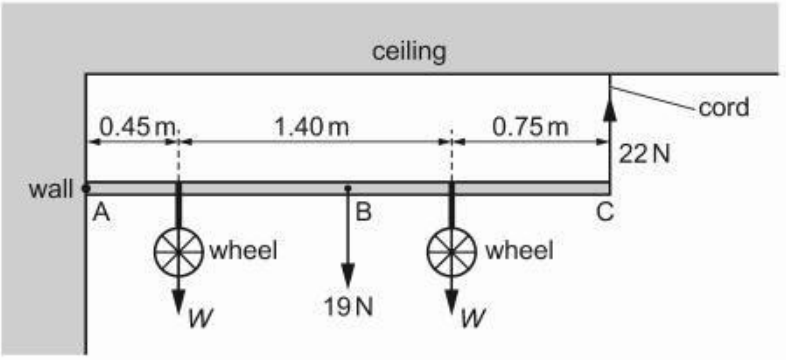


Fig. 3.1 (not to scale)

The rod has weight 19 N and is freely hinged to a wall at end A. The other end C of the rod is attached by a vertical elastic cord to the ceiling. The centre of gravity of the rod is at point B. The weight of each wheel is *W* and the tension in the cord is 22 N.

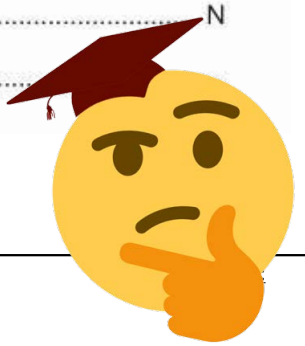
(i) By taking moments about end A, show that the weight *W* of each wheel is 14 N.

[2]

(ii) Determine the magnitude and the direction of the force acting on the rod at end A.

magnitude = ... N

direction .....



(c) The unstretched length of the cord in **(b)** is 0.25 m. The variation with length L of the tension F in the cord is shown in Fig. 3.2.

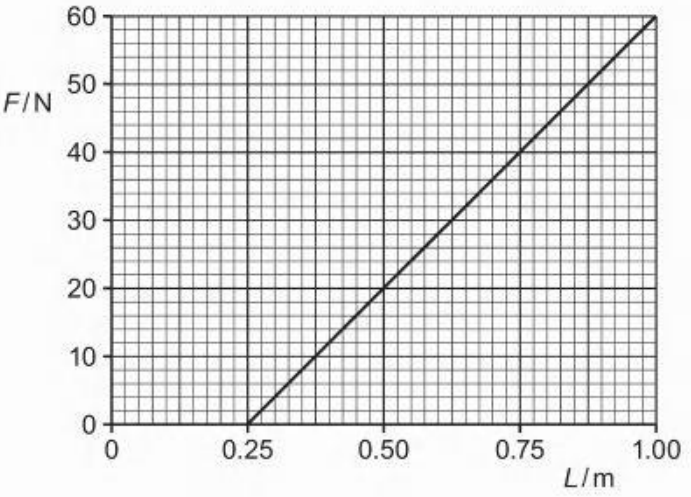


Fig. 3.2

(i) State and explain whether Fig. 3.2 suggests that the cord obeys Hooke's law.

.....

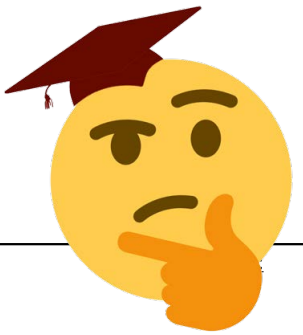
.....

..... [2]

(ii) Calculate the spring constant k of the cord.

k = ... $N\,m^{-1}$ [2]

(iii) On Fig. 3.2, shade the area that represents the work done to extend the cord when the tension is increased from $F = 0$ to $F = 40$ N. [1]



10 – (9702/22_Summer_2020_Q5) – *Deformation Of Solids, Current Of Electricity*

One end of a wire is attached to a fixed point. A force F is applied to the wire to cause extension x. The variation with F of x is shown in Fig. 5.1.

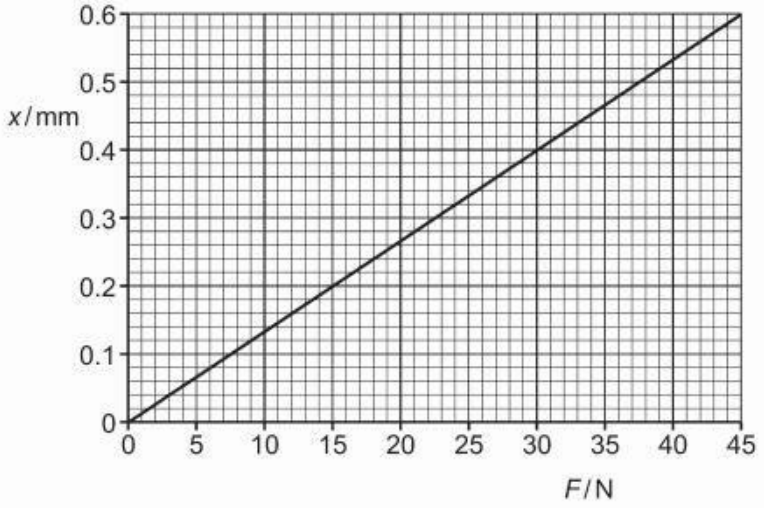


Fig. 5.1

The wire has a cross-sectional area of $4.1 \times 10^{-7}\,m^2$ and is made of metal of Young modulus 1.7×10^{11} Pa. Assume that the cross-sectional area of the wire remains constant as the wire extends.

(a) State the name of the law that describes the relationship between F and x shown in Fig. 5.1.

..... [1]

(b) The wire has an extension of 0.48 mm.

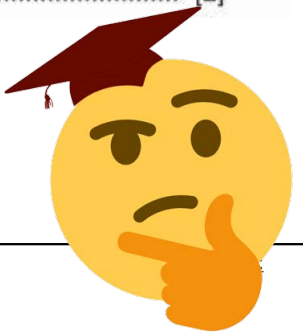
Determine:

(i) the stress

stress = ... Pa [2]

(ii) the strain.

strain = ... [2]



(c) The resistivity of the metal of the wire is $3.7 \times 10^{-7}\,\Omega\,\text{m}$.

Determine the change in resistance of the wire when the extension x of the wire changes from $x = 0.48\,\text{mm}$ to $x = 0.60\,\text{mm}$.

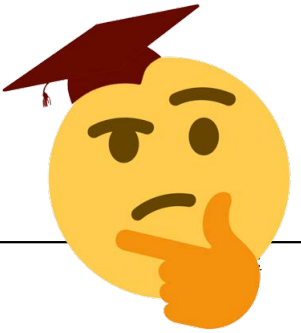
change in resistance = ... Ω [3]

(d) A force of greater than 45 N is now applied to the wire.

Describe how it may be checked that the elastic limit of the wire has not been exceeded.

.....

..... [1]



11 – (9702/22_Winter_2020_Q3) – *Work, Energy & Power, Deformation Of Solids*

(a) A spring is fixed at one end and is compressed by applying a force to the other end. The variation of the force F acting on the spring with its compression x is shown in Fig. 3.1.

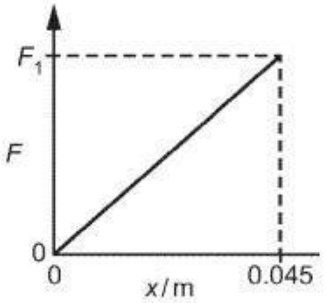


Fig. 3.1

A compression of 0.045 m is produced when a force F_1 acts on the spring. The spring has a spring constant of 800 N m^{-1}.

(i) Determine F_1.

F_1 = ... N [2]

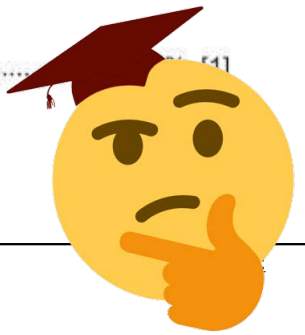
(ii) Use Fig. 3.1 to show that, for a compression of 0.045 m, the elastic potential energy of the spring is 0.81 J.

[2]

(b) A child's toy uses the spring in **(a)** to launch a ball of mass 0.020 kg vertically into the air. The ball is initially held against one end of the spring which has a compression of 0.045 m. The spring is then released to launch the ball. The kinetic energy of the ball as it leaves the toy is 0.72 J.

(i) The toy converts the elastic potential energy of the spring into the kinetic energy of the ball. Use the information in **(a)(ii)** to calculate the percentage efficiency of this conversion.

efficiency = ... % [1]



(ii) Determine the initial momentum of the ball as it leaves the toy.

momentum = ... N s [3]

(c) The ball in **(b)** leaves the toy at point A and moves vertically upwards through the air. Point B is the position of the ball when it is at maximum height *h* above point A, as illustrated in Fig. 3.2.

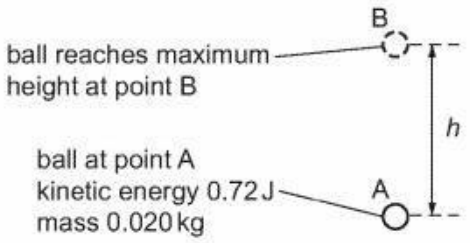


Fig. 3.2 (not to scale)

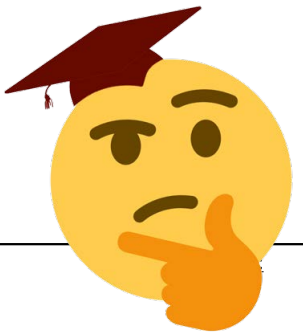
The gravitational potential energy of the ball increases by 0.60 J as it moves from A to B.

(i) Calculate *h*.

h = ... m [2]

(ii) Determine the average force due to air resistance acting on the ball for its movement from A to B.

average force = ... N [2]



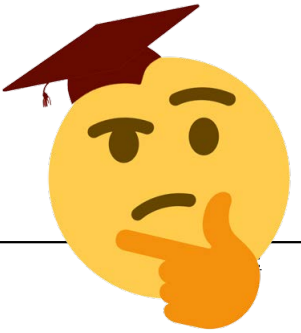
(iii) When there is air resistance, the ball takes time *T* to move from A to B.

State and explain whether the time taken for the ball to move from A to its maximum height will be more than, less than or equal to time *T* if there is **no** air resistance.

.....

..... [1]

[Total: 13]



12 – (9702/21_Winter_2020_Q4) – *Deformation Of Solids*

(a) Define, for a wire:

(i) *stress*

.....

..... [1]

(ii) *strain.*

.....

..... [1]

(b) **(i)** A school experiment is performed on a metal wire to determine the Young modulus of the metal. A force is applied to one end of the wire which is fixed at the other end. The variation of the force F with extension x of the wire is shown in Fig. 4.1.

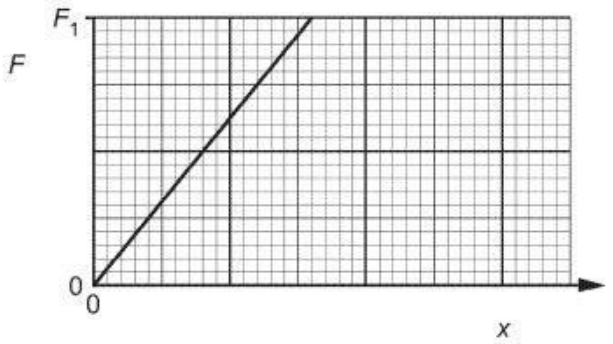


Fig. 4.1

The maximum force applied to the wire is F_1.

The gradient of the graph line in Fig. 4.1 is G. The wire has initial length L and cross-sectional area A.

Determine an expression, in terms of A, G and L, for the Young modulus E of the metal.

E = ... [2]

(ii) A student repeats the experiment in **(b)(i)** using a new wire that has twice the diameter of the first wire. The initial length of the wire and the metal of the wire are unchanged.

On Fig. 4.1, draw the graph line representing the new wire for the force increasing from $F = 0$ to $F = F_1$. [2]

(iii) Another student repeats the original experiment in **(b)(i)**, increasing the force beyond F_1 to a new maximum force F_2. The new graph obtained is shown in Fig. 4.2.

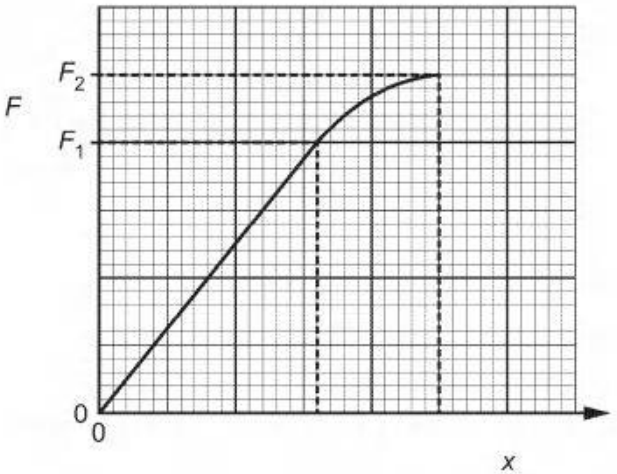


Fig. 4.2

1. On Fig. 4.2, shade an area that represents the work done to extend the wire when the force is increased from F_1 to F_2. [1]

2. Explain how the student can check that the elastic limit of the wire was not exceeded when force F_2 was applied.

.....

.....

..... [1]

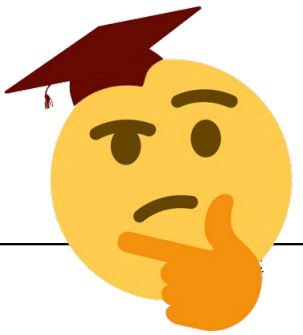
(iv) Each student in the class performs the experiment in **(b)(i)**. The teacher describes the values of the Young modulus calculated by the students as having high accuracy and low precision.

Explain what is meant by *low precision*.

.....

..... [1]

[Total: 9]



13 – (9702/23_Winter_2020_Q4) – *Work, Energy & Power, Deformation Of Solids*

(a) State Hooke's law.

.....

..... [1]

(b) A spring is fixed at one end. A compressive force F is applied to the other end. The variation of the force F with the compression x of the spring is shown in Fig. 4.1.

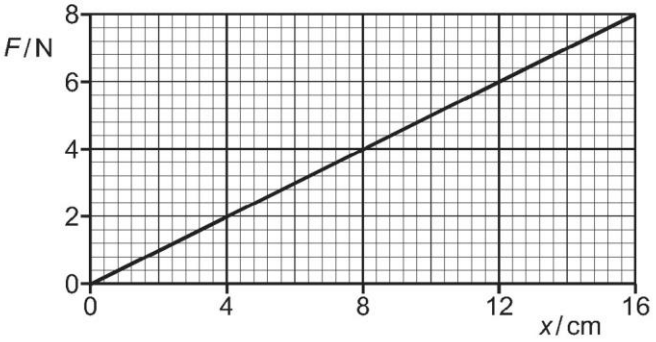


Fig. 4.1

Show that the elastic potential energy of the spring is 0.64 J when its compression is 16.0 cm.

[2]

(c) The spring in **(b)** is used to project a toy car along a track from point X to point Y, as illustrated in Fig. 4.2.

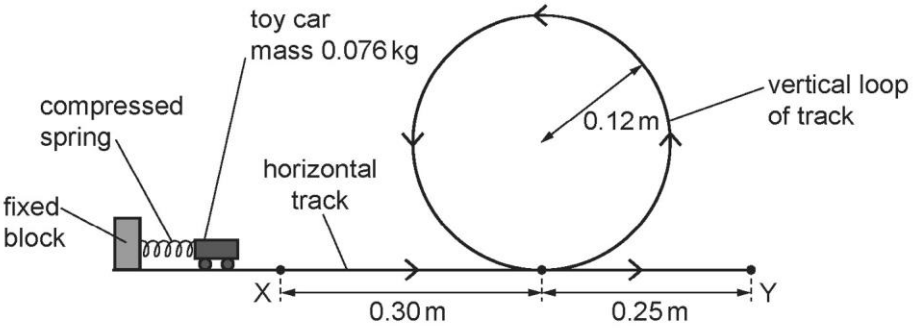
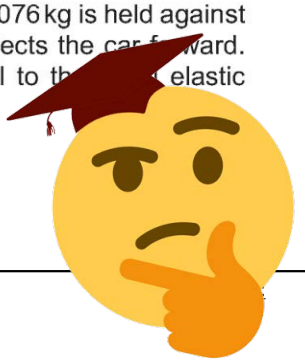


Fig. 4.2 (not to scale)

The spring is initially given a compression of 16.0 cm. The car of mass 0.076 kg is held against one end of the compressed spring. When the spring is released it projects the car forward. The car leaves the spring at point X with kinetic energy that is equal to the elastic potential energy of the compressed spring.



The car follows the track around a vertical loop of radius 0.12 m and then passes point Y. Assume that friction and air resistance are negligible.

Calculate:

(i) the speed of the car at X

speed = ... $m\,s^{-1}$ [2]

(ii) the kinetic energy of the car when it is at the top of the loop

kinetic energy = ... J [3]

(iii) the speed of the car at Y.

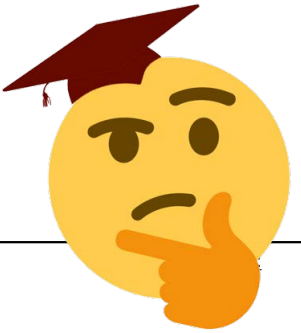
speed = ... $m\,s^{-1}$ [1]

(d) In practice, a resistive force due to friction and air resistance acts on the car so that its kinetic energy at Y is 0.23 J less than its kinetic energy at X.

Determine the average resistive force acting on the car for its movement from X to Y.

average resistive force = ... N [3]

[Total: 12]



14 – (9702/21_Summer_2022_Q4) – *Deformation Of Solids*

A spring is suspended from a fixed point at one end and a vertical force is applied to the other end, as shown in Fig. 4.1.

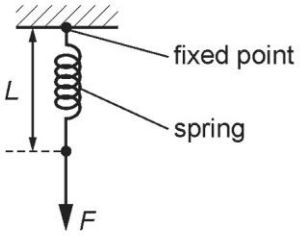


Fig. 4.1

The variation of the applied force *F* with the length *L* of the spring is shown in Fig. 4.2.

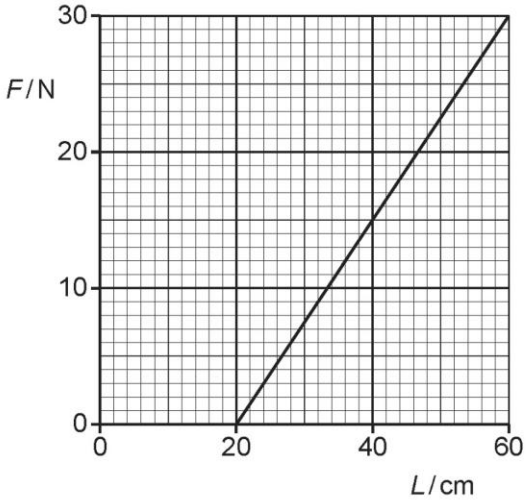
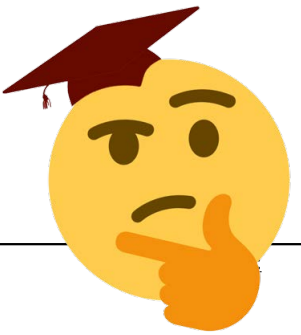


Fig. 4.2

(a) Determine the spring constant *k* of the spring.

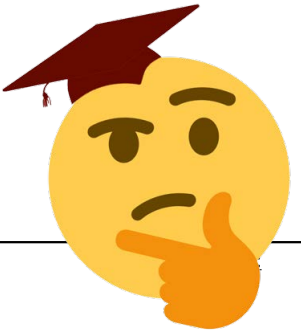
k = ... $N\,m^{-1}$ [2]



(b) Determine the elastic potential energy in the spring when the applied force F is 15 N.

elastic potential energy = ... J [3]

[Total: 5]



15 - (9702/22_Winter_2023_Q3) - *Work, Energy & Power, Deformation Of Solids*

A vertical rod is fixed to the horizontal surface of a table, as shown in Fig. 3.1.

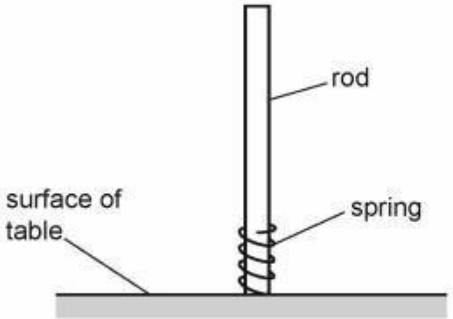


Fig. 3.1 (not to scale)

A spring of mass 7.5 g is able to slide along the full length of the rod.

The spring is first pushed against the surface of the table so that it has an initial compression of 2.1 cm. The spring is then suddenly released so that it leaves the surface of the table with a kinetic energy of 0.048 J and then moves up the rod.

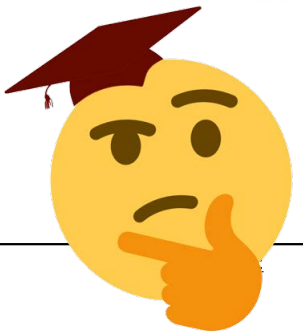
Assume that the spring obeys Hooke's law and that the initial elastic potential energy of the compressed spring is equal to the kinetic energy of the spring as it leaves the surface of the table. Air resistance is negligible.

(a) By using the initial elastic potential energy of the compressed spring, calculate its spring constant.

spring constant = ... $N\,m^{-1}$ [2]

(b) Calculate the speed of the spring as it leaves the surface of the table.

speed = ... $m\,s^{-1}$ [2]



(c) The spring rises to its maximum height up the rod from the surface of the table. This causes the gravitational potential energy of the spring to increase by 0.039 J.

(i) Calculate, for this movement of the spring, the increase in height of the spring after leaving the surface of the table.

increase in height = ... m [2]

(ii) Calculate the average frictional force exerted by the rod on the spring as it rises.

average frictional force = ... N [2]

(d) The rod is replaced by another rod that exerts negligible frictional force on the moving spring. The initial compression x of the spring is now varied in order to vary the maximum increase in height Δh of the spring after leaving the surface of the table. Assume that the spring obeys Hooke's law for all compressions.

On Fig. 3.2, sketch a graph to show the variation with x of Δh. Numerical values are not required.

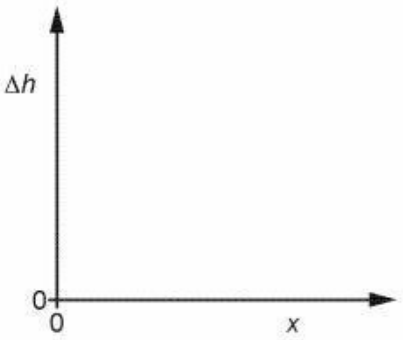
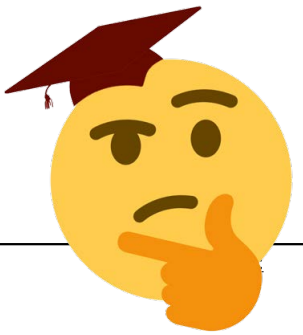


Fig. 3.2

[2]



16 – (9702/23_Winter_2023_Q4) – *Deformation Of Solids*

Fig. 4.1 shows the variation with extension x of the tensile force F for two wires, G and H, made from the same material.

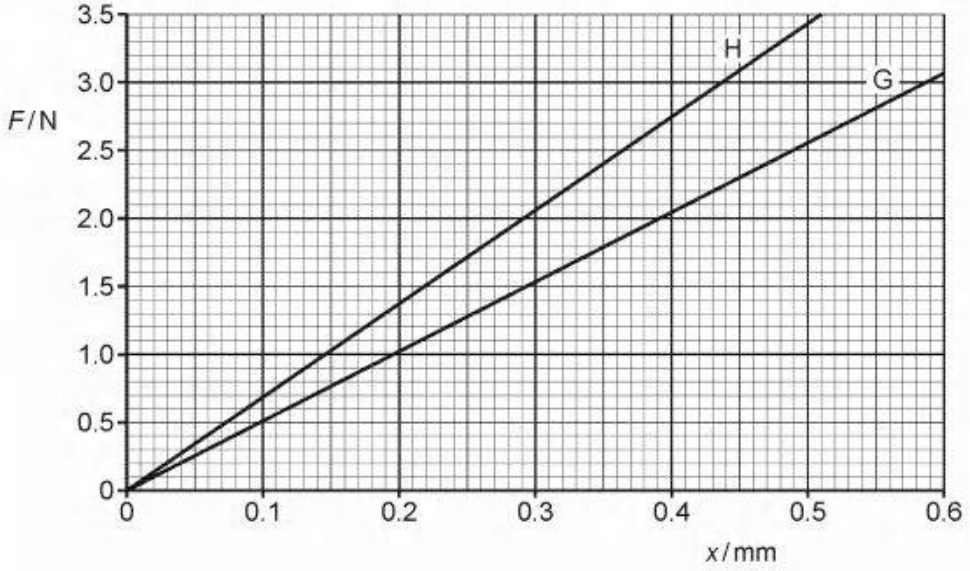


Fig. 4.1

The elastic limit has not been exceeded for G or H.

(a) For the lines in Fig. 4.1:

(i) state what is represented by the gradient

..... [1]

(ii) explain why the area under the line represents the elastic potential energy of the wire.

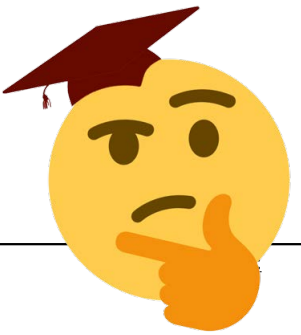
.....

.....

.....

..... [2]

(b) Wires G and H are joined together end-to-end to form a composite wire of negligible weight. The composite wire hangs vertically from a fixed support.



A block of weight of 2.0 N is attached to the end of the wire, as shown in Fig. 4.2.

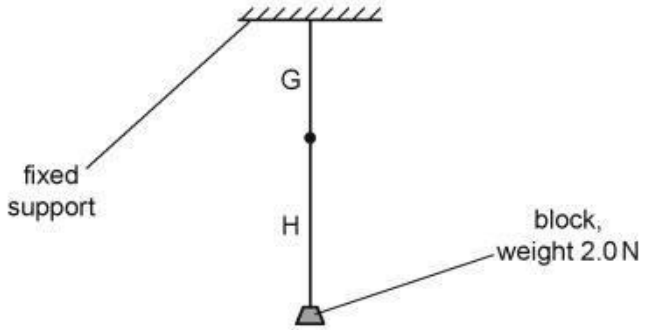


Fig. 4.2

(i) Use Fig. 4.1 to determine:

- the extension x_G of wire G

x_G = ... mm

- the extension x_H of wire H.

x_H = ... mm
[1]

(ii) Calculate the total elastic potential energy E_P of the composite wire due to the weight of the block.

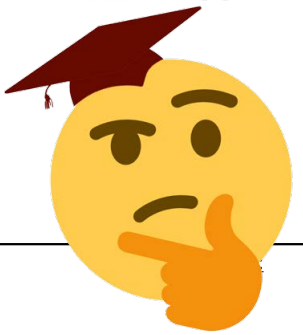
E_P = ... J [2]

(iii) The original length of wire G is L and the original length of wire H is $1.5L$.

Calculate the ratio

$$\frac{\text{cross-sectional area of wire G}}{\text{cross-sectional area of wire H}}.$$

ratio = ... [3]



1 - (9702/22_Winter_2022_Q4) - *Ideal Gases*

A horizontal spring is fixed at one end. A block is pushed against the other end of the spring so that the spring is compressed, as shown in Fig. 4.1.

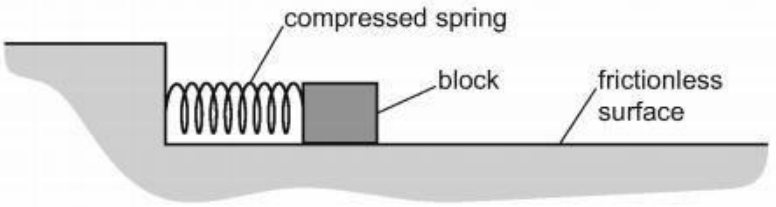


Fig. 4.1

The block is released and accelerates along a horizontal frictionless surface as the spring returns to its original length. The block leaves the end of the spring with a speed of $2.3\,m\,s^{-1}$, as shown in Fig. 4.2.

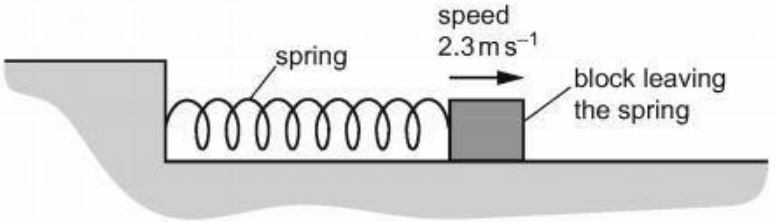


Fig. 4.2

The block has a mass of 250 g and the spring has a spring constant of $420\,N\,m^{-1}$.

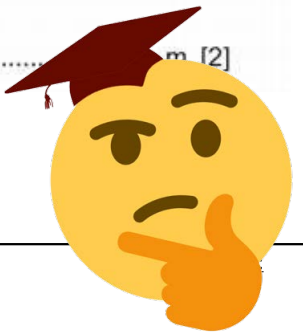
Assume that the spring always obeys Hooke's law and that all the elastic potential energy of the spring is transferred to the kinetic energy of the block.

(a) Calculate the kinetic energy of the block as it leaves the spring.

kinetic energy = ... J [2]

(b) Calculate the compression of the spring immediately before the block is released.

compression = ... m [2]



(c) After leaving the spring, the block moves along the surface until it hits a barrier at a speed of $2.3\,m\,s^{-1}$. The block then rebounds at a speed of $1.5\,m\,s^{-1}$ and moves back along its original path. The block is in contact with the barrier for a time of 0.086 s.

Calculate:

(i) the change in momentum of the block during the collision

change in momentum = ... N s [2]

(ii) the average resultant force exerted on the block during the collision.

average resultant force = ... N [1]

(d) The maximum compression x of the spring is now varied in order to vary the kinetic energy E_K of the block as it leaves the spring. Assume that all the elastic potential energy in the spring is always transferred to the kinetic energy of the block.

On Fig. 4.3, sketch a graph to show the variation with x of E_K.

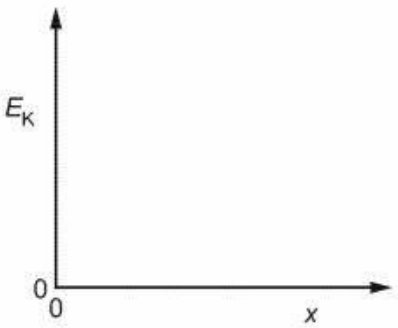
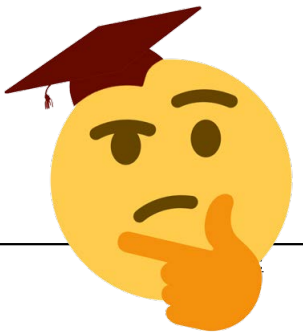


Fig. 4.3

[1]



1 - (9702/21_Summer_2017_Q5) - *Waves*

(a) Describe the Doppler effect.

.....

.....

.....[1]

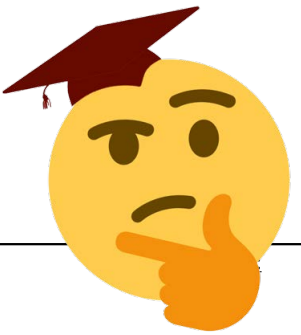
(b) A car travels with a constant velocity along a straight road. The car horn with a frequency of 400 Hz is sounded continuously. A stationary observer on the roadside hears the sound from the horn at a frequency of 360 Hz.
The speed of sound is 340 m s^{-1}.

Determine the magnitude v, and the direction, of the velocity of the car relative to the observer.

v = ...m s^{-1}

direction .....

[3]



2 – (9702/22_Summer_2017_Q5) – *Waves, Superposition*

(a) Define the *frequency* of a sound wave.

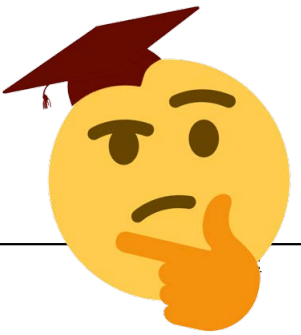
.....

.....[1]

(b) A sound wave travels through air. Describe the motion of the air particles relative to the direction of travel of the sound wave.

.....

.....[1]



(c) The sound wave emitted from the horn of a stationary car is detected with a microphone and displayed on a cathode-ray oscilloscope (c.r.o.), as shown in Fig. 5.1.

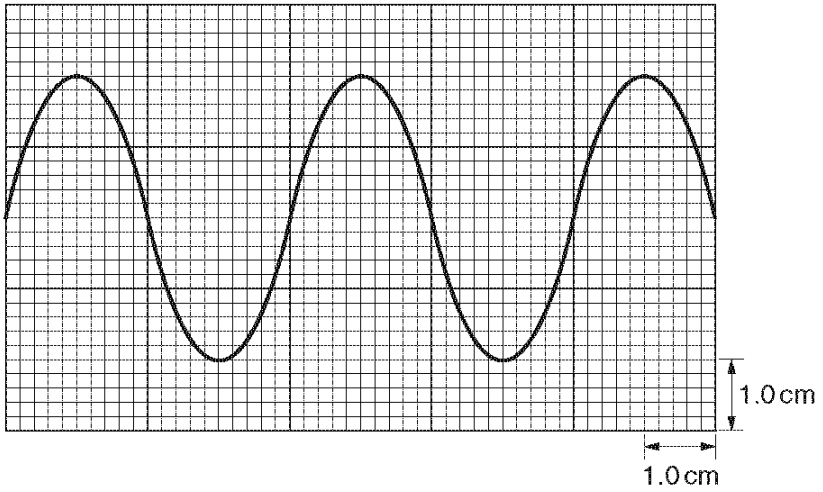


Fig. 5.1

The *y*-axis setting is $5.0\,\text{mV}\,\text{cm}^{-1}$.
The time-base setting is $0.50\,\text{ms}\,\text{cm}^{-1}$.

(i) Use Fig. 5.1 to determine the frequency of the sound wave.

frequency = ... Hz [2]

(ii) The horn of the car sounds continuously. Describe the changes to the trace seen on the c.r.o. as the car travels at constant speed

1. directly towards the stationary microphone,

.....

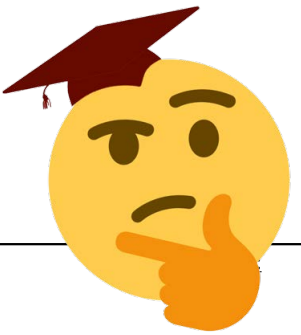
.....

2. directly away from the stationary microphone.

.....

.....

[3]



3 – (9702/21_Winter_2017_Q3) – *Waves, Superposition*

(a) State the difference between a stationary wave and a progressive wave in terms of

(i) the energy transfer along the wave,

.....

.....[1]

(ii) the phase of two adjacent vibrating particles.

.....

.....[1]

(b) A tube is open at both ends. A loudspeaker, emitting sound of a single frequency, is placed near one end of the tube, as shown in Fig. 3.1.

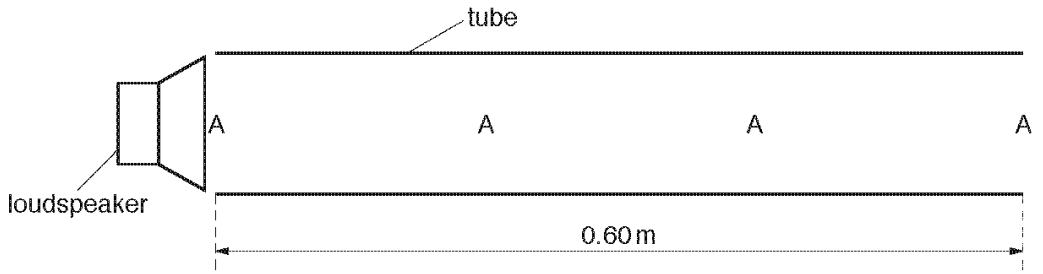


Fig. 3.1

The speed of the sound in the tube is $340\,m\,s^{-1}$. The length of the tube is 0.60 m.
A stationary wave is formed with an antinode A at each end of the tube and two antinodes inside the tube.

(i) State what is meant by an *antinode* of the stationary wave.

.....

.....[1]

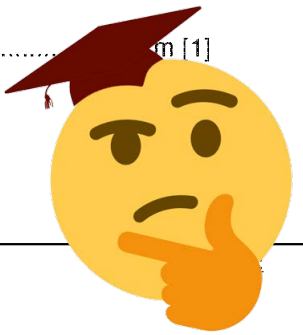
(ii) State the distance between a node and an adjacent antinode.

distance = ... m [1]

(iii) Determine, for the sound in the tube,

1. the wavelength,

wavelength = ... m [1]

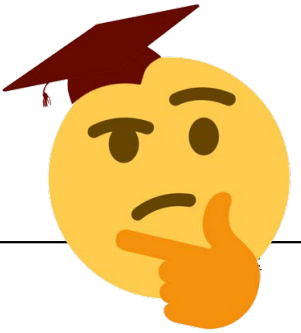


2. the frequency.

frequency = ... Hz [2]

(iv) Determine the minimum frequency of the sound from the loudspeaker that produces a stationary wave in the tube.

minimum frequency = ... Hz [2]



4 – (9702/22_Winter_2017_Q4) – *Waves, Superposition*

(a) State the conditions required for the formation of a stationary wave.

.....

.....

.....

.....[2]

(b) A horizontal string is stretched between two fixed points X and Y. The string is made to vibrate vertically so that a stationary wave is formed. At one instant, each particle of the string is at its maximum displacement, as shown in Fig. 4.1.

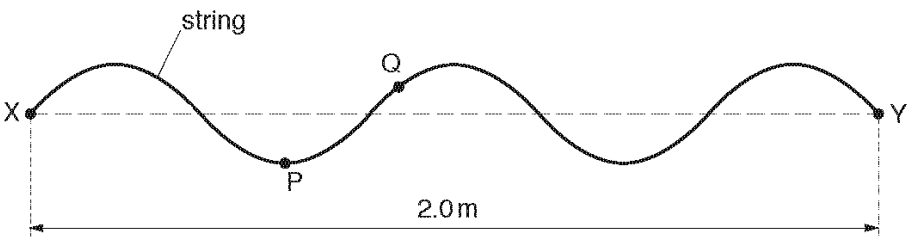


Fig. 4.1

P and Q are two particles of the string. The string vibrates with a frequency of 40 Hz. Distance XY is 2.0 m.

(i) State the number of antinodes in the stationary wave.

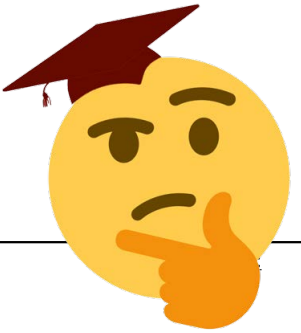
number = ...[1]

(ii) Determine the minimum time taken for the particle P to travel from its lowest point to its highest point.

time taken = ... s [2]

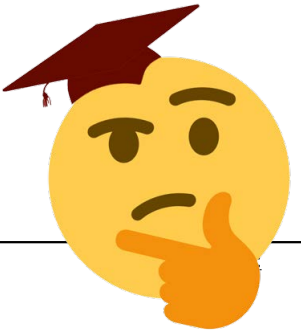
(iii) State the phase difference, with its unit, between the vibrations of particle P and of particle Q.

phase difference = ...[1]



(iv) Determine the speed of a progressive wave along the string.

speed = ...m s^{-1} [2]



5 – (9702/23_Winter_2017_Q4) – *Waves, Superposition*

(a) By reference to the direction of propagation of energy, explain what is meant by a *longitudinal* wave.

.....

.....[1]

(b) A car horn emits a sound wave of frequency 800 Hz. A microphone and a cathode-ray oscilloscope (c.r.o.) are used to analyse the sound wave. The waveform displayed on the c.r.o. screen is shown in Fig. 4.1.

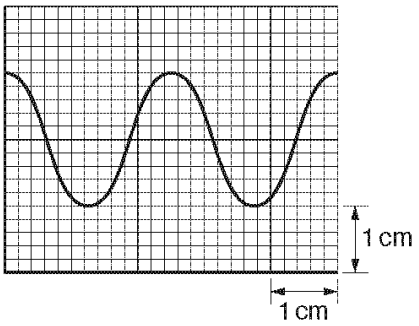


Fig. 4.1

Determine the time-base setting, in $s\,cm^{-1}$, of the c.r.o.

time-base setting = ... $s\,cm^{-1}$ [3]

(c) The intensity I of the sound at a distance r from the car horn in **(b)** is given by the expression

$$I = \frac{k}{r^2}$$

where k is a constant.

Fig. 4.2 shows the car in **(b)** on a road.

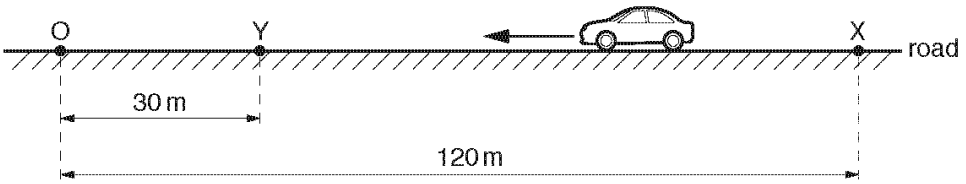
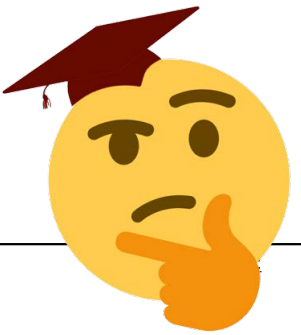


Fig. 4.2



An observer stands at point O. Initially the car is parked at point X which is 120 m away from point O. The car then moves directly towards the observer and stops at point Y, a distance of 30 m away from O.
The car horn continuously emits sound when the car is moving between points X and Y.

(i) The sound wave at point O has amplitude A_X when the car is at X and has amplitude A_Y when the car is at Y.

Calculate the ratio $\frac{A_Y}{A_X}$.

ratio = ...[3]

(ii) When the car is parked at X, the frequency of the sound from the horn that is detected by the observer is 800 Hz. As the car moves from X to Y, the maximum change in the detected frequency is 16 Hz. The speed of the sound in air is 330 m s^{-1}.

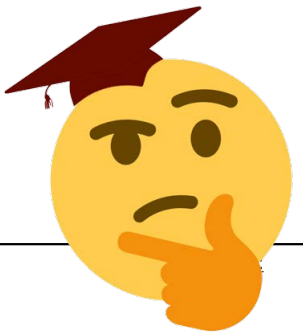
Determine, to two significant figures,

1. the minimum wavelength of the sound detected by the observer,

wavelength = ... m [2]

2. the maximum speed of the car.

speed = ... m s^{-1} [2]



6 – (9702/23_Summer_2018_Q2) – *Forces, Density & Pressure, Work, Energy & Power, Waves*

(a) State what is meant by *work done*.

.....

.....[1]

(b) A diver releases a solid sphere of radius 16 cm from the sea bed. The sphere moves vertically upwards towards the surface of the sea.

The weight of the sphere is 20 N. The upthrust acting on the sphere is 170 N. The upthrust remains constant as the sphere moves upwards.

(i) Calculate the density of the material of the sphere.

density = ... $kg\,m^{-3}$ [2]

(ii) Briefly explain the origin of the upthrust acting on the sphere.

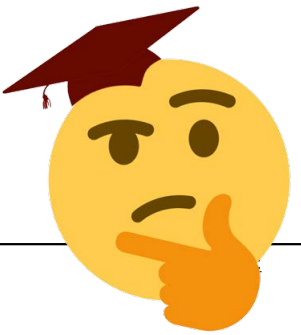
.....

.....

.....[1]

(iii) Calculate the acceleration of the sphere as it is released from rest.

acceleration = ... $m\,s^{-2}$ [2]



(iv) The viscous (drag) force D acting on the sphere is given by

$$D = kr^2v^2$$

where r is the radius of the sphere and v is its speed.
The constant k is equal to $810\,\text{kg}\,\text{m}^{-3}$.

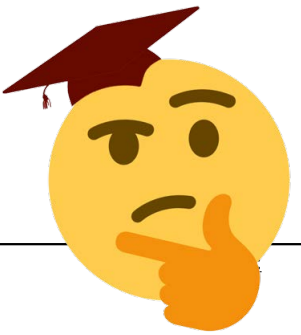
Determine the constant (terminal) speed reached by the sphere.

speed = ... $\text{m}\,\text{s}^{-1}$ [3]

(v) The diver releases a different sphere that moves with a constant speed of $6.30\,\text{m}\,\text{s}^{-1}$ directly towards a stationary ship. The sphere emits sound of frequency 4850 Hz. The ship detects sound of frequency 4870 Hz as the sphere moves towards it.

Determine, to three significant figures, the speed of the sound in the water.

speed = ... $\text{m}\,\text{s}^{-1}$ [2]



7 – (9702/22_Summer_2018_Q3) – *Kinematics, Dynamics, Waves*

A child on a sledge slides down a steep hill and then travels in a straight line up an ice-covered slope, as illustrated in Fig. 3.1.

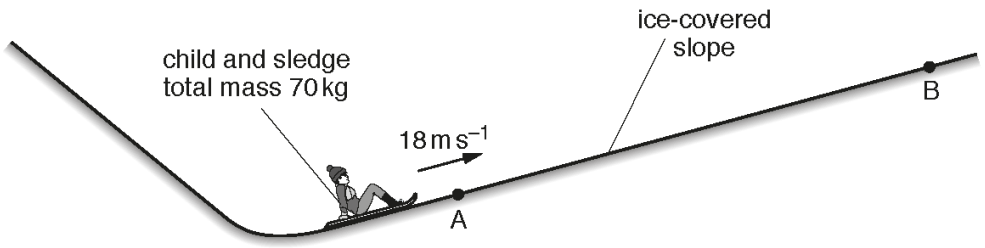


Fig. 3.1 (not to scale)

The sledge passes point A with speed $18\,\mathrm{m\,s^{-1}}$ at time $t = 0$ and then comes to rest at point B. The child applies a brake to the sledge at point B. The brake does not keep the sledge stationary and it immediately slides back down the slope towards A.

The variation with time t of the velocity v of the sledge from $t = 0$ to $t = 24\,\mathrm{s}$ is shown in Fig. 3.2.

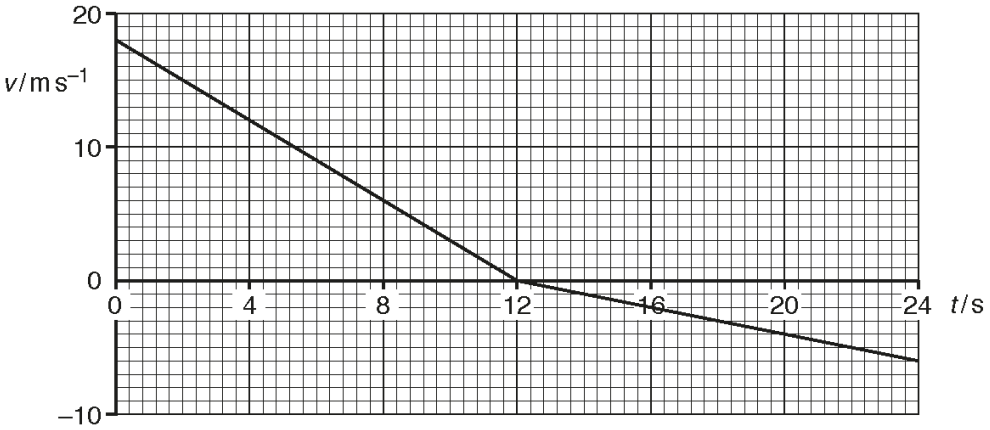
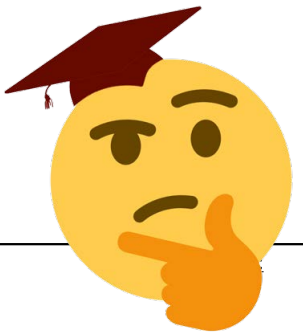


Fig. 3.2

(a) State the time taken for the sledge to travel from A to B.

time = ... s [1]



(b) Determine the displacement of the sledge up the slope from point A at time $t = 24$ s.

displacement = ...m [3]

(c) Show that the acceleration of the sledge as it moves from B back towards A is $0.50\,\text{m}\,\text{s}^{-2}$.

[2]

(d) The child and sledge have a total mass of 70 kg. The component of the total weight of the child and sledge that acts down the slope is 80 N.

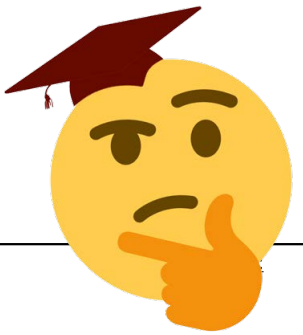
Determine

(i) the frictional force on the sledge as it moves from B towards A,

frictional force = ... N [2]

(ii) the angle θ of the slope to the horizontal.

θ = ... ° [2]



(e) The child on the sledge blows a whistle between $t = 4.0\,s$ and $t = 8.0\,s$. The whistle emits sound of frequency 900 Hz. The speed of the sound in the air is $340\,m\,s^{-1}$. A man standing at point A hears the sound.

Use Fig. 3.2 to

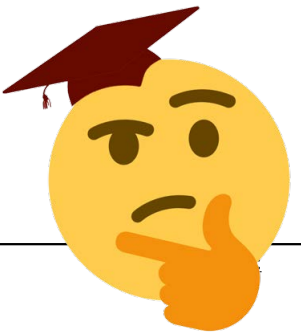
(i) determine the initial frequency of the sound heard by the man,

initial frequency = ... Hz [2]

(ii) describe and explain qualitatively the variation, if any, in the frequency of the sound heard by the man.

.....

.....[1]



8 – (9702/21_Summer_2018_Q4) – *Waves, Superposition*

(a) For a progressive wave, state what is meant by

(i) the *period*,

.....

.....[1]

(ii) the *wavelength*.

.....

.....[1]

(b) Fig. 4.1 shows the variation with time *t* of the displacement *x* of two progressive waves P and Q passing the same point.

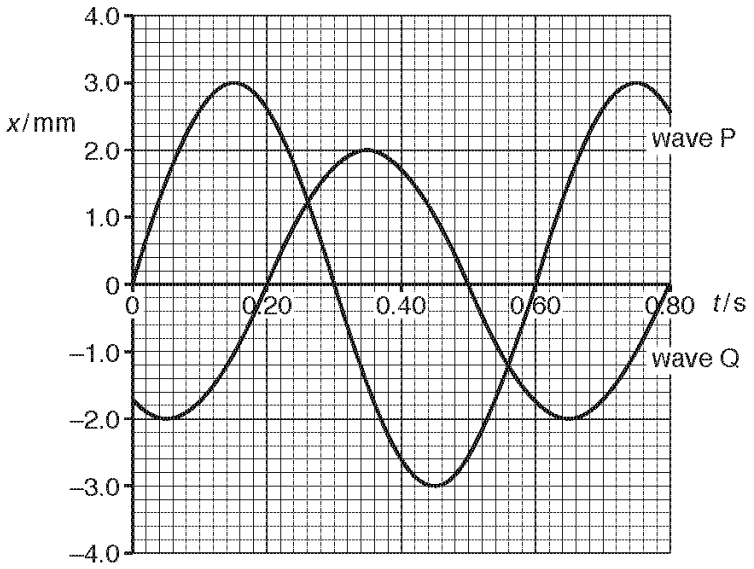
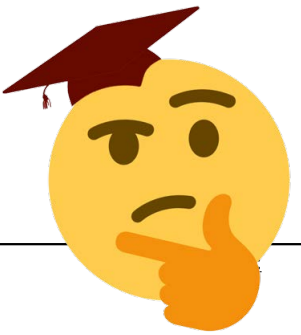


Fig. 4.1

The speed of the waves is $20\,\text{cm}\,\text{s}^{-1}$.

(i) Calculate the wavelength of the waves.

wavelength = ... cm [2]



(ii) Determine the phase difference between the two waves.

phase difference = ... ° [1]

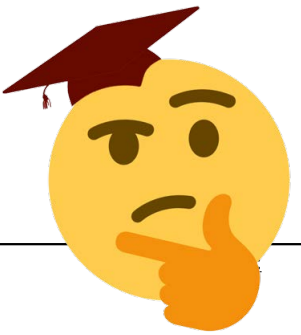
(iii) Calculate the ratio

$$\frac{\text{intensity of wave Q}}{\text{intensity of wave P}}.$$

ratio = ... [2]

(iv) The two waves superpose as they pass the same point. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.45$ s.

displacement = ... mm [1]



9 – (9702/22_Summer_2018_Q4) – *Waves, Superposition*

(a) **(i)** Define the *wavelength* of a progressive wave.

.....

.....[1]

(ii) State what is meant by an *antinode* of a stationary wave.

.....

.....[1]

(b) A loudspeaker producing sound of constant frequency is placed near the open end of a pipe, as shown in Fig. 4.1.

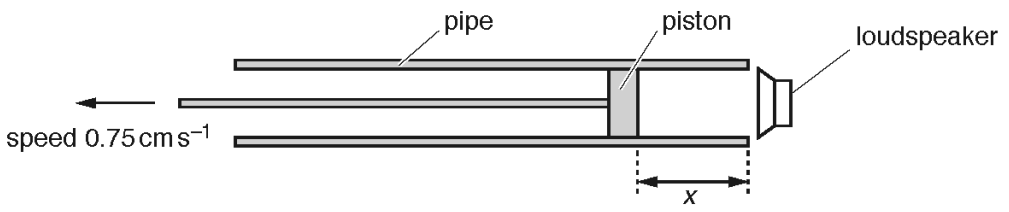


Fig. 4.1

A movable piston is at distance x from the open end of the pipe. Distance x is increased from $x = 0$ by moving the piston to the left with a constant speed of 0.75 cm s^{-1}.

The speed of the sound in the pipe is 340 m s^{-1}.

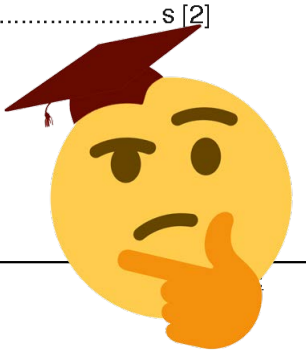
(i) A much louder sound is first heard when $x = 4.5$ cm. Assume that there is an antinode of a stationary wave at the open end of the pipe.

Determine the frequency of the sound in the pipe.

frequency = ... Hz [3]

(ii) After a time interval, a second much louder sound is heard. Calculate the time interval between the first louder sound and the second louder sound being heard.

time interval = ... s [2]



10 – (9702/21_Summer_2018_Q5) – *Waves, Superposition*

(a) When monochromatic light is incident normally on a diffraction grating, the emergent light waves have been diffracted and are coherent.

Explain what is meant by

(i) *diffracted* waves,

.....

.....[1]

(ii) *coherent* waves.

.....

.....[1]

(b) Light consisting of only two wavelengths λ_1 and λ_2 is incident normally on a diffraction grating.

The third order diffraction maximum of the light of wavelength λ_1 and the fourth order diffraction maximum of the light of wavelength λ_2 are at the same angle θ to the direction of the incident light.

(i) Show that the ratio $\frac{\lambda_2}{\lambda_1}$ is 0.75.

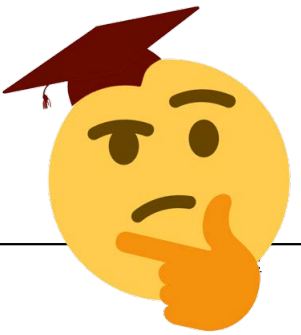
Explain your working.

[2]

(ii) The difference between the two wavelengths is 170 nm.

Determine wavelength λ_1.

λ_1 = ... nm [1]



11 – (9702/23_Summer_2018_Q5) – *Waves, Superposition*

(a) State the relationship between the intensity and the amplitude of a wave.

.....

.....[1]

(b) Microwaves of the same amplitude and wavelength are emitted in phase from two sources P and Q. The sources are arranged as shown in Fig. 5.1.

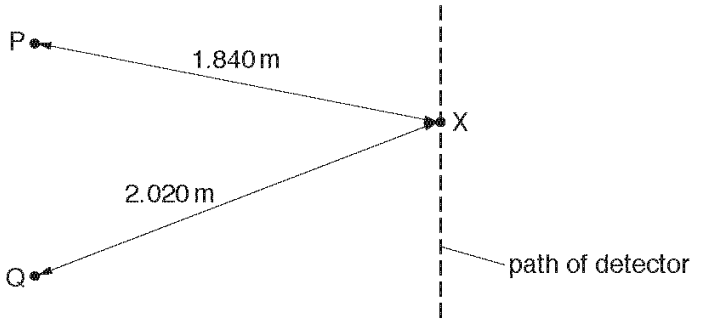


Fig. 5.1

A microwave detector is moved along a path that is parallel to the line joining P and Q. A series of intensity maxima and intensity minima are detected.

When the detector is at a point X, the distance PX is 1.840 m and the distance QX is 2.020 m. The microwaves have a wavelength of 6.0 cm.

(i) Calculate the frequency of the microwaves.

frequency = ... Hz [2]

(ii) Describe and explain the intensity of the microwaves detected at X.

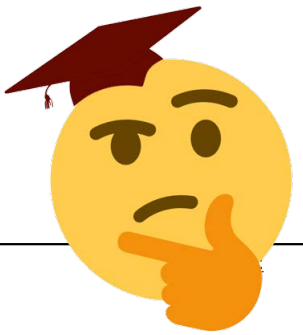
.....

.....

.....

.....

.....[3]



(iii) Describe the effect on the interference pattern along the path of the detector due to each of the following separate changes.

1. The wavelength of the microwaves decreases.

.....

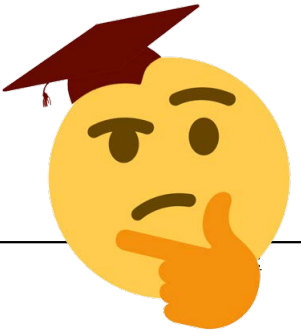
.....

2. The phase difference between the microwaves emitted from the sources changes to 180°.

.....

.....

[2]



12 – (9702/22_Winter_2018_Q4) – *Waves*

(a) Sound waves are longitudinal waves. By reference to the direction of propagation of energy, state what is meant by a *longitudinal* wave.

.....

.....[1]

(b) A stationary sound wave in air has amplitude A. In an experiment, a detector is used to determine A^2. The variation of A^2 with distance x along the wave is shown in Fig. 4.1.

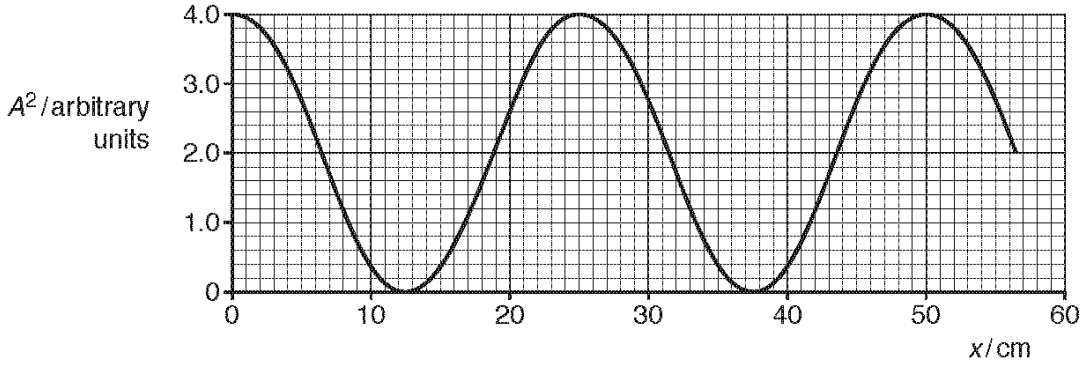


Fig. 4.1

(i) State the phase difference between the vibrations of an air particle at $x = 25$ cm and the vibrations of an air particle at $x = 50$ cm.

phase difference = ... ° [1]

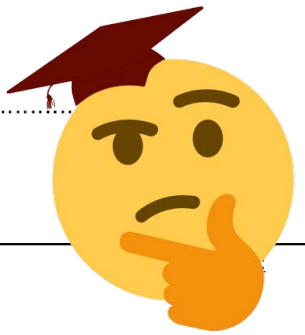
(ii) The speed of the sound in the air is $330\,\text{m}\,\text{s}^{-1}$. Determine the frequency of the sound wave.

frequency = ... Hz [3]

(iii) Determine the ratio

$$\frac{\text{amplitude } A \text{ of wave at } x = 20\,\text{cm}}{\text{amplitude } A \text{ of wave at } x = 25\,\text{cm}}.$$

ratio = ...



13 – (9702/23_Winter_2018_Q4) – *Waves, Superposition*

(a) On Fig. 4.1, complete the two graphs to illustrate what is meant by the amplitude A, the wavelength λ and the period T of a progressive wave.

Ensure that you label the axes of each graph.

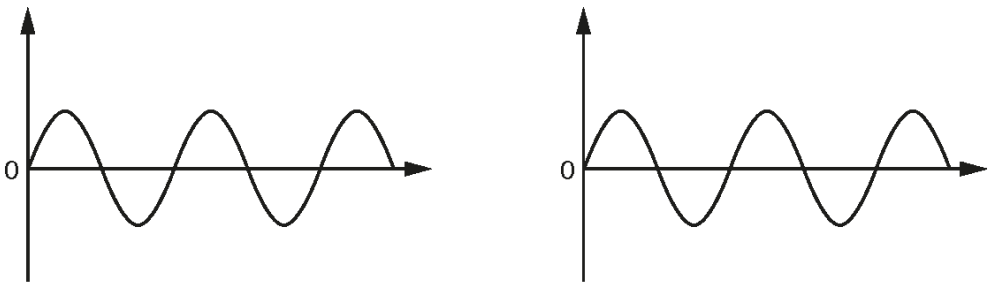


Fig. 4.1

[3]

(b) A horizontal string is stretched between two fixed points X and Y. A vibrator is used to oscillate the string and produce a stationary wave. Fig. 4.2 shows the string at one instant in time.

Fig. 4.2

The speed of a progressive wave along the string is $30\,\mathrm{m\,s^{-1}}$. The stationary wave has a period of 40 ms.

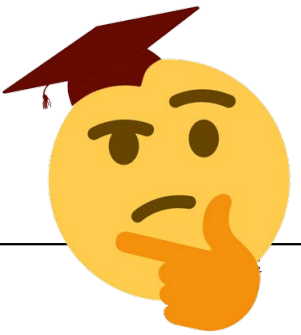
(i) Explain how the stationary wave is formed on the string.

.....

.....

.....

.....[2]



(ii) A particle on the string oscillates with an amplitude of 13 mm. At time t, the particle has zero displacement.

Calculate

1. the displacement of the particle at time (t + 100 ms),

displacement = ... mm

2. the total distance moved by the particle from time t to time (t + 100 ms).

distance = ... mm
[3]

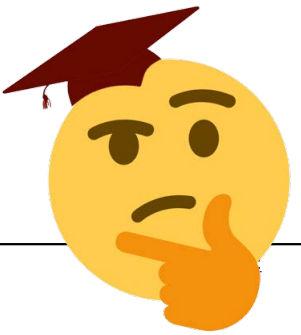
(iii) Determine

1. the frequency of the wave,

frequency = ... Hz [1]

2. the horizontal distance from X to Y.

distance = ... m [3]



14 – (9702/22_Summer_2019_Q4) – *Waves, Superposition*

(a) For a progressive water wave, state what is meant by:

(i) *displacement*

.....

.....[1]

(ii) *amplitude.*

.....

.....[1]

(b) Two coherent waves X and Y meet at a point and superpose. The phase difference between the waves at the point is 180°. Wave X has an amplitude of 1.2 cm and intensity I. Wave Y has an amplitude of 3.6 cm.

Calculate, in terms of I, the resultant intensity at the meeting point.

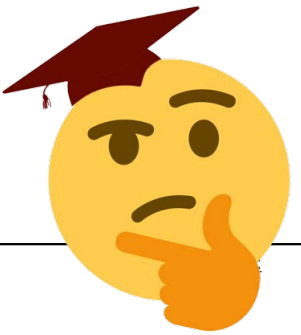
intensity = ... [2]

(c) **(i)** Monochromatic light is incident on a diffraction grating. Describe the diffraction of the light waves as they pass through the grating.

.....

.....

.....[2]



(ii) A parallel beam of light consists of two wavelengths 540 nm and 630 nm. The light is incident normally on a diffraction grating. Third-order diffraction maxima are produced for each of the two wavelengths. No higher orders are produced for either wavelength.

Determine the smallest possible line spacing d of the diffraction grating.

d = ... m [3]

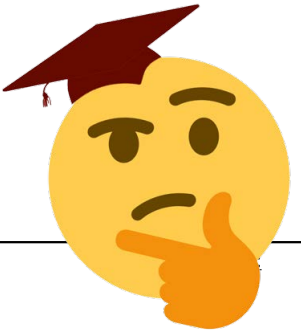
(iii) The beam of light in **(c)(ii)** is replaced by a beam of blue light incident on the same diffraction grating.

State and explain whether a third-order diffraction maximum is produced for this blue light.

.....

.....

.....[2]



15 – (9702/21_Summer_2019_Q5) – *Waves, Superposition*

(a) A loudspeaker oscillates with frequency f to produce sound waves of wavelength λ. The loudspeaker makes N oscillations in time t.

(i) State expressions, in terms of some or all of the symbols f, λ and N, for:

1. the distance moved by a wavefront in time t

distance = ...

2. time t.

time t = ...
[2]

(ii) Use your answers in **(i)** to deduce the equation relating the speed v of the sound wave to f and λ.

[1]

(b) The waveform of a sound wave is displayed on the screen of a cathode-ray oscilloscope (c.r.o.), as shown in Fig. 5.1.

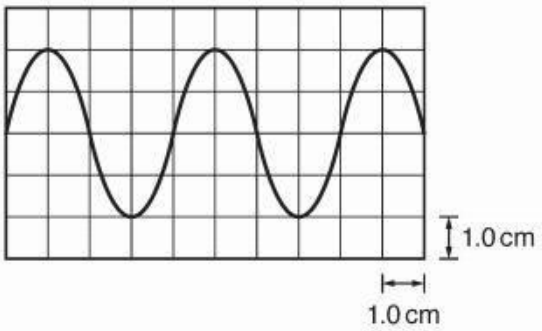
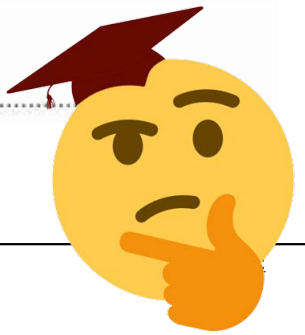


Fig. 5.1

The time-base setting is 0.20 ms cm^{-1}.

Determine the frequency of the sound wave.

frequency = ...



(c) Two sources S_1 and S_2 of sound waves are positioned as shown in Fig. 5.2.

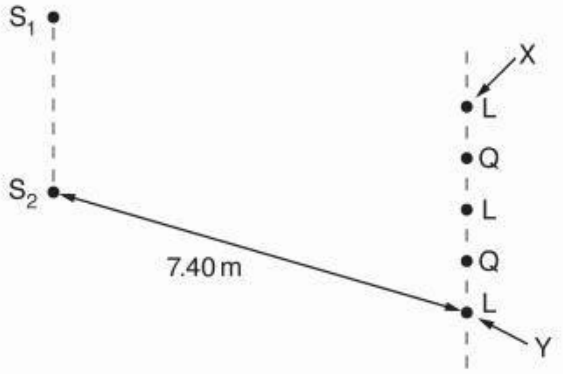


Fig. 5.2 (not to scale)

The sources emit coherent sound waves of wavelength 0.85 m. A sound detector is moved parallel to the line S_1S_2 from a point X to a point Y. Alternate positions of maximum loudness L and minimum loudness Q are detected, as illustrated in Fig. 5.2.

Distance S_1X is equal to distance S_2X. Distance S_2Y is 7.40 m.

(i) Explain what is meant by *coherent* waves.

.....

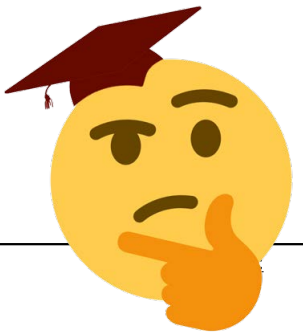
.....[1]

(ii) State the phase difference between the two waves arriving at the position of minimum loudness Q that is closest to point X.

phase difference = ... ° [1]

(iii) Determine the distance S_1Y.

distance = ... m [2]



16 – (9702/23_Summer_2019_Q5) – *Waves, Superposition*

A vertical tube of length 0.60 m is open at both ends, as shown in Fig. 5.1.

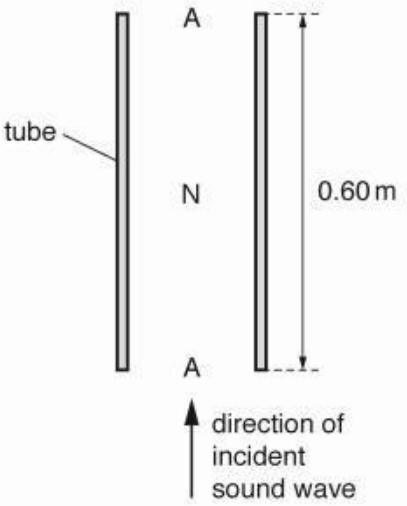


Fig. 5.1

An incident sinusoidal sound wave of a single frequency travels up the tube. A stationary wave is then formed in the air column in the tube with antinodes A at both ends and a node N at the midpoint.

(a) Explain how the stationary wave is formed from the incident sound wave.

.....

.....

.....

.....[2]

(b) On Fig. 5.2, sketch a graph to show the variation of the amplitude of the stationary wave with height *h* above the bottom of the tube.

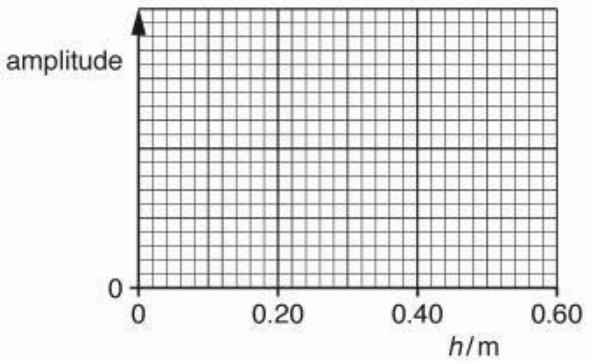


Fig. 5.2

[2]

(c) For the stationary wave, state:

(i) the direction of the oscillations of an air particle at a height of 0.15 m above the bottom of the tube

.....[1]

(ii) the phase difference between the oscillations of a particle at a height of 0.10 m and a particle at a height of 0.20 m above the bottom of the tube.

phase difference = ... ° [1]

(d) The speed of the sound wave is 340 m s^{-1}.

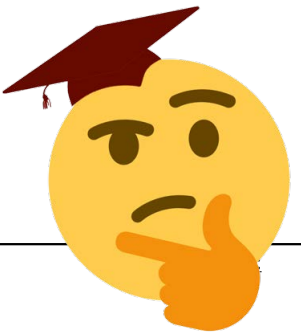
Calculate the frequency of the sound wave.

frequency = ... Hz [2]

(e) The frequency of the sound wave is gradually increased.

Determine the frequency of the wave when a stationary wave is next formed.

frequency = ... Hz [1]



17 - (9702/21_Winter_2019_Q3) - *Waves, Dynamics*

A small remote-controlled model aircraft has two propellers, each of diameter 16 cm.
Fig. 3.1 is a side view of the aircraft when hovering.

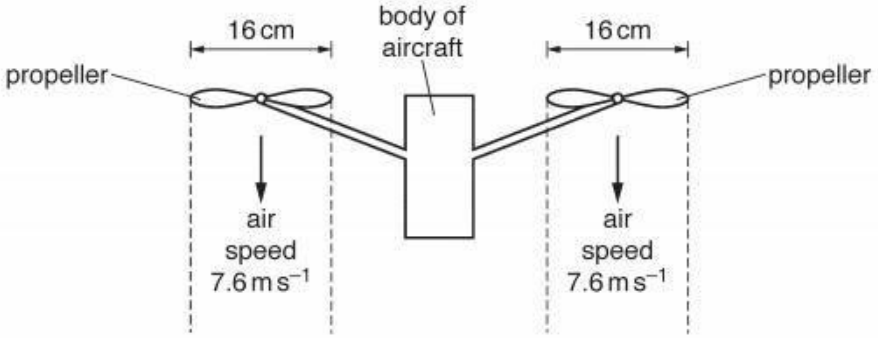


Fig. 3.1

Air is propelled vertically downwards by each propeller so that the aircraft hovers at a fixed position. The density of the air is $1.2\,kg\,m^{-3}$. Assume that the air from each propeller moves with a constant speed of $7.6\,m\,s^{-1}$ in a uniform cylinder of diameter 16 cm. Also assume that the air above each propeller is stationary.

(a) Show that, in a time interval of 3.0 s, the mass of air propelled downwards by **one** propeller is 0.55 kg.

[3]

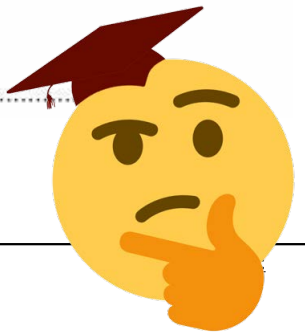
(b) Calculate:

(i) the increase in momentum of the mass of air in **(a)**

increase in momentum = ... N s [1]

(ii) the downward force exerted on this mass of air by the propeller.

force = ...



(c) State:

(i) the upward force acting on **one** propeller

force = ... N [1]

(ii) the name of the law that explains the relationship between the force in **(b)(ii)** and the force in **(c)(i)**.

..... [1]

(d) Determine the mass of the aircraft.

mass = ... kg [1]

(e) In order for the aircraft to hover at a very high altitude (height), the propellers must propel the air downwards with a greater speed than when the aircraft hovers at a low altitude. Suggest the reason for this.

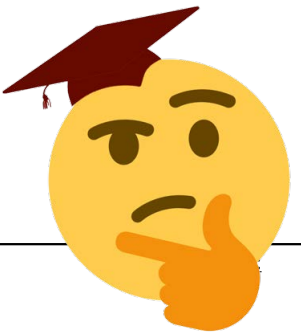
.....

..... [1]

(f) When the aircraft is hovering at a high altitude, an electric fault causes the propellers to stop rotating. The aircraft falls vertically downwards. When the aircraft reaches a constant speed of $22\,m\,s^{-1}$, it emits sound of frequency 3.0 kHz from an alarm. The speed of the sound in the air is $340\,m\,s^{-1}$.

Determine the frequency of the sound heard by a person standing vertically below the falling aircraft.

frequency = ... Hz [2]



18 – (9702/21_Winter_2019_Q5) – *Waves, Superposition*

A ripple tank is used to demonstrate the interference of water waves.
Two dippers D1 and D2 produce coherent waves that have circular wavefronts, as illustrated in Fig. 5.1.

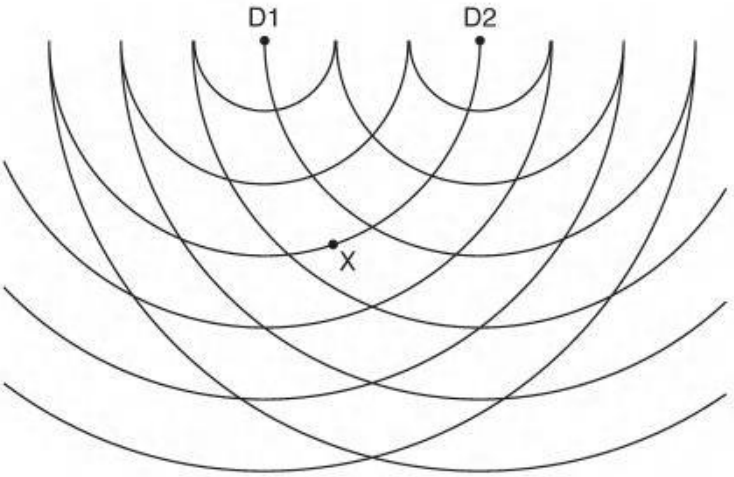


Fig. 5.1

The lines in the diagram represent crests. The waves have a wavelength of 6.0 cm.

(a) One condition that is required for an observable interference pattern is that the waves must be coherent.

(i) Describe how the apparatus is arranged to ensure that the waves from the dippers are coherent.

.....

..... [1]

(ii) State one other condition that must be satisfied by the waves in order for the interference pattern to be observable.

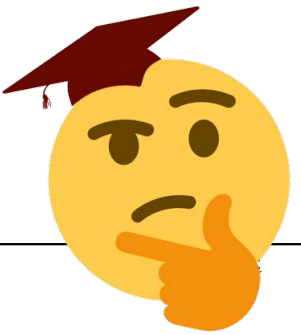
.....

..... [1]

(b) Light from a lamp above the ripple tank shines through the water onto a screen below the tank. Describe one way of seeing the illuminated pattern more clearly.

.....

..... [1]



(c) The speed of the waves is $0.40\,m\,s^{-1}$. Calculate the period of the waves.

period = ... s [2]

(d) Fig. 5.1 shows a point X that lies on a crest of the wave from D1 and midway between two adjacent crests of the wave from D2.

For the waves at point X, state:

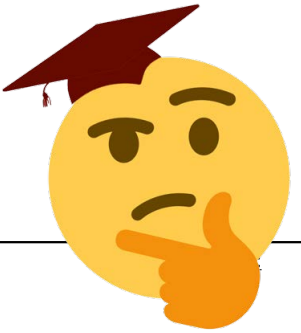
(i) the path difference, in cm

path difference = ... cm [1]

(ii) the phase difference.

phase difference = ... ° [1]

(e) On Fig. 5.1, draw **one** line, at least 4 cm long, which joins points where only maxima of the interference pattern are observed. [1]



19 – (9702/22_Winter_2019_Q5) – *Waves, Superposition*

(a) State what is meant by the *wavelength* of a progressive wave.

.....

..... [1]

(b) A cathode-ray oscilloscope (CRO) is used to analyse a sound wave. The screen of the CRO is shown in Fig. 5.1.

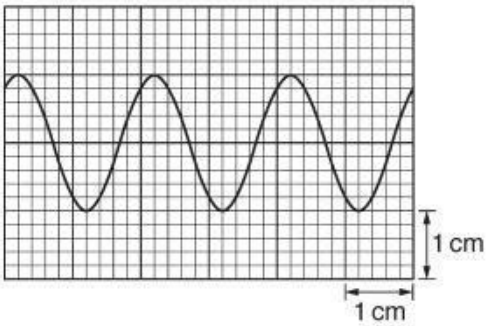
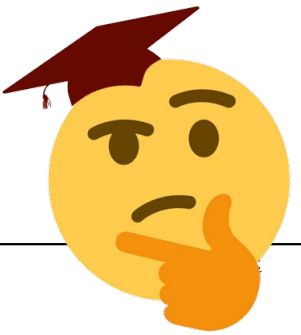


Fig. 5.1

The time-base setting of the CRO is 2.5 ms cm^{-1}.

Determine the frequency of the sound wave.

frequency = ... Hz [2]



(c) The source emitting the sound in **(b)** is at point A. Waves travel from the source to point C along two different paths, AC and ABC, as shown in Fig. 5.2.

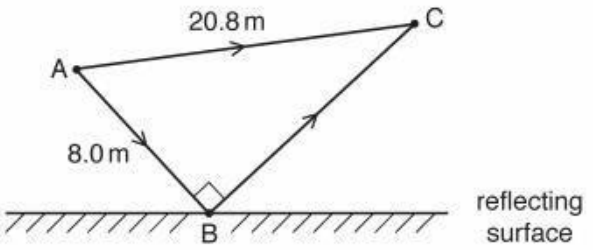


Fig. 5.2 (not to scale)

Distance AB is 8.0 m and distance AC is 20.8 m. Angle ABC is 90°. Assume that there is no phase change of the sound wave due to the reflection at point B. The wavelength of the waves is 1.6 m.

(i) Show that the waves meeting at C have a path difference of 6.4 m.

[1]

(ii) Explain why an intensity maximum is detected at point C.

.....

.....

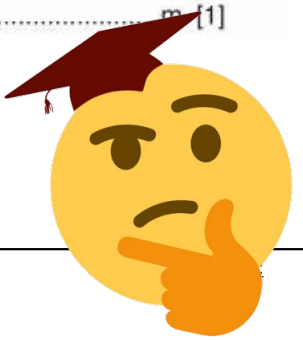
..... [2]

(iii) Determine the difference between the times taken for the sound to travel from the source to point C along the two different paths.

time difference = ... s [2]

(iv) The wavelength of the sound is gradually increased. Calculate the wavelength of the sound when an intensity maximum is next detected at point C.

wavelength = ... m [1]



20 – (9702/23_Winter_2019_Q5) – *Waves, Superposition*

(a) Light waves emerging from the slits of a diffraction grating are coherent and produce an interference pattern.

Explain what is meant by:

(i) *coherence*

.....

..... [1]

(ii) *interference.*

.....

..... [1]

(b) A narrow beam of light from a laser is incident normally on a diffraction grating, as shown in Fig. 5.1.

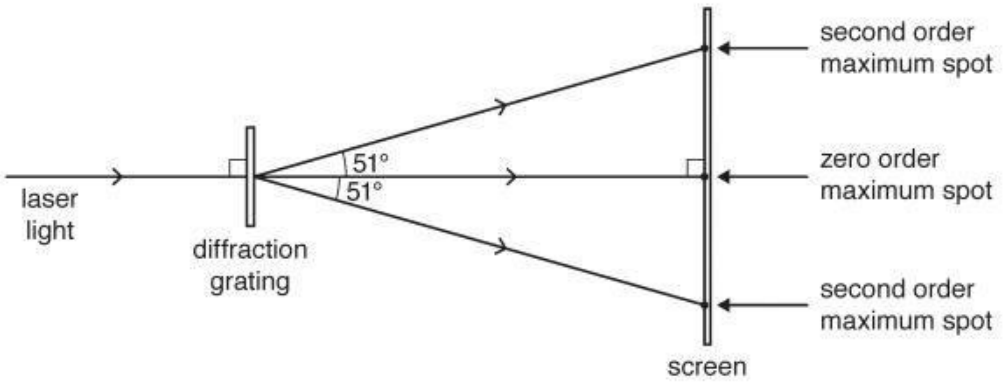
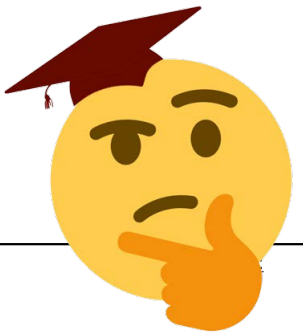


Fig. 5.1 (not to scale)

Spots of light are seen on a screen positioned parallel to the grating. The angle corresponding to each of the **second** order maxima is 51°. The number of lines per unit length on the diffraction grating is $6.7 \times 10^5\,m^{-1}$.

(i) Determine the wavelength of the light.

wavelength = ... m [2]

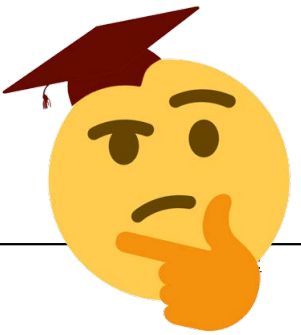


(ii) State and explain the change, if any, to the distance between the second order maximum spots on the screen when the light from the laser is replaced by light of a shorter wavelength.

.....

.....

.....[1]



21 – (9702/21_Summer_2020_Q4) – *Waves, Superposition*

(a) **(i)** By reference to the direction of propagation of energy, state what is meant by a *longitudinal* wave.

.....

..... [1]

(ii) State the principle of superposition.

.....

.....

..... [2]

(b) The wavelength of light from a laser is determined using the apparatus shown in Fig. 4.1.

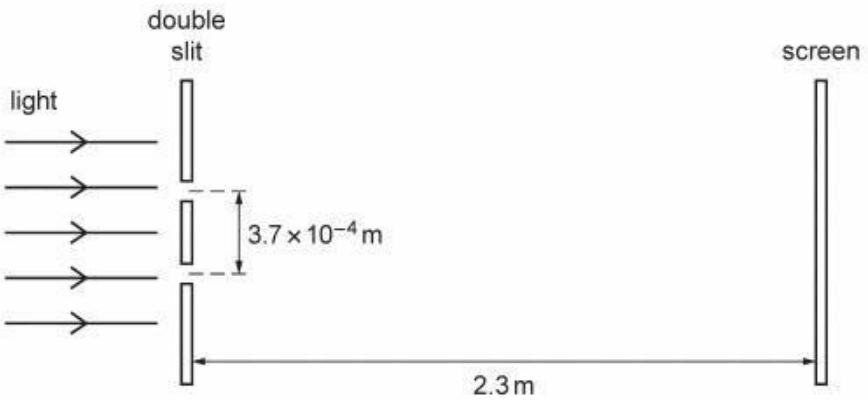


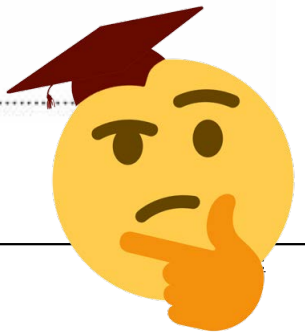
Fig. 4.1 (not to scale)

The light from the laser is incident normally on the plane of the double slit.
The separation of the two slits is 3.7×10^{-4} m. The screen is parallel to the plane of the double slit. The distance between the screen and the double slit is 2.3 m.

A pattern of bright fringes and dark fringes is seen on the screen. The separation of adjacent bright fringes on the screen is 4.3×10^{-3} m.

(i) Calculate the wavelength, in nm, of the light.

wavelength = ...



(ii) The intensity of the light passing through each slit was initially the same. The intensity of the light through **one** of the slits is now reduced.

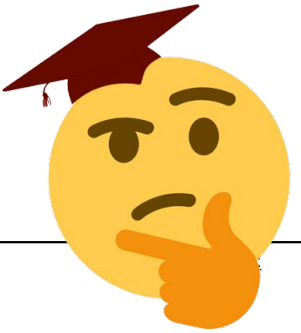
Compare the appearance of the fringes before and after the change of intensity.

.....

.....

.....

..... [2]



22 – (9702/22_Summer_2020_Q4) – *Waves, Superposition*

(a) State the difference between progressive waves and stationary waves in terms of the transfer of energy along the wave.

.....

..... [1]

(b) A progressive wave travels from left to right along a stretched string. Fig. 4.1 shows part of the string at one instant.

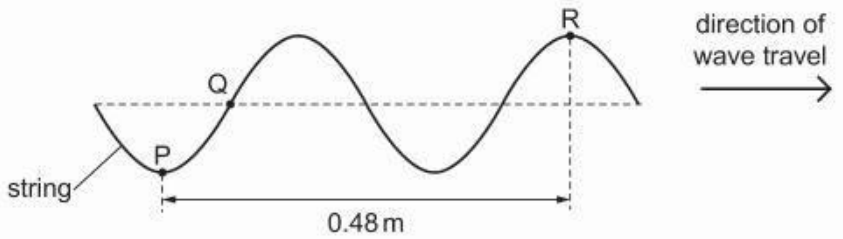


Fig. 4.1

P, Q and R are three different points on the string. The distance between P and R is 0.48 m. The wave has a period of 0.020 s.

(i) Use Fig. 4.1 to determine the wavelength of the wave.

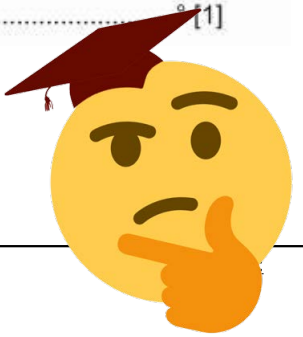
wavelength = ... m [1]

(ii) Calculate the speed of the wave.

speed = ... $m\,s^{-1}$ [2]

(iii) Determine the phase difference between points Q and R.

phase difference = ... ° [1]



(iv) Fig. 4.1 shows the position of the string at time $t = 0$. Describe how the displacement of point Q on the string varies with time from $t = 0$ to $t = 0.010$ s.

.....

.....

.....

..... [2]

(c) A stationary wave is formed on a different string that is stretched between two fixed points X and Y. Fig. 4.2 shows the position of the string when each point is at its maximum displacement.

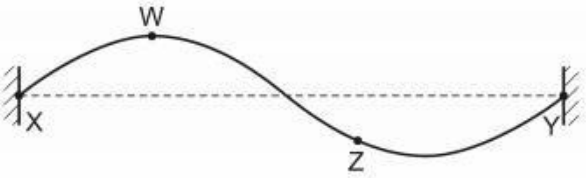


Fig. 4.2

(i) Explain what is meant by a *node* of a stationary wave.

..... [1]

(ii) State the number of antinodes of the wave shown in Fig. 4.2.

number = ... [1]

(iii) State the phase difference between points W and Z on the string.

phase difference = ...° [1]

(iv) A new stationary wave is now formed on the string. The new wave has a frequency that is half of the frequency of the wave shown in Fig. 4.2. The speed of the wave is unchanged.

On Fig. 4.3, draw a position of the string, for this new wave, when each point is at its maximum displacement.

Fig. 4.3

[1]

23 – (9702/23_Summer_2020_Q4) – *Waves*

Two progressive sound waves Y and Z meet at a fixed point P. The variation with time t of the displacement x of each wave at point P is shown in Fig. 4.1.

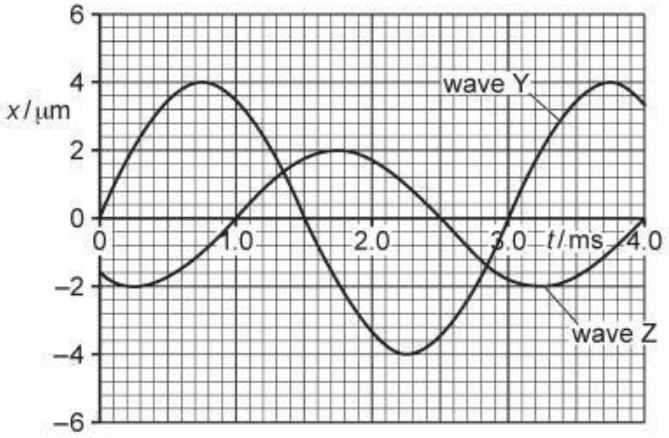


Fig. 4.1

(a) Use Fig. 4.1 to state **one** quantity of waves Y and Z that is:

(i) the same

..... [1]

(ii) different.

..... [1]

(b) State and explain whether waves Y and Z are coherent.

.....

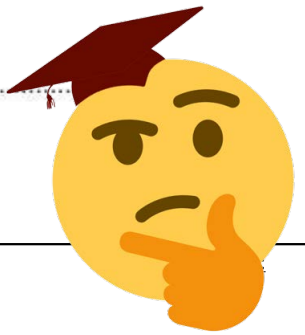
..... [1]

(c) Determine the phase difference between the waves.

phase difference = ... ° [1]

(d) The two waves superpose at P. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.75\,\text{ms}$.

resultant displacement = ...



(e) The intensity of wave Y at point P is I.

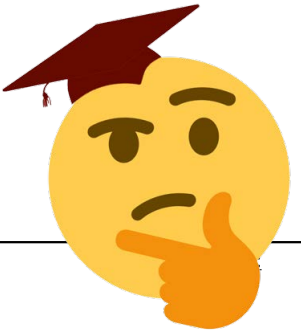
Determine, in terms of I, the intensity of wave Z.

intensity = ... [2]

(f) The speed of wave Z is $330\,\mathrm{m\,s^{-1}}$.

Determine the wavelength of wave Z.

wavelength = ... m [3]



24 - (9702/21_Winter_2020_Q5) - *Waves*

A progressive wave Y passes a point P. The variation with time t of the displacement x for the wave at P is shown in Fig. 5.1.

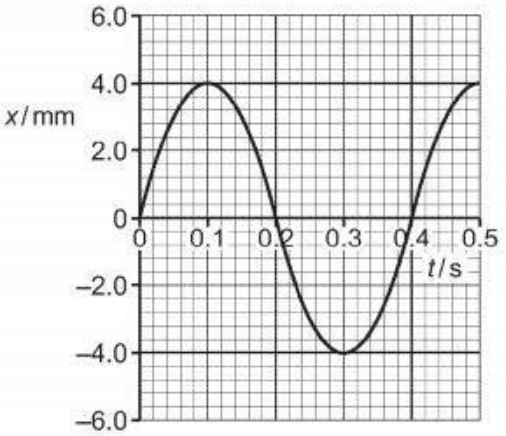


Fig. 5.1

The wave has a wavelength of 8.0 cm.

(a) Determine the speed of the wave.

speed = ... $m\,s^{-1}$ [2]

(b) A second wave Z has wavelength 8.0 cm and amplitude 2.0 mm at point P. Waves Y and Z have the same speed.

For the waves at point P, calculate the ratio

$$\frac{\text{intensity of wave Z}}{\text{intensity of wave Y}}.$$

ratio = ... [3]

[Total: 5]

25 - (9702/22_Winter_2020_Q5) - *Waves, Superposition*

Microwaves with the same wavelength and amplitude are emitted in phase from two sources X and Y, as shown in Fig. 5.1.

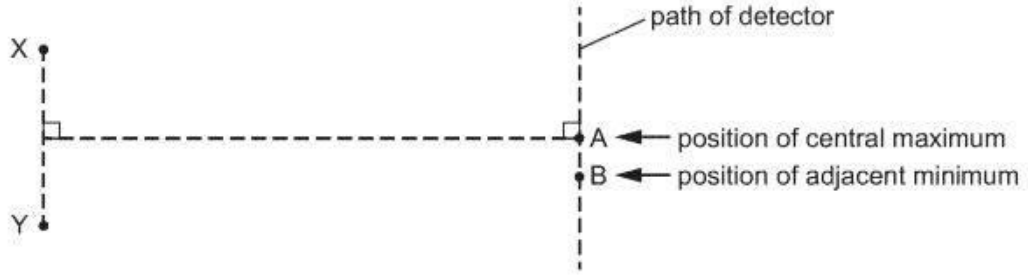


Fig. 5.1 (not to scale)

A microwave detector is moved along a path parallel to the line joining X and Y. An interference pattern is detected. A central intensity maximum is located at point A and there is an adjacent intensity minimum at point B. The microwaves have a wavelength of 0.040 m.

(a) Calculate the frequency, in GHz, of the microwaves.

frequency = ... GHz [3]

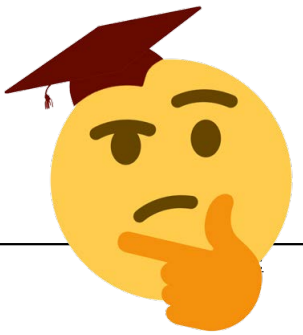
(b) For the waves arriving at point B, determine:

(i) the path difference

path difference = ... m [1]

(ii) the phase difference.

phase difference = ...° [1]



(c) The amplitudes of the waves from the sources are changed. This causes a change in the amplitude of the waves arriving at point A. At this point, the amplitude of the wave arriving from source X is doubled and the amplitude of the wave arriving from source Y is also doubled.

Describe the effect, if any, on the intensity of the central maximum at point A.

.....

.....

..... [2]

(d) Describe the effect, if any, on the positions of the central intensity maximum and the adjacent intensity minimum due to the following separate changes.

(i) The separation of the sources X and Y is increased.

.....

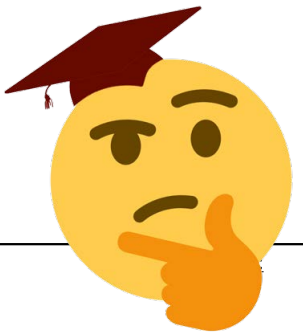
..... [1]

(ii) The phase difference between the microwaves emitted by the sources X and Y changes to 180°.

.....

..... [1]

[Total: 9]



26 – (9702/23_Winter_2020_Q5) – *Waves, Superposition*

(a) A sound wave is detected by a microphone that is connected to a cathode-ray oscilloscope (CRO). The trace on the screen of the CRO is shown in Fig. 5.1.

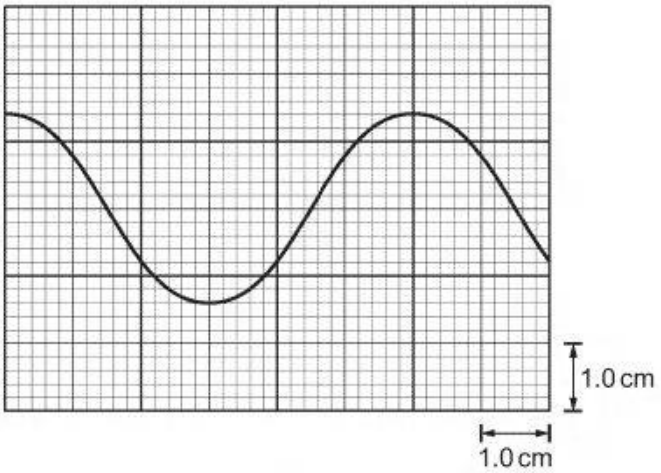


Fig. 5.1

The time-base setting of the CRO is $2.0 \times 10^{-5}\,\text{s cm}^{-1}$.

(i) Determine the frequency of the sound wave.

frequency = ... Hz [2]

(ii) The intensity of the sound wave is now doubled. The frequency is unchanged. Assume that the amplitude of the trace is proportional to the amplitude of the sound wave.

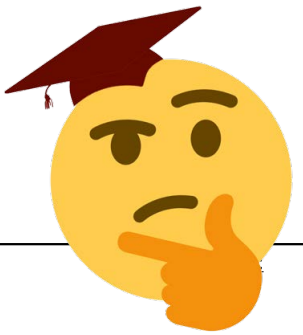
On Fig. 5.1, sketch the new trace shown on the screen. [2]

(iii) The time-base is now switched off.

Describe the trace seen on the screen.

.....

..... [1]



(b) A beam of light of a single wavelength is incident normally on a diffraction grating, as illustrated in Fig. 5.2.

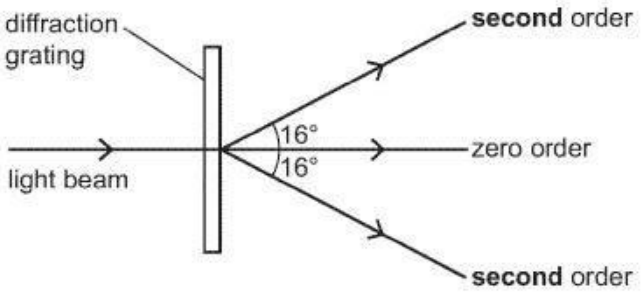


Fig. 5.2 (not to scale)

Fig. 5.2 does not show all of the emerging beams from the grating. The angle between the **second**-order emerging beam and the central zero-order beam is 16°. The grating has a line spacing of 3.4×10^{-6} m.

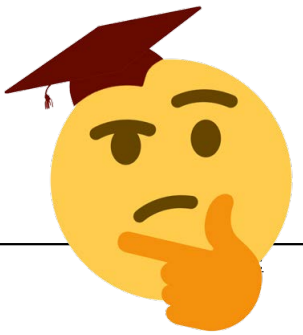
(i) Calculate the wavelength of the light.

wavelength = ... m [2]

(ii) Determine the highest order of emerging beam from the grating.

highest order = ... [2]

[Total: 9]



27 – (9702/21_Summer_2021_Q4) – *Waves, Superposition*

(a) For a progressive wave, state what is meant by *wavelength*.

.....

..... [1]

(b) A light wave from a laser has a wavelength of 460 nm in a vacuum.

Calculate the period of the wave.

period = ... s [3]

(c) The light from the laser is incident normally on a diffraction grating.

Describe the diffraction of the light waves at the grating.

.....

.....

..... [2]

(d) A diffraction grating is used with different wavelengths of visible light. The angle θ of the **fourth**-order maximum from the zero-order (central) maximum is measured for each wavelength. The variation with wavelength λ of $\sin\theta$ is shown in Fig. 4.1.

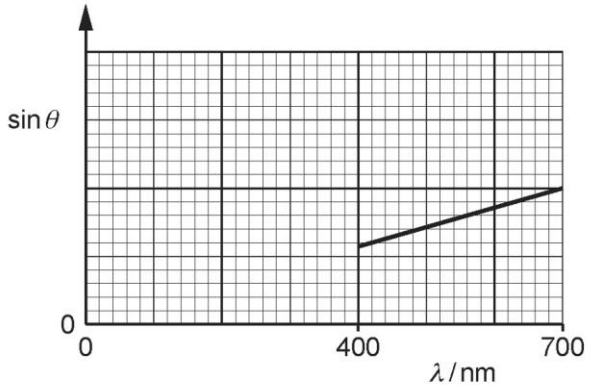
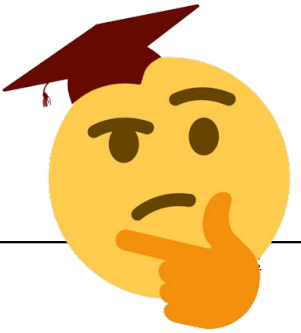


Fig. 4.1

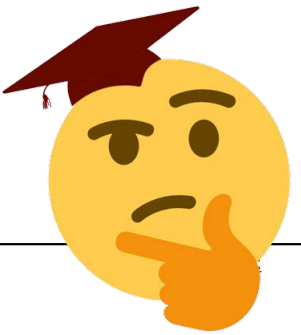


(i) The gradient of the graph is G.

Determine an expression, in terms of G, for the distance d between the centres of two adjacent slits in the diffraction grating.

d = ... [2]

(ii) On Fig. 4.1, sketch a graph to show the results that would be obtained for the **second**-order maxima. [2]



28 – (9702/22_Summer_2021_Q4) – *Waves, Superposition*

(a) For a progressive wave, state what is meant by its *period*.

.....

..... [1]

(b) State the principle of superposition.

.....

.....

..... [2]

(c) Electromagnetic waves of wavelength 0.040 m are emitted in phase from two sources X and Y and travel in a vacuum. The arrangement of the sources is shown in Fig. 4.1.

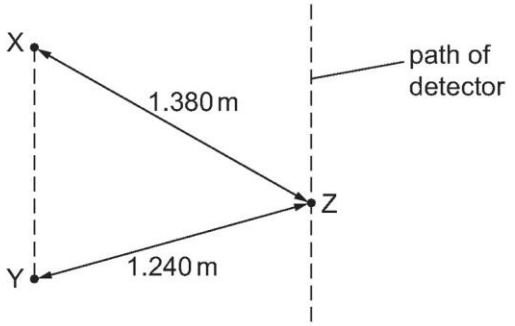


Fig. 4.1 (not to scale)

A detector moves along a path that is parallel to the line XY. A pattern of intensity maxima and minima is detected.

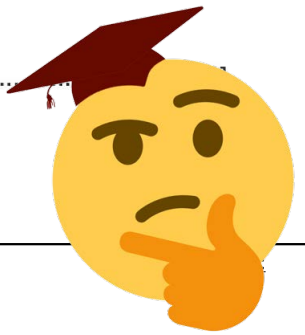
Distance XZ is 1.380 m and distance YZ is 1.240 m.

(i) State the name of the region of the electromagnetic spectrum that contains the waves from X and Y.

..... [1]

(ii) Calculate the period, in ps, of the waves.

period = ...



(iii) Show that the path difference at point Z between the waves from X and Y is 3.5 λ, where λ is the wavelength of the waves.

[1]

(iv) Calculate the phase difference between the waves at point Z.

phase difference = ...° [1]

(v) The waves from X alone have the same amplitude at point Z as the waves from Y alone.

State the intensity of the waves at point Z.

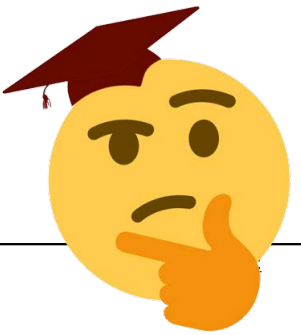
..... [1]

(vi) The frequencies of the waves from X and Y are both decreased to the same lower value. The waves stay within the same region of the electromagnetic spectrum.

Describe the effect of this change on the pattern of intensity maxima and minima along the path of the detector.

.....

..... [1]



29 – (9702/21_Winter_2021_Q4) – *Waves*

(a) By reference to the direction of transfer of energy, state what is meant by a *longitudinal* wave.

.....

..... [1]

(b) A vehicle travels at constant speed around a wide circular track. It continuously sounds its horn, which emits a single note of frequency 1.2 kHz. An observer is a large distance away from the track, as shown in the view from above in Fig. 4.1.

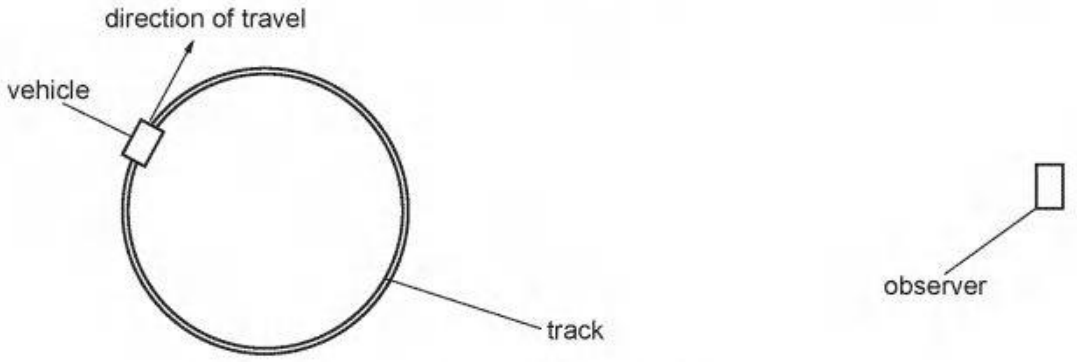


Fig. 4.1 (not to scale)

Fig. 4.2 shows the variation with time of the frequency *f* of the sound of the horn that is detected by the observer. The time taken for the vehicle to travel once around the track is *T*.

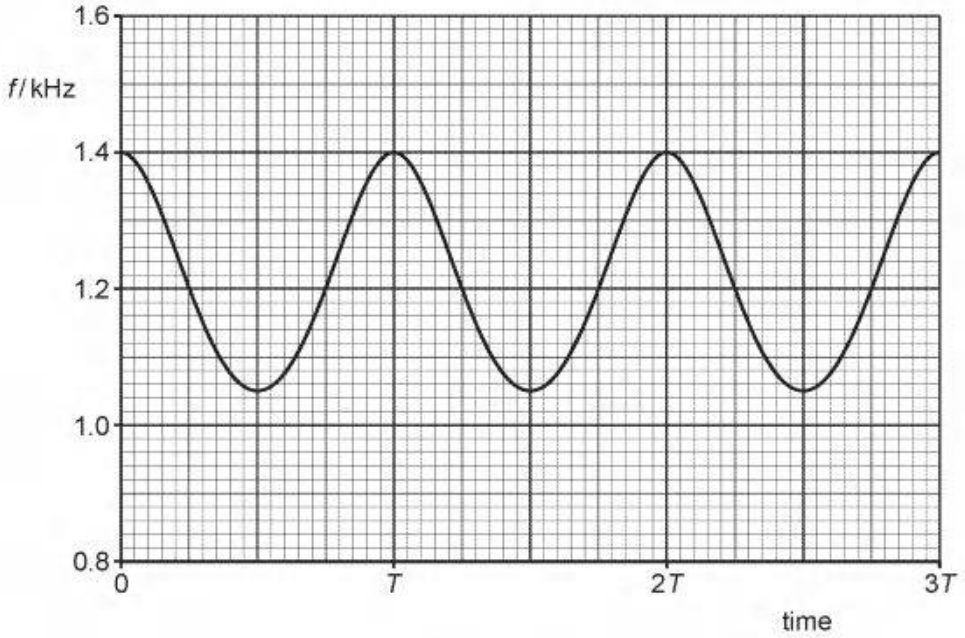


Fig. 4.2

(i) Explain why the frequency of the sound detected by the observer is sometimes above and sometimes below 1.2 kHz.

.....

.....

.....

..... [2]

(ii) State the name of the phenomenon in **(b)(i)**.

..... [1]

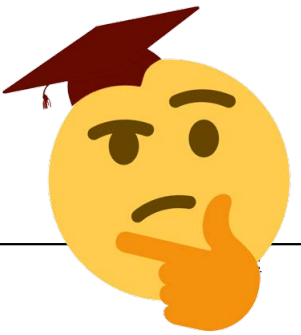
(iii) On Fig. 4.1, mark with a letter X the position of the vehicle when it emitted the sound that is detected at time *T*. [1]

(iv) On Fig. 4.1, mark with a letter Y the position of the vehicle when it emitted the sound that is detected at time $\frac{9T}{4}$. [1]

(c) The speed of the sound in the air is $320\,\mathrm{m\,s^{-1}}$.

Use Fig. 4.2 to determine the speed of the vehicle in **(b)**.

speed = ... $\mathrm{m\,s^{-1}}$ [3]



30 – (9702/22_Winter_2021_Q4) – *Waves*

A child sits on the ground next to a remote-controlled toy car. At time $t = 0$, the car begins to move in a straight line directly away from the child. The variation with time t of the velocity of the car along this line is shown in Fig. 4.1.

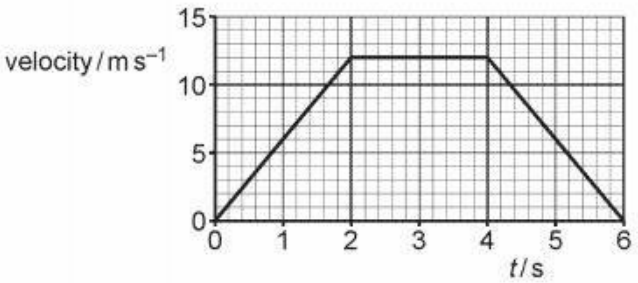


Fig. 4.1

The car's horn continually emits sound of frequency 925 Hz between time $t = 0$ and time $t = 6.0$ s. The speed of the sound in the air is $338\,\text{m s}^{-1}$.

(a) Describe qualitatively the variation, if any, in the frequency of the sound heard, by the child, that was emitted from the car horn:

(i) from time $t = 0$ to time $t = 2.0$ s

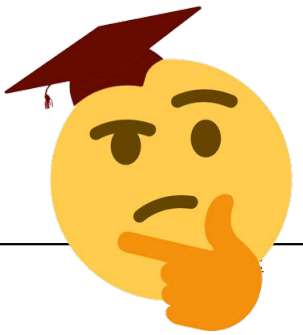
..... [1]

(ii) from time $t = 4.0$ s to time $t = 6.0$ s.

..... [1]

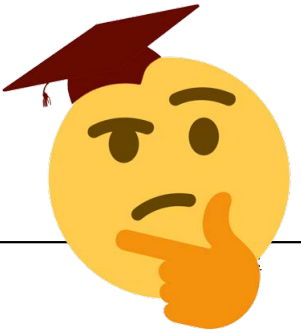
(b) Determine the frequency, to three significant figures, of the sound heard, by the child, that was emitted from the car horn at time $t = 3.0$ s.

frequency = ... Hz [2]



(c) Determine the time taken for the sound emitted at time $t = 4.0\,\text{s}$ to travel to the child.

time taken = ... s [2]



31 - (9702/23_Winter_2021_Q5) - *Waves*

(a) For a progressive wave on a stretched string, state what is meant by *amplitude*.

.....

..... [1]

(b) Light from a laser has a wavelength of 690 nm in a vacuum.

Calculate the period of the light wave.

period = ... s [3]

(c) A two-source interference experiment uses the arrangement shown in Fig. 5.1.

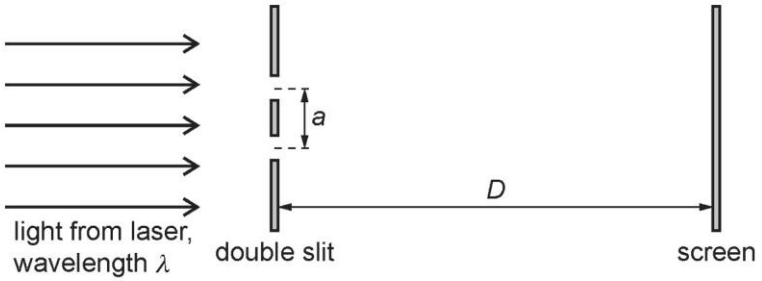
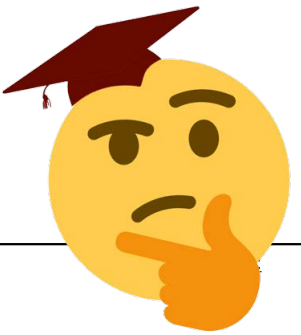


Fig. 5.1 (not to scale)

Light from a laser is incident normally on a double slit. A screen is parallel to the double slit.

Interference fringes are seen on the screen at distance *D* from the double slit. The separation of the centres of the slits is *a*. The light has wavelength λ.

The separation *x* of the centres of adjacent bright fringes is measured for different values of distance *D*.



The variation with D of x is shown in Fig. 5.2.

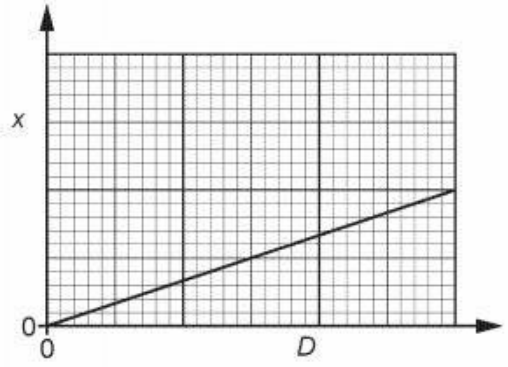


Fig. 5.2

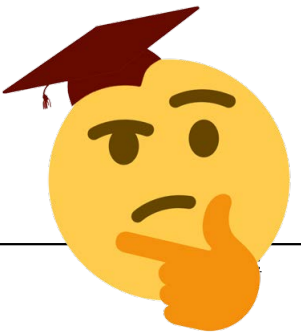
The gradient of the graph is G.

(i) Determine an expression, in terms of G and λ, for the separation a of the slits.

a = ... [2]

(ii) The experiment is repeated with slits of separation $2a$. The wavelength of the light is unchanged.

On Fig. 5.2, sketch a graph to show the results of this experiment. [2]



32 – (9702/21_Winter_2022_Q4) – *Waves*

(a) Polarisation is a phenomenon associated with light waves but not with sound waves.

(i) State the meaning of polarisation.

.....

.....

..... [1]

(ii) State why light waves can be plane polarised but sound waves cannot.

.....

.....

..... [1]

(b) Two polarising filters A and B are positioned so that their planes are parallel to each other and perpendicular to a central axis line XY, as shown in Fig. 4.1.

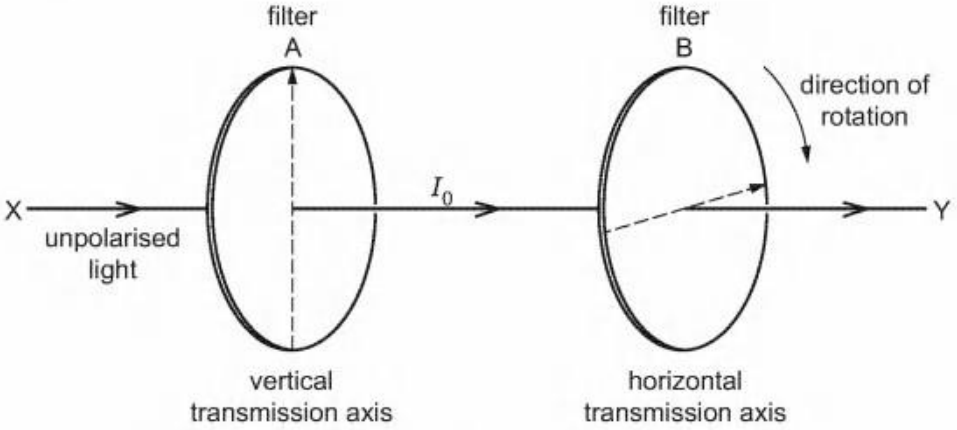


Fig. 4.1

The transmission axis of filter A is vertical and the transmission axis of filter B is horizontal.

Unpolarised light of a single frequency is directed along the line XY from a source positioned at X. The light emerging from filter A is vertically plane polarised and has intensity I_0.

Filter B is rotated from its starting position about the line XY, as shown in Fig. 4.1.

After rotation, the intensity of the light emerging from filter B is $\frac{1}{4} I_0$.

Calculate the angle of rotation of filter B from its starting position.

angle of rotation = ... ° [3]

(c) A microwave of intensity I_0 and amplitude A_0 meets another microwave of the same frequency and of intensity $\frac{1}{4} I_0$ travelling in the opposite direction. Both microwaves are vertically plane polarised and superpose where they meet.

(i) Explain, without calculation, why these two waves cannot form a stationary wave with zero amplitude at its nodes.

.....

.....

..... [2]

(ii) Determine, in terms of A_0, the maximum amplitude of the wave formed.

maximum amplitude = ... A_0 [3]

33 - (9702/23_Winter_2022_Q4) - *Waves*

(a) A progressive longitudinal wave travels through a medium from left to right. Fig. 4.1 shows the positions of some of the particles of the medium at time t_0 and a graph showing the particle displacements at the same time t_0.

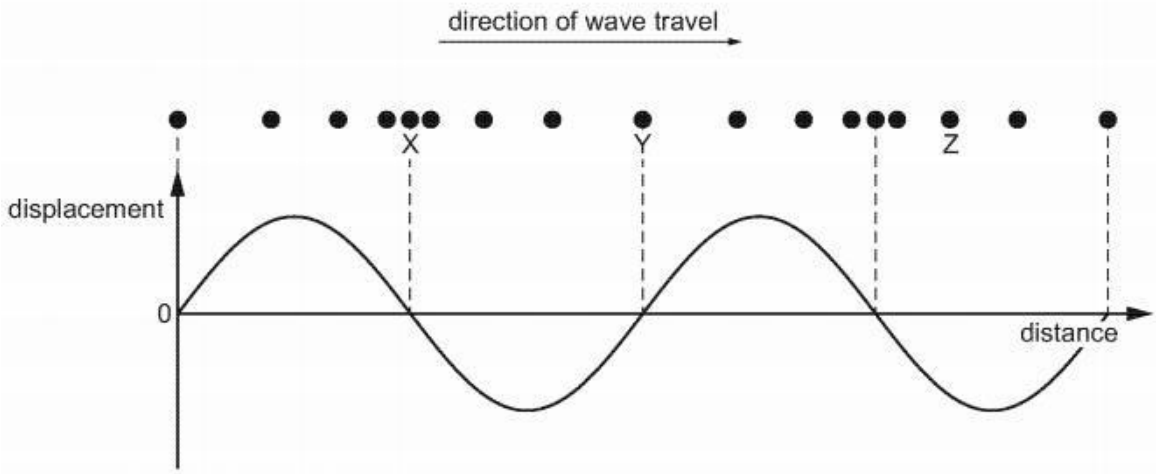


Fig. 4.1

Particle displacements to the right of their equilibrium positions are shown as positive on the graph and particle displacements to the left are shown as negative on the graph.

The period of the wave is T.

(i) On Fig. 4.1, draw circles around two particles which are exactly one wavelength apart. [1]

(ii) On Fig. 4.1, sketch a line on the graph to represent the displacements of the particles for the longitudinal wave at time $t_0 + \frac{T}{4}$. [3]

(iii) State the direction of motion of particle Z at time $t_0 + \frac{T}{4}$.

..... [1]

(b) The frequency of the wave in **(a)** is 16 kHz. The distance between particles X and Y is 0.19 m.

Calculate the speed of the wave as it travels through the medium.

speed = ... $m\,s^{-1}$ [3]

(c) A longitudinal sound wave is travelling through a solid. The initial intensity of the wave is I_0. The frequency of the wave remains constant and the amplitude falls to half of its original value.

Determine, in terms of I_0, the final intensity of the wave.

intensity = ... I_0 [2]

(d) The sound wave in **(c)** now meets another sound wave travelling in the opposite direction.

(i) State a condition necessary for these two waves to form a stationary wave.

..... [1]

(ii) State **two** ways in which a stationary wave differs from a progressive wave.

1 .....

.....

2 .....

.....

[2]

34 - (9702/22_Winter_2022_Q5) - *Waves*

(a) Two progressive sound waves meet to form a stationary wave. The two waves have the same amplitude, wavelength, frequency and speed.

State the other condition that must be fulfilled by the two waves in order for them to produce the stationary wave.

..... [1]

(b) A stationary wave is formed on a string that is stretched between two fixed points A and B. Fig. 5.1 shows the string at time t = 0 when each point is at its maximum displacement.

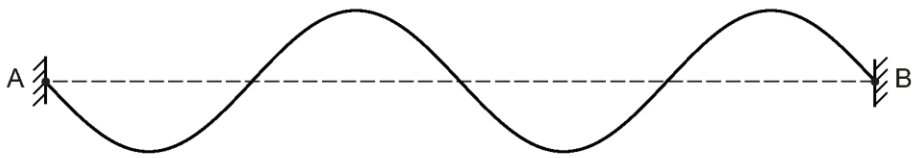


Fig. 5.1

Distance AB is 0.80 m. The period of the stationary wave is 0.016 s.

(i) On Fig. 5.1, sketch a solid line to show the position of the string:

- at time t = 0.004 s (label this line P)
- at time t = 0.024 s (label this line Q).

[2]

(ii) Determine the speed of a progressive wave along the string.

speed = ... m s^{-1} [3]

(c) A beam of vertically polarised light of intensity I_0 is incident normally on a polarising filter that has its transmission axis at 30° to the vertical, as shown in Fig. 5.2.

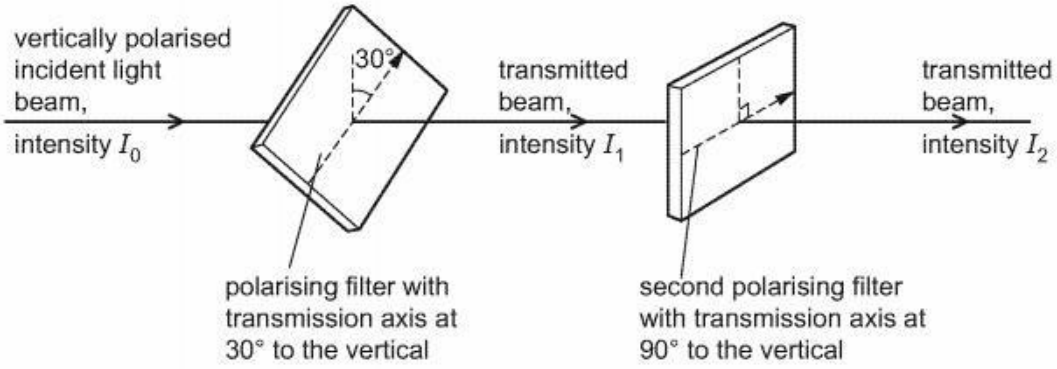


Fig. 5.2

The transmitted light from the first polarising filter has intensity I_1. This light is then incident normally on a second polarising filter that has its transmission axis at 90° to the vertical. The transmitted light from the second filter has intensity I_2.

Calculate:

(i) the ratio $\frac{I_1}{I_0}$

$\frac{I_1}{I_0}$ = ... [2]

(ii) the ratio $\frac{I_2}{I_0}$.

$\frac{I_2}{I_0}$ = ... [2]

35 – (9702/22_Summer_2023_Q5) – *Waves*

(a) A progressive wave travels through a medium. The wave causes a particle of the medium to vibrate along a line P. The energy of the wave propagates along a line Q.

Compare the directions of lines P and Q if the wave is:

(i) a transverse wave

..... [1]

(ii) a longitudinal wave.

..... [1]

(b) A tube is closed at one end. A loudspeaker is placed near the other end of the tube, as shown in Fig. 5.1.

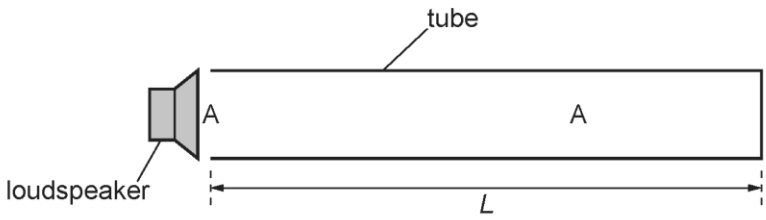


Fig. 5.1 (not to scale)

The loudspeaker emits sound of frequency 1.7 kHz. The speed of sound in the air in the tube is 340 m s^{-1}. A stationary wave is formed with an antinode A at the open end of the tube. There is only one other antinode A inside the tube, as shown in Fig. 5.1.

Determine:

(i) the wavelength of the sound

wavelength = ... m [2]

(ii) the length *L* of the tube

L = ... m [1]

(iii) the maximum wavelength of the sound from the loudspeaker that can produce a stationary wave in the tube.

maximum wavelength = ... m [1]

(c) Two polarising filters are arranged so that their planes are vertical and parallel. The first filter has its transmission axis at an angle of 35° to the vertical and the second filter has its transmission axis at angle α to the vertical, as shown in Fig. 5.2.

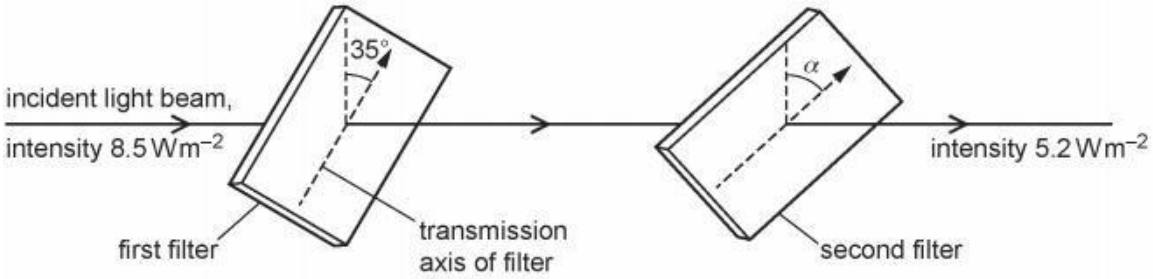


Fig. 5.2

Angle α is greater than 35° and less than 90°. A beam of vertically polarised light of intensity 8.5 W m^{-2} is incident normally on the first filter.

(i) Show that the intensity of the light transmitted by the first filter is 5.7 W m^{-2}.

[1]

(ii) The intensity of the light transmitted by the second filter is 5.2 W m^{-2}.

Calculate angle α.

α = ... ° [2]

36 - (9702/23_Summer_2023_Q4) - *Waves*

(a) For a progressive wave, state what is meant by the frequency.

.....

..... [1]

(b) A loudspeaker, microphone and cathode-ray oscilloscope (CRO) are arranged as shown in Fig. 4.1.

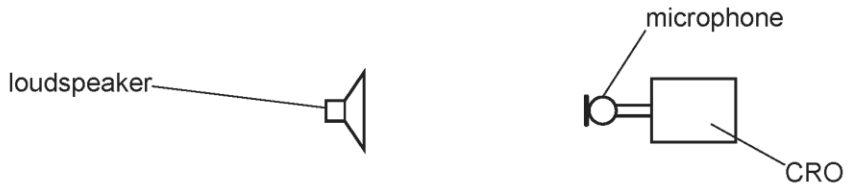


Fig. 4.1

The loudspeaker is emitting a sound wave which is detected by the microphone and displayed on the screen of the CRO as shown in Fig. 4.2.

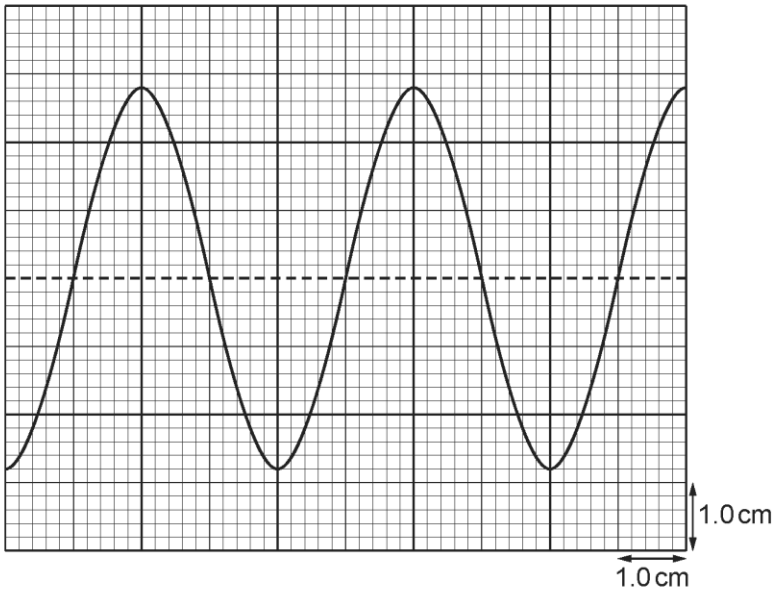


Fig. 4.2

The time-base on the CRO is set to 0.50 ms cm^{-1} and the *y*-gain is set to 0.20 V cm^{-1}.

Calculate:

(i) the frequency of the sound wave

frequency = ... Hz [2]

(ii) the amplitude of the signal received by the CRO.

amplitude = ... V [1]

(c) The intensity of the sound wave in **(b)** is reduced to a quarter of its original intensity without a change in frequency. Assume that the amplitude of the signal received by the CRO is proportional to the amplitude of the sound wave.

On Fig. 4.2, sketch the trace that is now seen on the screen of the CRO. [3]

(d) A metal sheet is now placed in front of the loudspeaker in **(b)**, as shown in Fig. 4.3.

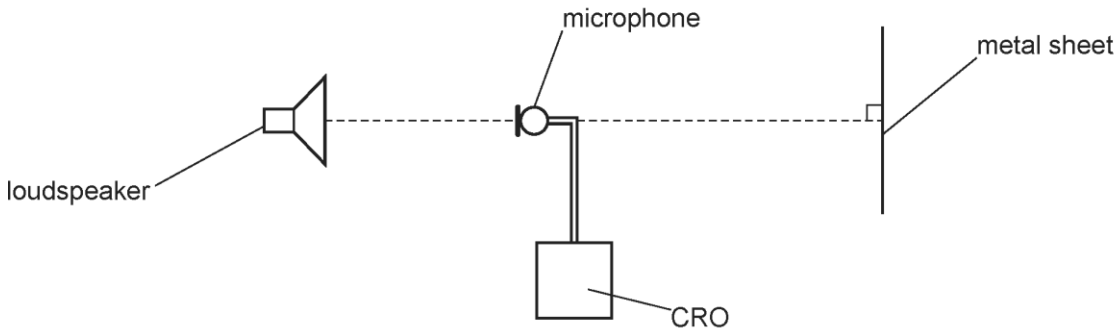


Fig. 4.3

A stationary wave is formed between the loudspeaker and the metal sheet.

(i) State the principle of superposition.

.....

.....

..... [2]

(ii) The initial position of the microphone is such that the trace on the CRO has an amplitude minimum. It is now moved a distance of 1.05 m away from the loudspeaker along the line joining the loudspeaker and metal sheet.

As the microphone moves, it passes through three positions where the trace has an amplitude maximum before ending at a position where the trace has an amplitude minimum.

Determine the wavelength of the sound wave.

wavelength = ... m [2]

(iii) Use your answers in **(b)(i)** and **(d)(ii)** to determine the speed of the sound in the air.

speed = ... $m\,s^{-1}$ [2]

37 - (9702/21_Winter_2023_Q5) - *Waves*

A train travels at a constant high speed along a straight horizontal track towards an observer standing adjacent to the track, as shown in Fig. 5.1.

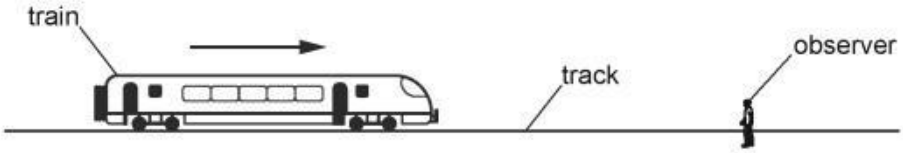


Fig. 5.1

The train sounds its horn continuously as it approaches the observer, from time $t = 0$ until it is well past the observer at time $t = t_2$. The train passes the observer at time $t = t_1$.
The horn emits a sound wave of constant frequency f_S.

(a) On Fig. 5.2, sketch the variation of the frequency of sound heard by the observer with time t, from time $t = 0$ to $t = t_2$.

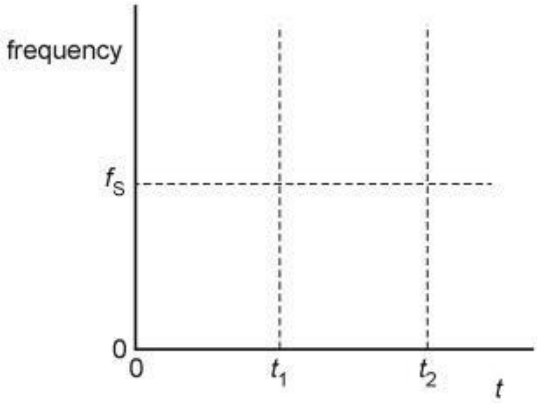


Fig. 5.2

[1]

(b) At a particular time, the sound waves at the observer have an intensity of $4.7 \times 10^{-3}\,\mathrm{W\,m^{-2}}$. The waves at the observer are incident at right angles on a circular detector of radius 2.8 cm.

Calculate the power P of the waves incident on the detector.

P = ... W [3]

38 - (9702/23_Winter_2023_Q5) - *Waves*

Two point sources, A and B, produce coherent electromagnetic waves. The waves from A and B are emitted in phase and have wavelength λ, as shown in Fig. 5.1.

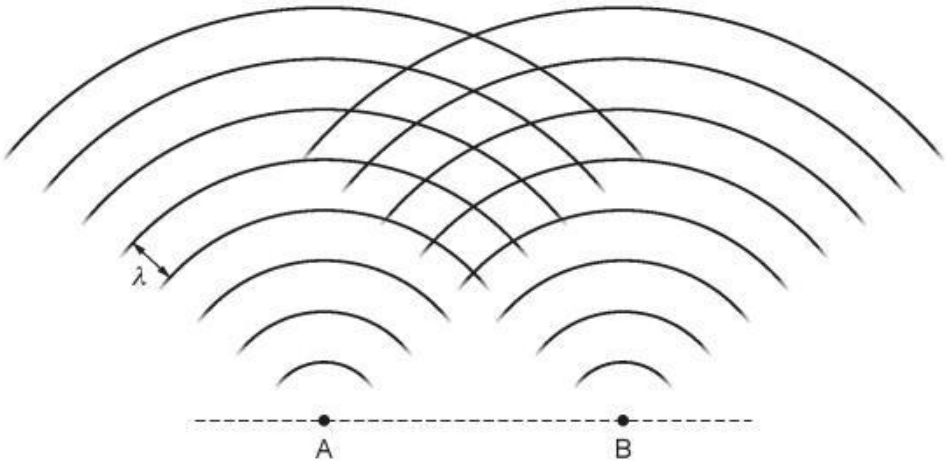


Fig. 5.1 (not to scale)

The lines on Fig. 5.1 represent wavefronts. All the points on a wavefront are in phase.

(a) On Fig. 5.1, mark with a cross (×):

(i) the position of an interference maximum (label this cross Y) [1]

(ii) the position of an interference minimum (label this cross Z). [1]

(b) The waves in air have a wavelength of 2.9×10^{-5} m.

An interference pattern is detected along a line parallel to AB and at a perpendicular distance of 140 m from AB. The spacing between adjacent interference maxima is 1.2 cm.

(i) Calculate the separation *a* of the sources A and B.

a = ... m [3]

(ii) State the principal region of the electromagnetic spectrum to which the waves belong.

..... [1]

1 - (9702/21_Summer_2017_Q4) - *Superposition*

(a) State the conditions required for the formation of stationary waves.

.....

.....

.....[2]

(b) One end of a string is attached to a vibrator. The string is stretched by passing the other end over a pulley and attaching a load, as illustrated in Fig. 4.1.

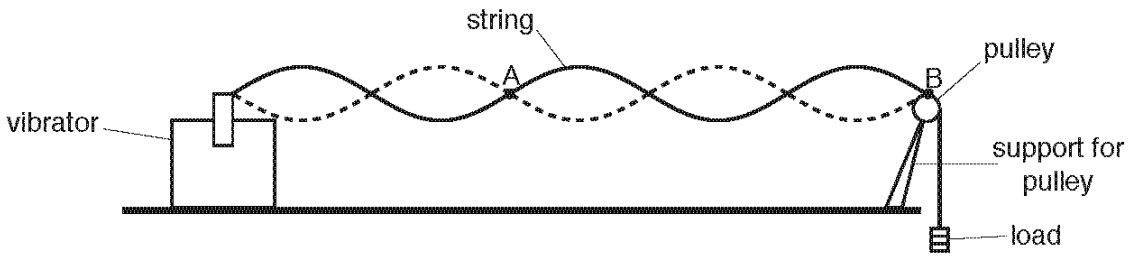


Fig. 4.1

The frequency of vibration of the vibrator is adjusted to 250 Hz and a transverse wave travels along the string with a speed of $12\,m\,s^{-1}$. The wave is reflected at the pulley and a stationary wave forms on the string.

Fig. 4.2 shows the string between points A and B at time $t = t_1$.

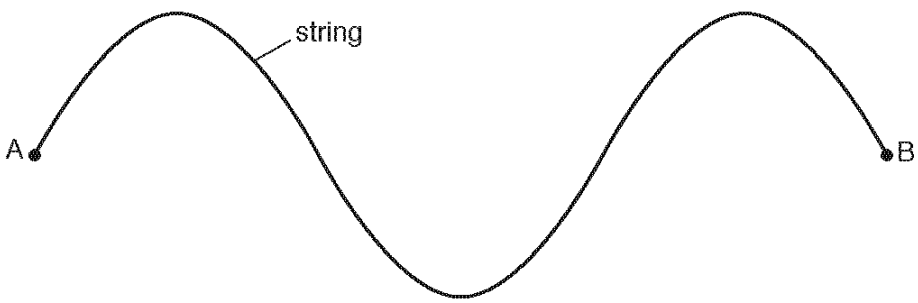


Fig. 4.2

At time $t = t_1$ the string has maximum displacement.

(i) Calculate the distance AB.

distance = ...m [2]

(ii) On Fig. 4.2, sketch the position of the string between A and B at times

1. $t = t_1 + 2.0\,\text{ms}$ (label this line P),

2. $t = t_1 + 5.0\,\text{ms}$ (label this line Q).

[3]

2 - (9702/22_Summer_2017_Q5) - *Waves, Superposition*

(a) Define the *frequency* of a sound wave.

.....

.....[1]

(b) A sound wave travels through air. Describe the motion of the air particles relative to the direction of travel of the sound wave.

.....

.....[1]

(c) The sound wave emitted from the horn of a stationary car is detected with a microphone and displayed on a cathode-ray oscilloscope (c.r.o.), as shown in Fig. 5.1.

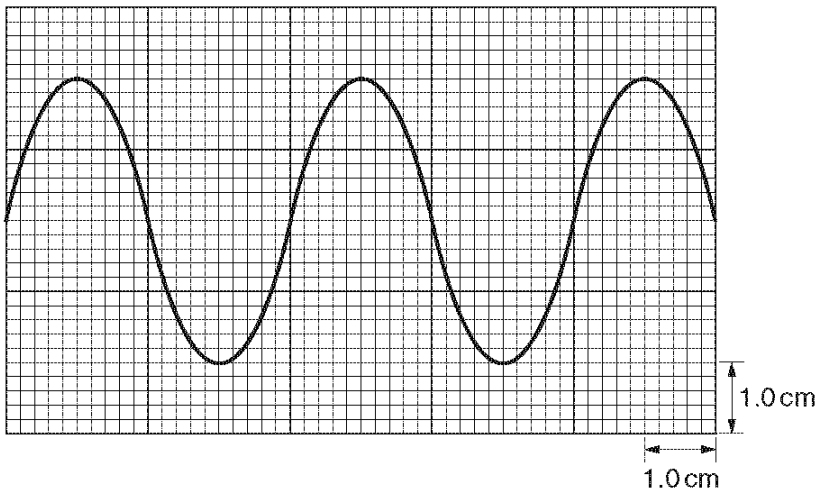


Fig. 5.1

The *y*-axis setting is $5.0\,mV\,cm^{-1}$.
The time-base setting is $0.50\,ms\,cm^{-1}$.

(i) Use Fig. 5.1 to determine the frequency of the sound wave.

frequency = ... Hz [2]

(ii) The horn of the car sounds continuously. Describe the changes to the trace seen on the c.r.o. as the car travels at constant speed

1. directly towards the stationary microphone,

.....

.....

2. directly away from the stationary microphone.

.....

.....

[3]

3 - (9702/23_Summer_2017_Q5) - *Superposition*

(a) A diffraction grating is used to determine the wavelength of light.

(i) Describe the diffraction of light at a diffraction grating.

.....

.....

.....[2]

(ii) By reference to interference, explain

1. the zero order maximum,

.....

.....

.....

2. the first order maximum.

.....

.....

[3]

(b) A diffraction grating is used with different wavelengths of light. The angle θ of the second order maximum is measured for each wavelength. The variation with wavelength λ of $\sin\theta$ is shown in Fig. 5.1.

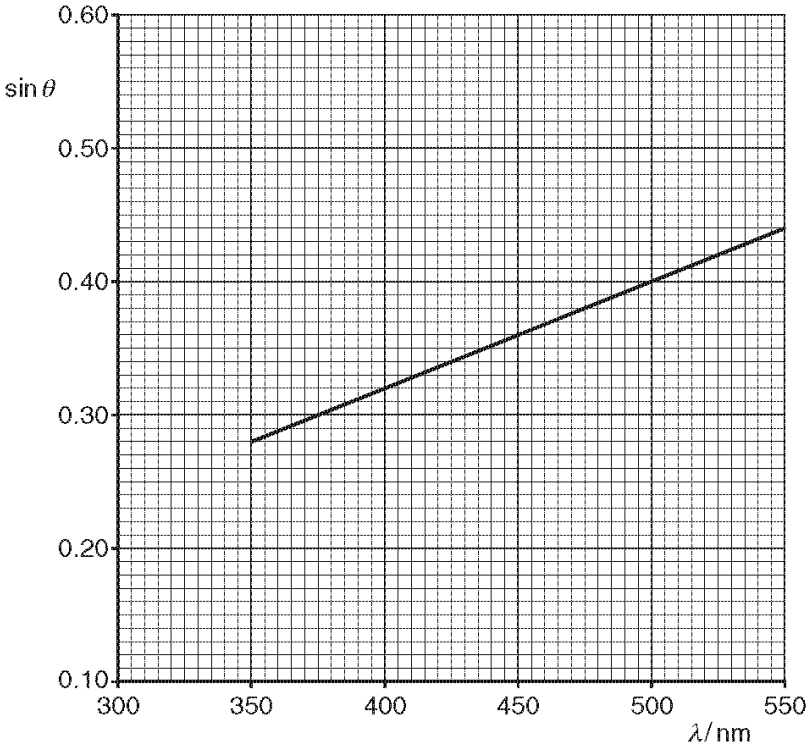


Fig. 5.1

(i) Determine the gradient of the line shown in Fig. 5.1.

gradient = ...[2]

(ii) Use the gradient determined in **(i)** to calculate the slit separation *d* of the diffraction grating.

d = ...m [2]

(iii) On Fig. 5.1, sketch a line to show the results that would be obtained for the first order maxima. [1]

4 - (9702/22_Summer_2017_Q6) - *Superposition*

(a) Interference fringes may be observed using a light-emitting laser to illuminate a double slit. The double slit acts as two sources of light.

Explain

(i) the part played by diffraction in the production of the fringes,

.....

.....

.....[2]

(ii) the reason why a double slit is used rather than two separate sources of light.

.....

.....

.....[1]

(b) A laser emitting light of a single wavelength is used to illuminate slits S_1 and S_2, as shown in Fig. 6.1.

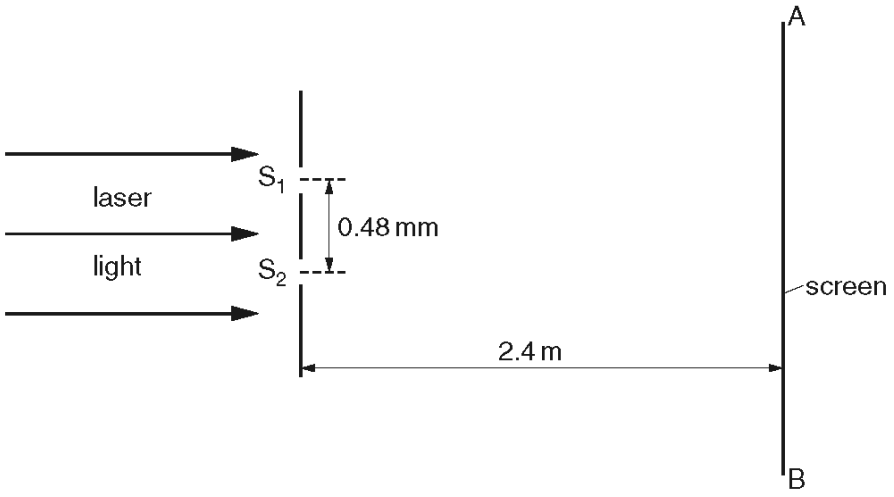


Fig. 6.1 (not to scale)

An interference pattern is observed on the screen AB. The separation of the slits is 0.48 mm. The slits are 2.4 m from AB. The distance on the screen across 16 fringes is 36 mm, as illustrated in Fig. 6.2.

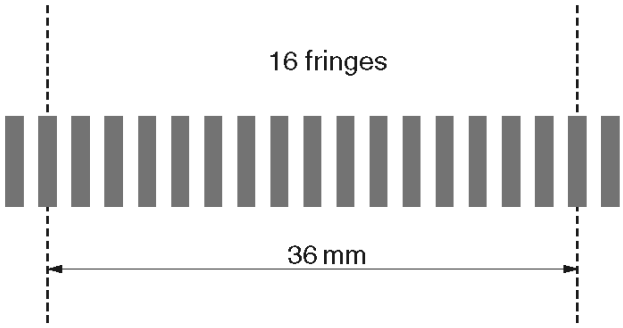


Fig. 6.2

Calculate the wavelength of the light emitted by the laser.

wavelength = ...m [3]

(c) Two dippers D_1 and D_2 are used to produce identical waves on the surface of water, as illustrated in Fig. 6.3.

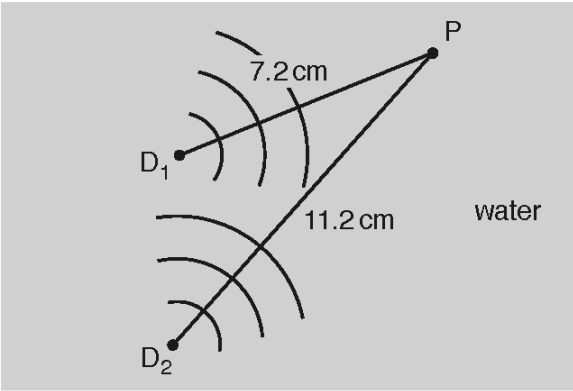


Fig. 6.3 (not to scale)

Point P is 7.2 cm from D_1 and 11.2 cm from D_2.

The wavelength of the waves is 1.6 cm. The phase difference between the waves produced at D_1 and D_2 is zero.

(i) State and explain what is observed at P.

.....

.....

.....[2]

(ii) State and explain the effect on the answer to **(c)(i)** if the apparatus is changed so that, separately,

1. the phase difference between the waves at D_1 and at D_2 is 180°,

.....

.....

.....

2. the intensity of the wave from D_1 is less than the intensity of that from D_2.

.....

.....

.....

[2]

5 - (9702/21_Winter_2017_Q3) - *Waves, Superposition*

(a) State the difference between a stationary wave and a progressive wave in terms of

(i) the energy transfer along the wave,

.....

.....[1]

(ii) the phase of two adjacent vibrating particles.

.....

.....[1]

(b) A tube is open at both ends. A loudspeaker, emitting sound of a single frequency, is placed near one end of the tube, as shown in Fig. 3.1.

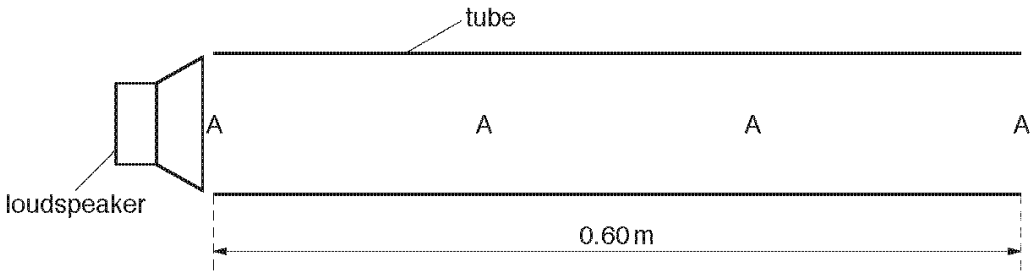


Fig. 3.1

The speed of the sound in the tube is $340\,m\,s^{-1}$. The length of the tube is 0.60 m.
A stationary wave is formed with an antinode A at each end of the tube and two antinodes inside the tube.

(i) State what is meant by an *antinode* of the stationary wave.

.....

.....[1]

(ii) State the distance between a node and an adjacent antinode.

distance = ... m [1]

(iii) Determine, for the sound in the tube,

1. the wavelength,

wavelength = ... m [1]

2. the frequency.

frequency = ... Hz [2]

(iv) Determine the minimum frequency of the sound from the loudspeaker that produces a stationary wave in the tube.

minimum frequency = ... Hz [2]

6 - (9702/22_Winter_2017_Q4) - *Waves, Superposition*

(a) State the conditions required for the formation of a stationary wave.

.....

.....

.....

.....[2]

(b) A horizontal string is stretched between two fixed points X and Y. The string is made to vibrate vertically so that a stationary wave is formed. At one instant, each particle of the string is at its maximum displacement, as shown in Fig. 4.1.

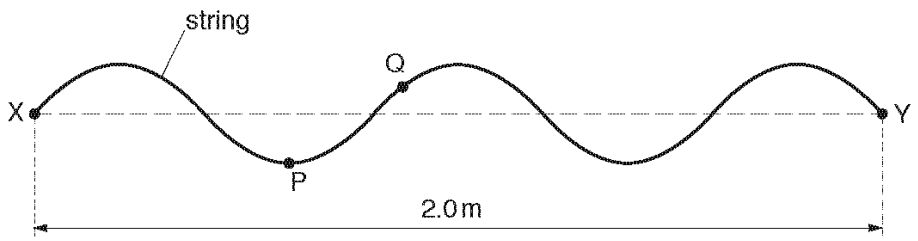


Fig. 4.1

P and Q are two particles of the string. The string vibrates with a frequency of 40 Hz. Distance XY is 2.0 m.

(i) State the number of antinodes in the stationary wave.

number = ...[1]

(ii) Determine the minimum time taken for the particle P to travel from its lowest point to its highest point.

time taken = ... s [2]

(iii) State the phase difference, with its unit, between the vibrations of particle P and of particle Q.

phase difference = ...[1]

(iv) Determine the speed of a progressive wave along the string.

speed = ...m s^{-1} [2]

7 - (9702/23_Winter_2017_Q4) - *Waves, Superposition*

(a) By reference to the direction of propagation of energy, explain what is meant by a *longitudinal* wave.

.....

.....[1]

(b) A car horn emits a sound wave of frequency 800 Hz. A microphone and a cathode-ray oscilloscope (c.r.o.) are used to analyse the sound wave. The waveform displayed on the c.r.o. screen is shown in Fig. 4.1.

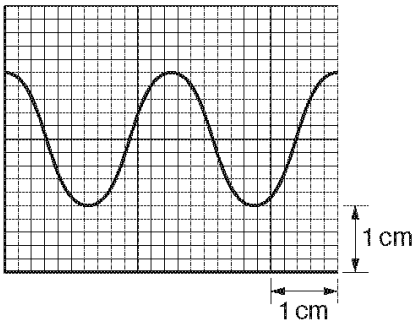


Fig. 4.1

Determine the time-base setting, in $s\,cm^{-1}$, of the c.r.o.

time-base setting = ... $s\,cm^{-1}$ [3]

(c) The intensity I of the sound at a distance r from the car horn in **(b)** is given by the expression

$$I = \frac{k}{r^2}$$

where k is a constant.

Fig. 4.2 shows the car in **(b)** on a road.

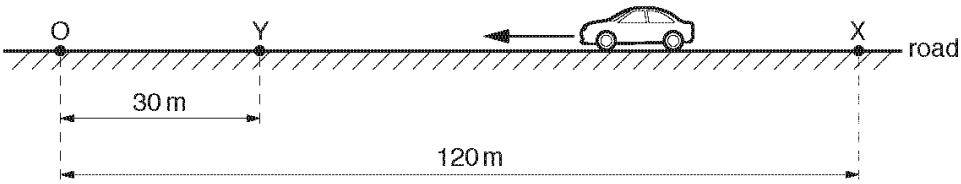


Fig. 4.2

An observer stands at point O. Initially the car is parked at point X which is 120 m away from point O. The car then moves directly towards the observer and stops at point Y, a distance of 30 m away from O.
The car horn continuously emits sound when the car is moving between points X and Y.

(i) The sound wave at point O has amplitude A_X when the car is at X and has amplitude A_Y when the car is at Y.

Calculate the ratio $\frac{A_Y}{A_X}$.

ratio = ... [3]

(ii) When the car is parked at X, the frequency of the sound from the horn that is detected by the observer is 800 Hz. As the car moves from X to Y, the maximum change in the detected frequency is 16 Hz. The speed of the sound in air is 330 m s^{-1}.

Determine, to two significant figures,

1. the minimum wavelength of the sound detected by the observer,

wavelength = ... m [2]

2. the maximum speed of the car.

speed = ... m s^{-1} [2]

8 - (9702/21_Summer_2018_Q4) - *Waves, Superposition*

(a) For a progressive wave, state what is meant by

(i) the *period*,

.....

.....[1]

(ii) the *wavelength.*

.....

.....[1]

(b) Fig. 4.1 shows the variation with time *t* of the displacement *x* of two progressive waves P and Q passing the same point.

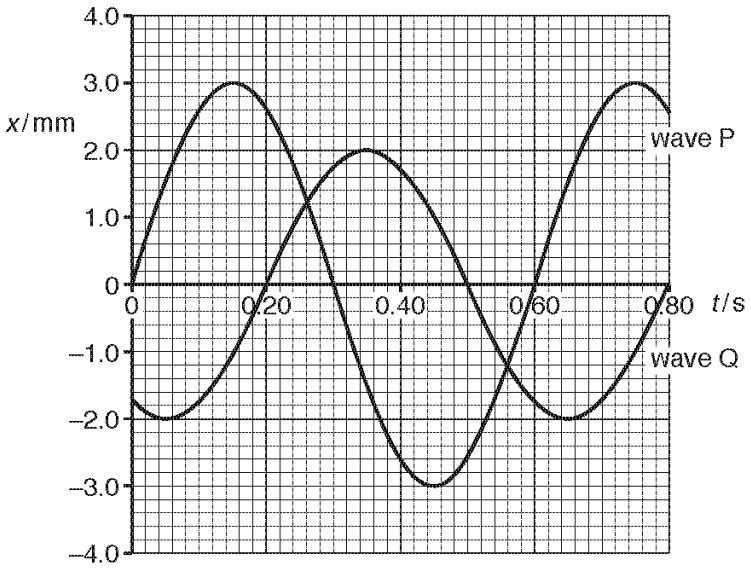


Fig. 4.1

The speed of the waves is $20\,cm\,s^{-1}$.

(i) Calculate the wavelength of the waves.

wavelength = ... cm [2]

(ii) Determine the phase difference between the two waves.

phase difference = ... ° [1]

(iii) Calculate the ratio

$$\frac{\text{intensity of wave Q}}{\text{intensity of wave P}}.$$

ratio = ... [2]

(iv) The two waves superpose as they pass the same point. Use Fig. 4.1 to determine the resultant displacement at time $t = 0.45$ s.

displacement = ... mm [1]

9 - (9702/22_Summer_2018_Q4) - *Waves, Superposition*

(a) **(i)** Define the *wavelength* of a progressive wave.

.....

.....[1]

(ii) State what is meant by an *antinode* of a stationary wave.

.....

.....[1]

(b) A loudspeaker producing sound of constant frequency is placed near the open end of a pipe, as shown in Fig. 4.1.

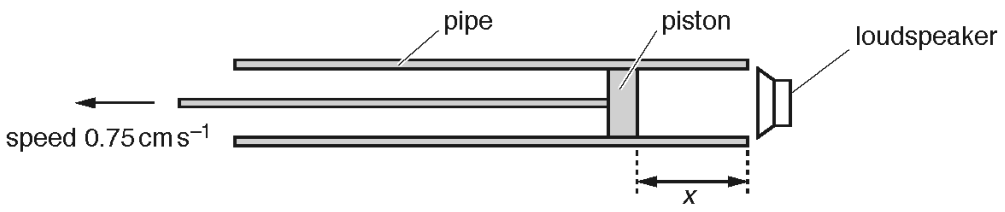


Fig. 4.1

A movable piston is at distance x from the open end of the pipe. Distance x is increased from $x = 0$ by moving the piston to the left with a constant speed of 0.75 cm s^{-1}.

The speed of the sound in the pipe is 340 m s^{-1}.

(i) A much louder sound is first heard when $x = 4.5$ cm. Assume that there is an antinode of a stationary wave at the open end of the pipe.

Determine the frequency of the sound in the pipe.

frequency = ... Hz [3]

(ii) After a time interval, a second much louder sound is heard. Calculate the time interval between the first louder sound and the second louder sound being heard.

time interval = ... s [2]

10 - (9702/21_Summer_2018_Q5) - *Waves, Superposition*

(a) When monochromatic light is incident normally on a diffraction grating, the emergent light waves have been diffracted and are coherent.

Explain what is meant by

(i) *diffracted* waves,

.....

.....[1]

(ii) *coherent* waves.

.....

.....[1]

(b) Light consisting of only two wavelengths λ_1 and λ_2 is incident normally on a diffraction grating.

The third order diffraction maximum of the light of wavelength λ_1 and the fourth order diffraction maximum of the light of wavelength λ_2 are at the same angle θ to the direction of the incident light.

(i) Show that the ratio $\frac{\lambda_2}{\lambda_1}$ is 0.75.

Explain your working.

[2]

(ii) The difference between the two wavelengths is 170 nm.

Determine wavelength λ_1.

λ_1 = ... nm [1]

11 - (9702/23_Summer_2018_Q5) - *Waves, Superposition*

(a) State the relationship between the intensity and the amplitude of a wave.

.....

.....[1]

(b) Microwaves of the same amplitude and wavelength are emitted in phase from two sources P and Q. The sources are arranged as shown in Fig. 5.1.

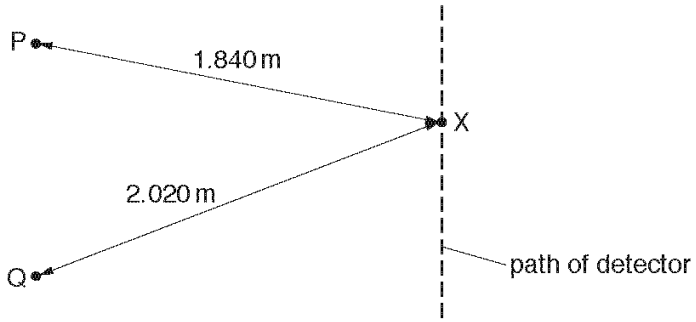


Fig. 5.1

A microwave detector is moved along a path that is parallel to the line joining P and Q. A series of intensity maxima and intensity minima are detected.

When the detector is at a point X, the distance PX is 1.840 m and the distance QX is 2.020 m. The microwaves have a wavelength of 6.0 cm.

(i) Calculate the frequency of the microwaves.

frequency = ... Hz [2]

(ii) Describe and explain the intensity of the microwaves detected at X.

.....

.....

.....

.....

.....[3]

(iii) Describe the effect on the interference pattern along the path of the detector due to each of the following separate changes.

1. The wavelength of the microwaves decreases.

.....

.....

2. The phase difference between the microwaves emitted from the sources changes to 180°.

.....

.....

[2]

12 - (9702/21_Winter_2018_Q4) - *Superposition*

(a) State the principle of superposition.

.....

.....

..... [2]

(b) An arrangement for demonstrating the interference of light is shown in Fig. 4.1.

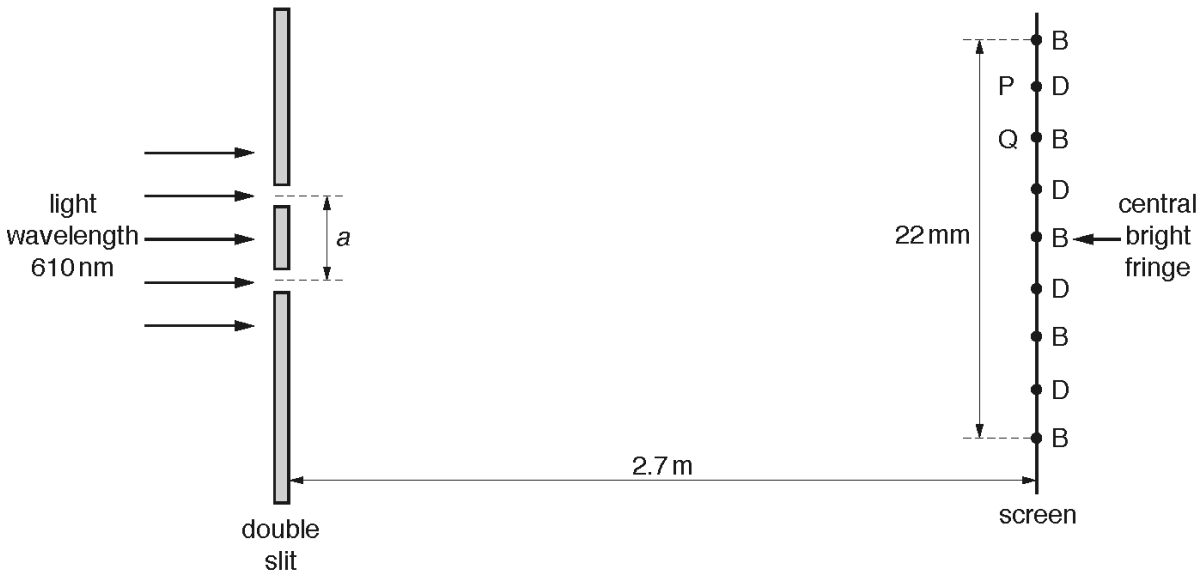


Fig. 4.1 (not to scale)

The wavelength of the light is 610 nm. The distance between the double slit and the screen is 2.7 m.

An interference pattern of bright fringes and dark fringes is observed on the screen. The centres of the bright fringes are labelled B and centres of the dark fringes are labelled D. Point P is the centre of a particular dark fringe and point Q is the centre of a particular bright fringe, as shown in Fig. 4.1. The distance across five bright fringes is 22 mm.

(i) The light waves leaving the two slits are coherent.

State what is meant by *coherent*.

.....

..... [1]

(ii) **1.** State the phase difference between the waves meeting at Q.

phase difference = ... °

2. Calculate the path difference, in nm, of the waves meeting at P.

path difference = ... nm
[2]

(iii) Determine the distance *a* between the two slits.

a = ... m [3]

(iv) A higher frequency of visible light is now used. State and explain the change to the separation of the fringes.

.....

..... [1]

(v) The intensity of the light incident on the double slit is now increased without altering its frequency. Compare the appearance of the fringes after this change with their appearance before this change.

.....

.....

.....

..... [2]

13 - (9702/23_Winter_2018_Q4) - *Waves, Superposition*

(a) On Fig. 4.1, complete the two graphs to illustrate what is meant by the amplitude A, the wavelength λ and the period T of a progressive wave.

Ensure that you label the axes of each graph.

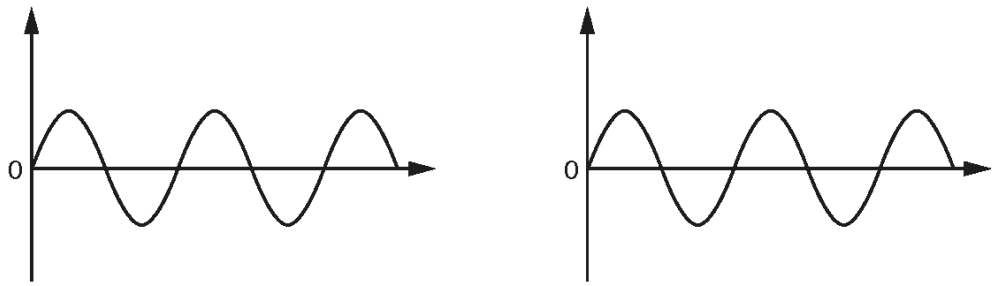


Fig. 4.1

[3]

(b) A horizontal string is stretched between two fixed points X and Y. A vibrator is used to oscillate the string and produce a stationary wave. Fig. 4.2 shows the string at one instant in time.

Fig. 4.2

The speed of a progressive wave along the string is $30\,\mathrm{m\,s^{-1}}$. The stationary wave has a period of 40 ms.

(i) Explain how the stationary wave is formed on the string.

.....

.....

.....

.....[2]

(ii) A particle on the string oscillates with an amplitude of 13 mm. At time t, the particle has zero displacement.

Calculate

1. the displacement of the particle at time (t + 100 ms),

displacement = ... mm

2. the total distance moved by the particle from time t to time (t + 100 ms).

distance = ... mm
[3]

(iii) Determine

1. the frequency of the wave,

frequency = ... Hz [1]

2. the horizontal distance from X to Y.

distance = ... m [3]

14 - (9702/22_Winter_2018_Q5) - *Superposition*

Red light of wavelength 640 nm is incident normally on a diffraction grating having a line spacing of 1.7×10^{-6} m, as shown in Fig. 5.1.

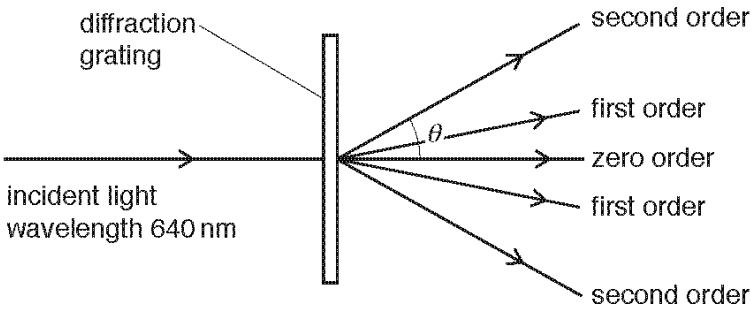


Fig. 5.1 (not to scale)

The second order diffraction maximum of the light is at an angle θ to the direction of the incident light.

(a) Show that angle θ is 49°.

[3]

(b) Determine a different wavelength of **visible** light that will also produce a diffraction maximum at an angle of 49°.

wavelength = ... m [2]

15 - (9702/22_Summer_2019_Q4) - *Waves, Superposition*

(a) For a progressive water wave, state what is meant by:

(i) *displacement*

.....

.....[1]

(ii) *amplitude.*

.....

.....[1]

(b) Two coherent waves X and Y meet at a point and superpose. The phase difference between the waves at the point is 180°. Wave X has an amplitude of 1.2 cm and intensity I. Wave Y has an amplitude of 3.6 cm.

Calculate, in terms of I, the resultant intensity at the meeting point.

intensity = ... [2]

(c) **(i)** Monochromatic light is incident on a diffraction grating. Describe the diffraction of the light waves as they pass through the grating.

.....

.....

.....[2]

(ii) A parallel beam of light consists of two wavelengths 540 nm and 630 nm. The light is incident normally on a diffraction grating. Third-order diffraction maxima are produced for each of the two wavelengths. No higher orders are produced for either wavelength.

Determine the smallest possible line spacing d of the diffraction grating.

d = ... m [3]

(iii) The beam of light in **(c)(ii)** is replaced by a beam of blue light incident on the same diffraction grating.

State and explain whether a third-order diffraction maximum is produced for this blue light.

.....

.....

.....[2]

16 - (9702/21_Summer_2019_Q5) - *Waves, Superposition*

(a) A loudspeaker oscillates with frequency f to produce sound waves of wavelength λ. The loudspeaker makes N oscillations in time t.

(i) State expressions, in terms of some or all of the symbols f, λ and N, for:

1. the distance moved by a wavefront in time t

distance = ...

2. time t.

time t = ...
[2]

(ii) Use your answers in **(i)** to deduce the equation relating the speed v of the sound wave to f and λ.

[1]

(b) The waveform of a sound wave is displayed on the screen of a cathode-ray oscilloscope (c.r.o.), as shown in Fig. 5.1.

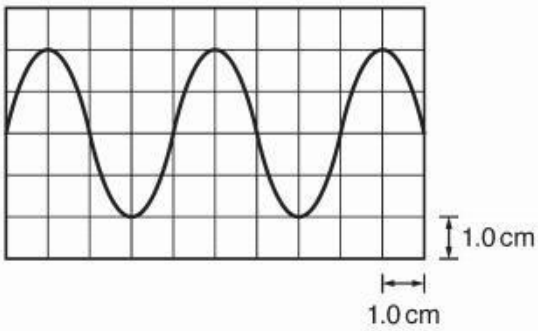


Fig. 5.1

The time-base setting is 0.20 ms cm^{-1}.

Determine the frequency of the sound wave.

frequency = ... Hz [2]

(c) Two sources S_1 and S_2 of sound waves are positioned as shown in Fig. 5.2.

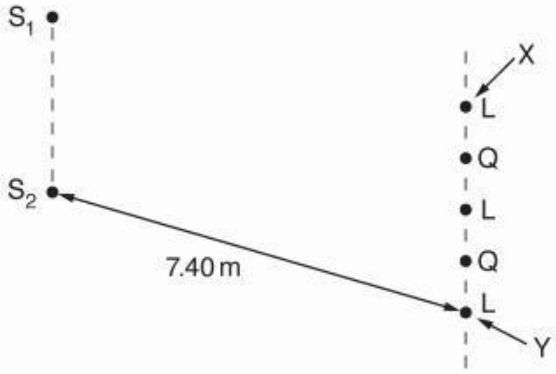


Fig. 5.2 (not to scale)

The sources emit coherent sound waves of wavelength 0.85 m. A sound detector is moved parallel to the line S_1S_2 from a point X to a point Y. Alternate positions of maximum loudness L and minimum loudness Q are detected, as illustrated in Fig. 5.2.

Distance S_1X is equal to distance S_2X. Distance S_2Y is 7.40 m.

(i) Explain what is meant by *coherent* waves.

.....

.....[1]

(ii) State the phase difference between the two waves arriving at the position of minimum loudness Q that is closest to point X.

phase difference = ... ° [1]

(iii) Determine the distance S_1Y.

distance = ... m [2]

17 - (9702/23_Summer_2019_Q5) - *Waves, Superposition*

A vertical tube of length 0.60 m is open at both ends, as shown in Fig. 5.1.

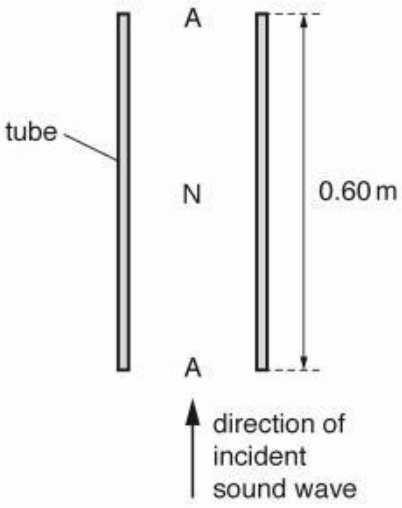


Fig. 5.1

An incident sinusoidal sound wave of a single frequency travels up the tube. A stationary wave is then formed in the air column in the tube with antinodes A at both ends and a node N at the midpoint.

(a) Explain how the stationary wave is formed from the incident sound wave.

.....

.....

.....

.....[2]

(b) On Fig. 5.2, sketch a graph to show the variation of the amplitude of the stationary wave with height *h* above the bottom of the tube.

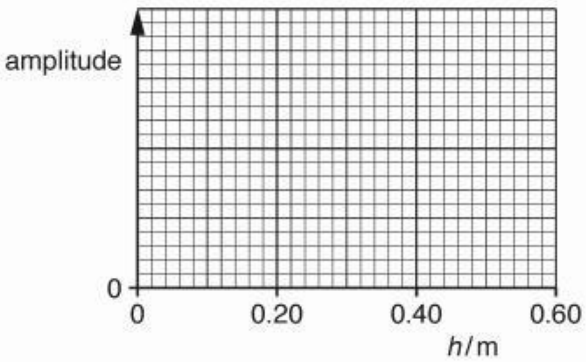


Fig. 5.2

[2]

(c) For the stationary wave, state:

(i) the direction of the oscillations of an air particle at a height of 0.15 m above the bottom of the tube

.....[1]

(ii) the phase difference between the oscillations of a particle at a height of 0.10 m and a particle at a height of 0.20 m above the bottom of the tube.

phase difference = ... ° [1]

(d) The speed of the sound wave is 340 m s^{-1}.

Calculate the frequency of the sound wave.

frequency = ... Hz [2]

(e) The frequency of the sound wave is gradually increased.

Determine the frequency of the wave when a stationary wave is next formed.

frequency = ... Hz [1]

18 - (9702/21_Winter_2019_Q5) - *Waves, Superposition*

A ripple tank is used to demonstrate the interference of water waves.
Two dippers D1 and D2 produce coherent waves that have circular wavefronts, as illustrated in Fig. 5.1.

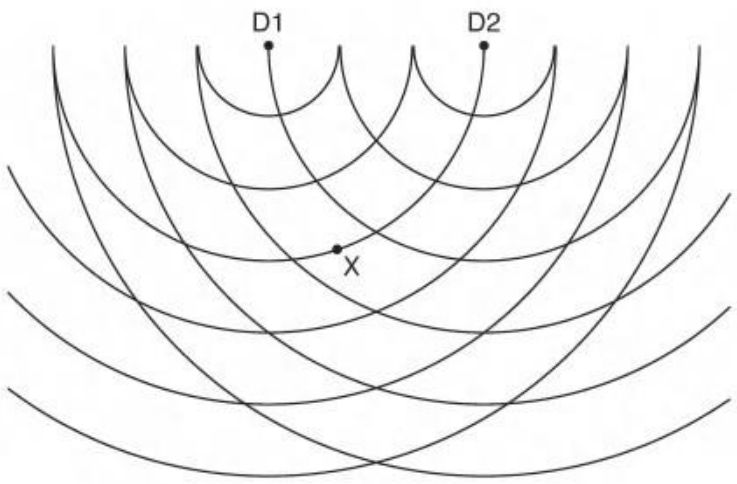


Fig. 5.1

The lines in the diagram represent crests. The waves have a wavelength of 6.0 cm.

(a) One condition that is required for an observable interference pattern is that the waves must be coherent.

(i) Describe how the apparatus is arranged to ensure that the waves from the dippers are coherent.

.....

..... [1]

(ii) State one other condition that must be satisfied by the waves in order for the interference pattern to be observable.

.....

..... [1]

(b) Light from a lamp above the ripple tank shines through the water onto a screen below the tank. Describe one way of seeing the illuminated pattern more clearly.

.....

..... [1]

(c) The speed of the waves is $0.40\,m\,s^{-1}$. Calculate the period of the waves.

period = ... s [2]

(d) Fig. 5.1 shows a point X that lies on a crest of the wave from D1 and midway between two adjacent crests of the wave from D2.

For the waves at point X, state:

(i) the path difference, in cm

path difference = ... cm [1]

(ii) the phase difference.

phase difference = ... ° [1]

(e) On Fig. 5.1, draw **one** line, at least 4 cm long, which joins points where only maxima of the interference pattern are observed. [1]

19 - (9702/22_Winter_2019_Q5) - *Waves, Superposition*

(a) State what is meant by the *wavelength* of a progressive wave.

.....

..... [1]

(b) A cathode-ray oscilloscope (CRO) is used to analyse a sound wave. The screen of the CRO is shown in Fig. 5.1.

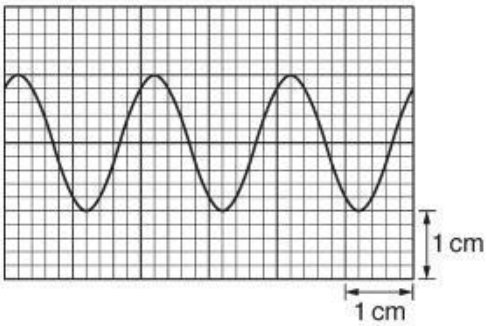


Fig. 5.1

The time-base setting of the CRO is $2.5\,\text{ms}\,\text{cm}^{-1}$.

Determine the frequency of the sound wave.

frequency = ... Hz [2]

(c) The source emitting the sound in **(b)** is at point A. Waves travel from the source to point C along two different paths, AC and ABC, as shown in Fig. 5.2.

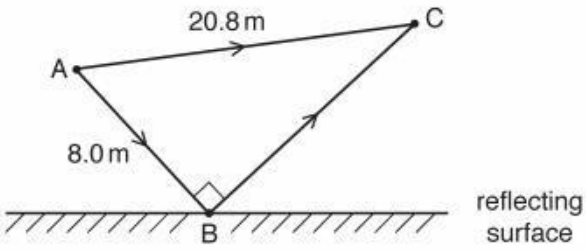


Fig. 5.2 (not to scale)

Distance AB is 8.0 m and distance AC is 20.8 m. Angle ABC is 90°. Assume that there is no phase change of the sound wave due to the reflection at point B. The wavelength of the waves is 1.6 m.

(i) Show that the waves meeting at C have a path difference of 6.4 m.

[1]

(ii) Explain why an intensity maximum is detected at point C.

.....

.....

..... [2]

(iii) Determine the difference between the times taken for the sound to travel from the source to point C along the two different paths.

time difference = ... s [2]

(iv) The wavelength of the sound is gradually increased. Calculate the wavelength of the sound when an intensity maximum is next detected at point C.

wavelength = ... m [1]

20 - (9702/23_Winter_2019_Q5) - *Waves, Superposition*

(a) Light waves emerging from the slits of a diffraction grating are coherent and produce an interference pattern.

Explain what is meant by:

(i) *coherence*

.....

..... [1]

(ii) *interference.*

.....

..... [1]

(b) A narrow beam of light from a laser is incident normally on a diffraction grating, as shown in Fig. 5.1.

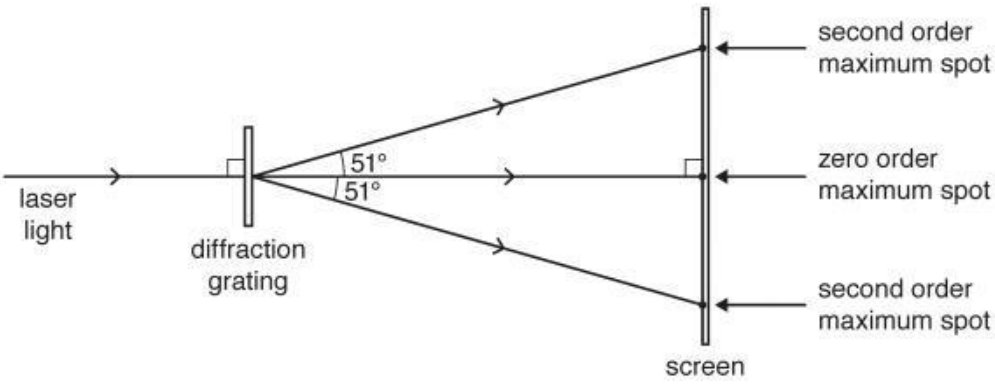


Fig. 5.1 (not to scale)

Spots of light are seen on a screen positioned parallel to the grating. The angle corresponding to each of the **second** order maxima is 51°. The number of lines per unit length on the diffraction grating is $6.7 \times 10^5\,m^{-1}$.

(i) Determine the wavelength of the light.

wavelength = ... m [2]

(ii) State and explain the change, if any, to the distance between the second order maximum spots on the screen when the light from the laser is replaced by light of a shorter wavelength.

.....

.....

.....[1]

21 - (9702/21_Summer_2020_Q4) - *Waves, Superposition*

(a) **(i)** By reference to the direction of propagation of energy, state what is meant by a *longitudinal* wave.

.....

..... [1]

(ii) State the principle of superposition.

.....

.....

..... [2]

(b) The wavelength of light from a laser is determined using the apparatus shown in Fig. 4.1.

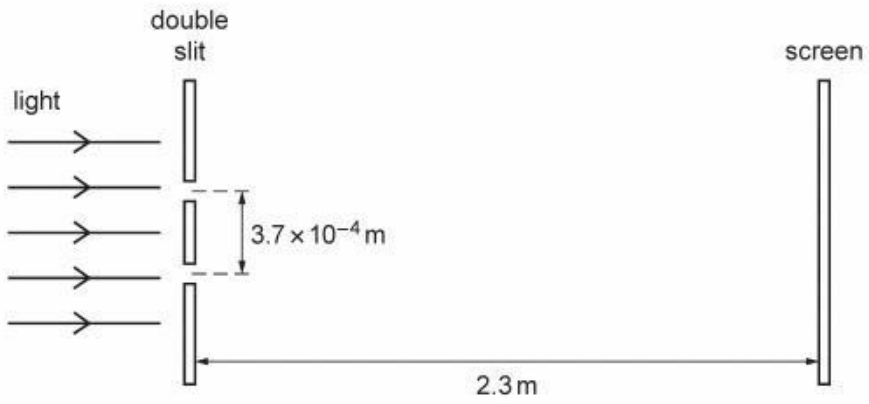


Fig. 4.1 (not to scale)

The light from the laser is incident normally on the plane of the double slit.
The separation of the two slits is 3.7×10^{-4} m. The screen is parallel to the plane of the double slit. The distance between the screen and the double slit is 2.3 m.

A pattern of bright fringes and dark fringes is seen on the screen. The separation of adjacent bright fringes on the screen is 4.3×10^{-3} m.

(i) Calculate the wavelength, in nm, of the light.

wavelength = ... nm [3]

(ii) The intensity of the light passing through each slit was initially the same. The intensity of the light through **one** of the slits is now reduced.

Compare the appearance of the fringes before and after the change of intensity.

.....

.....

.....

..... [2]

22 - (9702/22_Summer_2020_Q4) - *Waves, Superposition*

(a) State the difference between progressive waves and stationary waves in terms of the transfer of energy along the wave.

.....

..... [1]

(b) A progressive wave travels from left to right along a stretched string. Fig. 4.1 shows part of the string at one instant.

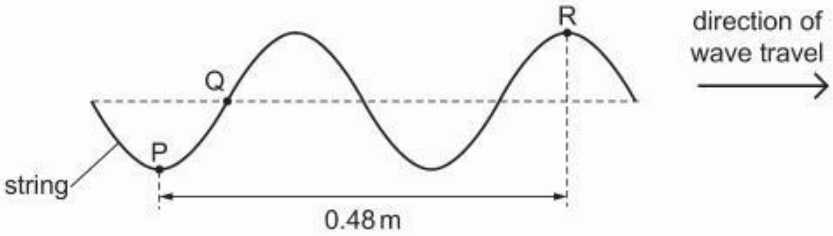


Fig. 4.1

P, Q and R are three different points on the string. The distance between P and R is 0.48 m. The wave has a period of 0.020 s.

(i) Use Fig. 4.1 to determine the wavelength of the wave.

wavelength = ... m [1]

(ii) Calculate the speed of the wave.

speed = ... $m\,s^{-1}$ [2]

(iii) Determine the phase difference between points Q and R.

phase difference = ... ° [1]

(iv) Fig. 4.1 shows the position of the string at time $t = 0$. Describe how the displacement of point Q on the string varies with time from $t = 0$ to $t = 0.010$ s.

.....

.....

.....

..... [2]

(c) A stationary wave is formed on a different string that is stretched between two fixed points X and Y. Fig. 4.2 shows the position of the string when each point is at its maximum displacement.

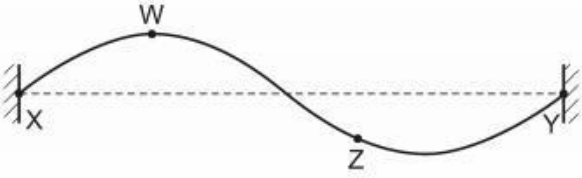


Fig. 4.2

(i) Explain what is meant by a *node* of a stationary wave.

..... [1]

(ii) State the number of antinodes of the wave shown in Fig. 4.2.

number = ... [1]

(iii) State the phase difference between points W and Z on the string.

phase difference = ...° [1]

(iv) A new stationary wave is now formed on the string. The new wave has a frequency that is half of the frequency of the wave shown in Fig. 4.2. The speed of the wave is unchanged.

On Fig. 4.3, draw a position of the string, for this new wave, when each point is at its maximum displacement.

Fig. 4.3

[1]

23 – (9702/22_Winter_2020_Q5) – *Waves, Superposition*

Microwaves with the same wavelength and amplitude are emitted in phase from two sources X and Y, as shown in Fig. 5.1.

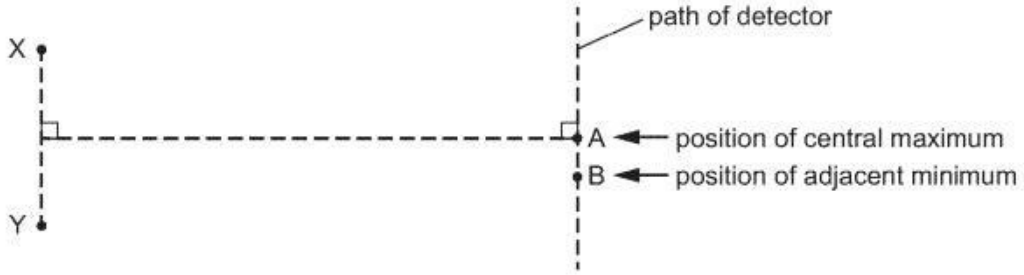


Fig. 5.1 (not to scale)

A microwave detector is moved along a path parallel to the line joining X and Y. An interference pattern is detected. A central intensity maximum is located at point A and there is an adjacent intensity minimum at point B. The microwaves have a wavelength of 0.040 m.

(a) Calculate the frequency, in GHz, of the microwaves.

frequency = ... GHz [3]

(b) For the waves arriving at point B, determine:

(i) the path difference

path difference = ... m [1]

(ii) the phase difference.

phase difference = ...° [1]

(c) The amplitudes of the waves from the sources are changed. This causes a change in the amplitude of the waves arriving at point A. At this point, the amplitude of the wave arriving from source X is doubled and the amplitude of the wave arriving from source Y is also doubled.

Describe the effect, if any, on the intensity of the central maximum at point A.

.....

.....

..... [2]

(d) Describe the effect, if any, on the positions of the central intensity maximum and the adjacent intensity minimum due to the following separate changes.

(i) The separation of the sources X and Y is increased.

.....

..... [1]

(ii) The phase difference between the microwaves emitted by the sources X and Y changes to 180°.

.....

..... [1]

[Total: 9]

24 - (9702/23_Winter_2020_Q5) - *Waves, Superposition*

(a) A sound wave is detected by a microphone that is connected to a cathode-ray oscilloscope (CRO). The trace on the screen of the CRO is shown in Fig. 5.1.

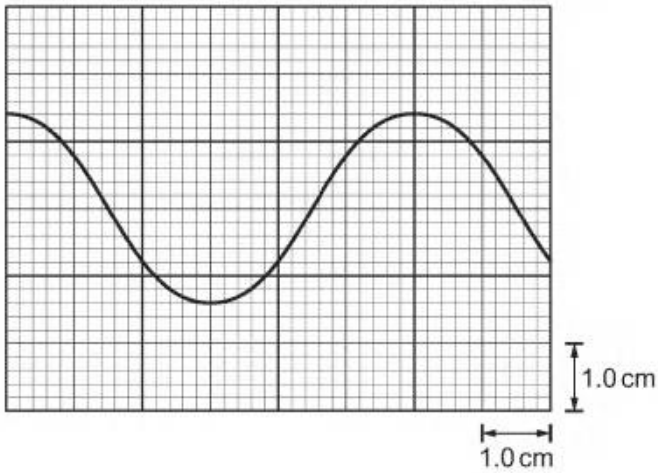


Fig. 5.1

The time-base setting of the CRO is $2.0 \times 10^{-5}\,\text{s cm}^{-1}$.

(i) Determine the frequency of the sound wave.

frequency = ... Hz [2]

(ii) The intensity of the sound wave is now doubled. The frequency is unchanged. Assume that the amplitude of the trace is proportional to the amplitude of the sound wave.

On Fig. 5.1, sketch the new trace shown on the screen. [2]

(iii) The time-base is now switched off.

Describe the trace seen on the screen.

.....

..... [1]

(b) A beam of light of a single wavelength is incident normally on a diffraction grating, as illustrated in Fig. 5.2.

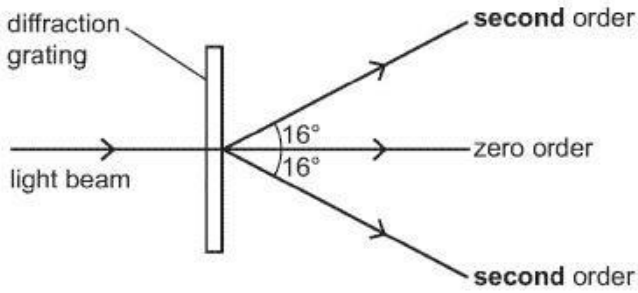


Fig. 5.2 (not to scale)

Fig. 5.2 does not show all of the emerging beams from the grating. The angle between the **second**-order emerging beam and the central zero-order beam is 16°. The grating has a line spacing of 3.4×10^{-6} m.

(i) Calculate the wavelength of the light.

wavelength = ... m [2]

(ii) Determine the highest order of emerging beam from the grating.

highest order = ... [2]

[Total: 9]

25 - (9702/21_Winter_2020_Q6) - *Superposition*

(a) Describe the conditions required for two waves to be able to form a stationary wave.

.....

.....

.....

..... [2]

(b) A stationary wave on a string has nodes and antinodes. The distance between a node and an adjacent antinode is 6.0 cm.

(i) State what is meant by a *node*.

..... [1]

(ii) Calculate the wavelength of the two waves forming the stationary wave.

wavelength = ... cm [1]

(iii) State the phase difference between the particles at two adjacent antinodes of the stationary wave.

phase difference = ... ° [1]

[Total: 5]

26 - (9702/21_Summer_2021_Q4) - *Waves, Superposition*

(a) For a progressive wave, state what is meant by *wavelength*.

.....

..... [1]

(b) A light wave from a laser has a wavelength of 460 nm in a vacuum.

Calculate the period of the wave.

period = ... s [3]

(c) The light from the laser is incident normally on a diffraction grating.

Describe the diffraction of the light waves at the grating.

.....

.....

..... [2]

(d) A diffraction grating is used with different wavelengths of visible light. The angle θ of the **fourth**-order maximum from the zero-order (central) maximum is measured for each wavelength. The variation with wavelength λ of $\sin\theta$ is shown in Fig. 4.1.

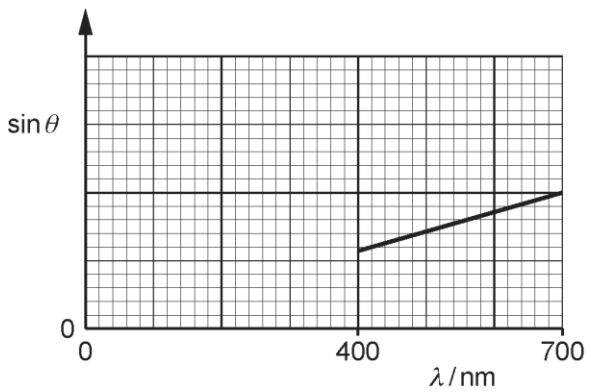


Fig. 4.1

(i) The gradient of the graph is G.

Determine an expression, in terms of G, for the distance d between the centres of two adjacent slits in the diffraction grating.

d = ... [2]

(ii) On Fig. 4.1, sketch a graph to show the results that would be obtained for the **second**-order maxima. [2]

27 - (9702/22_Summer_2021_Q4) - *Waves, Superposition*

(a) For a progressive wave, state what is meant by its *period*.

.....

..... [1]

(b) State the principle of superposition.

.....

.....

..... [2]

(c) Electromagnetic waves of wavelength 0.040 m are emitted in phase from two sources X and Y and travel in a vacuum. The arrangement of the sources is shown in Fig. 4.1.

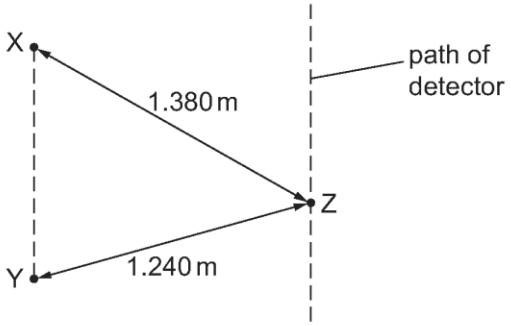


Fig. 4.1 (not to scale)

A detector moves along a path that is parallel to the line XY. A pattern of intensity maxima and minima is detected.

Distance XZ is 1.380 m and distance YZ is 1.240 m.

(i) State the name of the region of the electromagnetic spectrum that contains the waves from X and Y.

..... [1]

(ii) Calculate the period, in ps, of the waves.

period = ... ps [3]

(iii) Show that the path difference at point Z between the waves from X and Y is 3.5 λ, where λ is the wavelength of the waves.

[1]

(iv) Calculate the phase difference between the waves at point Z.

phase difference = ...° [1]

(v) The waves from X alone have the same amplitude at point Z as the waves from Y alone.

State the intensity of the waves at point Z.

..... [1]

(vi) The frequencies of the waves from X and Y are both decreased to the same lower value. The waves stay within the same region of the electromagnetic spectrum.

Describe the effect of this change on the pattern of intensity maxima and minima along the path of the detector.

.....

..... [1]

28 - (9702/23_Summer_2021_Q4) - *Superposition*

(a) State the principle of superposition.

.....

.....

..... [2]

(b) Two waves, with intensities I and $4I$, superpose. The waves have the same frequency.

Determine, in terms of I, the maximum possible intensity of the resulting wave.

maximum intensity = ... I [2]

(c) Coherent light of wavelength 550 nm is incident normally on a double slit of slit separation 0.35 mm. A series of bright and dark fringes forms on a screen placed a distance of 1.2 m from the double slit, as shown in Fig. 4.1. The screen is parallel to the double slit.

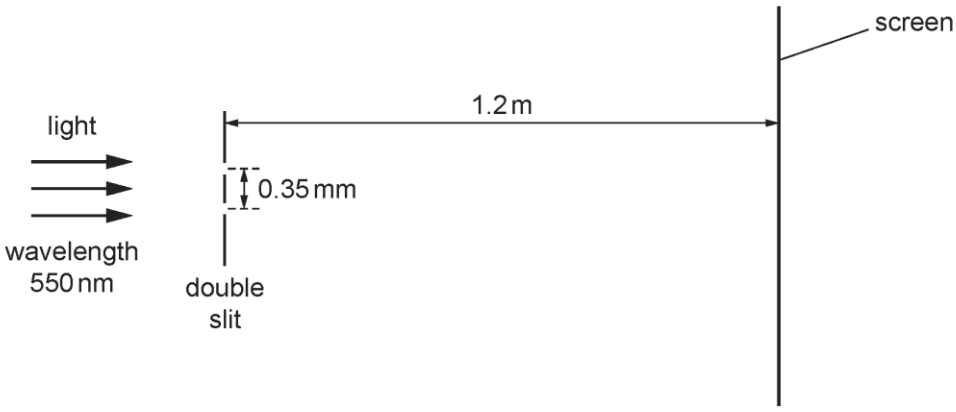


Fig. 4.1 (not to scale)

(i) Determine the distance between the centres of adjacent bright fringes on the screen.

distance = ... m [3]

(ii) The light of wavelength 550 nm is replaced with red light of a single frequency.

State and explain the change, if any, in the distance between the centres of adjacent bright fringes.

.....

.....

..... [1]

29 - (9702/22_Winter_2021_Q5) - *Superposition*

A tube is initially fully submerged in water. The axis of the tube is kept vertical as the tube is slowly raised out of the water, as shown in Fig. 5.1.

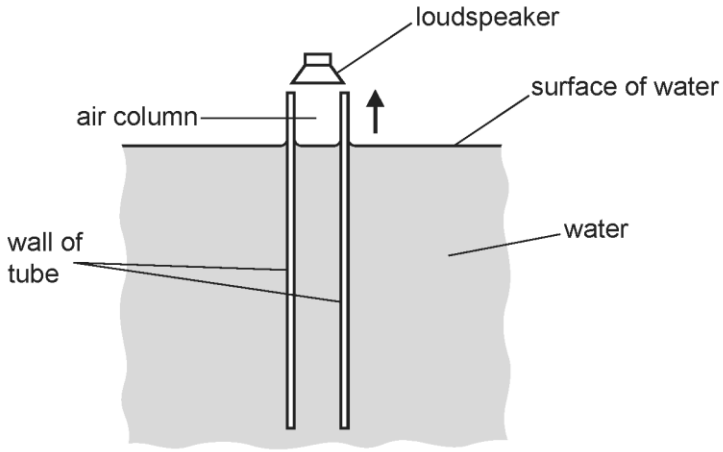


Fig. 5.1

A loudspeaker producing sound of frequency 530 Hz is positioned at the open top end of the tube as it is raised. The water surface inside the tube is always level with the water surface outside the tube. The speed of the sound in the air column in the tube is 340 m s^{-1}.

(a) Describe a simple way that a student, without requiring any additional equipment, can detect when a stationary wave is formed in the air column as the tube is being raised.

.....

..... [1]

(b) Determine the height of the top end of the tube above the surface of the water when a stationary wave is first produced in the tube. Assume that an antinode is formed level with the top of the tube.

height = ... m [3]

(c) Determine the distance moved by the tube between the positions at which the first and second stationary waves are formed.

distance = ... m [1]

30 - (9702/21_Summer_2022_Q5) - *Superposition*

A horizontal string is stretched between two fixed points A and B. A vibrator is used to oscillate the string and produce an observable stationary wave.

At one instant, the moving string is straight, as shown in Fig. 5.1.

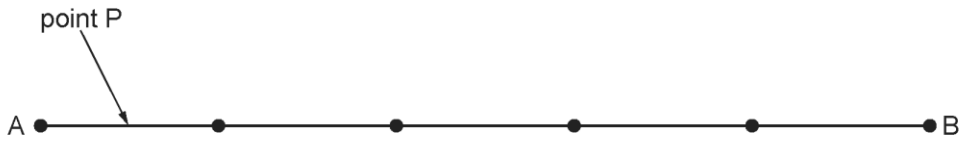


Fig. 5.1

The dots in the diagram represent the positions of the nodes on the string. Point P on the string is moving downwards.

The wave on the string has a speed of $35\,\mathrm{m\,s^{-1}}$ and a period of $0.040\,\mathrm{s}$.

(a) Explain how the stationary wave is formed on the string.

.....

.....

.....

..... [2]

(b) On Fig. 5.1, sketch a line to show a possible position of the string a quarter of a cycle later than the position shown in the diagram. [1]

(c) Determine the horizontal distance from A to B.

distance = ... m [3]

(d) A particle on the string has zero displacement at time $t = 0$. From time $t = 0$ to time $t = 0.060\,s$, the particle moves through a total distance of 72 mm.

Calculate the amplitude of oscillation of the particle.

amplitude = ... mm [2]

[Total: 8]

31 - (9702/22_Summer_2022_Q5) - *Superposition*

Light from a laser is used to produce an interference pattern on a screen, as shown in Fig. 5.1.

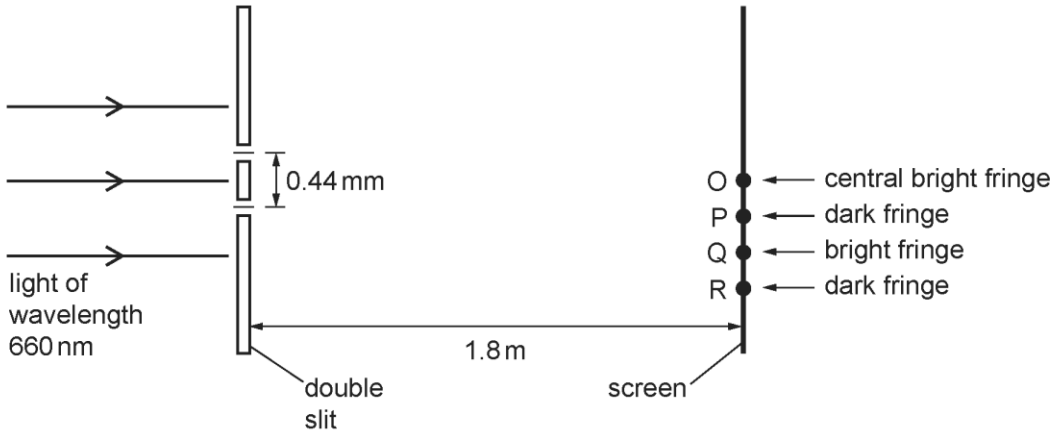


Fig. 5.1 (not to scale)

The light of wavelength 660 nm is incident normally on two slits that have a separation of 0.44 mm. The double slit is parallel to the screen. The perpendicular distance between the double slit and the screen is 1.8 m.

The central bright fringe on the screen is formed at point O. The next dark fringe below point O is formed at point P. The next bright fringe and the next dark fringe below point P are formed at points Q and R respectively.

(a) The light waves from the two slits are coherent.

State what is meant by coherent.

.....

..... [1]

(b) For the two light waves superposing at R, calculate:

(i) the difference in their path lengths, in nm, from the slits

path difference = ... nm [1]

(ii) their phase difference.

phase difference = ... ° [1]

(c) Calculate the distance OQ.

distance OQ = ... m [3]

(d) The intensity of the light incident on the double slit is increased without changing the frequency.

Describe how the appearance of the fringes after this change is different from, and similar to, their appearance before the change.

.....

.....

.....

.....

..... [3]

(e) The light of wavelength 660 nm is now replaced by blue light from a laser.

State and explain the change, if any, that must be made to the separation of the two slits so that the fringe separation on the screen is the same as it was for light of wavelength 660 nm.

.....

.....

.....

..... [2]

[Total: 11]

32 – (9702/23_Summer_2022_Q5) – *Superposition*

(a) Parallel light rays from the Sun are incident normally on a magnifying glass. The magnifying glass directs the light to an area A of radius *r*, as shown in Fig. 5.1.

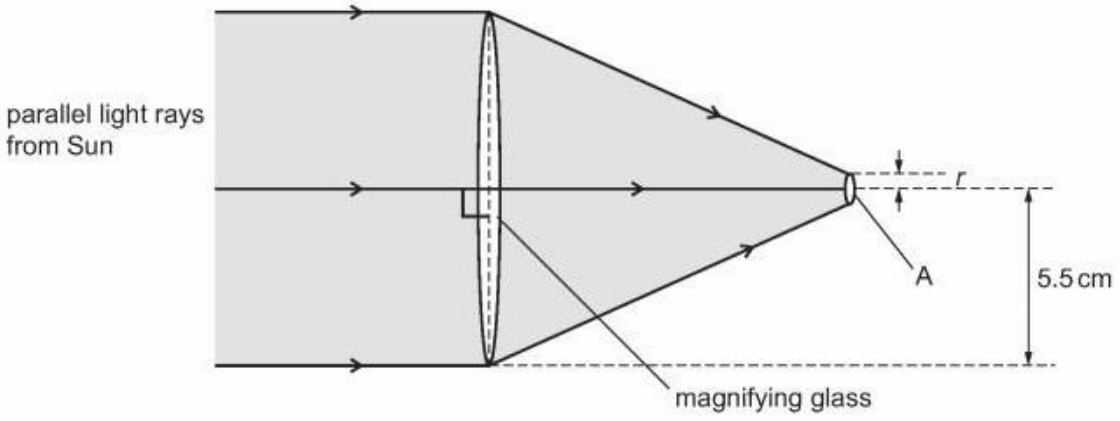


Fig. 5.1 (not to scale)

The magnifying glass is circular in cross-section with a radius of 5.5 cm. The intensity of the light from the Sun incident on the magnifying glass is 1.3 kW m^{-2}.

Assume that all of the light incident on the magnifying glass is transmitted through it.

(i) Calculate the power of the light from the Sun incident on the magnifying glass.

power = ... W [2]

(ii) The value of *r* is 1.5 mm.

Calculate the intensity of the light on area A.

intensity = ... W m^{-2} [1]

(b) A laser emits a beam of electromagnetic waves of frequency 3.7×10^{15} Hz in a vacuum.

(i) Show that the wavelength of the waves is 8.1×10^{-8} m.

[2]

(ii) State the region of the electromagnetic spectrum to which these waves belong.

..... [1]

(iii) The beam from the laser now passes through a diffraction grating with 2400 lines per millimetre. A detector sensitive to the waves emitted by the laser is moved through an arc of 180° in order to detect the maxima produced by the waves passing through the grating, as shown in Fig. 5.2.

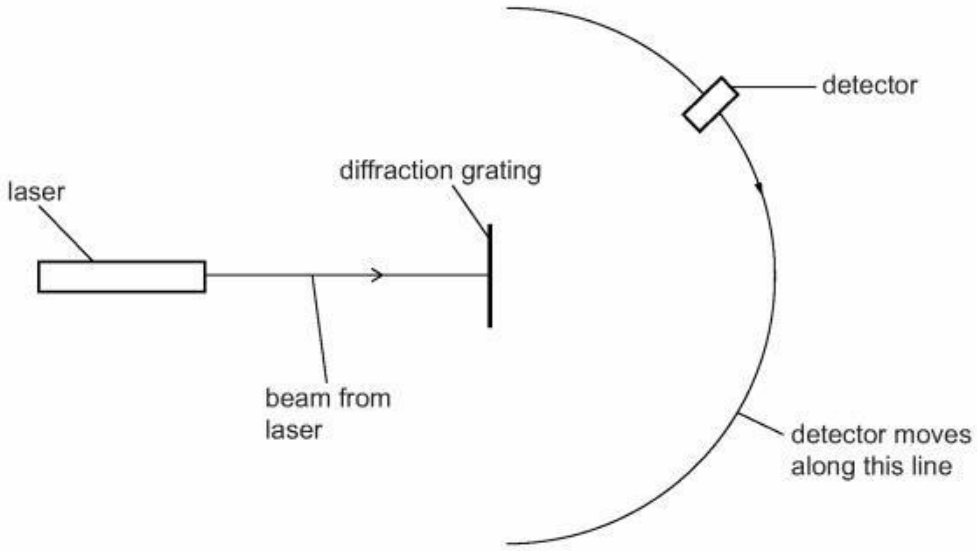


Fig. 5.2

Calculate the number of maxima detected as the detector moves through 180° along the line shown in Fig. 5.2. Show your working.

number of maxima detected = ... [4]

(iv) The laser is now replaced with one that emits electromagnetic waves with a wavelength of 300 nm.

Explain, without calculation, what happens to the number of maxima now detected. Assume that the detector is also sensitive to this wavelength of electromagnetic waves.

.....

.....

..... [2]

[Total: 12]

33 - (9702/21_Summer_2023_Q5) - *Superposition*

(a) An electromagnetic wave in a vacuum has a wavelength of 8.4×10^{-6} m.

(i) State the name of the principal region of the electromagnetic spectrum for the wave.

..... [1]

(ii) Calculate the frequency, in THz, of the wave.

frequency = ... THz [2]

(b) An arrangement that uses a double slit to demonstrate the interference of light from a laser is shown in Fig. 5.1.

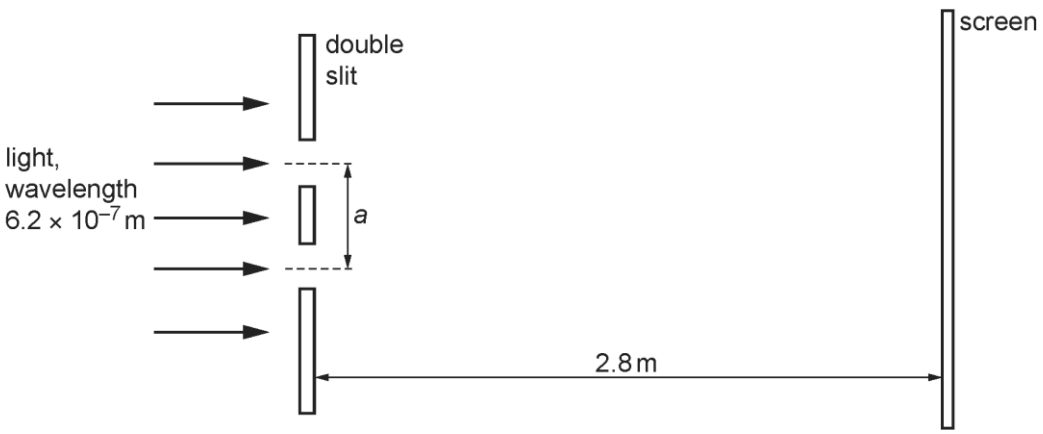


Fig. 5.1 (not to scale)

The light from the laser has a wavelength of 6.2×10^{-7} m and is incident normally on the slits. The separation of the two slits is *a*. The slits and screen are parallel and separated by a distance of 2.8 m.

An interference pattern of bright fringes and dark fringes is formed on the screen. The distance on the screen across 8 bright fringes is 22 mm, as illustrated in Fig. 5.2.

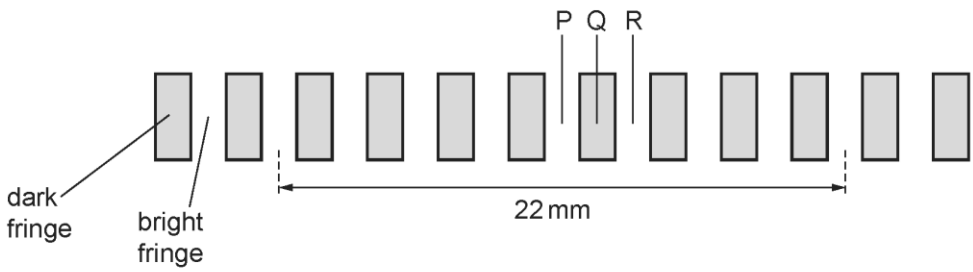


Fig. 5.2

(i) The light waves emerging from the two slits are coherent.

State what is meant by coherent.

.....

..... [1]

(ii) Calculate the separation *a* of the slits.

a = ... m [3]

(c) Fringe P is the central bright fringe of the interference pattern in **(b)**. Fringe Q and fringe R are the nearest dark fringe and the nearest bright fringe respectively to the right of fringe P, as shown in Fig. 5.2.

(i) Calculate the difference in the distances (the path difference) from each slit to the centre of fringe Q.

difference in the distances = ... m [1]

(ii) State the phase difference between the light waves meeting at the centre of fringe R.

phase difference = ...° [1]

34 - (9702/21_Winter_2023_Q4) - *Superposition*

(a) State the principle of superposition.

.....

.....

..... [2]

(b) Coherent light is incident normally on two identical slits X and Y. The diffracted light emerging from the slits superposes to produce an interference pattern on a screen positioned at a distance of 1.9 m from the slits.

Fig. 4.1 shows the arrangement and the central part of the interference pattern of bright and dark fringes formed on the screen.

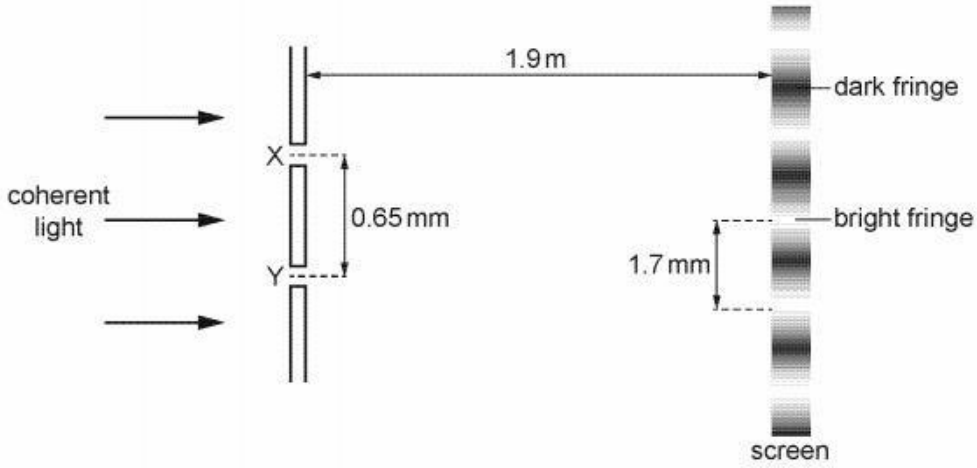


Fig. 4.1 (not to scale)

The separation of the slits is 0.65 mm. The distance between the centres of adjacent bright fringes is 1.7 mm.

Calculate the wavelength λ of the light.

λ = ... m [3]

(c) Light waves from slits X and Y in **(b)** arrive at a point between adjacent bright fringes on the screen. Fig. 4.2 shows the variation of displacement with time for the waves arriving at the point where they meet.

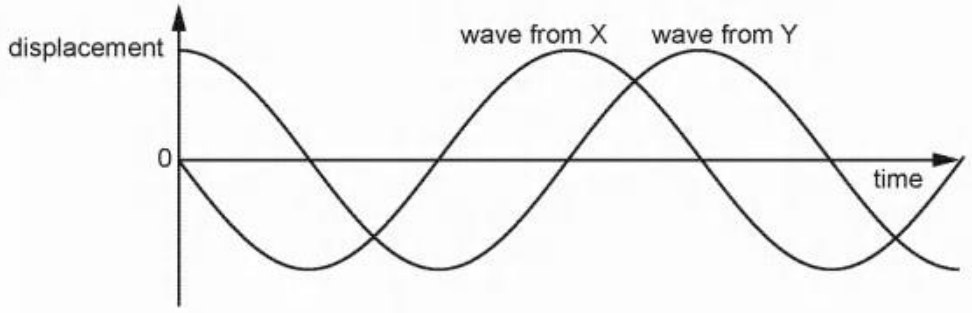


Fig. 4.2

A student makes two statements about the waves at this point:

Statement 1: 'The phase difference between the waves is 90°.'

Statement 2: 'The amplitude of the resultant wave is zero.'

(i) Explain how statement 1 is correct.

.....

.....

..... [1]

(ii) State and explain whether statement 2 is correct.

.....

.....

..... [1]

(d) The width of each slit in **(b)** is decreased by the same amount. There is no change to the separation of the slits.

Describe and explain the effect, if any, of this change on the appearance of the interference pattern.

.....

.....

..... [2]

35 - (9702/22_Winter_2023_Q5) - *Superposition*

(a) A beam of vertically polarised light is incident normally on a polarising filter, as shown in Fig. 5.1.

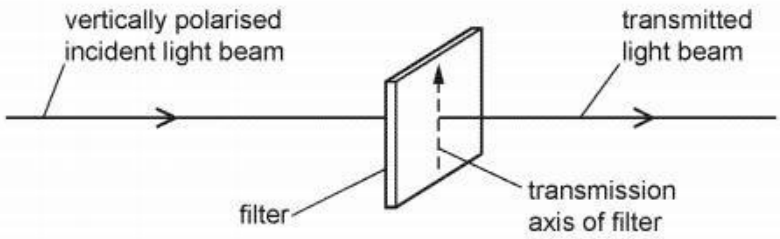


Fig. 5.1

(i) The transmission axis of the filter is initially vertical. The filter is then rotated through an angle of 360° while the plane of the filter remains perpendicular to the beam.

On Fig. 5.2, sketch a graph to show the variation of the intensity of the light in the transmitted beam with the angle through which the transmission axis is rotated.

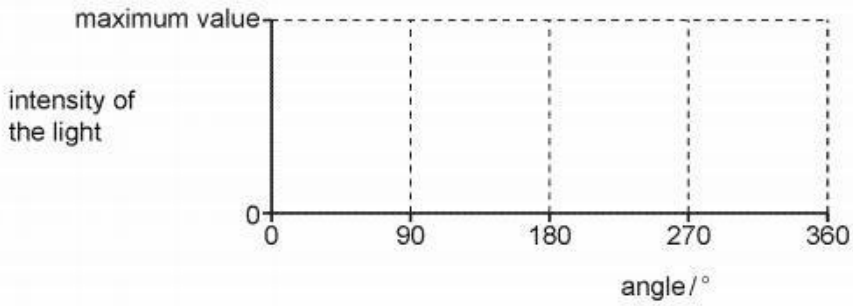


Fig. 5.2

[2]

(ii) The intensity of the light in the incident beam is $7.6\,W\,m^{-2}$. When the transmission axis of the filter is at angle θ to the vertical, the light intensity of the transmitted beam is $4.2\,W\,m^{-2}$.

Calculate angle θ.

θ = ...° [2]

(b) State what is meant by the diffraction of a wave.

.....

.....

..... [2]

(c) A beam of light of wavelength 4.3×10^{-7} m is incident normally on a diffraction grating in air, as shown in Fig. 5.3.

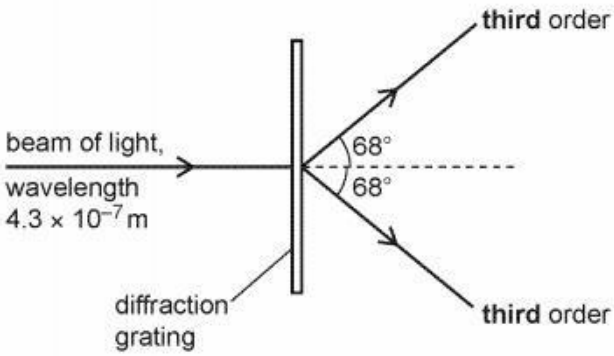


Fig. 5.3 (not to scale)

The **third**-order diffraction maximum of the light is at an angle of 68° to the direction of the incident light beam.

(i) Calculate the line spacing *d* of the diffraction grating.

d = ... m [2]

(ii) Determine a different wavelength of **visible** light that will also produce a diffraction maximum at an angle of 68°.

wavelength = ... m [2]

36 - (9702/23_Winter_2023_Q6) - *Superposition*

A train travels at constant speed along a straight horizontal track towards an observer standing adjacent to the track, as shown in Fig. 6.1.

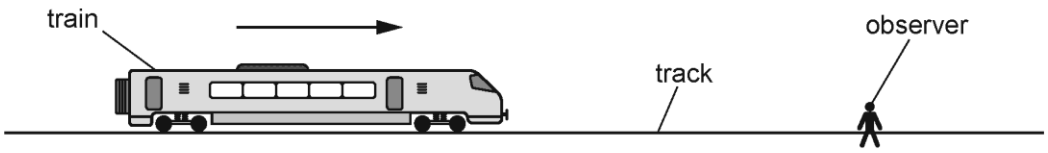


Fig. 6.1

The train sounds its horn continuously as it approaches the observer. The horn emits a sound of constant frequency 251 Hz. The frequency of sound heard by the observer is 291 Hz. The speed of sound in air is 340 m s^{-1}.

(a) Calculate the speed of the train.

speed = ... m s^{-1} [2]

(b) The train approaches and then passes the observer. The intensity I of the sound heard by the observer varies with the distance d of the horn from the observer.

When the horn is at a distance x_0 from the observer, the intensity I of the sound heard is I_0 and the amplitude A of the sound wave at the observer is A_0.

Fig. 6.2 shows the variation with d/x_0 of I/I_0 as the train moves away from the observer.

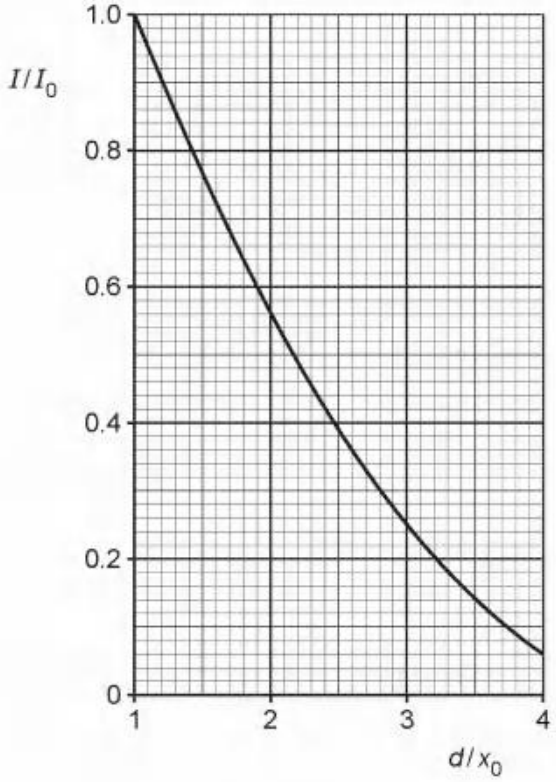


Fig. 6.2

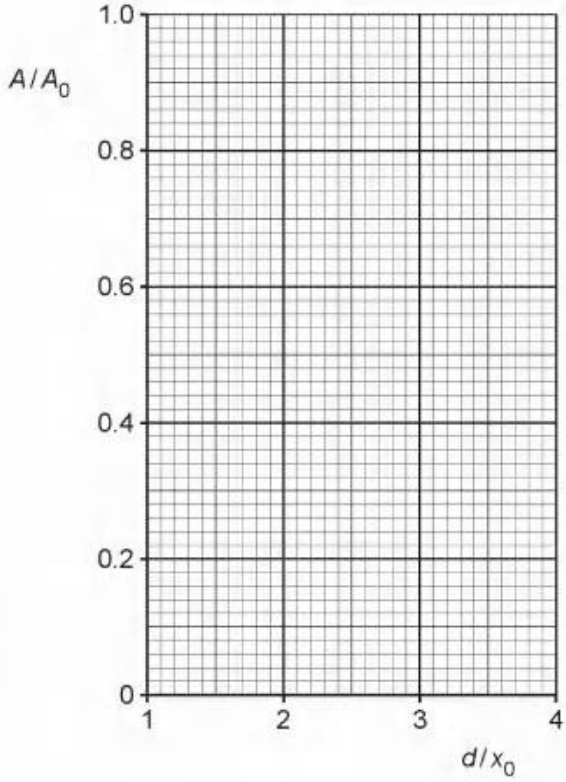


Fig. 6.3

(i) State the relationship between amplitude A and intensity I for a progressive wave.

..... [1]

(ii) On Fig. 6.3, sketch the variation with d/x_0 of A/A_0. [2]

1 - (9702/23_Summer_2017_Q3) - *Electric Fields, Particle & Nuclear Physics*

(a) Define *electric field strength*.

.....

.....[1]

(b) An electron is accelerated from point A to point B by a uniform electric field, as illustrated in Fig. 3.1.

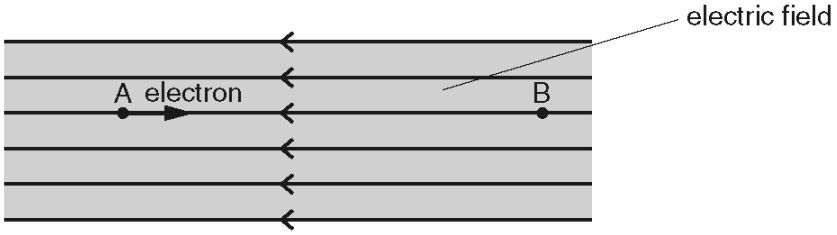


Fig. 3.1

The distance between A and B is 12 mm. The velocity of the electron at A is 2.5 km s^{-1} and at B is 18 Mm s^{-1}.

Calculate

(i) the acceleration of the electron,

acceleration = ...m s^{-2} [2]

(ii) the change in kinetic energy of the electron,

change in kinetic energy = ...J [3]

(iii) the electric field strength.

electric field strength = ... $V m^{-1}$ [3]

(c) An α-particle moves from A to B in the electric field in **(b)**.

Describe and explain how the change in the kinetic energy of the α-particle compares with that of the electron. Numerical values are not required.

.....

.....

.....

.....

.....[3]

2 - (9702/22_Winter_2017_Q5) - *Electric Fields*

(a) Define the *coulomb*.

.....[1]

(b) Two vertical metal plates in a vacuum have a separation of 4.0 cm. A potential difference of 2.0×10^2 V is applied between the plates. Fig. 5.1 shows a side view of this arrangement.

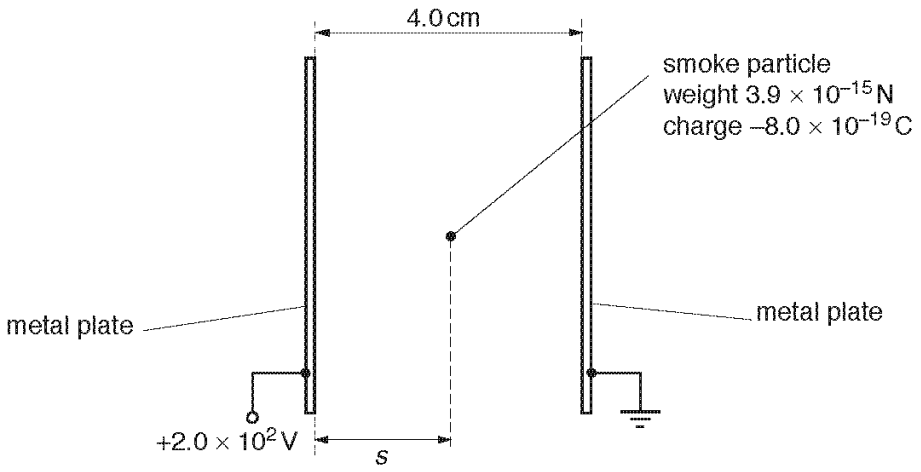


Fig. 5.1

A smoke particle is in the uniform electric field between the plates. The particle has weight 3.9×10^{-15} N and charge -8.0×10^{-19} C.

(i) Show that the electric force acting on the particle is 4.0×10^{-15} N.

[2]

(ii) On Fig. 5.1, draw labelled arrows to show the directions of the two forces acting on the smoke particle. [1]

(iii) The resultant force acting on the particle is F.

Determine

1. the magnitude of F,

magnitude = ... N

2. the angle of F to the horizontal.

angle = ... °

[3]

(c) The electric field in **(b)** is switched on at time $t = 0$ when the particle is at a horizontal displacement $s = 2.0$ cm from the left-hand plate. At time $t = 0$ the horizontal velocity of the particle is zero. The particle is then moved by the electric field until it hits a plate at time $t = T$.

On Fig. 5.2, sketch the variation with time t of the horizontal displacement s of the particle from the left-hand plate.

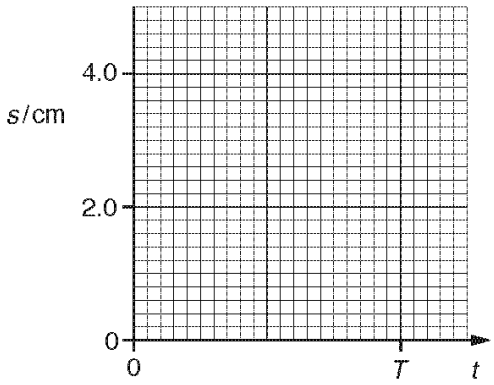


Fig. 5.2

[2]

3 - (9702/23_Winter_2017_Q5) - *Electric Fields*

(a) Define *electric field strength*.

.....

.....[1]

(b) Two parallel metal plates in a vacuum are separated by 0.045 m. A potential difference V is applied between the plates, as shown in Fig. 5.1.

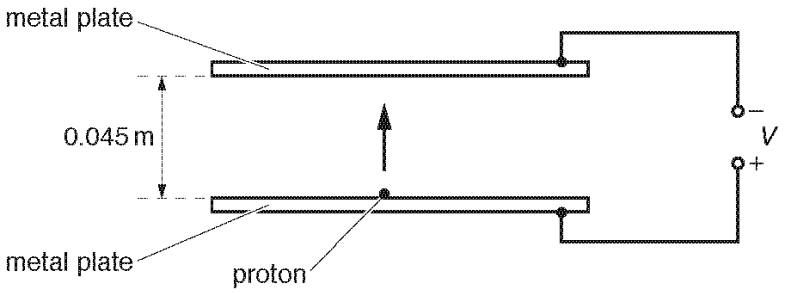


Fig. 5.1

A proton is initially at rest on the surface of the positive plate. The proton in the uniform electric field takes a time of 1.5×10^{-7} s to reach the negative plate.

(i) Show that the acceleration of the proton is $4.0 \times 10^{12}\,\text{m s}^{-2}$.

[2]

(ii) Calculate the electric force on the proton.

force = ... N [1]

(iii) Use your answer in **(ii)** to determine

1. the electric field strength,

field strength = ... $N\,C^{-1}$ [2]

2. the potential difference V between the plates.

V = ... V [2]

(c) An α particle is now accelerated between the two metal plates in **(b)** by the electric field.

Calculate the ratio

$$\frac{\text{acceleration of } \alpha \text{ particle}}{\text{acceleration of proton}}.$$

ratio = ...[2]

4 - (9702/21_Winter_2017_Q6) - *Electric Fields*

(a) Define *electric field strength.*

.....

.....[1]

(b) Two parallel metal plates in a vacuum are separated by a distance of 15 mm, as shown in Fig. 6.1.

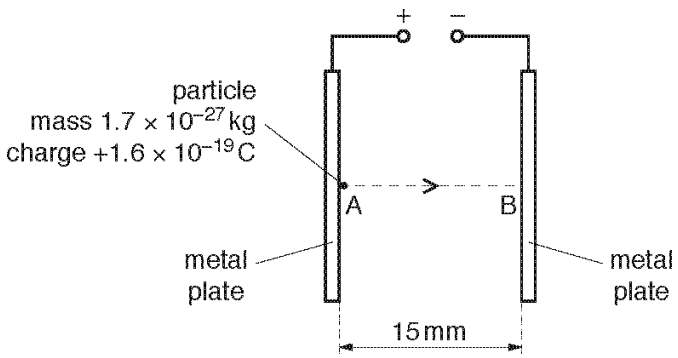


Fig. 6.1

A uniform electric field is produced between the plates by applying a potential difference between them.

A particle of mass 1.7×10^{-27} kg and charge $+1.6 \times 10^{-19}$ C is initially at rest at point A on one plate. The particle is moved by the electric field to point B on the other plate. The particle reaches point B with kinetic energy 2.4×10^{-16} J.

(i) Calculate the speed of the particle at point B.

speed = ... $m\,s^{-1}$ [2]

(ii) State the work done by the electric field to move the particle from A to B.

work done = ... J [1]

(iii) Use your answer in **(ii)** to determine the force on the particle.

force = ... N [2]

(iv) Determine the potential difference between the plates.

potential difference = ... V [3]

(v) On Fig. 6.2, sketch a graph to show the variation of the kinetic energy of the particle with the distance *x* from point A along the line AB.
Numerical values for the kinetic energy are not required.

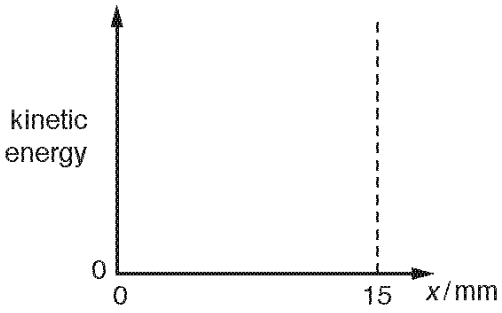


Fig. 6.2

[1]

5 - (9702/21_Summer_2018_Q7) - *Electric Fields*

A β^- particle from a radioactive source is travelling in a vacuum with kinetic energy 460 eV. The particle enters a uniform electric field at a right-angle and follows the path shown in Fig. 7.1.

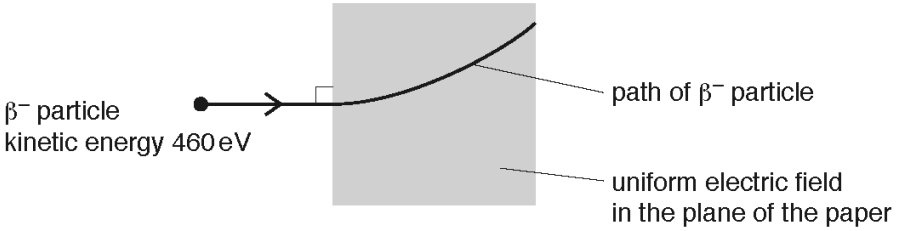


Fig. 7.1

(a) The direction of the electric field is in the plane of the paper.
On Fig. 7.1, draw an arrow to show the direction of the electric field. [1]

(b) Calculate the speed of the β^- particle before it enters the electric field.

speed = ... $m\,s^{-1}$ [3]

(c) Other β^- particles from the same radioactive source travel outside the electric field along the same incident path as that shown in Fig. 7.1.

State and briefly explain whether those β^- particles will all follow the same path inside the electric field.

.....

.....

.....

.....[2]

6 - (9702/21_Winter_2018_Q5) - *Electric Fields, Particle & Nuclear Physics, Kinematics*

(a) State what is meant by an *electric field*.

.....

..... [1]

(b) A particle of mass m and charge q is in a uniform electric field of strength E. The particle has acceleration a due to the field.

Show that

$$a = \frac{Eq}{m}.$$

[2]

(c) A stationary nucleus X decays by emitting an α-particle to form a nucleus of plutonium, $^{240}_{94}Pu$, as shown.

$$X \longrightarrow {}^{240}_{94}Pu + \alpha$$

(i) Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...

number of neutrons = ...

[2]

(ii) The total mass of the plutonium nucleus and the α-particle is less than that of nucleus X. Explain this difference in mass.

.....

.....

.....

..... [2]

(iii) The plutonium nucleus and the α-particle are both accelerated by the same uniform electric field.

Use the expression in **(b)** to determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particle}}{\text{acceleration of the plutonium nucleus}}.$$

ratio = ... [2]

7 - (9702/23_Winter_2018_Q5) - *Electric Fields, Particle & Nuclear Physics*

A particle of mass m and charge q is in a uniform electric field of strength E. The particle has acceleration a due to the field.

(a) Show that

$$\frac{q}{m} = \frac{a}{E}.$$

[2]

(b) The particle has a charge of $4e$ where e is the elementary charge. The electric field strength is $3.5 \times 10^4\,\text{V m}^{-1}$. The acceleration of the particle is $1.5 \times 10^{12}\,\text{m s}^{-2}$.

Use the expression in **(a)** to show that the mass of the particle is 9.0 u.

[2]

(c) The particle is a nucleus. State the number of protons and the number of neutrons in the nucleus.

number of protons = ...

number of neutrons = ...
[1]

(d) A second nucleus that is an isotope of the nucleus in **(c)** is in the same uniform electric field.

State and explain whether the electric field produces, for the two nuclei, the same magnitudes of

(i) force,

.....

.....[1]

(ii) acceleration.

.....

.....[1]

8 - (9702/22_Summer_2019_Q2) - *Kinematics, Dynamics, Electric Fields*

(a) State Newton's second law of motion.

.....

.....[1]

(b) A car of mass 850 kg tows a trailer in a straight line along a horizontal road, as shown in Fig. 2.1.

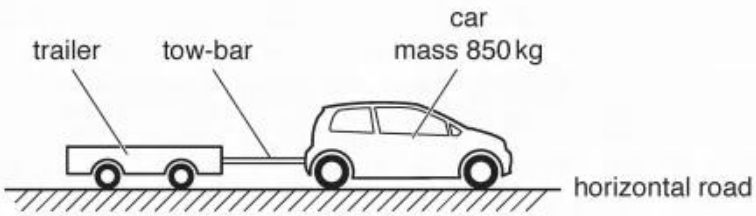


Fig. 2.1

The car and the trailer are connected by a horizontal tow-bar.

The variation with time *t* of the velocity *v* of the car for a part of its journey is shown in Fig. 2.2.

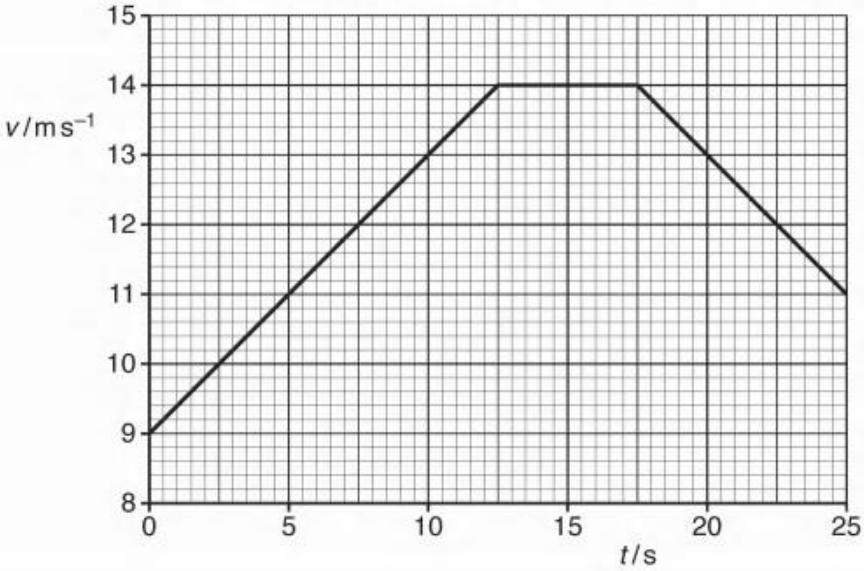


Fig. 2.2

(i) Calculate the distance travelled by the car from time $t = 0$ to $t = 10\,s$.

distance = ... m [2]

(ii) At time $t = 10\,s$, the resistive force acting on the car due to air resistance and friction is 510 N. The tension in the tow-bar is 440 N.

For the car at time $t = 10\,s$:

1. use Fig. 2.2 to calculate the acceleration

acceleration = ... $m\,s^{-2}$ [2]

2. use your answer to calculate the resultant force acting on the car

resultant force = ... N [1]

3. show that a horizontal force of 1300 N is exerted on the car by its engine

[1]

4. determine the useful output power of the engine.

output power = ... W [2]

(c) A short time later, the car in **(b)** is travelling at a constant speed and the tension in the tow-bar is 480 N.

The tow-bar is a solid metal rod that obeys Hooke's law. Some data for the tow-bar are listed below.

Young modulus of metal = 2.2×10^{11} Pa

original length of tow-bar = 0.48 m

cross-sectional area of tow-bar = 3.0×10^{-4} m^2

Determine the extension of the tow-bar.

extension = ... m [3]

(d) The driver of the car in **(b)** sees a pedestrian standing directly ahead in the distance. The driver operates the horn of the car from time $t = 15$ s to $t = 17$ s. The frequency of the sound heard by the pedestrian is 480 Hz. The speed of the sound in the air is 340 m s^{-1}.

Use Fig. 2.2 to calculate the frequency of the sound emitted by the horn.

frequency = ... Hz [2]

9 - (9702/21_Summer_2019_Q4) - *Electric Fields*

(a) A spherical oil drop has a radius of 1.2×10^{-6} m. The density of the oil is $940\,\text{kg m}^{-3}$.

(i) Show that the mass of the oil drop is 6.8×10^{-15} kg.

[2]

(ii) The oil drop is charged. Explain why it is impossible for the magnitude of the charge to be 8.0×10^{-20} C.

.....

.....[1]

(b) The charged oil drop in **(a)** is in a vacuum between two horizontal metal plates, as illustrated in Fig. 4.1.

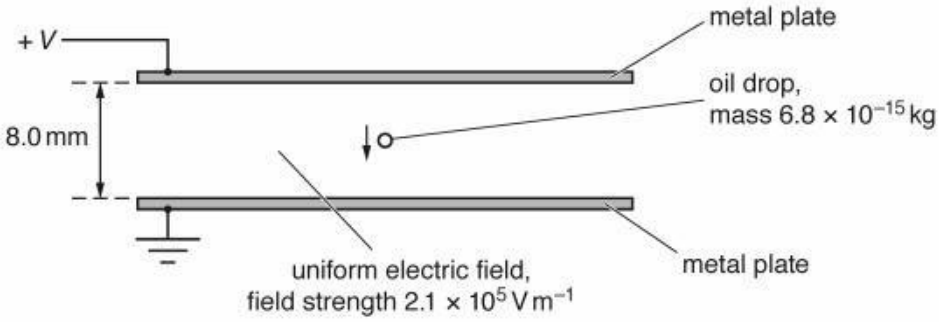


Fig. 4.1

The plates are separated by a distance of 8.0 mm. The electric field between the plates is uniform and has a field strength of $2.1 \times 10^5\,\text{V m}^{-1}$.

The oil drop moves vertically downwards with a constant speed.

(i) Calculate the potential difference V between the plates.

V = ... V [2]

(ii) Explain how the motion of the oil drop shows that it is in equilibrium.

.....

.....[1]

(iii) Determine the charge on the oil drop.

charge = ... C

sign of charge .....

[3]

(c) The magnitude of the potential difference between the plates in **(b)** is decreased.

(i) Explain why the oil drop accelerates downwards.

.....

.....

.....

.....[2]

(ii) Describe the change to the pattern of the field lines (lines of force) representing the uniform electric field as the potential difference decreases.

.....

.....[1]

(d) Two types of force, X and Y, can act on an oil drop when it is in air, but cannot act on an oil drop when it is in a vacuum. Force X can act on an oil drop when it is stationary or when it is moving. Force Y can only act on an oil drop when it is moving.

State the name of:

(i) force X

.....[1]

(ii) force Y.

.....[1]

10 - (9702/23_Summer_2019_Q4) - *Electric Fields*

Two vertical metal plates in a vacuum are separated by a distance of 0.12 m.
Fig. 4.1 shows a side view of this arrangement.

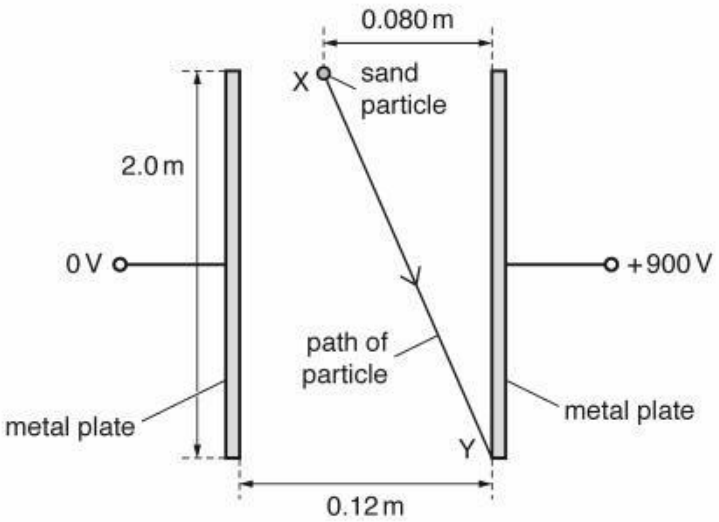


Fig. 4.1 (not to scale)

Each plate has a length of 2.0 m. The potential difference between the plates is 900 V. The electric field between the plates is uniform.

A negatively charged sand particle is released from rest at point X, which is a horizontal distance of 0.080 m from the top of the positively charged plate. The particle then travels in a straight line and collides with the positively charged plate at its lowest point Y, as illustrated in Fig. 4.1.

(a) Describe the pattern of the field lines (lines of force) between the plates.

.....

.....

.....[2]

(b) State the names of the **two** forces acting on the particle as it moves from X to Y.

.....[1]

(c) By considering the vertical motion of the sand particle, show that the time taken for the particle to move from X to Y is 0.64 s.

[2]

(d) Calculate the horizontal component of the acceleration of the particle.

horizontal component of acceleration = ... $m\,s^{-2}$ [2]

(e) **(i)** Calculate the magnitude of the electric field strength.

electric field strength = ... $N\,C^{-1}$ [2]

(ii) The sand particle has mass m and charge q. Use your answers in **(d)** and **(e)(i)** to determine the ratio $\frac{q}{m}$.

ratio = ... $C\,kg^{-1}$ [2]

(f) Another particle has a smaller magnitude of the ratio $\frac{q}{m}$ than the sand particle. This particle is also released from point X.

For the movement of this particle, state the effect, if any, of the decreased magnitude of the ratio on:

(i) the vertical component of the acceleration

.....[1]

(ii) the horizontal component of the acceleration.

.....[1]

11 - (9702/22_Summer_2019_Q6) - *Electric Fields, Particle & Nuclear Physics*

(a) State what is meant by a *field line* (*line of force*) in an electric field.

.....

.....[1]

(b) An electric field has two different regions X and Y. The field strength in X is less than that in Y. Describe a difference between the pattern of field lines (lines of force) in X and in Y.

.....

.....[1]

(c) A particle P has a mass of 0.15 u and a charge of $-1e$, where e is the elementary charge.

(i) Particle P and an α-particle are in the same uniform electric field. Calculate the ratio

$$\frac{\text{magnitude of acceleration of particle P}}{\text{magnitude of acceleration of } \alpha\text{-particle}}.$$

ratio = ... [3]

(ii) Particle P is a hadron composed of only two quarks. One of them is a down (d) quark.

By considering charge, determine a possible type (flavour) of the other quark.
Explain your working.

.....

.....[3]

12 - (9702/21_Winter_2019_Q2) - *Kinematics, Dynamics, Electric Fields*

A small charged glass bead of weight 5.4×10^{-5} N is initially at rest at point A in a vacuum. The bead then falls through a uniform horizontal electric field as it moves in a straight line to point B, as illustrated in Fig. 2.1.

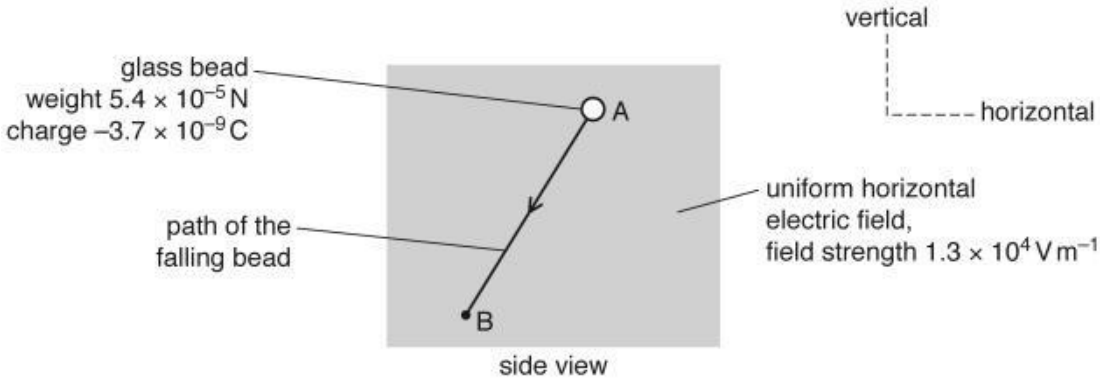


Fig. 2.1 (not to scale)

The electric field strength is 1.3×10^{4} V m^{-1}. The charge on the bead is -3.7×10^{-9} C.

(a) Describe how two metal plates could be used to produce the electric field. Numerical values are not required.

.....

.....

..... [2]

(b) Determine the magnitude of the electric force acting on the bead.

electric force = ... N [2]

(c) Use your answer in **(b)** and the weight of the bead to show that the resultant force acting on it is 7.2×10^{-5} N.

[1]

(d) Explain why the resultant force on the bead of 7.2×10^{-5} N is constant as the bead moves along path AB.

.....

.....

.....

..... [2]

(e) **(i)** Calculate the magnitude of the acceleration of the bead along the path AB.

acceleration = ... $m\,s^{-2}$ [2]

(ii) The path AB has length 0.58 m.

Use your answer in **(i)** to determine the speed of the bead at point B.

speed = ... $m\,s^{-1}$ [2]

13 - (9702/23_Winter_2019_Q3) - *Kinematics, Electric Fields*

(a) State the property of an object that experiences a force when the object is placed in:

(i) a gravitational field

..... [1]

(ii) an electric field.

..... [1]

(b) A potential difference of 1.2×10^3 V is applied between a pair of horizontal metal plates in a vacuum, as shown in Fig. 3.1.

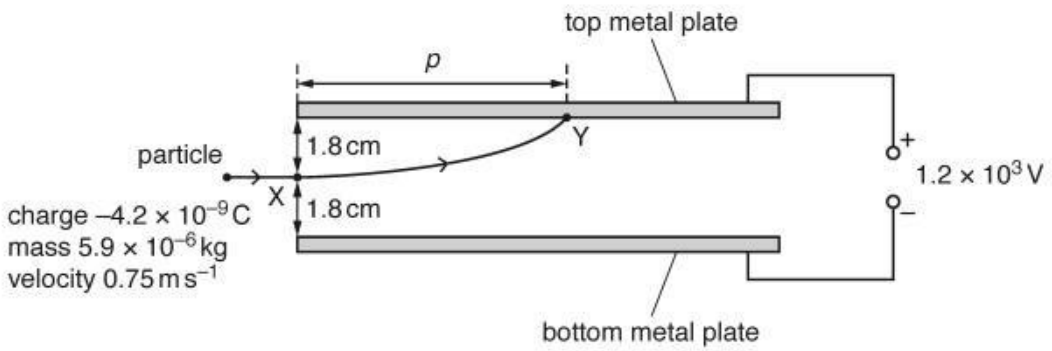


Fig. 3.1 (not to scale)

The separation of the plates is 3.6 cm. The electric field between the plates is uniform.

A particle of mass 5.9×10^{-6} kg and charge -4.2×10^{-9} C enters the field at point X with a horizontal velocity of $0.75\,\text{m s}^{-1}$ along a line midway between the two plates.
The particle is deflected by the field and hits the top plate at point Y.

(i) Calculate the magnitude of the electric force acting on the particle in the field.

electric force = ... N [3]

(ii) By considering the resultant vertical force acting on the particle, show that the acceleration of the particle in the electric and gravitational fields is $14\,m\,s^{-2}$.

[4]

(iii) Determine:

1. the time taken for the particle to move from X to Y

time taken = ... s [2]

2. the distance p of point Y from the left-hand edge of the top plate.

p = ... m [1]

14 - (9702/21_Summer_2020_Q6) - *Electric Fields, Particle & Nuclear Physics*

(a) Two horizontal metal plates are separated by a distance of 2.0 cm in a vacuum, as shown in Fig. 6.1.

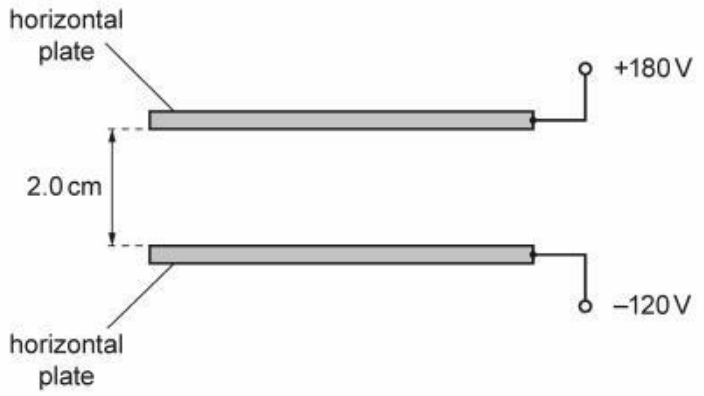


Fig. 6.1

The top plate has an electric potential of +180 V and the bottom plate has an electric potential of –120 V.

(i) Determine the magnitude of the electric field strength between the plates.

electric field strength = ... $N\,C^{-1}$ [2]

(ii) State the direction of the electric field.

..... [1]

(b) An uncharged atom of uranium-238 ($^{238}_{92}U$) has a change made to its number of orbital electrons. This causes the atom to change into a new particle (ion) X that has an overall charge of +2*e*, where *e* is the elementary charge.

(i) Determine the number of protons, neutrons and electrons in the particle (ion) X.

number of protons = ...

number of neutrons = ...

number of electrons = ...

[3]

(ii) The particle (ion) X is in the electric field in **(a)** at a point midway between the plates.

Determine the magnitude of the electric force acting on X.

force = ... N [2]

(iii) The nucleus of uranium-238 ($^{238}_{92}U$) decays in stages, by emitting α-particles and β^- particles, to form a nucleus of thorium-230 ($^{230}_{90}Th$).

Calculate the total number of α-particles and the total number of β^- particles that are emitted during the decay of uranium-238 to thorium-230.

number of α-particles = ...

number of β^- particles = ...
[2]

15 - (9702/23_Summer_2020_Q7) - *Electric Fields, Particle & Nuclear Physics*

A potential difference is applied between two horizontal metal plates that are a distance of 6.0 mm apart in a vacuum, as shown in Fig. 7.1.

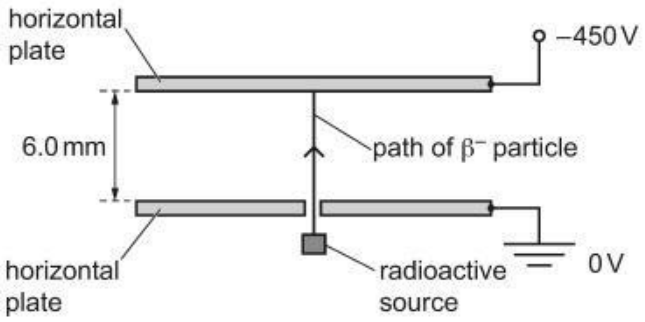


Fig. 7.1

The top plate has a potential of −450 V and the bottom plate is earthed. Assume that there is a uniform electric field produced between the plates.

A radioactive source emits a β^- particle that travels through a hole in the bottom plate and along a vertical path until it reaches the top plate.

(a) (i) Determine the magnitude and the direction of the electric force acting on the β^- particle as it moves between the plates.

magnitude of force = ... N

direction of force .....

[4]

(ii) Calculate the work done by the electric field on the β^- particle for its movement from the bottom plate to the top plate.

work done = ... J [2]

(b) The β^- particle is emitted from the source with a kinetic energy of 3.4×10^{-16} J.

Calculate the speed at which the β^- particle is emitted.

speed = ... $m\,s^{-1}$ [2]

(c) The β^- particle is produced by the decay of a neutron.

(i) Complete the equation below to represent the decay of the neutron.

$$^{1}_{0}n \rightarrow {}^{0}_{-1}\beta^- + \begin{matrix}\cdots\cdots\\ \cdots\cdots\end{matrix}\cdots\cdots + \begin{matrix}\cdots\cdots\\ \cdots\cdots\end{matrix}\cdots\cdots$$

[2]

(ii) State the name of the group (class) of particles that includes:

1. neutrons

.....

2. β^- particles.

.....

[2]

16 - (9702/22_Winter_2020_Q7) - *Electric Fields, Particle & Nuclear Physics*

(a) State a similarity and a difference between an up quark and an up antiquark.

similarity: .....

difference: .....

[2]

(b) Fig. 7.1 shows an electron in an electric field, in a vacuum, at an instant when the electron is stationary.

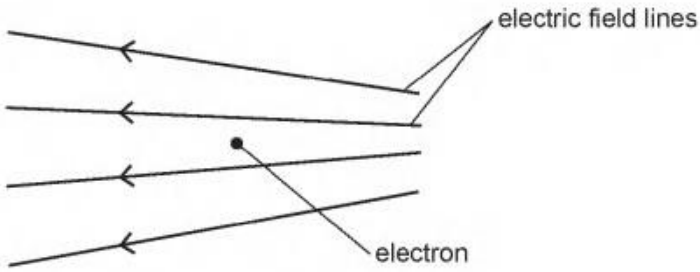


Fig. 7.1

(i) On Fig. 7.1, draw an arrow to show the direction of the electric force acting on the stationary electron. [1]

(ii) The electric field causes the electron to move from its initial position.

Describe and explain the acceleration of the electron due to the field, as the electron moves through the field.

.....

.....

.....

..... [2]

(iii) A stationary α-particle is now placed in the same electric field at the same initial position that was occupied by the electron.

Compare the initial electric force acting on the α-particle with the initial electric force that acted on the electron.

.....

.....

.....

..... [2]

[Total: 7]

17 - (9702/23_Winter_2020_Q7) - *Electric Fields, Particle & Nuclear Physics*

Two vertical metal plates are separated by a distance *d* in a vacuum, as shown in Fig. 7.1.

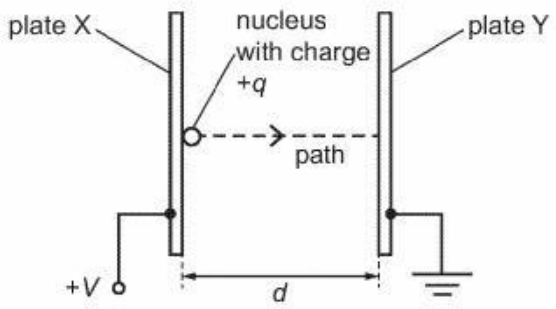


Fig. 7.1 (not to scale)

The potential difference (p.d.) between the plates is *V*. A nucleus with charge +*q* is initially at rest on plate X. The nucleus is accelerated by the uniform electric field from plate X along a horizontal path to plate Y.

(a) State expressions, in terms of some or all of *d*, *q* and *V*, for:

(i) the magnitude of the electric field strength

electric field strength = ... [1]

(ii) the magnitude of the electric force acting on the nucleus

force = ... [1]

(iii) the kinetic energy of the nucleus when it reaches plate Y.

kinetic energy = ... [1]

(b) State the change, if any, in the kinetic energy of the nucleus on reaching plate Y when the following separate changes are made.

(i) The distance *d* is halved, but the p.d. *V* remains the same.

..... [1]

(ii) The nucleus is replaced by a different nucleus that is an isotope of the original nucleus with fewer neutrons.

..... [1]

(c) The nucleus is carbon-14 ($^{14}_{6}C$). This nucleus decays to form a new nucleus by releasing a β^- particle and only one other particle of negligible mass.

(i) Calculate the nucleon number and the proton number of the **new** nucleus.

nucleon number = ...

proton number = ...
[1]

(ii) State the name of the particle of negligible mass.

..... [1]

[Total: 7]

18 - (9702/22_Winter_2021_Q2) - *Electric Fields*

A charged oil drop is in a vacuum between two horizontal metal plates. A uniform electric field is produced between the plates by applying a potential difference of 1340 V across them, as shown in Fig. 2.1.

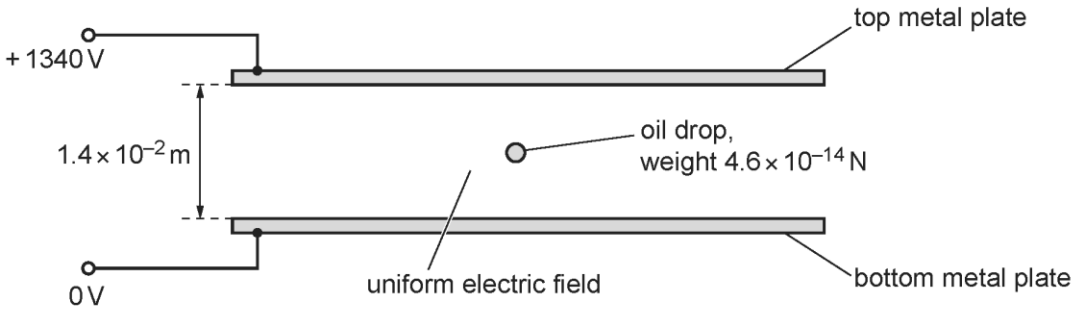


Fig. 2.1

The separation of the plates is 1.4×10^{-2} m.

The oil drop of weight 4.6×10^{-14} N remains stationary at a point mid-way between the plates.

(a) **(i)** Calculate the magnitude of the electric field strength.

electric field strength = ... $N\,C^{-1}$ [2]

(ii) Determine the magnitude and the sign of the charge on the oil drop.

magnitude of charge = ... C

sign of charge .....
[3]

(b) The electric potentials of the plates are instantaneously reversed so that the top plate is at a potential of 0 V and the bottom plate is at a potential of +1340 V. This change causes the oil drop to start moving downwards.

(i) Compare the new pattern of the electric field lines between the plates with the original pattern.

.....

..... [2]

(ii) Determine the magnitude of the resultant force acting on the oil drop.

resultant force = ... N [1]

(iii) Show that the magnitude of the acceleration of the oil drop is $20\,m\,s^{-2}$.

[2]

(iv) Assume that the radius of the oil drop is negligible.

Use the information in **(b)(iii)** to calculate the time taken for the oil drop to move to the bottom metal plate from its initial position mid-way between the plates.

time = ... s [2]

(c) The oil drop in **(b)** starts to move at time $t = 0$. The distance of the oil drop from the bottom plate is x.

On Fig. 2.2, sketch the variation with time t of distance x for the movement of the drop from its initial position until it hits the surface of the bottom plate. Numerical values of t are not required.

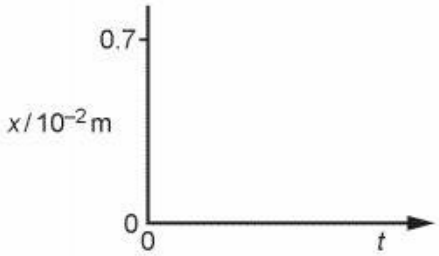


Fig. 2.2

[2]

19 - (9702/23_Winter_2021_Q4) - *Electric Fields*

An α-particle moves in a straight line through a vacuum with a constant speed of $4.1 \times 10^6\,m\,s^{-1}$. The α-particle enters a uniform electric field at point A, as shown in Fig. 4.1.

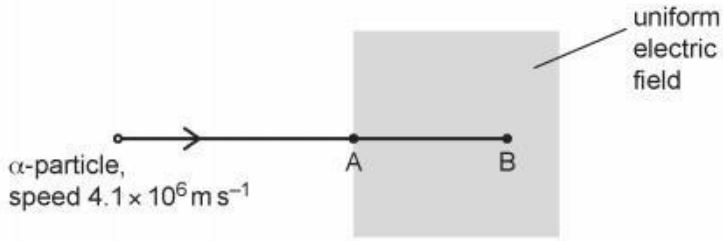


Fig. 4.1

The α-particle continues to move in the same straight line until it is brought to rest at point B by the electric field. The deceleration of the α-particle by the electric field is $2.7 \times 10^{14}\,m\,s^{-2}$.

(a) State the direction of the electric field.

..... [1]

(b) Calculate the distance AB.

distance = ... m [2]

(c) Calculate the electric field strength.

electric field strength = ... $V\,m^{-1}$ [3]

(d) The α-particle is at point A at time $t = 0$.

On Fig. 4.2, sketch the variation with time t of the momentum of the α-particle as it travels from point A to point B. Numerical values are not required.

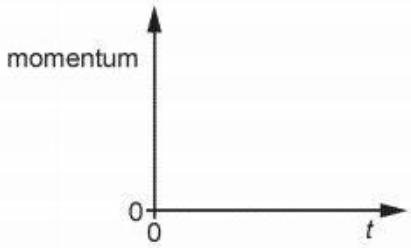


Fig. 4.2

[1]

(e) State the name of the quantity that is represented by the gradient of the graph in **(d)**.

..... [1]

(f) A β^- particle now enters the electric field along the same initial path as the α-particle and with the same initial speed of $4.1 \times 10^6\,\text{m s}^{-1}$.

(i) Calculate the kinetic energy, in J, of the β^- particle at point A.

kinetic energy = ... J [3]

(ii) State and explain the differences between the electric force on the β^- particle in the electric field and the electric force on the α-particle in the electric field.

.....

.....

.....

.....

..... [3]

(iii) The β^- particle is produced by the decay of a nucleus. State the name of another lepton that is produced at the same time as the β^- particle.

..... [1]

1 - (9702/21_Summer_2017_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define the *ohm*.

.....

.....[1]

(b) A cell X of electromotive force (e.m.f.) 1.5 V and negligible internal resistance is connected in series to three resistors A, B and C, as shown in Fig. 6.1.

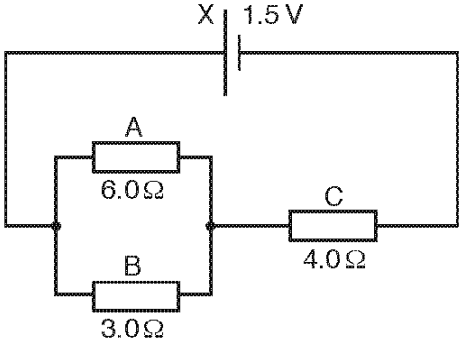


Fig. 6.1

Resistors A and B have resistances 6.0 Ω and 3.0 Ω respectively and are connected in parallel. Resistor C has resistance 4.0 Ω and is connected in series with the parallel combination.

Calculate

(i) the current in the circuit,

current = ...A [3]

(ii) the current in resistor B,

current = ...A [1]

(iii) the ratio

$$\frac{\text{power dissipated in resistor B}}{\text{power dissipated in resistor C}}.$$

ratio = ...[2]

(c) The resistors A, B and C in **(b)** are wires of the same material and have the same length.

(i) Explain how the resistors may be made with different resistance values.

.....[1]

(ii) Calculate the ratio

$$\frac{\text{average drift speed of the charge carriers in resistor B}}{\text{average drift speed of the charge carriers in resistor C}}.$$

ratio = ...[2]

(d) A cell of e.m.f. 1.5 V and negligible internal resistance is connected in parallel with cell X in Fig. 6.1 with their positive terminals together.

State the change, if any, to the current in

(i) cell X,

.....[1]

(ii) resistor C.

.....[1]

2 - (9702/23_Summer_2017_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Describe the I–V characteristic of

(i) a metallic conductor at constant temperature,

.....

.....[1]

(ii) a semiconductor diode.

.....

.....

.....[2]

(b) Two identical filament lamps are connected in series and then in parallel to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance, as shown in Fig. 6.1a and Fig. 6.1b.

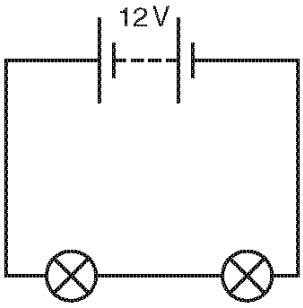


Fig. 6.1a

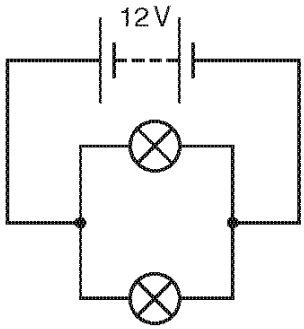


Fig. 6.1b

The I–V characteristic of each lamp is shown in Fig. 6.2.

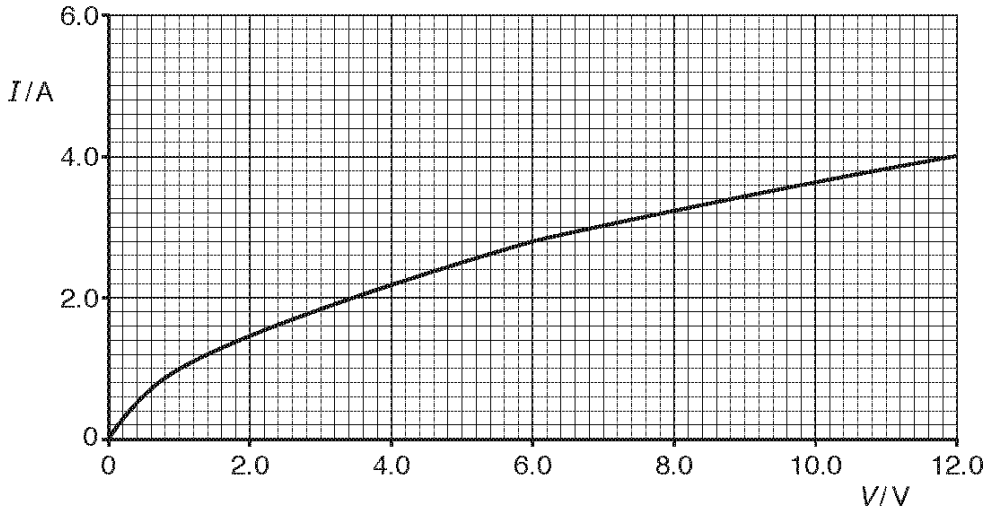


Fig. 6.2

(i) Use the information shown in Fig. 6.2 to determine the current through the battery in

1. the circuit of Fig. 6.1a,

current = ...A

2. the circuit of Fig. 6.1b.

current = ...A
[3]

(ii) Calculate the total resistance in

1. the circuit of Fig. 6.1a,

resistance = ...Ω

2. the circuit of Fig. 6.1b.

resistance = ...Ω
[3]

(iii) Calculate the ratio

$$\frac{\text{power dissipated in a lamp in the circuit of Fig. 6.1a}}{\text{power dissipated in a lamp in the circuit of Fig. 6.1b}}.$$

ratio = ...[2]

3 - (9702/21_Winter_2017_Q5) - *Current Of Electricity, D.c. Circuits*

Three cells of electromotive forces (e.m.f.) E_1, E_2 and E_3 are connected into a circuit, as shown in Fig. 5.1.

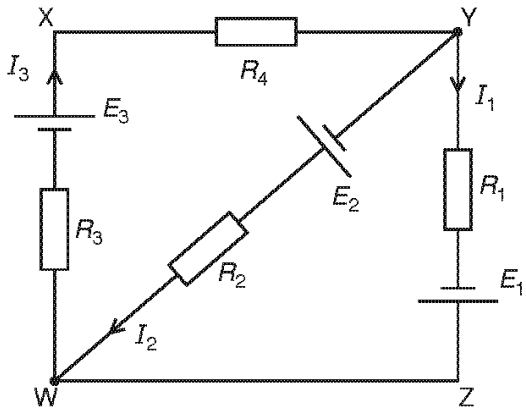


Fig. 5.1

The circuit contains resistors of resistances R_1, R_2, R_3 and R_4.
The currents in the different parts of the circuit are I_1, I_2 and I_3.
The cells have negligible internal resistance.

Use Kirchhoff's laws to state an equation relating

(a) I_1, I_2 and I_3,

.....[1]

(b) E_1, E_3, R_1, R_3, R_4, I_1 and I_3 in loop WXYZW,

.....

.....[1]

(c) E_1, E_2, R_1, R_2, I_1 and I_2 in loop YZWY.

.....

.....[1]

4 - (9702/22_Winter_2017_Q6) - *Current Of Electricity*

(a) State what is meant by an *electric current*.

.....[1]

(b) A metal wire has length L and cross-sectional area A, as shown in Fig. 6.1.

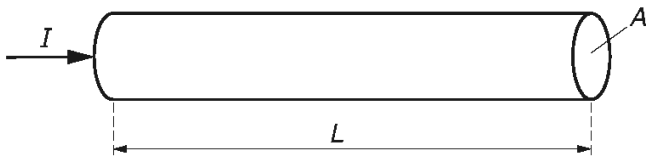


Fig. 6.1

I is the current in the wire,
n is the number of free electrons per unit volume in the wire,
v is the average drift speed of a free electron and
e is the charge on an electron.

(i) State, in terms of A, e, L and n, an expression for the total charge of the free electrons in the wire.

.....[1]

(ii) Use your answer in **(i)** to show that the current I is given by the equation

$$I = nAve.$$

[2]

(c) A metal wire in a circuit is damaged. The resistivity of the metal is unchanged but the cross-sectional area of the wire is reduced over a length of 3.0 mm, as shown in Fig. 6.2.

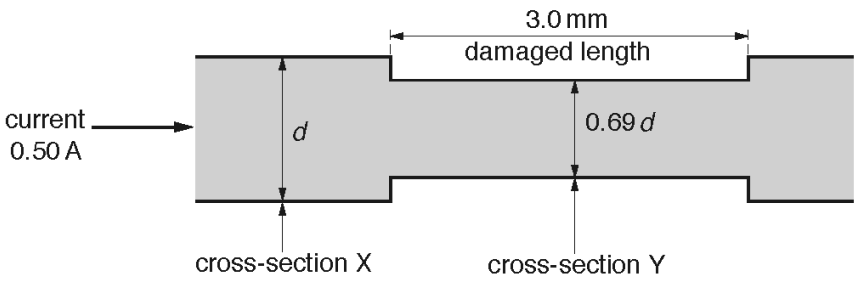


Fig. 6.2

The wire has diameter d at cross-section X and diameter $0.69\,d$ at cross-section Y.
The current in the wire is 0.50 A.

(i) Determine the ratio

$$\frac{\text{average drift speed of free electrons at cross-section Y}}{\text{average drift speed of free electrons at cross-section X}}.$$

ratio = ...[2]

(ii) The main part of the wire with cross-section X has a resistance per unit length of $1.7 \times 10^{-2}\,\Omega\,m^{-1}$.

For the damaged length of the wire, calculate

1. the resistance per unit length,

resistance per unit length = ... $\Omega\,m^{-1}$ [2]

2. the power dissipated.

power = ... W [2]

(iii) The diameter of the damaged length of the wire is further decreased. Assume that the current in the wire remains constant.

State and explain qualitatively the change, if any, to the power dissipated in the damaged length of the wire.

.....

.....

.....[2]

5 - (9702/23_Winter_2017_Q6) - *Current Of Electricity, D.c. Circuits*

A filament lamp is rated as 30 W, 120 V. A potential difference of 120 V is applied across the lamp.

(a) For the filament wire of the lamp, calculate

(i) the current,

current = ... A [2]

(ii) the number of electrons passing a point in 3.0 hours.

number = ...[2]

(b) Show that the resistance of the filament wire is 480 Ω.

[2]

(c) The filament wire has an uncoiled length of 580 mm and is made of metal. The metal has resistivity $6.1 \times 10^{-7}\,\Omega\,m$ at the operating temperature of the lamp.

Calculate the diameter of the wire.

diameter = ... m [3]

(d) The potential difference across the lamp is now reduced. State and explain the effect, if any, on the resistance of the filament wire.

.....

.....[1]

6 - (9702/21_Winter_2017_Q7) - *Current Of Electricity, D.c. Circuits*

(a) Define the *ohm*.

.....[1]

(b) Wires are used to connect a battery of negligible internal resistance to a lamp, as shown in Fig. 7.1.

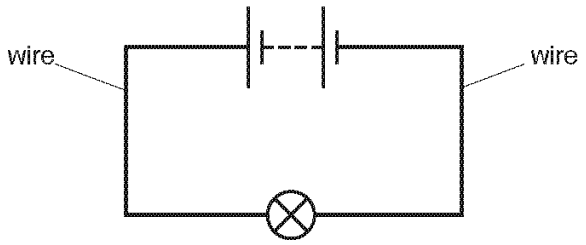


Fig. 7.1

The lamp is at its normal operating temperature. Some data for the filament wire of the lamp and for the connecting wires of the circuit are shown in Fig. 7.2.

	filament wire	connecting wires
diameter	d	$14\,d$
total length	L	$7.0\,L$
resistivity of metal (at normal operating temperature)	ρ	$0.028\,\rho$

Fig. 7.2

(i) Show that

$$\frac{\text{resistance of filament wire}}{\text{total resistance of connecting wires}} = 1000.$$

[2]

(ii) Use the information in **(i)** to explain qualitatively why the power dissipated in the filament wire of the lamp is greater than the total power dissipated in the connecting wires.

.....

.....

.....[1]

(iii) The lamp is rated as 12 V, 6.0 W. Use the information in **(i)** to determine the total resistance of the connecting wires.

total resistance of connecting wires = ... Ω [3]

(iv) The diameter of the connecting wires is decreased. The total length of the connecting wires and the resistivity of the metal of the connecting wires remain the same.

State and explain the change, if any, that occurs to the resistance of the filament wire of the lamp.

.....

.....

.....

.....

.....[3]

7 - (9702/21_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define the *volt*.

.....[1]

(b) A battery of electromotive force (e.m.f.) 4.5 V and negligible internal resistance is connected to two filament lamps P and Q and a resistor R, as shown in Fig. 6.1.

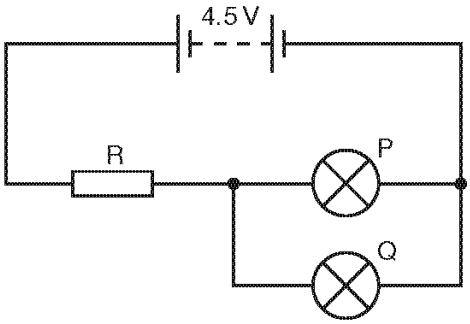


Fig. 6.1

The current in lamp P is 0.15 A.
The I–V characteristics of the filament lamps are shown in Fig. 6.2.

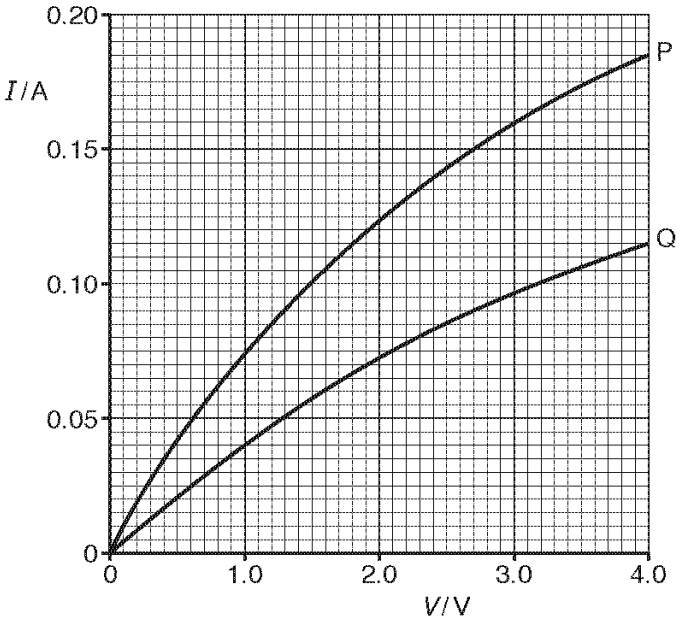


Fig. 6.2

(i) Use Fig. 6.2 to determine the current in the battery. Explain your working.

current = ... A [2]

(ii) Calculate the resistance of resistor R.

resistance = ... Ω [2]

(iii) The filament wires of the two lamps are made from material with the same resistivity at their operating temperature in the circuit. The diameter of the wire of lamp P is twice the diameter of the wire of lamp Q.

Determine the ratio

$$\frac{\text{length of filament wire of lamp P}}{\text{length of filament wire of lamp Q}}.$$

ratio = ... [3]

(iv) The filament wire of lamp Q breaks and stops conducting.

State and explain, qualitatively, the effect on the resistance of lamp P.

.....

.....

.....

.....[2]

8 - (9702/22_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a) **(i)** State Kirchhoff's first law.

.....

.....[1]

(ii) Kirchhoff's first law is linked to the conservation of a certain quantity. State this quantity.

.....[1]

(b) A battery of electromotive force (e.m.f.) 8.0 V and internal resistance 2.0 Ω is connected to a resistor X and a wire Y, as shown in Fig. 6.1.

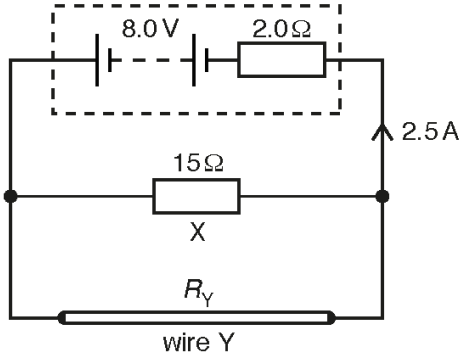


Fig. 6.1

The resistance of X is 15 Ω. The resistance of Y is R_Y. The current in the battery is 2.5 A.

(i) Calculate

1. the thermal energy dissipated in the battery in a time of 5.0 minutes,

energy = ...J [2]

2. the terminal potential difference of the battery.

terminal potential difference = ... V [1]

(ii) Determine the resistance R_Y.

R_Y = ...Ω [3]

(iii) A new wire Z has the same length but less resistance than wire Y.

1. State two possible differences between wire Z and wire Y that would separately cause wire Z to have less resistance than wire Y.

first difference: .....

.....

second difference: .....

.....
[2]

2. Wire Y is replaced in the circuit by wire Z. By considering the current in the battery, state and explain the effect of changing the wires on the total power produced by the battery.

.....

.....

.....[2]

9 - (9702/23_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

A wire X has a constant resistance per unit length of $3.0\,\Omega\,m^{-1}$ and a diameter of 0.48 mm.

(a) Calculate the resistivity of the metal of wire X.

resistivity = ... Ω m [3]

(b) The wire X is connected into the circuit shown in Fig. 6.1.

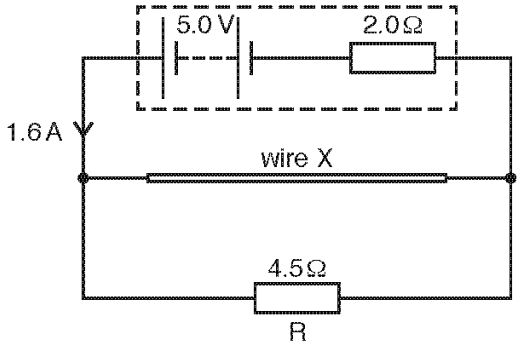


Fig. 6.1

The battery has an electromotive force (e.m.f.) of 5.0 V and an internal resistance of 2.0 Ω. The wire X and a resistor R of resistance 4.5 Ω are connected in parallel. The current in the battery is 1.6 A.

(i) Calculate the potential difference across resistor R.

potential difference = ... V [1]

(ii) Determine, for wire X,

1. its resistance,

resistance = ... Ω [3]

2. its length.

length = ... m [1]

10 - (9702/21_Winter_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a) State Kirchhoff's second law.

.....

.....

..... [2]

(b) An electric heater containing two heating wires X and Y is connected to a power supply of electromotive force (e.m.f.) 9.0 V and negligible internal resistance, as shown in Fig. 6.1.

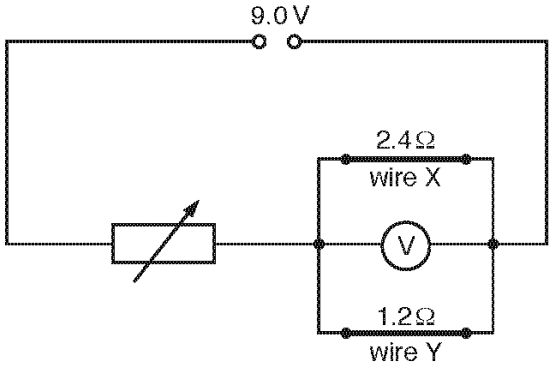


Fig. 6.1

Wire X has a resistance of 2.4 Ω and wire Y has a resistance of 1.2 Ω. A voltmeter is connected in parallel with the wires. A variable resistor is used to adjust the power dissipated in wires X and Y.

The variable resistor is adjusted so that the voltmeter reads 6.0 V.

(i) Calculate the resistance of the variable resistor.

resistance = ... Ω [3]

(ii) Calculate the power dissipated in wire X.

power = ... W [2]

(iii) The cross-sectional area of wire X is three times the cross-sectional area of wire Y. Assume that the resistivity and the number density of free electrons for the metal of both wires are the same.

Determine the ratio

1. $\frac{\text{length of wire X}}{\text{length of wire Y}}$,

ratio = ... [2]

2. $\frac{\text{average drift velocity of free electrons in wire X}}{\text{average drift velocity of free electrons in wire Y}}$.

ratio = ... [2]

11 - (9702/22_Winter_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define the *volt*.

.....

.....[1]

(b) A battery of electromotive force (e.m.f.) 7.0 V and negligible internal resistance is connected in series with three components, as shown in Fig. 6.1.

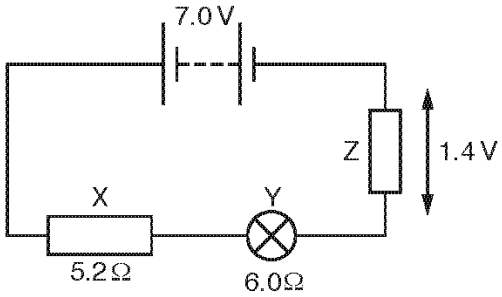


Fig. 6.1

Resistor X has a resistance of 5.2 Ω. The resistance of the filament wire of lamp Y is 6.0 Ω. The potential difference across resistor Z is 1.4 V.

(i) Calculate the current in the circuit.

current = ... A [2]

(ii) Determine the resistance of resistor Z.

resistance = ... Ω [1]

(iii) Calculate the percentage efficiency with which the battery supplies power to the lamp.

efficiency = ... % [3]

(iv) The filament wire of the lamp is made of metal of resistivity $3.7 \times 10^{-7}\,\Omega\,\text{m}$ at its operating temperature in the circuit.

Determine, for the filament wire, the value of α where

$$\alpha = \frac{\text{cross-sectional area}}{\text{length}}.$$

α = ... m [2]

12 - (9702/23_Winter_2018_Q6) - *Current Of Electricity*

(a) Define the *coulomb*.

.....

.....[1]

(b) An electric current is a flow of charge carriers.

In the following list, underline the possible charges for a charge carrier.

8.0×10^{-19} C 4.0×10^{-19} C 1.6×10^{-19} C 1.6×10^{-20} C [1]

(c) The diameter of a wire ST varies linearly with distance along the wire as shown in Fig. 6.1.

Fig. 6.1

There is a current I in the wire. At end S of the wire, the diameter is d and the average drift speed of the free electrons is v_s. At end T of the wire, the diameter is $2d$.

On Fig. 6.2, sketch a graph to show the variation of the average drift speed with position along the wire between S and T.

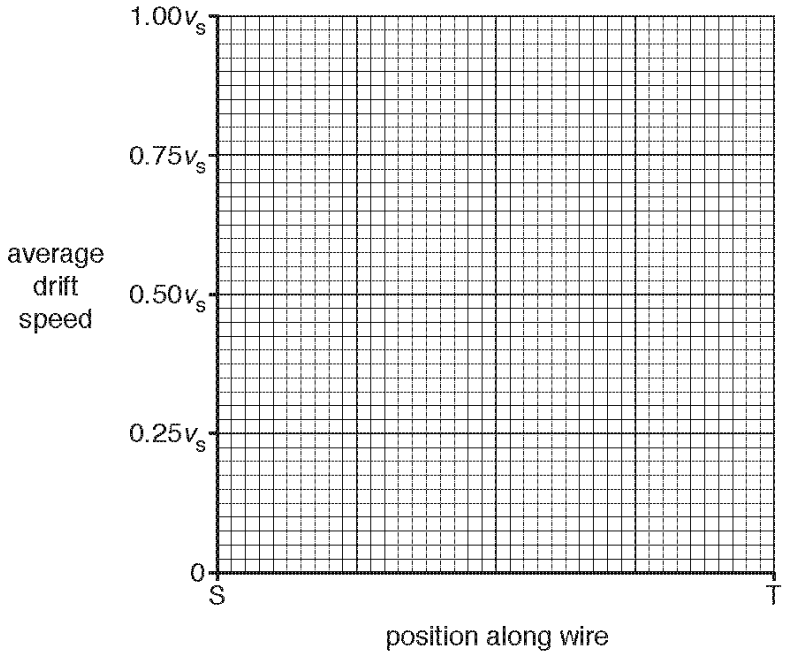


Fig. 6.2

[2]

13 – (9702/22_Winter_2018_Q7) – *Current Of Electricity*

(a) The current I in a metal wire is given by the expression

$$I = Anve.$$

State what is meant by the symbols A and n.

A: .....

n: .....

[2]

(b) The diameter of a wire XY varies linearly with distance along the wire as shown in Fig. 7.1.

Fig. 7.1

There is a current I in the wire. At end X of the wire, the diameter is d and the average drift speed of the free electrons is v_x. At end Y of the wire, the diameter is $\frac{d}{2}$.

On Fig. 7.2, sketch a graph to show the variation of the average drift speed with position along the wire between X and Y.

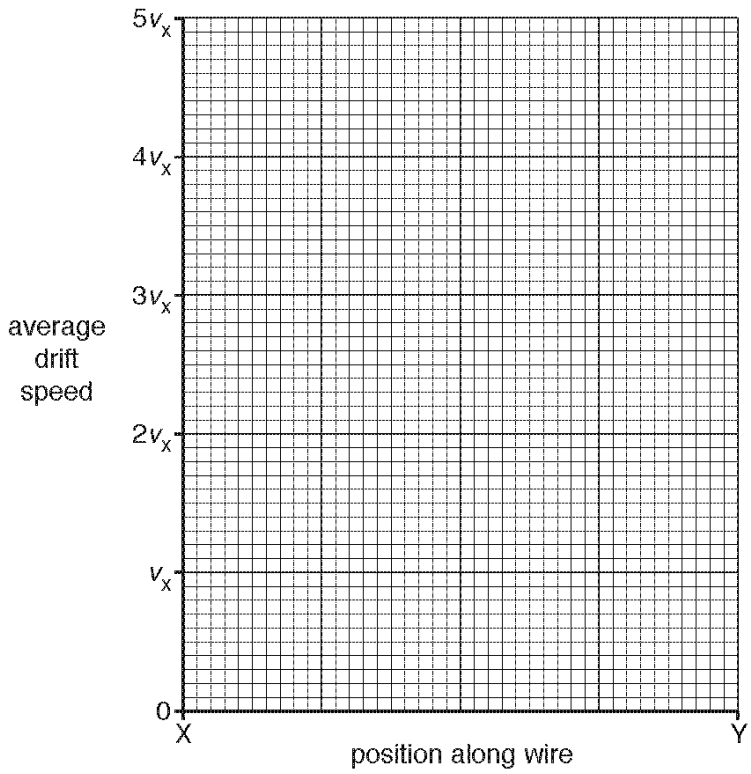


Fig. 7.2

[2]

14 - (9702/23_Winter_2018_Q7) - *Current Of Electricity, D.c. Circuits*

(a) State Kirchhoff's first law.

.....

.....[1]

(b) A potentiometer is connected to a battery of electromotive force (e.m.f.) 9.6 V and negligible internal resistance, as shown in Fig. 7.1.

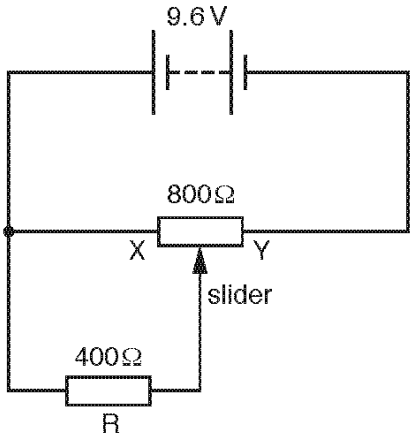


Fig. 7.1

The maximum resistance of the potentiometer is 800 Ω. A resistor R of resistance 400 Ω is connected between the slider and end X of the potentiometer.

(i) State the potential difference across resistor R when the slider is positioned

1. at end X of the potentiometer,

potential difference = ... V

2. at end Y of the potentiometer.

potential difference = ... V
[2]

(ii) Calculate the potential difference across resistor R when the slider is positioned half-way between X and Y.

potential difference = ... V [3]

15 – (9702/23_Summer_2019_Q1) – *Current Of Electricity, Physical Quantities & Units*

(a) **(i)** Define *resistance*.

.....

.....[1]

(ii) A potential difference of 0.60 V is applied across a resistor of resistance 4.0 GΩ.

Calculate the current, in pA, in the resistor.

current = ... pA [2]

(b) The energy E transferred when charge Q moves through an electrical component is given by the equation

$$E = QV$$

where V is the potential difference across the component.

Use the equation to determine the SI base units of potential difference.

SI base units ..... [3]

16 – (9702/22_Summer_2019_Q5) – *Current Of Electricity, D.c. Circuits*

(a) State Kirchhoff's second law.

.....

.....[2]

(b) A battery of electromotive force (e.m.f.) 5.6 V and internal resistance *r* is connected to two external resistors, as shown in Fig. 5.1.

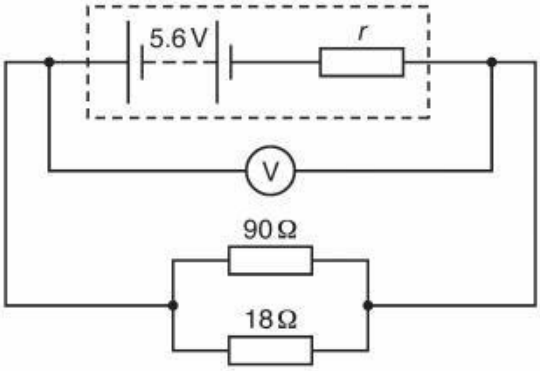


Fig. 5.1

The reading on the voltmeter is 4.8 V.

(i) Calculate:

1. the combined resistance of the two resistors connected in parallel

combined resistance = ... Ω [2]

2. the current in the battery.

current = ... A [2]

(ii) Show that the internal resistance *r* is 2.5 Ω.

[2]

(iii) Determine the ratio

$$\frac{\text{power dissipated by internal resistance } r}{\text{total power produced by battery}}.$$

ratio = ... [3]

(c) The battery in **(b)** is now connected to a battery of e.m.f. 7.2 V and internal resistance 3.5 Ω. The new circuit is shown in Fig. 5.2.

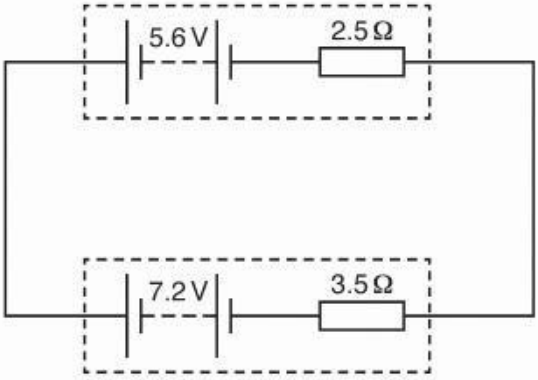


Fig. 5.2

Determine the current in the circuit.

current = ... A [2]

17 - (9702/21_Summer_2019_Q6) - *Current Of Electricity, D.c. Circuits*

A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 6.1.

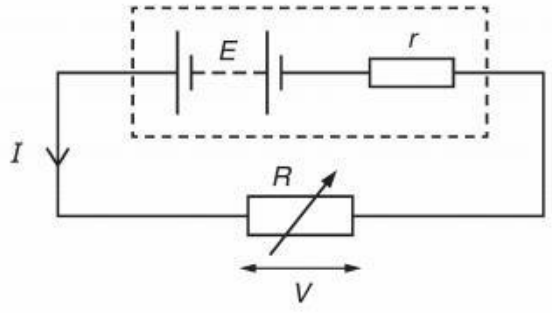


Fig. 6.1

The current in the circuit is I and the potential difference across the variable resistor is V.

(a) Explain, in terms of energy, why V is less than E.

.....

.....[1]

(b) State an equation relating E, I, r and V.

.....[1]

(c) The resistance R of the variable resistor is varied. The variation with I of V is shown in Fig. 6.2.

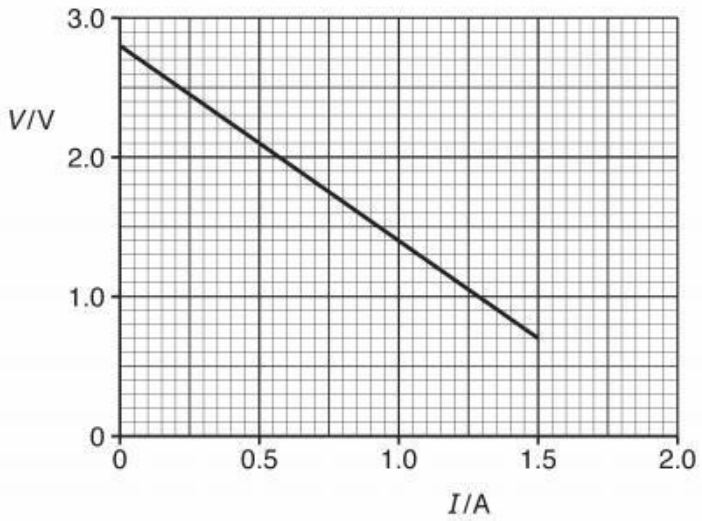


Fig. 6.2

Use Fig. 6.2 to:

(i) explain how it may be deduced that the e.m.f. of the battery is 2.8 V

.....

.....[1]

(ii) calculate the internal resistance *r*.

r = ... Ω [2]

(d) The battery stores 9.2 kJ of energy. The variable resistor is adjusted so that $V = 2.1$ V. Use Fig. 6.2 to:

(i) calculate resistance *R*

R = ... Ω [1]

(ii) calculate the number of conduction electrons moving through the battery in a time of 1.0 s

number = ... [1]

(iii) determine the time taken for the energy in the battery to become equal to 1.6 kJ.
(Assume that the e.m.f. of the battery and the current in the battery remain constant.)

time taken = ... s [3]

18 - (9702/23_Summer_2019_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define the *ohm*.

.....[1]

(b) A battery of electromotive force (e.m.f.) E and internal resistance 1.5 Ω is connected to a network of resistors, as shown in Fig. 6.1.

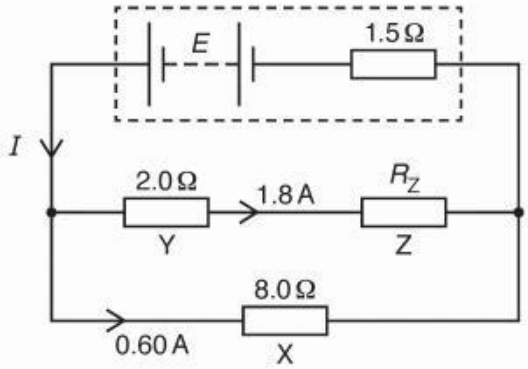


Fig. 6.1

Resistor X has a resistance of 8.0 Ω. Resistor Y has a resistance of 2.0 Ω. Resistor Z has a resistance of R_Z. The current in X is 0.60 A and the current in Y is 1.8 A.

(i) Calculate:

1. the current I in the battery

I = ... A [1]

2. resistance R_Z

R_Z = ... Ω [2]

3. e.m.f. E.

E = ... V [2]

(ii) Resistors X and Y are each made of wire. The two wires have the same length and are made of the same metal.

Determine the ratio:

1. $\dfrac{\text{cross-sectional area of wire X}}{\text{cross-sectional area of wire Y}}$

ratio = ... [2]

2. $\dfrac{\text{average drift speed of free electrons in X}}{\text{average drift speed of free electrons in Y}}$.

ratio = ... [2]

19 - (9702/21_Winter_2019_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define *electric potential difference* (*p.d.*).

.....

..... [1]

(b) The variation with potential difference V of the current I in a semiconductor diode is shown in Fig. 6.1.

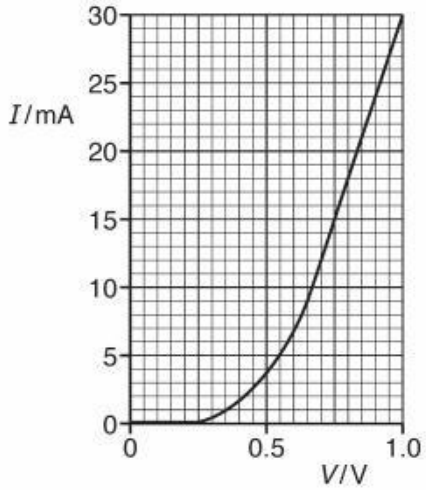


Fig. 6.1

Use Fig. 6.1 to describe qualitatively the variation of the resistance of the diode as V increases from 0 to 1.0 V.

.....

.....

.....

..... [2]

(c) The diode in **(b)** is part of the circuit shown in Fig. 6.2.

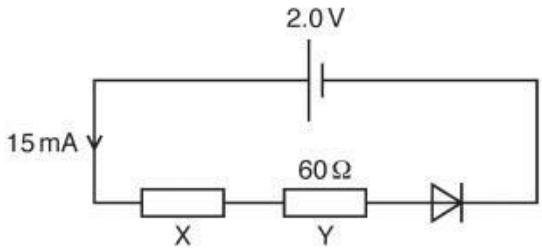


Fig. 6.2

The cell of electromotive force (e.m.f.) 2.0 V and negligible internal resistance is connected in series with the diode and resistors X and Y. The resistance of Y is 60 Ω. The current in the cell is 15 mA.

(i) Use Fig. 6.1 to determine the resistance of the diode.

resistance = ... Ω [3]

(ii) Calculate:

1. the resistance of X

resistance = ... Ω [3]

2. the ratio

$$\frac{\text{power dissipated in resistor Y}}{\text{total power produced by the cell}}.$$

ratio = ... [2]

20 - (9702/22_Winter_2019_Q6) - *Current Of Electricity, D.c. Circuits*

(a) State Kirchhoff's first law.

.....

..... [1]

(b) The variations with potential difference V of the current I for a resistor X and for a semiconductor diode are shown in Fig. 6.1.

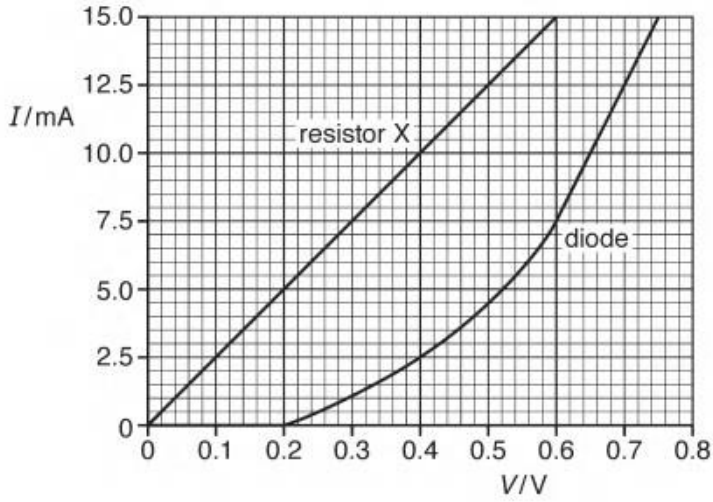


Fig. 6.1

(i) Determine the resistance of the diode for a potential difference V of 0.60 V.

resistance = ... Ω [3]

(ii) Describe, qualitatively, the variation of the resistance of the diode as V increases from 0.60 V to 0.75 V.

..... [1]

(c) The diode and the resistor X in **(b)** are connected into the circuit shown in Fig. 6.2.

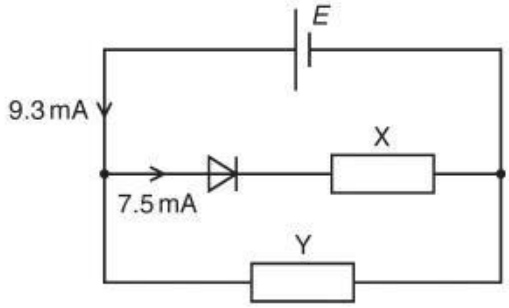


Fig. 6.2

The cell has electromotive force (e.m.f.) *E* and negligible internal resistance. Resistor Y is connected in parallel with resistor X and the diode. The current in the cell is 9.3 mA and the current in the diode is 7.5 mA.

(i) Use Fig. 6.1 to determine *E*.

E = ...V [1]

(ii) Determine the resistance of resistor Y.

resistance = ... Ω [2]

(iii) Calculate the power dissipated in the diode.

power = ...W [2]

(iv) The cell is now replaced by a new cell of e.m.f. 0.50 V and negligible internal resistance. Use Fig. 6.1 to determine the new current in the diode.

current = ...mA [1]

21 - (9702/23_Winter_2019_Q6) - *Current Of Electricity, D.c. Circuits*

A battery of electromotive force (e.m.f.) 12 V and negligible internal resistance is connected to a network of two lamps and two resistors, as shown in Fig. 6.1.

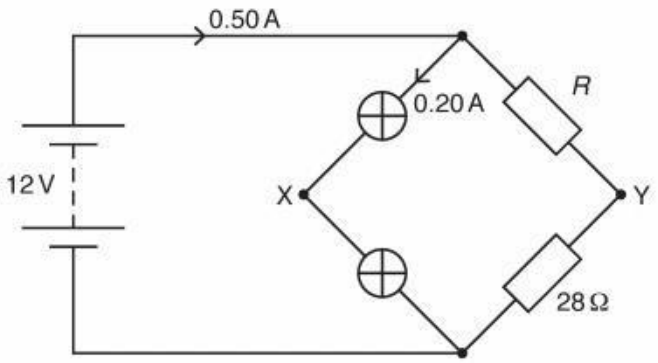


Fig. 6.1

The two lamps in the circuit have equal resistances. The two resistors have resistances R and 28 Ω. The lamps are connected at junction X and the resistors are connected at junction Y. The current in the battery is 0.50 A and the current in the lamps is 0.20 A.

(a) Calculate:

(i) the resistance of each lamp

resistance = ... Ω [2]

(ii) resistance R.

R = ... Ω [2]

(b) Determine the potential difference V_{XY} between points X and Y.

V_{XY} = ... V [3]

(c) Calculate the ratio

$$\frac{\text{total power dissipated by the lamps}}{\text{total power produced by the battery}}.$$

ratio = ... [2]

(d) The resistor of resistance *R* is now replaced by another resistor of lower resistance.

State and explain the effect, if any, of this change on the ratio in **(c)**.

.....

.....

.....

.....

..... [2]

22 - (9702/21_Summer_2020_Q5) - *Current Of Electricity, D.c. Circuits*

(a) Metal wire is used to connect a power supply to a lamp. The wire has a total resistance of $3.4\,\Omega$ and the metal has a resistivity of $2.6 \times 10^{-8}\,\Omega\,m$. The total length of the wire is 59 m.

(i) Show that the wire has a cross-sectional area of $4.5 \times 10^{-7}\,m^2$.

[2]

(ii) The potential difference across the total length of wire is 1.8 V.

Calculate the current in the wire.

current = ... A [1]

(iii) The number density of the free electrons in the wire is $6.1 \times 10^{28}\,m^{-3}$.

Calculate the average drift speed of the free electrons in the wire.

average drift speed = ... $m\,s^{-1}$ [2]

(b) A different wire carries a current. This wire has a part that is thinner than the rest of the wire, as shown in Fig. 5.1.

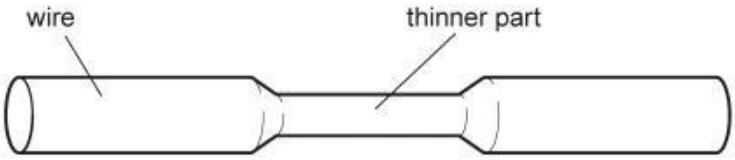


Fig. 5.1

(i) State and explain qualitatively how the average drift speed of the free electrons in the thinner part compares with that in the rest of the wire.

.....

.....

..... [2]

(ii) State and explain whether the power dissipated in the thinner part is the same, less or more than the power dissipated in an equal length of the rest of the wire.

.....

.....

..... [2]

(c) Three resistors have resistances of 180 Ω, 90 Ω and 30 Ω.

(i) Sketch a diagram showing how **two** of these three resistors may be connected together to give a combined resistance of 60 Ω between the terminals shown.
Ensure you label the values of the resistances in your diagram.

[1]

(ii) A potential divider circuit is produced by connecting the three resistors to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance. The potential divider circuit provides an output potential difference V_{OUT} of 8.0 V.
Fig. 5.2 shows the circuit diagram.

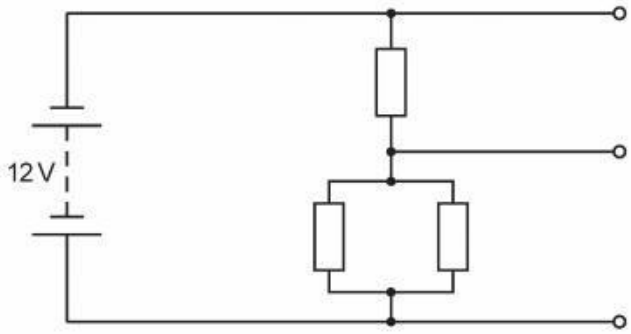


Fig. 5.2

On Fig. 5.2, label the resistances of all three resistors and the potential difference V_{OUT}. [2]

23 - (9702/22_Summer_2020_Q5) - *Deformation Of Solids, Current Of Electricity*

One end of a wire is attached to a fixed point. A force F is applied to the wire to cause extension x. The variation with F of x is shown in Fig. 5.1.

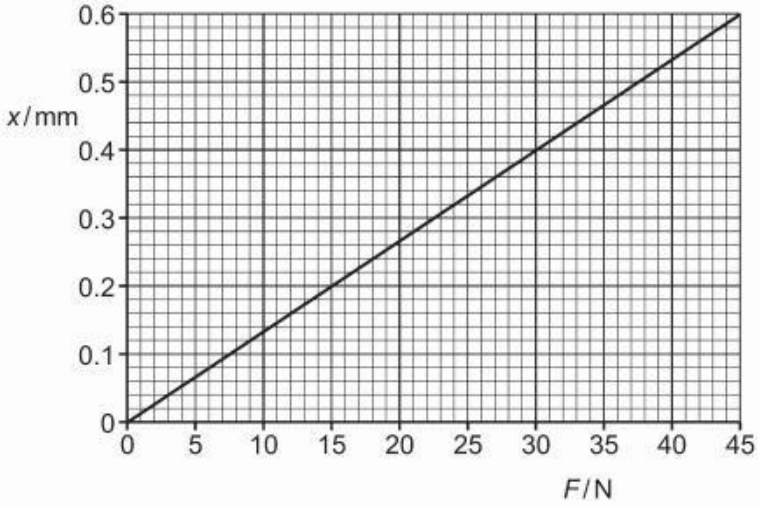


Fig. 5.1

The wire has a cross-sectional area of $4.1 \times 10^{-7}\,m^2$ and is made of metal of Young modulus 1.7×10^{11} Pa. Assume that the cross-sectional area of the wire remains constant as the wire extends.

(a) State the name of the law that describes the relationship between F and x shown in Fig. 5.1.

..... [1]

(b) The wire has an extension of 0.48 mm.

Determine:

(i) the stress

stress = ... Pa [2]

(ii) the strain.

strain = ... [2]

(c) The resistivity of the metal of the wire is $3.7 \times 10^{-7}\ \Omega\,\text{m}$.

Determine the change in resistance of the wire when the extension x of the wire changes from $x = 0.48\,\text{mm}$ to $x = 0.60\,\text{mm}$.

change in resistance = ... Ω [3]

(d) A force of greater than 45 N is now applied to the wire.

Describe how it may be checked that the elastic limit of the wire has not been exceeded.

.....

..... [1]

24 - (9702/23_Summer_2020_Q6) - *Current Of Electricity*

The current I in a metal wire is given by the expression

$$I = Anve$$

where v is the average drift speed of the free electrons in the wire and e is the elementary charge.

(a) State what is meant by the symbols A and n.

A: .....

n: .....
[2]

(b) Use the above expression to determine the SI base units of e.
Show your working.

base units ..... [2]

(c) Two lamps P and Q are connected in series to a battery, as shown in Fig. 6.1.

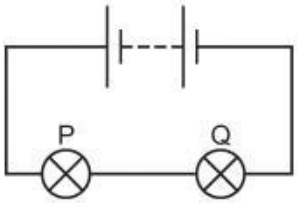


Fig. 6.1

The radius of the filament wire of lamp P is twice the radius of the filament wire of lamp Q.
The filament wires are made of metals with the same value of n.

Calculate the ratio

$$\frac{\text{average drift speed of free electrons in filament wire of P}}{\text{average drift speed of free electrons in filament wire of Q}}.$$

ratio = ... [2]

25 - (9702/22_Winter_2020_Q6) - *Current Of Electricity, D.c. Circuits*

(a) A network of three resistors of resistances R_1, R_2 and R_3 is shown in Fig. 6.1.

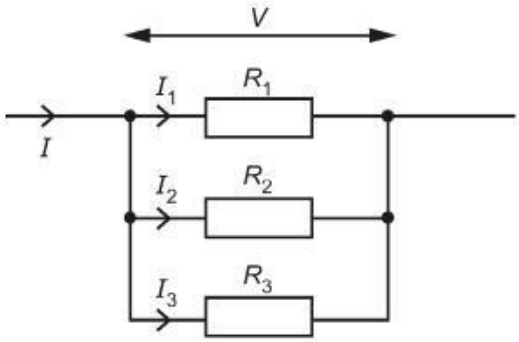


Fig. 6.1

The individual currents in the resistors are I_1, I_2 and I_3. The total current in the combination of resistors is I and the potential difference across the combination is V.

Show that the combined resistance R of the network is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

[2]

(b) A battery of electromotive force (e.m.f.) 8.0 V and internal resistance r is connected to three resistors X, Y and Z, as shown in Fig. 6.2.

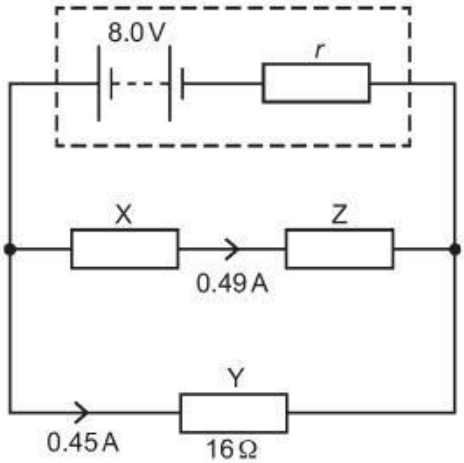


Fig. 6.2

Resistor Y has a resistance of 16 Ω. The current in resistor X is 0.49 A and the current in resistor Y is 0.45 A.

Calculate:

(i) the current in the battery

current = ... A [1]

(ii) the internal resistance *r* of the battery.

r = ... Ω [2]

(c) Resistors X and Y in Fig. 6.2 are made from wires of the same material and cross-sectional area. The average drift speed of the free electrons in X is $2.1 \times 10^{-4}\,\mathrm{m\,s^{-1}}$.

Calculate the average drift speed *v* of the free electrons in Y.

v = ... $\mathrm{m\,s^{-1}}$ [2]

(d) Resistor Z in Fig. 6.2 is replaced by a new resistor of smaller resistance.

State and explain the effect, if any, on the terminal potential difference of the battery.

.....

.....

..... [2]

[Total: 9]

26 - (9702/23_Winter_2020_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define *electric potential difference* (*p.d.*).

.....

..... [1]

(b) A wire of cross-sectional area A is made from metal of resistivity ρ. The wire is extended. Assume that the volume V of the wire remains constant as it extends.

Show that the resistance R of the extending wire is inversely proportional to A^2.

[2]

(c) A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 6.1.

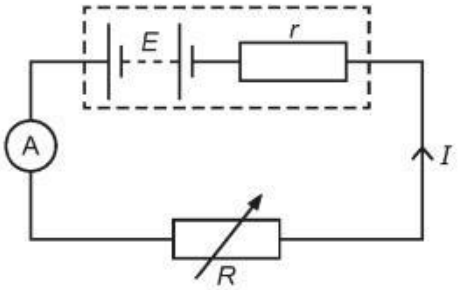


Fig. 6.1

The current in the circuit is I.

Use Kirchhoff's second law to show that

$$R = \left(\frac{E}{I}\right) - r.$$

[1]

(d) An ammeter is used in the circuit in **(c)** to measure the current I as resistance R is varied. Fig. 6.2 is a graph of R against $\frac{1}{I}$.

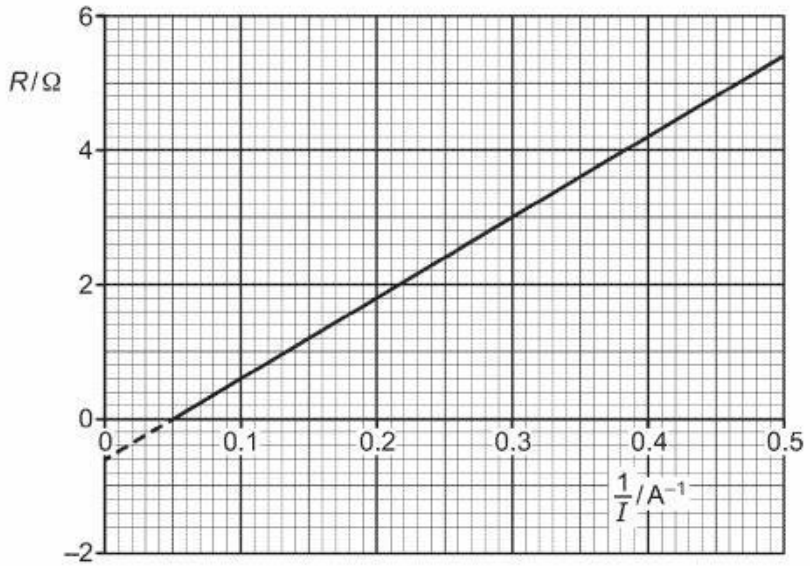


Fig. 6.2

(i) Use Fig. 6.2 to determine the power dissipated in the variable resistor when there is a current of 2.0 A in the circuit.

power = ... W [3]

(ii) Use Fig. 6.2 and the equation in **(c)** to:

1. state the internal resistance r of the battery

r = ... Ω

2. determine the e.m.f. E of the battery.

E = ... V
[3]

[Total: 10]

27 - (9702/21_Winter_2020_Q7) - *Current Of Electricity, D.c. Circuits*

(a) Define the *ohm*.

.....

..... [1]

(b) A uniform wire has resistance 3.2 Ω. The wire has length 2.5 m and is made from metal of resistivity 460 nΩ m.

Calculate the cross-sectional area of the wire.

cross-sectional area = ... m^2 [3]

(c) A cell of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 7.1.

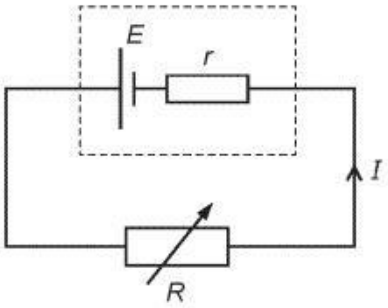


Fig. 7.1

The current in the circuit is I.

(i) State, in terms of energy, why the potential difference across the variable resistor is less than the e.m.f. of the cell.

.....

..... [1]

(ii) State an expression for E in terms of I, R and r.

E = ... [1]

(iii) The resistance R of the variable resistor is changed so that it is equal to r.

Determine an expression, in terms of only E and r, for the power P dissipated in the variable resistor.

P = ... [2]

[Total: 8]

28 - (9702/21_Summer_2021_Q5) - *Current Of Electricity, D.c. Circuits*

(a) State Kirchhoff's second law.

.....

.....

..... [2]

(b) A battery has electromotive force (e.m.f.) 4.0 V and internal resistance 0.35 Ω. The battery is connected to a uniform resistance wire XY and a fixed resistor of resistance *R*, as shown in Fig. 5.1.

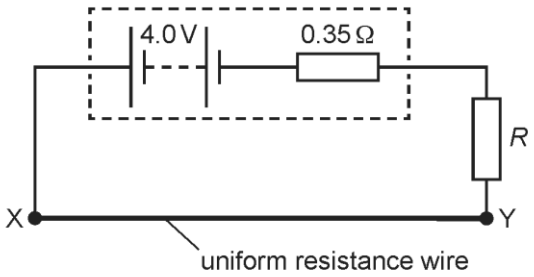


Fig. 5.1

Wire XY has resistance 0.90 Ω. The potential difference across wire XY is 1.8 V.

Calculate:

(i) the current in wire XY

current = ... A [1]

(ii) the number of free electrons that pass a point in the battery in a time of 45 s

number = ... [2]

(iii) resistance *R*.

R = ... Ω [2]

(c) A cell of e.m.f. 1.2 V is connected to the circuit in **(b)**, as shown in Fig. 5.2.

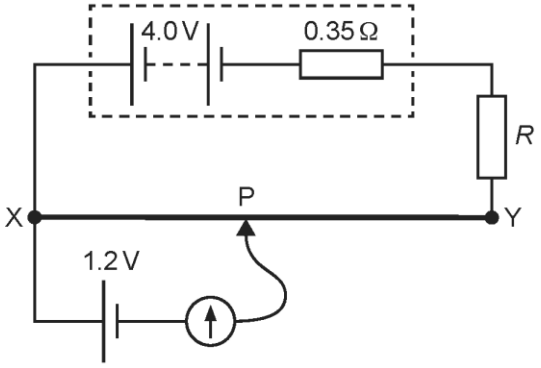


Fig. 5.2

The connection P is moved along the wire XY. The galvanometer reading is zero when distance XP is 0.30 m.

(i) Calculate the total length *L* of wire XY.

L = ... m [2]

(ii) The fixed resistor is replaced by a different fixed resistor of resistance greater than *R*.

State and explain the change, if any, that must be made to the position of P on wire XY so that the galvanometer reading is zero.

.....

.....

.....

..... [2]

29 - (9702/22_Summer_2021_Q5) - *Current Of Electricity, D.c. Circuits*

(a) Define the *ohm*.

.....

..... [1]

(b) A wire is made of metal of resistivity ρ. The length L of the wire is gradually increased. Assume that the volume V of the wire remains constant as its length is increased.

Show that the resistance R of the extending wire is proportional to L^2.

[2]

(c) A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 5.1.

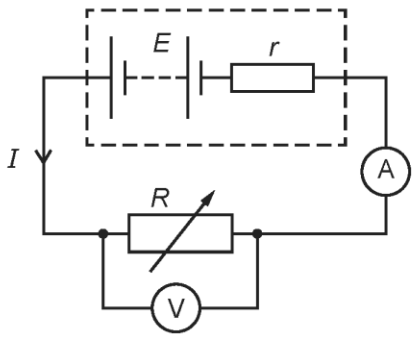


Fig. 5.1

An ammeter measures the current I in the circuit. A voltmeter measures the potential difference V across the variable resistor.

The resistance R is now varied to change the values of I and V.

The variation with I of V is shown in Fig. 5.2.

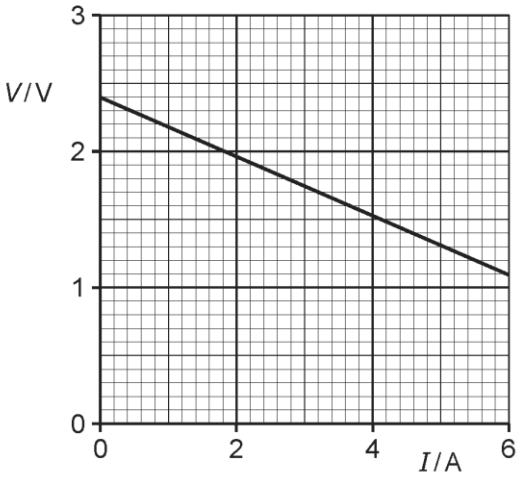


Fig. 5.2

(i) Use Fig. 5.2 to state the e.m.f. E of the battery.

E = ... V [1]

(ii) Use Fig. 5.2 to determine the power dissipated in the variable resistor when there is a current of 5.0 A.

power = ... W [3]

(iii) State what is represented by the value of the gradient of the graph.

..... [1]

30 - (9702/21_Winter_2021_Q5) - *Current Of Electricity*

(a) State Kirchhoff's first law.

.....

.....

..... [2]

(b) The circuit shown in Fig. 5.1 contains a battery of electromotive force (e.m.f.) *E* and negligible internal resistance connected to four resistors R_1, R_2, R_3 and R_4, each of resistance *R*.

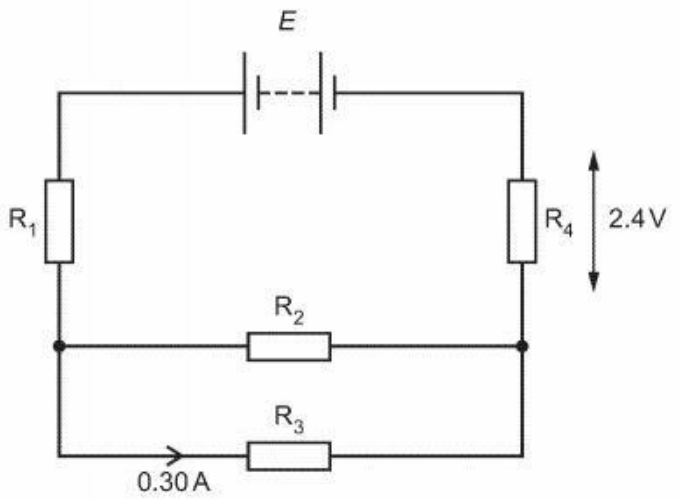


Fig. 5.1

The current in R_3 is 0.30 A and the potential difference (p.d.) across R_4 is 2.4 V.

(i) Show that *R* is equal to 4.0 Ω.

[2]

(ii) Determine the e.m.f. *E* of the battery.

E = ... V [2]

(c) The battery in **(b)** is replaced with another battery of the same e.m.f. *E* but with an internal resistance that is not negligible.

State and explain the change, if any, in the total power produced by the battery.

.....

.....

..... [2]

(d) The resistors in the circuit of Fig. 5.1 are made from nichrome wire of uniform radius 240 μm. The length of this wire needed to make each resistor is 0.67 m.

Calculate the resistivity of nichrome.

resistivity = ... Ω m [3]

31 - (9702/23_Winter_2021_Q6) - *Current Of Electricity*

(a) A resistance wire of uniform cross-sectional area $3.3 \times 10^{-7}\,m^2$ and length 2.0 m is made of metal of resistivity $5.0 \times 10^{-7}\,\Omega\,m$.

Show that the resistance of the wire is 3.0 Ω.

[2]

(b) The ends of the resistance wire in **(a)** are connected to the terminals X and Y in the circuit shown in Fig. 6.1.

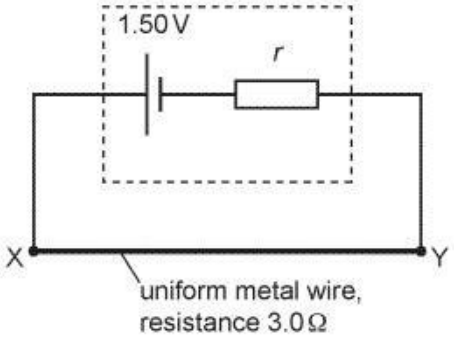


Fig. 6.1

The cell has an electromotive force (e.m.f.) of 1.50 V and internal resistance *r*. The potential difference between X and Y is 1.20 V.

Calculate:

(i) the current in the circuit

current = ... A [1]

(ii) the internal resistance *r*.

r = ... Ω [2]

(c) A galvanometer and a cell of e.m.f. *E* with negligible internal resistance are connected to the circuit in **(b)**, as shown in Fig. 6.2.

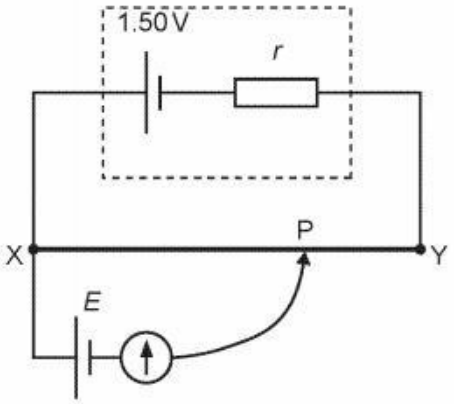


Fig. 6.2

The resistance wire between X and Y has a length of 2.0 m. The galvanometer has a reading of zero when the connection P is adjusted so that the length XP is 1.4 m.

Determine the e.m.f. *E* of the cell.

E = ... V [2]

(d) The circuit in Fig. 6.2 is modified by replacing the original resistance wire with a second resistance wire. The second wire has the same length as the original wire and is made of the same metal.

The second wire has a smaller cross-sectional area than the original wire.

Connection P is adjusted on the second wire so that the galvanometer has a reading of zero.

State and explain whether length XP for the second wire is shorter than, longer than or the same as length XP for the original wire when the galvanometer reading is zero.

.....

.....

.....

.....

..... [3]

32 - (9702/22_Summer_2022_Q6) - *Current Of Electricity*

(a) A network of three resistors of resistances R_1, R_2 and R_3 is shown in Fig. 6.1.

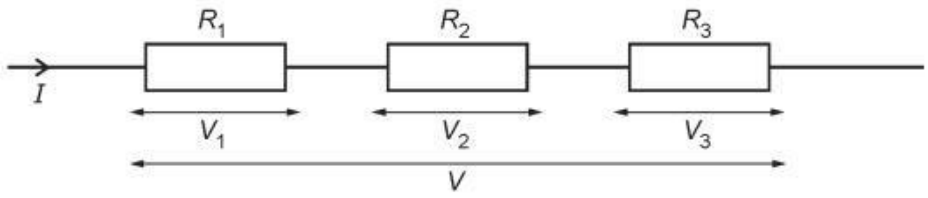


Fig. 6.1

The individual potential differences across the resistors are V_1, V_2 and V_3. The current in the combination of resistors is I and the total potential difference across the combination is V.

Show that the combined resistance R of the network is given by

$$R = R_1 + R_2 + R_3.$$

[2]

(b) A battery of electromotive force (e.m.f.) 8.0 V and negligible internal resistance is connected to a thermistor, a switch X and two fixed resistors, as shown in Fig. 6.2.

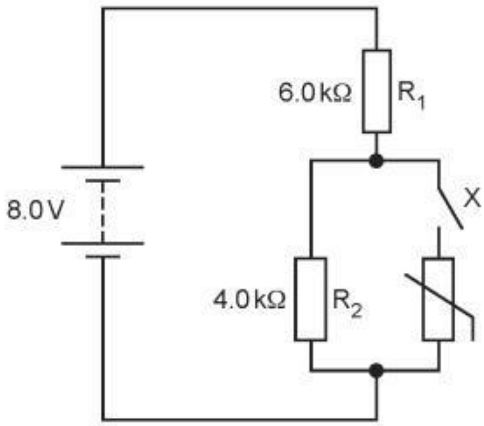


Fig. 6.2

Resistor R_1 has resistance 6.0 kΩ and resistor R_2 has resistance 4.0 kΩ.

(i) Switch X is open.

Calculate the potential difference across R_1.

potential difference = ... V [2]

(ii) Switch X is now closed. The resistance of the thermistor is 12.0 kΩ.

Calculate the current in the battery.

current = ... A [2]

(c) The switch X in the circuit in **(b)** remains closed. The temperature of the thermistor decreases.

By reference to the current in the battery, state and explain the effect, if any, of the decrease in temperature on the power produced by the battery.

.....

.....

.....

.....

..... [3]

[Total: 9]

33 - (9702/23_Summer_2022_Q6) - *Current Of Electricity*

(a) **(i)** On Fig. 6.1, sketch the I–V characteristic of a filament lamp.

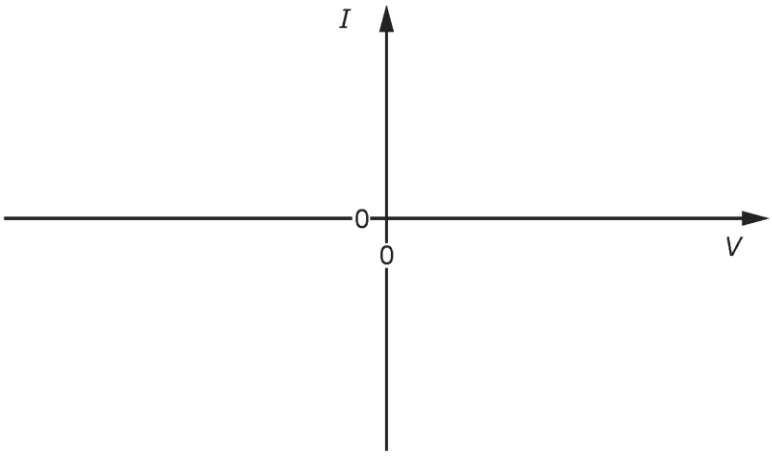


Fig. 6.1

[2]

(ii) Explain the shape of the line in **(a)(i)**.

.....

.....

.....

..... [3]

(b) A conducting wire has length 5.8 m and cross-sectional area $3.4 \times 10^{-8}\,m^2$. The resistivity of the metal of the wire is $5.6 \times 10^{-8}\,\Omega\,m$.

Calculate the resistance of the wire.

resistance = ... Ω [2]

(c) A resistor of resistance *R* is placed in a circuit with a cell of negligible internal resistance, two switches S_1 and S_2, a second resistor of resistance 2*R* and three ammeters X, Y and Z. The circuit is shown in Fig. 6.2.

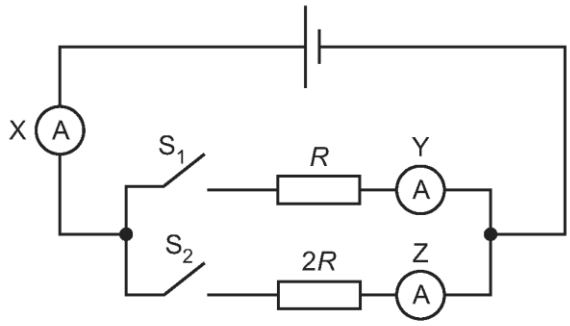


Fig. 6.2

The reading on X is 1.0 A when S_1 is open and S_2 is closed.

Complete Table 6.1.

Table 6.1

position of switches		ammeter readings		
S_1	S_2	reading on X / A	reading on Y / A	reading on Z / A
open	open	0	0	0
open	closed	1.0		
closed	open			
closed	closed			

[4]

[Total: 11]

34 - (9702/21_Winter_2022_Q5) - *Current Of Electricity*

(a) State Ohm's law.

.....

.....

..... [2]

(b) The variation of current I with potential difference V for a filament lamp is shown in Fig. 5.1.

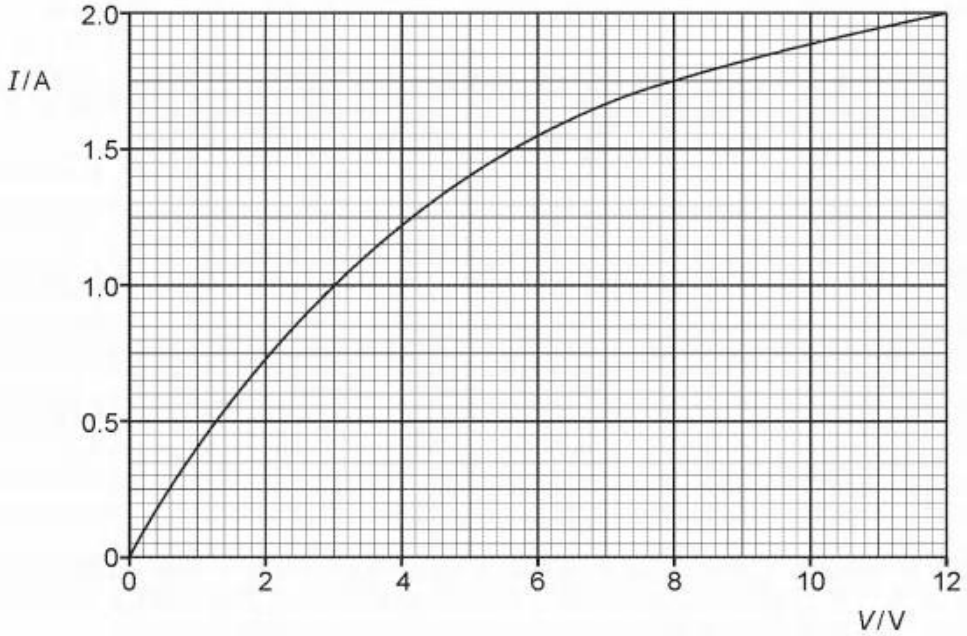


Fig. 5.1

The resistance of the filament lamp increases with potential difference.

(i) State how Fig. 5.1 shows this.

.....

..... [1]

(ii) Explain why the resistance varies in this way.

.....

..... [1]

(c) Fig. 5.2 shows a circuit with a battery of electromotive force (e.m.f.) 12.0 V connected to a linear potentiometer AB and two identical filament lamps P and Q.

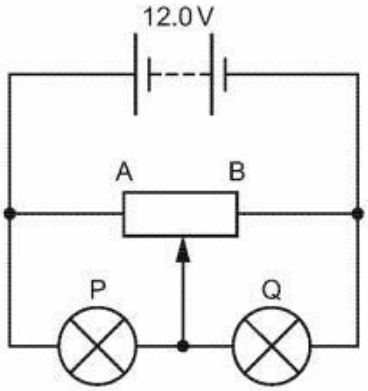


Fig. 5.2

The battery has negligible internal resistance and the lamps each have the same I–V characteristic shown in Fig. 5.1.

When the slider of the potentiometer is at its midpoint, as shown in Fig. 5.2, the current I in the battery is 1.78 A.

Determine:

(i) the current in lamp P

current = ... A [1]

(ii) the total power dissipated in lamps P and Q

total power = ... W [2]

(iii) the resistance of the potentiometer between its ends A and B.

resistance = ... Ω [2]

(d) The slider of the potentiometer in **(c)** is moved to end A.

State and explain the effect on the brightness of lamps P and Q.

lamp P: .....

.....

lamp Q: .....

.....

[2]

35 - (9702/23_Winter_2022_Q5) - *Current Of Electricity*

(a) State Kirchhoff's second law.

.....

.....

..... [2]

(b) Three identical cells, each of electromotive force (e.m.f.) 1.5 V and internal resistance 590 mΩ, are connected in parallel across a conductor, as shown in Fig. 5.1.

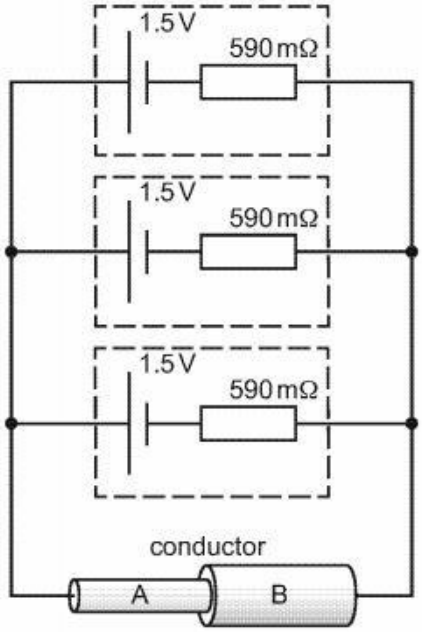


Fig. 5.1

The conductor is composed of two cylindrical sections A and B.
The total resistance of the circuit is 2.2 Ω.

(i) Show that the resistance of the conductor is 2.0 Ω.

[2]

(ii) Calculate the current in the conductor.

current = ... A [2]

(c) The two cylindrical sections A and B of the conductor in Fig. 5.1 are made from the same material and have the same length.
The diameter of section A is 4.3 mm and the diameter of section B is 7.6 mm.
The resistance of section A is R_A and the resistance of section B is R_B.

(i) Calculate the ratio $\frac{R_A}{R_B}$.

$\frac{R_A}{R_B}$ = ... [3]

(ii) Calculate the ratio

$$\frac{\text{average drift speed of free electrons in section A}}{\text{average drift speed of free electrons in section B}}.$$

Explain your reasoning.

ratio = ... [2]

(d) The circuit of Fig. 5.1 is altered by removing one of the cells.

State and explain the effect, if any, of this change on the potential difference across the conductor.

.....

.....

.....

.....

..... [3]

36 - (9702/22_Winter_2022_Q6) - *Current Of Electricity*

(a) Define electric potential difference.

.....

..... [1]

(b) A battery is connected to two resistors X and Y, as shown in Fig. 6.1.

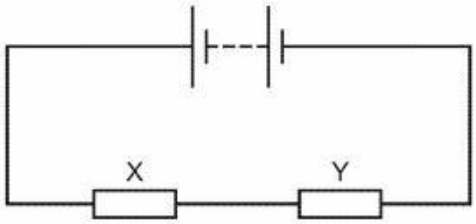


Fig. 6.1

The resistance of resistor X is greater than the resistance of resistor Y.

State and explain which resistor dissipates more power.

.....

.....

.....

.....

..... [3]

(c) A battery of electromotive force (e.m.f.) 9.0 V and internal resistance *r* is connected to two resistors P and Q, as shown in Fig. 6.2.

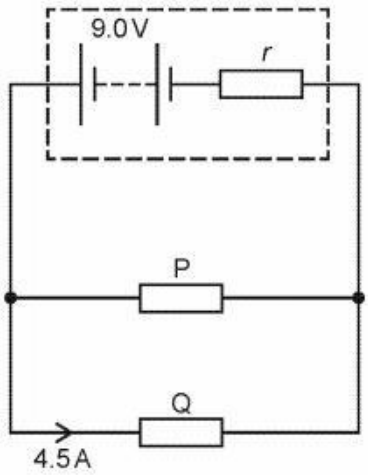


Fig. 6.2

A total charge of 650 C moves through resistor P in a time interval of 540 s. During this time resistor P dissipates 4800 J of energy. The current in resistor Q is 4.5A. Assume that the e.m.f. of the battery remains constant.

Calculate:

(i) the current in resistor P

current = ...A [2]

(ii) the potential difference across resistor P

potential difference = ... V [2]

(iii) the internal resistance *r* of the battery.

r = ... Ω [2]

37 - (9702/21_Summer_2023_Q6) - *Current Of Electricity*

A metal wire in a circuit has a length of 1.8 m and a cross-sectional area of $1.5 \times 10^{-6}\,m^2$.
The total number of free electrons (charge carriers) in the wire is 2.3×10^{23}.

There is a current in the wire so that a charge of 172 C moves past a fixed point in the wire in a time of 2.5 minutes.

(a) Show that the number density of the free electrons in the wire is $8.5 \times 10^{28}\,m^{-3}$.

[1]

(b) Calculate the average drift speed of the free electrons.

average drift speed = ... $m\,s^{-1}$ [3]

38 - (9702/21_Summer_2023_Q7) - *Current Of Electricity*

A battery of electromotive force (e.m.f.) 9.6 V and negligible internal resistance is connected in series with two fixed resistors and a thermistor, as shown in Fig. 7.1.

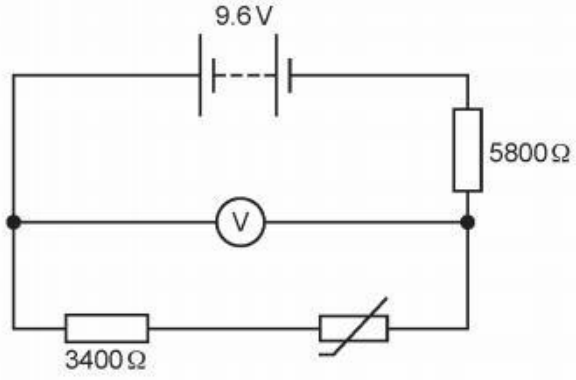


Fig. 7.1

The fixed resistors have resistances of 3400 Ω and 5800 Ω. The reading on the voltmeter in the circuit is 6.0 V.

(a) Calculate the current in the resistor of resistance 5800 Ω.

current = ...A [2]

(b) Calculate the resistance of the thermistor.

resistance = ... Ω [2]

(c) The initial energy stored in the battery is 2.6×10^4 J.

Assume that the e.m.f. of the battery is constant.

Determine the final energy stored in the battery after a charge of 330 C has moved through it.

final stored energy = ... J [2]

(d) The environmental conditions change causing an increase in the resistance of the thermistor.

State whether there is a decrease, increase or no change to:

(i) the temperature of the thermistor

..... [1]

(ii) the current in the thermistor

..... [1]

(iii) the potential difference across the thermistor.

..... [1]

39 - (9702/22_Summer_2023_Q6) - *Current Of Electricity*

(a) The current in a filament lamp decreases.

State and explain how the resistance of the lamp changes.

.....

..... [1]

(b) A cylindrical wire has length *L* and resistance *R*. The **total** number of free electrons (charge carriers) contained in the volume of the wire is *N*. Each free electron has charge *e*. The potential difference between the ends of the wire is *V*.

Determine expressions, in terms of some or all of the symbols *e*, *L*, *N*, *R* and *V* for:

(i) the current in the wire

current = ... [1]

(ii) the average drift speed of the free electrons

average drift speed = ... [2]

(iii) the average time taken for a free electron to move along the full length of the wire.

time taken = ... [1]

40 - (9702/22_Summer_2023_Q7) - *Current Of Electricity*

(a) A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected to a light-dependent resistor (LDR) and a fixed resistor, as shown in Fig. 7.1.

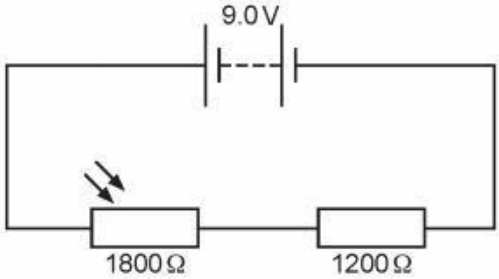


Fig. 7.1

The LDR and fixed resistor have resistances of 1800 Ω and 1200 Ω respectively.

Calculate the potential difference across the LDR.

potential difference = ... V [2]

(b) The circuit in **(a)** is now modified by adding a uniform resistance wire XY and a galvanometer, as shown in Fig. 7.2.

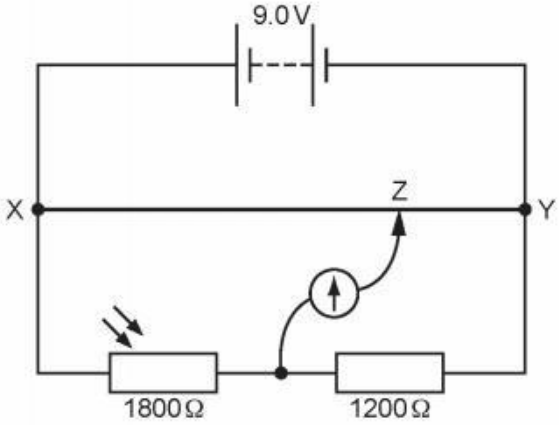


Fig. 7.2 (not to scale)

The length of the wire XY is 1.2 m. The movable connection Z is positioned on the wire XY so that the galvanometer reading is zero.

(i) Calculate the length XZ along the resistance wire.

length XZ = ... m [2]

(ii) The environmental conditions change causing a decrease in the resistance of the LDR. The temperature of the LDR remains constant.

State whether there is a decrease, increase or no change to:

- the intensity of the light illuminating the LDR

.....

- the total power produced by the battery

.....

- the length XZ so that the galvanometer reads zero.

.....

[3]

41 - (9702/23_Summer_2023_Q5) - *Current Of Electricity*

A student sets up a circuit with a battery, an ammeter, a heater and a light-dependent resistor (LDR) all in series.

The battery has negligible internal resistance.

A voltmeter is connected across (in parallel with) the heater.

(a) On Fig. 5.1, complete the circuit diagram of this arrangement.

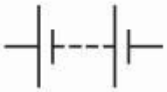


Fig. 5.1

[3]

(b) The heater is a wire made of metal of resistivity $1.1 \times 10^{-6}\,\Omega\,m$. The wire has length 2.0 m and cross-sectional area $3.8 \times 10^{-7}\,m^2$.

The reading on the voltmeter is 4.8 V.

Calculate:

(i) the resistance of the heater

resistance = ... Ω [2]

(ii) the reading on the ammeter.

reading on ammeter = ... A [1]

(c) The heater is replaced by a new wire. The new wire is made of the same metal as the wire in **(b)** and has the same length but a larger diameter.

The resistance of the LDR remains constant.

(i) State and explain whether the new wire has a resistance that is greater than, less than or the same as that of the wire in **(b)**.

.....

.....

..... [2]

(ii) State and explain whether the new reading on the voltmeter is greater than, less than or equal to 4.8 V.

.....

.....

..... [2]

42 - (9702/21_Winter_2023_Q6) - *Current Of Electricity*

A battery is connected in a circuit with a light-dependent resistor (LDR), two fixed resistors and a voltmeter, as shown in Fig. 6.1.

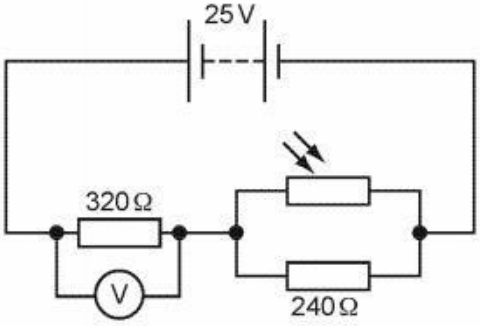


Fig. 6.1

The battery has an electromotive force (e.m.f.) of 25 V and negligible internal resistance.
The resistors have resistances of 320 Ω and 240 Ω.

(a) The voltmeter displays a reading of 16 V.

(i) Show that the current in the battery is 0.050 A.

[1]

(ii) Calculate the resistance of the LDR.

resistance = ... Ω [3]

(iii) Determine the ratio

$$\frac{\text{power dissipated in the LDR}}{\text{power dissipated in the } 240\,\Omega \text{ resistor}}.$$

ratio = ... [2]

(b) The intensity of the light incident on the LDR increases.

State and explain what happens to the voltmeter reading.

.....

.....

.....

..... [3]

43 - (9702/22_Winter_2023_Q6) - *Current Of Electricity*

(a) A metal wire has a resistance per unit length of $0.92\,\Omega\,m^{-1}$. The wire has a uniform cross-sectional area of $5.3 \times 10^{-7}\,m^2$.

Calculate the resistivity of the metal of the wire.

resistivity = ... Ω m [2]

(b) A battery of electromotive force (e.m.f.) *E* and negligible internal resistance is connected in series with a fixed resistor and a light-dependent resistor (LDR), as shown in Fig. 6.1.

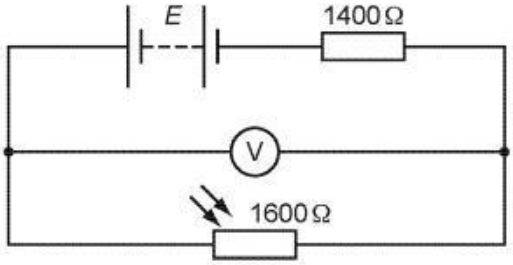


Fig. 6.1

The resistance of the fixed resistor is 1400 Ω. The intensity of the light illuminating the LDR causes it to have a resistance of 1600 Ω. A voltmeter connected across the LDR reads 6.4 V.

(i) Show that the current in the LDR is 4.0×10^{-3} A.

[1]

(ii) Calculate the number of free electrons passing through the LDR in a time of 3.2 minutes.

number of free electrons = ... [2]

(iii) Calculate the e.m.f. *E*.

E = ... V [2]

(iv) Determine the ratio

$$\frac{\text{power dissipated in LDR}}{\text{power dissipated in fixed resistor}}.$$

ratio = ... [2]

(c) The environmental conditions change causing a decrease in the resistance of the LDR in **(b)**. The temperature of the environment does not change.

State whether there is a decrease, increase or no change to:

(i) the intensity of the light illuminating the LDR

..... [1]

(ii) the current in the battery

..... [1]

(iii) the reading of the voltmeter.

..... [1]

44 - (9702/23_Winter_2023_Q7) - *Current Of Electricity*

(a) State Ohm's law.

.....

.....

..... [2]

(b) A battery of electromotive force (e.m.f.) 6.2 V and negligible internal resistance is connected in a circuit to a uniform resistance wire, a voltmeter, a fixed resistor and a switch, as shown in Fig. 7.1.

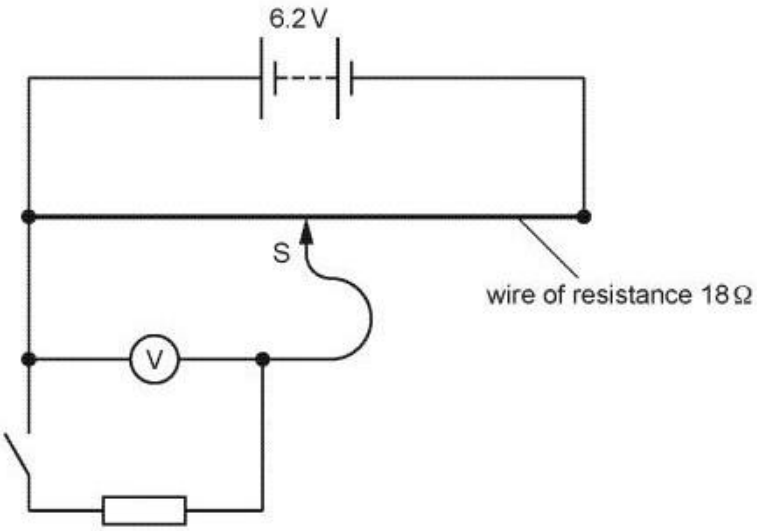


Fig. 7.1

The resistance wire has resistance 18 Ω, length 0.94 m and cross-sectional area $7.2 \times 10^{-8}\,m^2$. The slider S is positioned half-way along the length of the wire.

(i) Calculate the resistivity ρ of the material of the resistance wire.

ρ = ... Ω m [2]

(ii) The switch is open.
State the reading on the voltmeter.

voltmeter reading = ... V [1]

(iii) The switch is now closed.

State whether there is an increase, decrease or no change to:

- the current in the battery

  .....

- the voltmeter reading.

  .....

[2]

(iv) The switch remains closed. The slider S is moved along the resistance wire so that the voltmeter reading is 3.1 V.

On Fig. 7.1, draw a cross (×) on the resistance wire to show a possible new position of the slider. [1]

(c) The circuit in **(b)** is altered by changing the battery for one of a different e.m.f.
The switch is open.

A student records the following data for the resistance wire:

current in the wire	0.93 A
mean drift speed of charge carriers	$1.3 \times 10^{-3}\,\mathrm{m\,s^{-1}}$
number density of charge carriers	$9.0 \times 10^{28}\,\mathrm{m^{-3}}$.

(i) Determine the charge q of a charge carrier in the wire suggested by this data.

q = ... C [2]

(ii) With reference to the value of q, explain why the data recorded by the student cannot be correct.

.....

..... [1]

1 - (9702/21_Summer_2017_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define the *ohm*.

.....

.....[1]

(b) A cell X of electromotive force (e.m.f.) 1.5 V and negligible internal resistance is connected in series to three resistors A, B and C, as shown in Fig. 6.1.

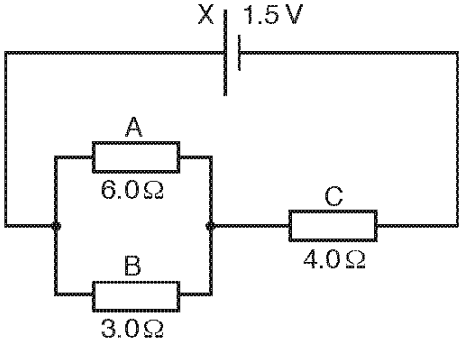


Fig. 6.1

Resistors A and B have resistances 6.0 Ω and 3.0 Ω respectively and are connected in parallel. Resistor C has resistance 4.0 Ω and is connected in series with the parallel combination.

Calculate

(i) the current in the circuit,

current = ...A [3]

(ii) the current in resistor B,

current = ...A [1]

(iii) the ratio

$$\frac{\text{power dissipated in resistor B}}{\text{power dissipated in resistor C}}.$$

ratio = ...[2]

(c) The resistors A, B and C in **(b)** are wires of the same material and have the same length.

(i) Explain how the resistors may be made with different resistance values.

.....[1]

(ii) Calculate the ratio

$$\frac{\text{average drift speed of the charge carriers in resistor B}}{\text{average drift speed of the charge carriers in resistor C}}.$$

ratio = ...[2]

(d) A cell of e.m.f. 1.5 V and negligible internal resistance is connected in parallel with cell X in Fig. 6.1 with their positive terminals together.

State the change, if any, to the current in

(i) cell X,

.....[1]

(ii) resistor C.

.....[1]

2 - (9702/23_Summer_2017_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Describe the I–V characteristic of

(i) a metallic conductor at constant temperature,

.....

.....[1]

(ii) a semiconductor diode.

.....

.....

.....[2]

(b) Two identical filament lamps are connected in series and then in parallel to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance, as shown in Fig. 6.1a and Fig. 6.1b.

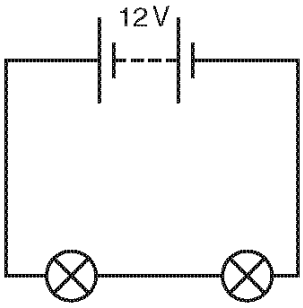


Fig. 6.1a

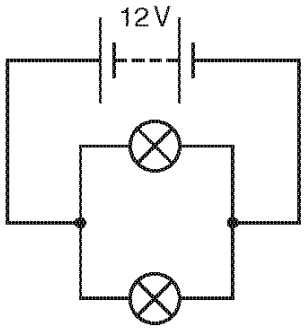


Fig. 6.1b

The I–V characteristic of each lamp is shown in Fig. 6.2.

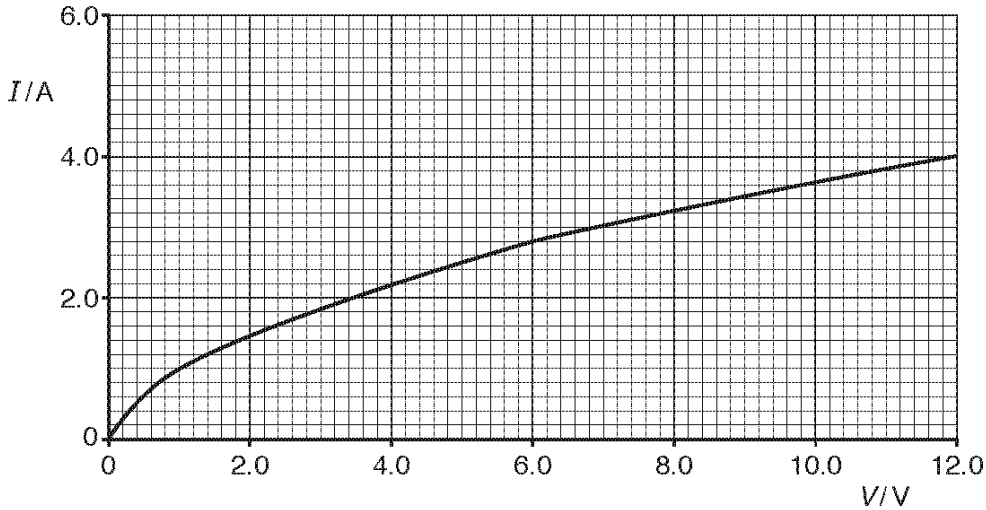


Fig. 6.2

(i) Use the information shown in Fig. 6.2 to determine the current through the battery in

1. the circuit of Fig. 6.1a,

current = ...A

2. the circuit of Fig. 6.1b.

current = ...A
[3]

(ii) Calculate the total resistance in

1. the circuit of Fig. 6.1a,

resistance = ...Ω

2. the circuit of Fig. 6.1b.

resistance = ...Ω
[3]

(iii) Calculate the ratio

$$\frac{\text{power dissipated in a lamp in the circuit of Fig. 6.1a}}{\text{power dissipated in a lamp in the circuit of Fig. 6.1b}}.$$

ratio = ...[2]

3 - (9702/22_Summer_2017_Q7) - *D.c. Circuits*

(a) Define *electromotive force* (e.m.f.) of a cell.

.....

.....[1]

(b) A cell C of e.m.f. 1.50 V and internal resistance 0.200 Ω is connected in series with resistors X and Y, as shown in Fig. 7.1.

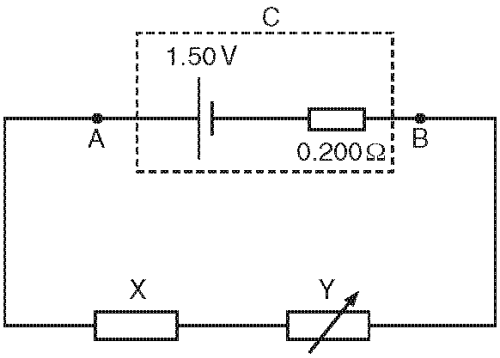


Fig. 7.1

The resistance of X is constant and the resistance of Y can be varied.

(i) The resistance of Y is varied from 0 to 8.00 Ω.

State and explain the variation in the potential difference (p.d.) between points A and B (terminal p.d. across C). Numerical values are not required.

.....

.....

.....

.....[3]

(ii) The resistance of Y is set at 6.00 Ω. The current in the circuit is 0.180 A.

Calculate

1. the resistance of X,

resistance = ...Ω [2]

2. the p.d. between points A and B,

p.d. = ... V [2]

3. the efficiency of the cell.

efficiency = ...[2]

4 - (9702/21_Winter_2017_Q5) - *Current Of Electricity, D.c. Circuits*

Three cells of electromotive forces (e.m.f.) E_1, E_2 and E_3 are connected into a circuit, as shown in Fig. 5.1.

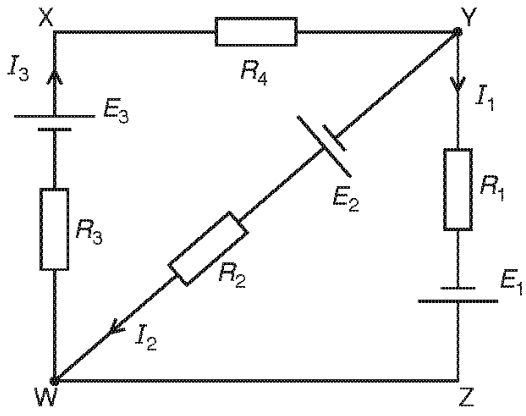


Fig. 5.1

The circuit contains resistors of resistances R_1, R_2, R_3 and R_4.
The currents in the different parts of the circuit are I_1, I_2 and I_3.
The cells have negligible internal resistance.

Use Kirchhoff's laws to state an equation relating

(a) I_1, I_2 and I_3,

.....[1]

(b) E_1, E_3, R_1, R_3, R_4, I_1 and I_3 in loop WXYZW,

.....

.....[1]

(c) E_1, E_2, R_1, R_2, I_1 and I_2 in loop YZWY.

.....

.....[1]

5 - (9702/23_Winter_2017_Q6) - *Current Of Electricity, D.c. Circuits*

A filament lamp is rated as 30 W, 120 V. A potential difference of 120 V is applied across the lamp.

(a) For the filament wire of the lamp, calculate

(i) the current,

current = ... A [2]

(ii) the number of electrons passing a point in 3.0 hours.

number = ...[2]

(b) Show that the resistance of the filament wire is 480 Ω.

[2]

(c) The filament wire has an uncoiled length of 580 mm and is made of metal. The metal has resistivity $6.1 \times 10^{-7}\,\Omega\,m$ at the operating temperature of the lamp.

Calculate the diameter of the wire.

diameter = ... m [3]

(d) The potential difference across the lamp is now reduced. State and explain the effect, if any, on the resistance of the filament wire.

.....

.....[1]

6 - (9702/21_Winter_2017_Q7) - *Current Of Electricity, D.c. Circuits*

(a) Define the *ohm*.

.....[1]

(b) Wires are used to connect a battery of negligible internal resistance to a lamp, as shown in Fig. 7.1.

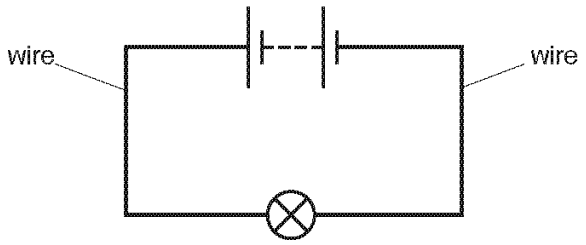


Fig. 7.1

The lamp is at its normal operating temperature. Some data for the filament wire of the lamp and for the connecting wires of the circuit are shown in Fig. 7.2.

	filament wire	connecting wires
diameter	d	$14\,d$
total length	L	$7.0\,L$
resistivity of metal (at normal operating temperature)	ρ	$0.028\,\rho$

Fig. 7.2

(i) Show that

$$\frac{\text{resistance of filament wire}}{\text{total resistance of connecting wires}} = 1000.$$

[2]

(ii) Use the information in **(i)** to explain qualitatively why the power dissipated in the filament wire of the lamp is greater than the total power dissipated in the connecting wires.

.....

.....

.....[1]

(iii) The lamp is rated as 12 V, 6.0 W. Use the information in **(i)** to determine the total resistance of the connecting wires.

total resistance of connecting wires = ... Ω [3]

(iv) The diameter of the connecting wires is decreased. The total length of the connecting wires and the resistivity of the metal of the connecting wires remain the same.

State and explain the change, if any, that occurs to the resistance of the filament wire of the lamp.

.....

.....

.....

.....

.....[3]

7 - (9702/21_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define the *volt*.

.....[1]

(b) A battery of electromotive force (e.m.f.) 4.5 V and negligible internal resistance is connected to two filament lamps P and Q and a resistor R, as shown in Fig. 6.1.

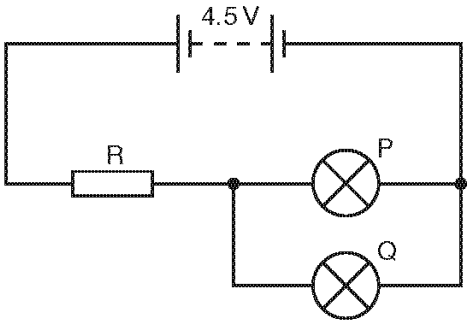


Fig. 6.1

The current in lamp P is 0.15 A.
The I–V characteristics of the filament lamps are shown in Fig. 6.2.

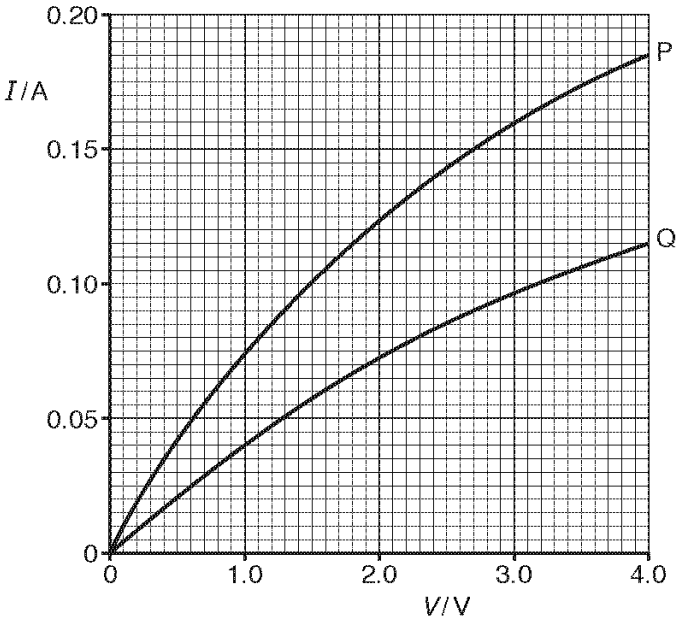


Fig. 6.2

(i) Use Fig. 6.2 to determine the current in the battery. Explain your working.

current = ... A [2]

(ii) Calculate the resistance of resistor R.

resistance = ... Ω [2]

(iii) The filament wires of the two lamps are made from material with the same resistivity at their operating temperature in the circuit. The diameter of the wire of lamp P is twice the diameter of the wire of lamp Q.

Determine the ratio

$$\frac{\text{length of filament wire of lamp P}}{\text{length of filament wire of lamp Q}}.$$

ratio = ... [3]

(iv) The filament wire of lamp Q breaks and stops conducting.

State and explain, qualitatively, the effect on the resistance of lamp P.

.....

.....

.....

.....[2]

8 - (9702/22_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a) **(i)** State Kirchhoff's first law.

.....

.....[1]

(ii) Kirchhoff's first law is linked to the conservation of a certain quantity. State this quantity.

.....[1]

(b) A battery of electromotive force (e.m.f.) 8.0 V and internal resistance 2.0 Ω is connected to a resistor X and a wire Y, as shown in Fig. 6.1.

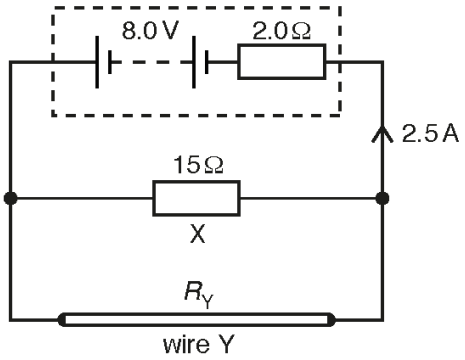


Fig. 6.1

The resistance of X is 15 Ω. The resistance of Y is R_Y. The current in the battery is 2.5 A.

(i) Calculate

1. the thermal energy dissipated in the battery in a time of 5.0 minutes,

energy = ...J [2]

2. the terminal potential difference of the battery.

terminal potential difference = ... V [1]

(ii) Determine the resistance R_Y.

R_Y = ...Ω [3]

(iii) A new wire Z has the same length but less resistance than wire Y.

1. State two possible differences between wire Z and wire Y that would separately cause wire Z to have less resistance than wire Y.

first difference: .....

.....

second difference: .....

.....
[2]

2. Wire Y is replaced in the circuit by wire Z. By considering the current in the battery, state and explain the effect of changing the wires on the total power produced by the battery.

.....

.....

.....[2]

9 - (9702/23_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

A wire X has a constant resistance per unit length of $3.0\,\Omega\,m^{-1}$ and a diameter of 0.48 mm.

(a) Calculate the resistivity of the metal of wire X.

resistivity = ... Ω m [3]

(b) The wire X is connected into the circuit shown in Fig. 6.1.

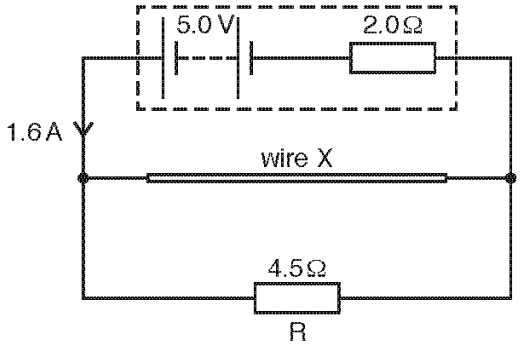


Fig. 6.1

The battery has an electromotive force (e.m.f.) of 5.0 V and an internal resistance of 2.0 Ω. The wire X and a resistor R of resistance 4.5 Ω are connected in parallel. The current in the battery is 1.6 A.

(i) Calculate the potential difference across resistor R.

potential difference = ... V [1]

(ii) Determine, for wire X,

1. its resistance,

resistance = ... Ω [3]

2. its length.

length = ... m [1]

10 - (9702/21_Winter_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a) State Kirchhoff's second law.

.....

.....

..... [2]

(b) An electric heater containing two heating wires X and Y is connected to a power supply of electromotive force (e.m.f.) 9.0 V and negligible internal resistance, as shown in Fig. 6.1.

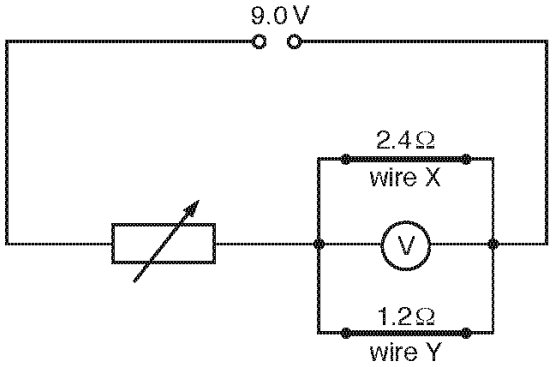


Fig. 6.1

Wire X has a resistance of 2.4 Ω and wire Y has a resistance of 1.2 Ω. A voltmeter is connected in parallel with the wires. A variable resistor is used to adjust the power dissipated in wires X and Y.

The variable resistor is adjusted so that the voltmeter reads 6.0 V.

(i) Calculate the resistance of the variable resistor.

resistance = ... Ω [3]

(ii) Calculate the power dissipated in wire X.

power = ... W [2]

(iii) The cross-sectional area of wire X is three times the cross-sectional area of wire Y. Assume that the resistivity and the number density of free electrons for the metal of both wires are the same.

Determine the ratio

1. $\dfrac{\text{length of wire X}}{\text{length of wire Y}}$,

ratio = ... [2]

2. $\dfrac{\text{average drift velocity of free electrons in wire X}}{\text{average drift velocity of free electrons in wire Y}}$.

ratio = ... [2]

11 - (9702/22_Winter_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define the *volt*.

.....

.....[1]

(b) A battery of electromotive force (e.m.f.) 7.0 V and negligible internal resistance is connected in series with three components, as shown in Fig. 6.1.

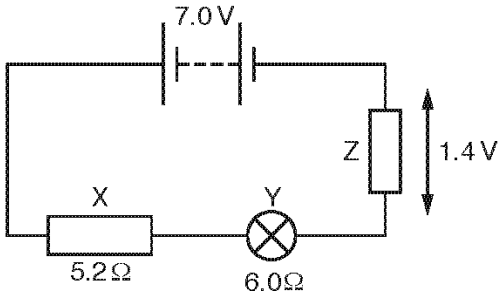


Fig. 6.1

Resistor X has a resistance of 5.2 Ω. The resistance of the filament wire of lamp Y is 6.0 Ω. The potential difference across resistor Z is 1.4 V.

(i) Calculate the current in the circuit.

current = ... A [2]

(ii) Determine the resistance of resistor Z.

resistance = ... Ω [1]

(iii) Calculate the percentage efficiency with which the battery supplies power to the lamp.

efficiency = ... % [3]

(iv) The filament wire of the lamp is made of metal of resistivity $3.7 \times 10^{-7}\,\Omega\,\text{m}$ at its operating temperature in the circuit.

Determine, for the filament wire, the value of α where

$$\alpha = \frac{\text{cross-sectional area}}{\text{length}}.$$

$\alpha =$ ..... m [2]

12 - (9702/23_Winter_2018_Q7) - *Current Of Electricity, D.c. Circuits*

(a) State Kirchhoff's first law.

.....

.....[1]

(b) A potentiometer is connected to a battery of electromotive force (e.m.f.) 9.6 V and negligible internal resistance, as shown in Fig. 7.1.

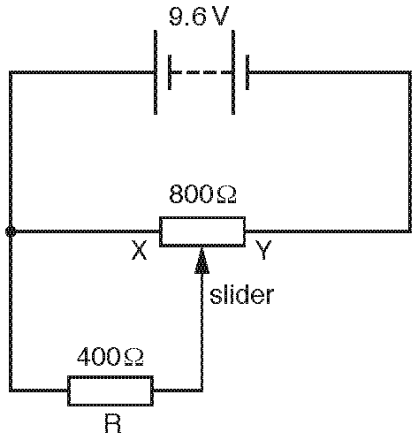


Fig. 7.1

The maximum resistance of the potentiometer is 800 Ω. A resistor R of resistance 400 Ω is connected between the slider and end X of the potentiometer.

(i) State the potential difference across resistor R when the slider is positioned

1. at end X of the potentiometer,

potential difference = ... V

2. at end Y of the potentiometer.

potential difference = ... V
[2]

(ii) Calculate the potential difference across resistor R when the slider is positioned half-way between X and Y.

potential difference = ... V [3]

13 - (9702/22_Summer_2019_Q5) - *Current Of Electricity, D.c. Circuits*

(a) State Kirchhoff's second law.

.....

.....[2]

(b) A battery of electromotive force (e.m.f.) 5.6 V and internal resistance *r* is connected to two external resistors, as shown in Fig. 5.1.

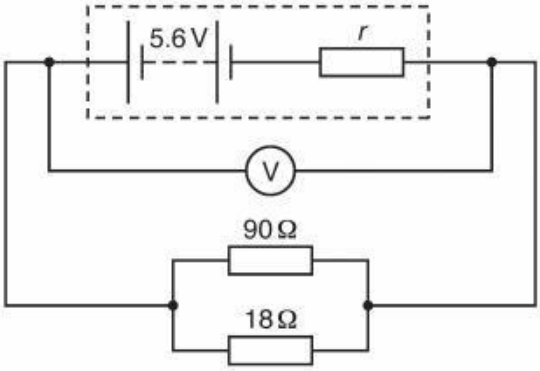


Fig. 5.1

The reading on the voltmeter is 4.8 V.

(i) Calculate:

1. the combined resistance of the two resistors connected in parallel

combined resistance = ... Ω [2]

2. the current in the battery.

current = ... A [2]

(ii) Show that the internal resistance *r* is 2.5 Ω.

[2]

(iii) Determine the ratio

$$\frac{\text{power dissipated by internal resistance } r}{\text{total power produced by battery}}.$$

ratio = ... [3]

(c) The battery in **(b)** is now connected to a battery of e.m.f. 7.2 V and internal resistance 3.5 Ω. The new circuit is shown in Fig. 5.2.

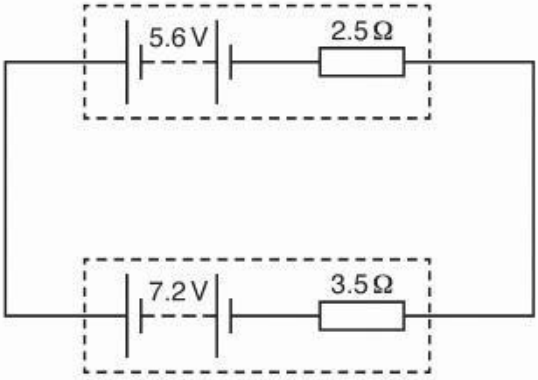


Fig. 5.2

Determine the current in the circuit.

current = ... A [2]

14 - (9702/21_Summer_2019_Q6) - *Current Of Electricity, D.c. Circuits*

A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 6.1.

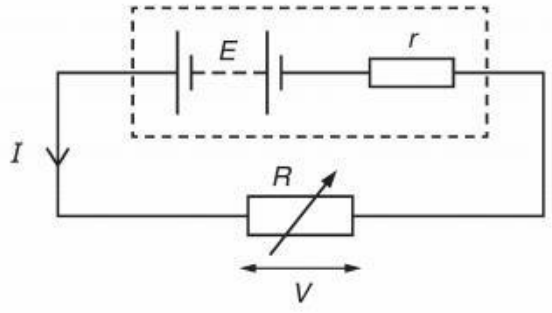


Fig. 6.1

The current in the circuit is I and the potential difference across the variable resistor is V.

(a) Explain, in terms of energy, why V is less than E.

.....

.....[1]

(b) State an equation relating E, I, r and V.

.....[1]

(c) The resistance R of the variable resistor is varied. The variation with I of V is shown in Fig. 6.2.

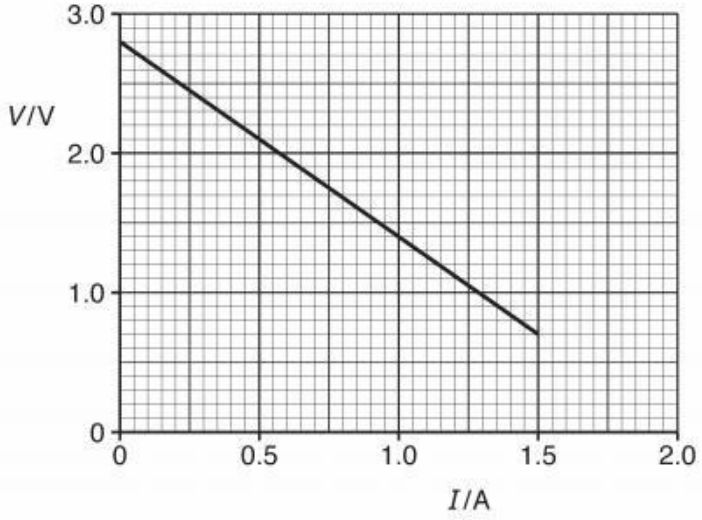


Fig. 6.2

Use Fig. 6.2 to:

(i) explain how it may be deduced that the e.m.f. of the battery is 2.8 V

.....

.....[1]

(ii) calculate the internal resistance *r*.

r = ... Ω [2]

(d) The battery stores 9.2 kJ of energy. The variable resistor is adjusted so that $V = 2.1$ V. Use Fig. 6.2 to:

(i) calculate resistance *R*

R = ... Ω [1]

(ii) calculate the number of conduction electrons moving through the battery in a time of 1.0 s

number = ... [1]

(iii) determine the time taken for the energy in the battery to become equal to 1.6 kJ.
(Assume that the e.m.f. of the battery and the current in the battery remain constant.)

time taken = ... s [3]

15 - (9702/23_Summer_2019_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define the *ohm*.

.....[1]

(b) A battery of electromotive force (e.m.f.) E and internal resistance 1.5 Ω is connected to a network of resistors, as shown in Fig. 6.1.

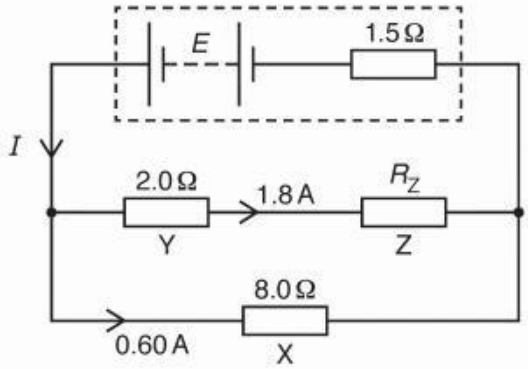


Fig. 6.1

Resistor X has a resistance of 8.0 Ω. Resistor Y has a resistance of 2.0 Ω. Resistor Z has a resistance of R_Z. The current in X is 0.60 A and the current in Y is 1.8 A.

(i) Calculate:

1. the current I in the battery

I = ... A [1]

2. resistance R_Z

R_Z = ... Ω [2]

3. e.m.f. E.

E = ... V [2]

(ii) Resistors X and Y are each made of wire. The two wires have the same length and are made of the same metal.

Determine the ratio:

1. $\dfrac{\text{cross-sectional area of wire X}}{\text{cross-sectional area of wire Y}}$

ratio = ... [2]

2. $\dfrac{\text{average drift speed of free electrons in X}}{\text{average drift speed of free electrons in Y}}$.

ratio = ... [2]

16 - (9702/21_Winter_2019_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define *electric potential difference* (*p.d.*).

.....

..... [1]

(b) The variation with potential difference V of the current I in a semiconductor diode is shown in Fig. 6.1.

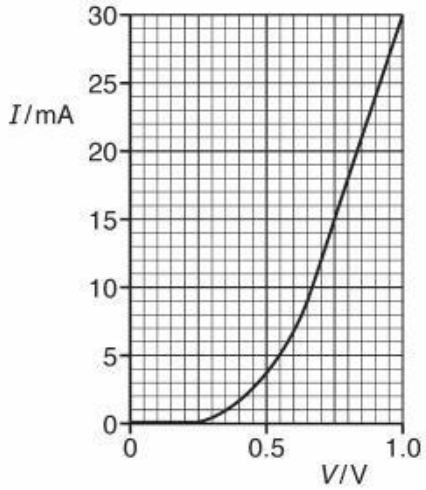


Fig. 6.1

Use Fig. 6.1 to describe qualitatively the variation of the resistance of the diode as V increases from 0 to 1.0 V.

.....

.....

.....

..... [2]

(c) The diode in **(b)** is part of the circuit shown in Fig. 6.2.

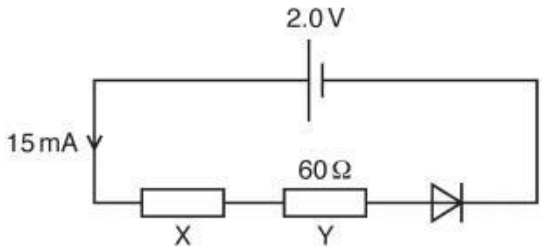


Fig. 6.2

The cell of electromotive force (e.m.f.) 2.0 V and negligible internal resistance is connected in series with the diode and resistors X and Y. The resistance of Y is 60 Ω. The current in the cell is 15 mA.

(i) Use Fig. 6.1 to determine the resistance of the diode.

resistance = ... Ω [3]

(ii) Calculate:

1. the resistance of X

resistance = ... Ω [3]

2. the ratio

$$\frac{\text{power dissipated in resistor Y}}{\text{total power produced by the cell}}.$$

ratio = ... [2]

17 - (9702/22_Winter_2019_Q6) - *Current Of Electricity, D.c. Circuits*

(a) State Kirchhoff's first law.

.....

..... [1]

(b) The variations with potential difference V of the current I for a resistor X and for a semiconductor diode are shown in Fig. 6.1.

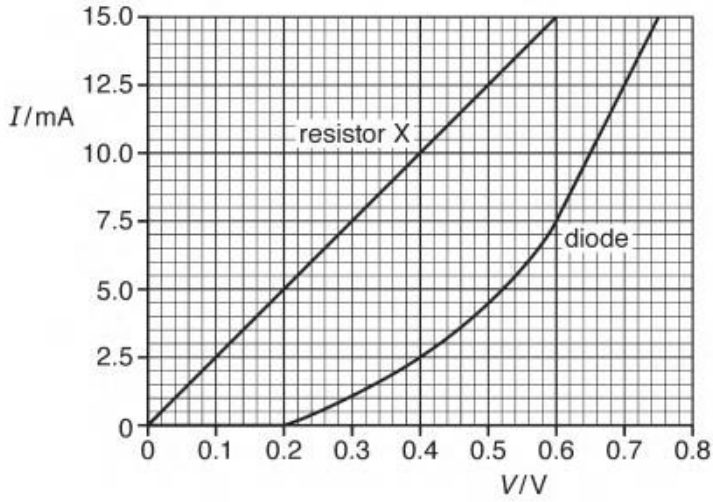


Fig. 6.1

(i) Determine the resistance of the diode for a potential difference V of 0.60 V.

resistance = ... Ω [3]

(ii) Describe, qualitatively, the variation of the resistance of the diode as V increases from 0.60 V to 0.75 V.

..... [1]

(c) The diode and the resistor X in **(b)** are connected into the circuit shown in Fig. 6.2.

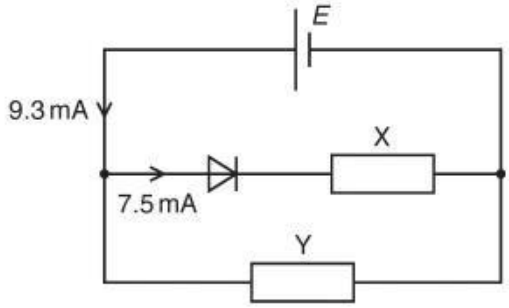


Fig. 6.2

The cell has electromotive force (e.m.f.) *E* and negligible internal resistance. Resistor Y is connected in parallel with resistor X and the diode. The current in the cell is 9.3 mA and the current in the diode is 7.5 mA.

(i) Use Fig. 6.1 to determine *E*.

E = ...V [1]

(ii) Determine the resistance of resistor Y.

resistance = ... Ω [2]

(iii) Calculate the power dissipated in the diode.

power = ...W [2]

(iv) The cell is now replaced by a new cell of e.m.f. 0.50 V and negligible internal resistance. Use Fig. 6.1 to determine the new current in the diode.

current = ...mA [1]

18 - (9702/23_Winter_2019_Q6) - *Current Of Electricity, D.c. Circuits*

A battery of electromotive force (e.m.f.) 12 V and negligible internal resistance is connected to a network of two lamps and two resistors, as shown in Fig. 6.1.

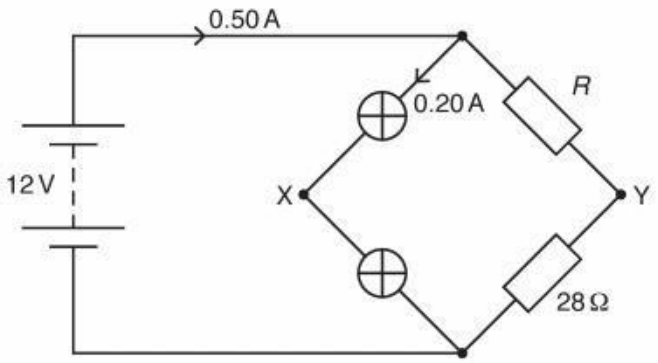


Fig. 6.1

The two lamps in the circuit have equal resistances. The two resistors have resistances R and 28 Ω. The lamps are connected at junction X and the resistors are connected at junction Y. The current in the battery is 0.50 A and the current in the lamps is 0.20 A.

(a) Calculate:

(i) the resistance of each lamp

resistance = ... Ω [2]

(ii) resistance R.

R = ... Ω [2]

(b) Determine the potential difference V_{XY} between points X and Y.

V_{XY} = ... V [3]

(c) Calculate the ratio

$$\frac{\text{total power dissipated by the lamps}}{\text{total power produced by the battery}}.$$

ratio = ... [2]

(d) The resistor of resistance *R* is now replaced by another resistor of lower resistance.

State and explain the effect, if any, of this change on the ratio in **(c)**.

.....

.....

.....

.....

..... [2]

19 – (9702/21_Summer_2020_Q5) – *Current Of Electricity, D.c. Circuits*

(a) Metal wire is used to connect a power supply to a lamp. The wire has a total resistance of $3.4\,\Omega$ and the metal has a resistivity of $2.6 \times 10^{-8}\,\Omega\,m$. The total length of the wire is 59 m.

(i) Show that the wire has a cross-sectional area of $4.5 \times 10^{-7}\,m^2$.

[2]

(ii) The potential difference across the total length of wire is 1.8 V.

Calculate the current in the wire.

current = ... A [1]

(iii) The number density of the free electrons in the wire is $6.1 \times 10^{28}\,m^{-3}$.

Calculate the average drift speed of the free electrons in the wire.

average drift speed = ... $m\,s^{-1}$ [2]

(b) A different wire carries a current. This wire has a part that is thinner than the rest of the wire, as shown in Fig. 5.1.

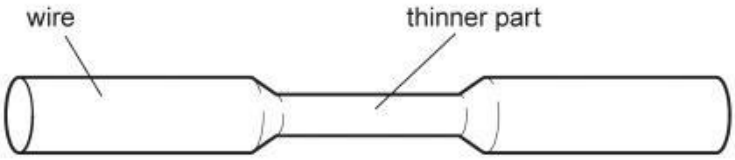


Fig. 5.1

(i) State and explain qualitatively how the average drift speed of the free electrons in the thinner part compares with that in the rest of the wire.

.....

.....

..... [2]

(ii) State and explain whether the power dissipated in the thinner part is the same, less or more than the power dissipated in an equal length of the rest of the wire.

.....

.....

..... [2]

(c) Three resistors have resistances of 180 Ω, 90 Ω and 30 Ω.

(i) Sketch a diagram showing how **two** of these three resistors may be connected together to give a combined resistance of 60 Ω between the terminals shown.
Ensure you label the values of the resistances in your diagram.

[1]

(ii) A potential divider circuit is produced by connecting the three resistors to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance. The potential divider circuit provides an output potential difference V_{OUT} of 8.0 V.
Fig. 5.2 shows the circuit diagram.

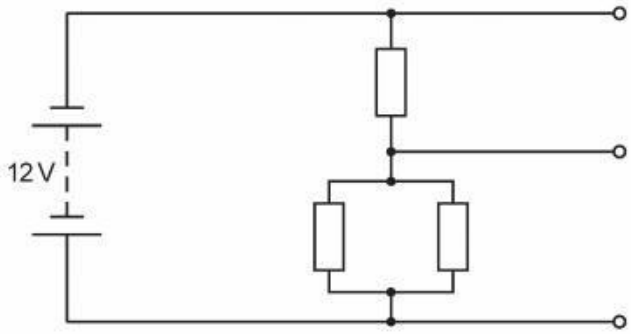


Fig. 5.2

On Fig. 5.2, label the resistances of all three resistors and the potential difference V_{OUT}. [2]

20 - (9702/23_Summer_2020_Q5) - *D.c. Circuits*

(a) Define the *volt*.

.....

..... [1]

(b) Fig. 5.1 shows a network of three resistors.

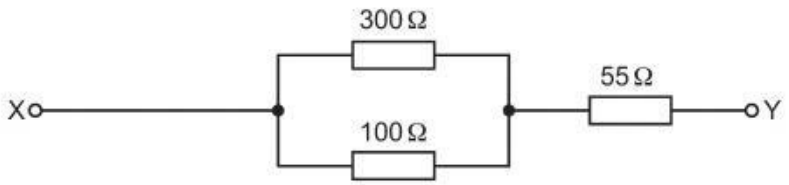


Fig. 5.1

Calculate:

(i) the combined resistance of the two resistors connected in parallel

combined resistance = ... Ω [1]

(ii) the total resistance between terminals X and Y.

total resistance = ... Ω [1]

(c) The network in **(b)** is connected to a power supply so that there is a potential difference between terminals X and Y. The power dissipated in the resistor of resistance 55 Ω is 0.20 W.

(i) Calculate the current in the resistor of resistance:

1. 55 Ω

current = ... A

2. 300 Ω.

current = ... A
[3]

(ii) Calculate the potential difference between X and Y.

potential difference = ... V [1]

21 - (9702/22_Summer_2020_Q6) - *D.c. Circuits*

(a) A battery of electromotive force (e.m.f.) 7.8 V and internal resistance r is connected to a filament lamp, as shown in Fig. 6.1.

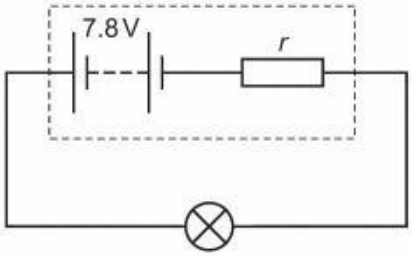


Fig. 6.1

A total charge of 750 C moves through the battery in a time interval of 1500 s. During this time the filament lamp dissipates 5.7 kJ of energy. The e.m.f. of the battery remains constant.

(i) Explain, in terms of energy and without a calculation, why the potential difference across the lamp must be less than the e.m.f. of the battery.

.....

..... [1]

(ii) Calculate:

1. the current in the circuit

current = ... A [2]

2. the potential difference across the lamp

potential difference = ... V [2]

3. the internal resistance of the battery.

internal resistance = ... Ω [2]

(b) A student is provided with three resistors of resistances 90 Ω, 45 Ω and 20 Ω.

(i) Sketch a circuit diagram showing how **two** of these three resistors may be connected together to give a combined resistance of 30 Ω between the terminals shown. Label the values of the resistances on your diagram.

[1]

(ii) A potential divider circuit is produced by connecting the three resistors to a battery of e.m.f. 9.0 V and negligible internal resistance. The potential divider circuit provides an output potential difference V_{OUT} of 3.6 V. The circuit diagram is shown in Fig. 6.2.

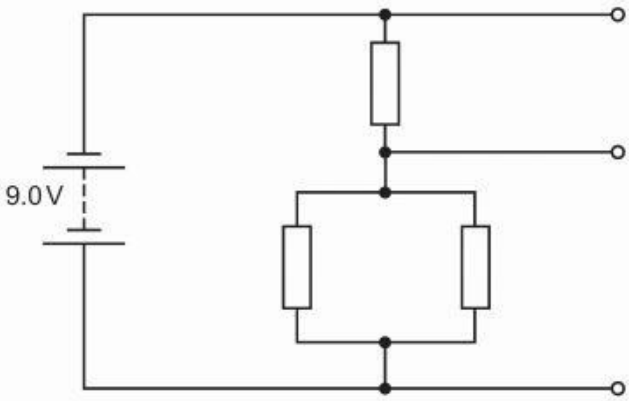


Fig. 6.2

On Fig. 6.2, label the resistances of all three resistors and the potential difference V_{OUT}.
[2]

22 - (9702/22_Winter_2020_Q6) - *Current Of Electricity, D.c. Circuits*

(a) A network of three resistors of resistances R_1, R_2 and R_3 is shown in Fig. 6.1.

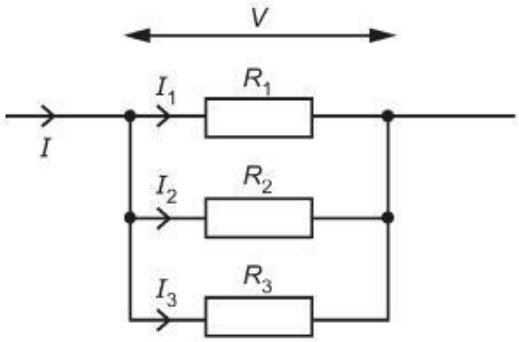


Fig. 6.1

The individual currents in the resistors are I_1, I_2 and I_3. The total current in the combination of resistors is I and the potential difference across the combination is V.

Show that the combined resistance R of the network is given by

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$

[2]

(b) A battery of electromotive force (e.m.f.) 8.0 V and internal resistance r is connected to three resistors X, Y and Z, as shown in Fig. 6.2.

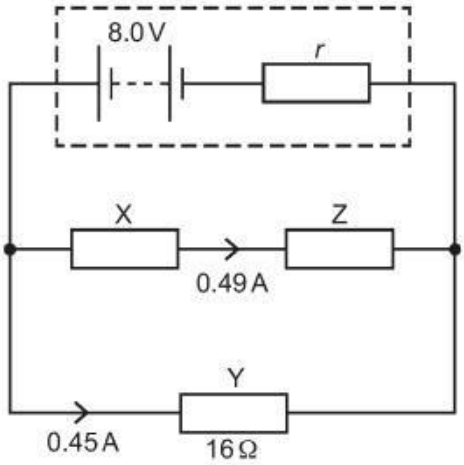


Fig. 6.2

Resistor Y has a resistance of 16 Ω. The current in resistor X is 0.49 A and the current in resistor Y is 0.45 A.

Calculate:

(i) the current in the battery

current = ... A [1]

(ii) the internal resistance r of the battery.

r = ... Ω [2]

(c) Resistors X and Y in Fig. 6.2 are made from wires of the same material and cross-sectional area. The average drift speed of the free electrons in X is $2.1 \times 10^{-4}\,\mathrm{m\,s^{-1}}$.

Calculate the average drift speed v of the free electrons in Y.

v = ... $\mathrm{m\,s^{-1}}$ [2]

(d) Resistor Z in Fig. 6.2 is replaced by a new resistor of smaller resistance.

State and explain the effect, if any, on the terminal potential difference of the battery.

.....

.....

..... [2]

[Total: 9]

23 - (9702/23_Winter_2020_Q6) - *Current Of Electricity, D.c. Circuits*

(a) Define *electric potential difference* (*p.d.*).

.....

..... [1]

(b) A wire of cross-sectional area A is made from metal of resistivity ρ. The wire is extended. Assume that the volume V of the wire remains constant as it extends.

Show that the resistance R of the extending wire is inversely proportional to A^2.

[2]

(c) A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 6.1.

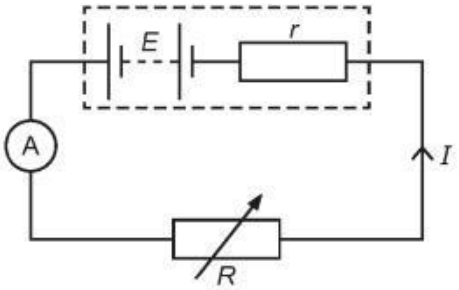


Fig. 6.1

The current in the circuit is I.

Use Kirchhoff's second law to show that

$$R = \left(\frac{E}{I}\right) - r.$$

[1]

(d) An ammeter is used in the circuit in **(c)** to measure the current I as resistance R is varied. Fig. 6.2 is a graph of R against $\frac{1}{I}$.

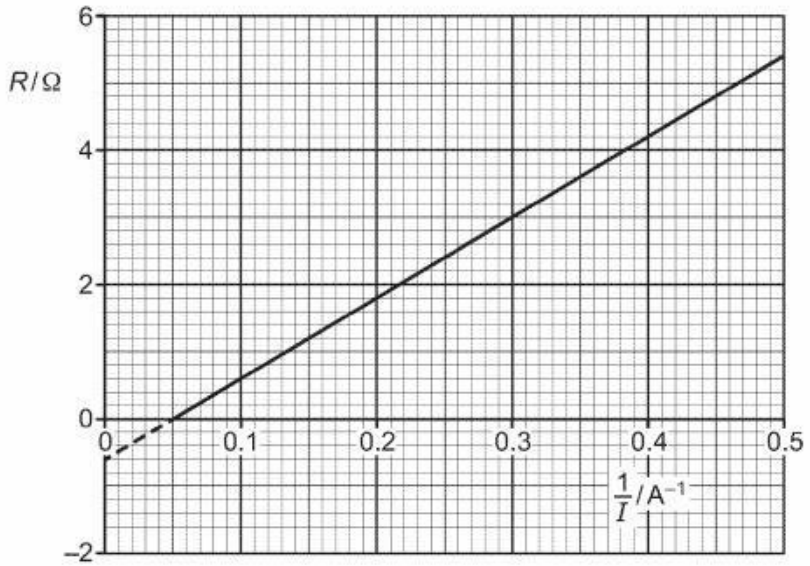


Fig. 6.2

(i) Use Fig. 6.2 to determine the power dissipated in the variable resistor when there is a current of 2.0 A in the circuit.

power = ... W [3]

(ii) Use Fig. 6.2 and the equation in **(c)** to:

1. state the internal resistance r of the battery

r = ... Ω

2. determine the e.m.f. E of the battery.

E = ... V
[3]

[Total: 10]

24 - (9702/21_Winter_2020_Q7) - *Current Of Electricity, D.c. Circuits*

(a) Define the *ohm*.

.....

..... [1]

(b) A uniform wire has resistance 3.2 Ω. The wire has length 2.5 m and is made from metal of resistivity 460 nΩ m.

Calculate the cross-sectional area of the wire.

cross-sectional area = ... m^2 [3]

(c) A cell of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 7.1.

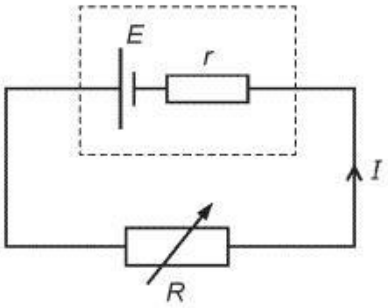


Fig. 7.1

The current in the circuit is I.

(i) State, in terms of energy, why the potential difference across the variable resistor is less than the e.m.f. of the cell.

.....

..... [1]

(ii) State an expression for E in terms of I, R and r.

E = ... [1]

(iii) The resistance R of the variable resistor is changed so that it is equal to r.

Determine an expression, in terms of only E and r, for the power P dissipated in the variable resistor.

P = ... [2]

[Total: 8]

25 - (9702/21_Summer_2021_Q5) - *Current Of Electricity, D.c. Circuits*

(a) State Kirchhoff's second law.

.....

.....

..... [2]

(b) A battery has electromotive force (e.m.f.) 4.0 V and internal resistance 0.35 Ω. The battery is connected to a uniform resistance wire XY and a fixed resistor of resistance *R*, as shown in Fig. 5.1.

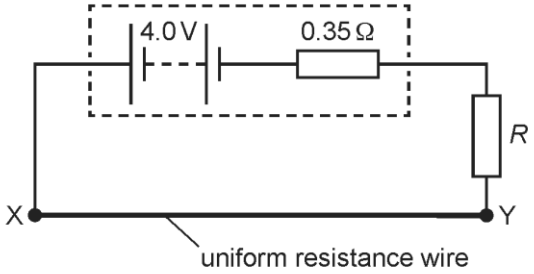


Fig. 5.1

Wire XY has resistance 0.90 Ω. The potential difference across wire XY is 1.8 V.

Calculate:

(i) the current in wire XY

current = ... A [1]

(ii) the number of free electrons that pass a point in the battery in a time of 45 s

number = ... [2]

(iii) resistance *R*.

R = ... Ω [2]

(c) A cell of e.m.f. 1.2 V is connected to the circuit in **(b)**, as shown in Fig. 5.2.

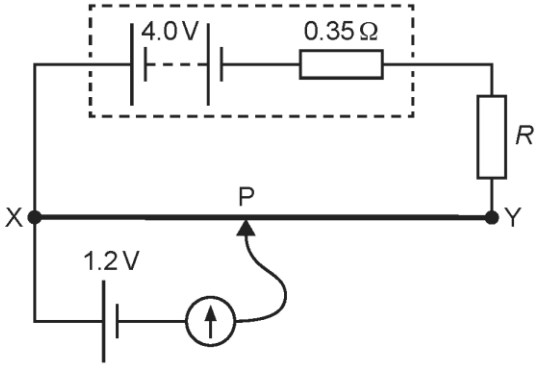


Fig. 5.2

The connection P is moved along the wire XY. The galvanometer reading is zero when distance XP is 0.30 m.

(i) Calculate the total length *L* of wire XY.

L = ... m [2]

(ii) The fixed resistor is replaced by a different fixed resistor of resistance greater than *R*.

State and explain the change, if any, that must be made to the position of P on wire XY so that the galvanometer reading is zero.

.....

.....

.....

..... [2]

26 - (9702/22_Summer_2021_Q5) - *Current Of Electricity, D.c. Circuits*

(a) Define the *ohm*.

.....

..... [1]

(b) A wire is made of metal of resistivity ρ. The length L of the wire is gradually increased. Assume that the volume V of the wire remains constant as its length is increased.

Show that the resistance R of the extending wire is proportional to L^2.

[2]

(c) A battery of electromotive force (e.m.f.) E and internal resistance r is connected to a variable resistor of resistance R, as shown in Fig. 5.1.

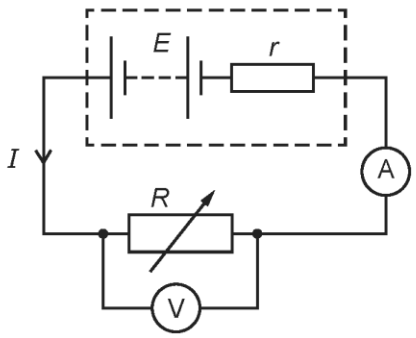


Fig. 5.1

An ammeter measures the current I in the circuit. A voltmeter measures the potential difference V across the variable resistor.

The resistance R is now varied to change the values of I and V.

The variation with I of V is shown in Fig. 5.2.

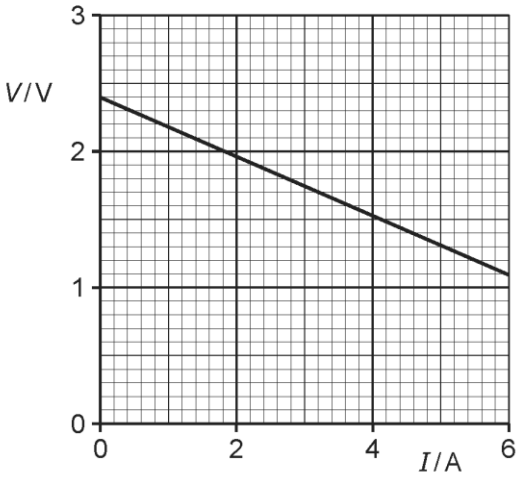


Fig. 5.2

(i) Use Fig. 5.2 to state the e.m.f. E of the battery.

E = ... V [1]

(ii) Use Fig. 5.2 to determine the power dissipated in the variable resistor when there is a current of 5.0 A.

power = ... W [3]

(iii) State what is represented by the value of the gradient of the graph.

..... [1]

27 - (9702/23_Summer_2021_Q5) - *D.c. Circuits*

(a) Define the *electromotive force* (*e.m.f.*) of a source.

.....

.....

..... [2]

(b) The circuit shown in Fig. 5.1 contains a battery of e.m.f. E that has internal resistance r, a variable resistor, a voltmeter and an ammeter.

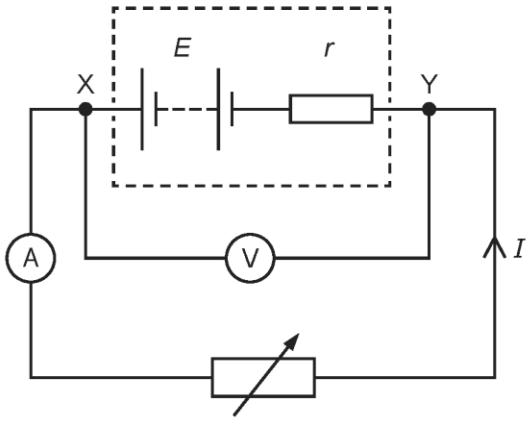


Fig. 5.1

Readings from the two meters are taken for different settings of the variable resistor. The variation with current I of the potential difference (p.d.) V across the terminals XY of the battery is shown in Fig. 5.2.

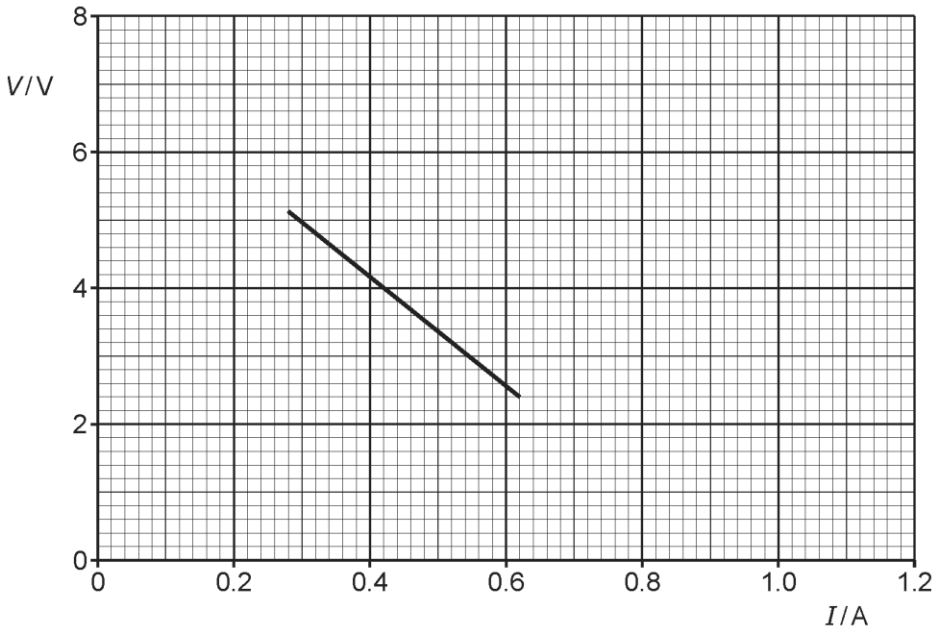


Fig. 5.2

Explain why V is not constant.

.....

.....

.....

..... [3]

(c) For the battery in **(b)**, use Fig. 5.2 to determine:

(i) the e.m.f. E

E = ... V [1]

(ii) the maximum current that the battery can supply

maximum current = ... A [1]

(iii) the internal resistance r.

r = ... Ω [2]

(d) On Fig. 5.2, sketch a line to show a possible variation with I of V for a battery with a lower e.m.f. and a lower internal resistance than the battery in **(b)**. Your line should extend over at least the same range of currents as the original line. [2]

28 - (9702/22_Winter_2021_Q6) - *D.c. Circuits*

A cell of electromotive force (e.m.f.) 0.48 V is connected to a metal wire X, as shown in Fig. 6.1.

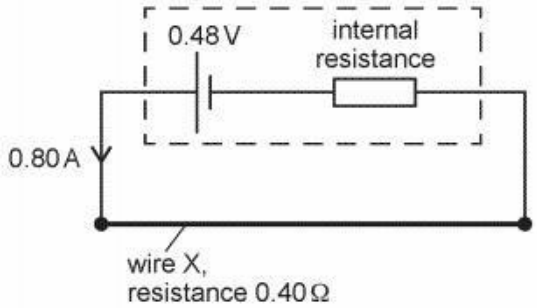


Fig. 6.1

The cell has internal resistance. The current in the cell is 0.80 A.

Wire X has length 3.0 m, cross-sectional area $1.3 \times 10^{-7}\,m^2$ and resistance 0.40 Ω.

(a) Calculate the charge passing through the cell in a time of 7.5 minutes.

charge = ... C [2]

(b) Calculate the percentage efficiency with which the cell supplies power to wire X.

efficiency = ... % [3]

(c) There are 3.2×10^{22} free (conduction) electrons contained in the volume of wire X.

For wire X, calculate:

(i) the number density n of the free electrons

n = ... m^{-3} [1]

(ii) the average drift speed of the free electrons.

average drift speed = ... $m\,s^{-1}$ [2]

(d) A wire Y has the same cross-sectional area as wire X and is made of the same metal. Wire Y is longer than wire X.

Wire X in the circuit is now replaced by wire Y. Assume that wire Y has the same temperature as wire X.

State and explain whether the average drift speed of the free electrons in wire Y is greater than, the same as, or less than that in wire X.

.....

.....

.....

.....

.....

..... [3]

29 – (9702/21_Summer_2022_Q6) – *D.c. Circuits*

(a) State Kirchhoff's first law.

.....

..... [1]

(b) A battery is connected to two resistors X and Y, as shown in Fig. 6.1.

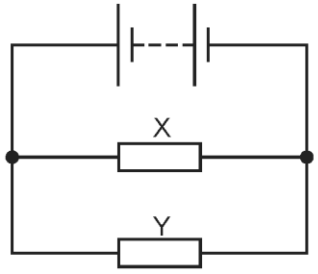


Fig. 6.1

The resistance of resistor X is greater than the resistance of resistor Y.

(i) State and explain which resistor dissipates more power.

.....

.....

.....

.....

..... [3]

(ii) The two resistors are made of wires that have the same length. Both wires are made from metal of the same resistivity.

State and explain which resistor is made of wire with the larger cross-sectional area.

.....

.....

..... [2]

(c) A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected in series with a light-dependent resistor (LDR) and a fixed resistor of resistance 1800 Ω, as shown in Fig. 6.2.

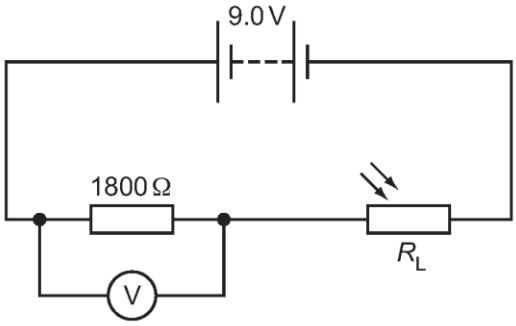


Fig. 6.2

A voltmeter is connected across the fixed resistor. The reading on the voltmeter is 5.4 V.

(i) Calculate the current in the circuit.

current = ... A [1]

(ii) Calculate the resistance R_L of the LDR.

R_L = ... Ω [2]

(iii) The intensity of the light illuminating the LDR increases.

By reference to the current in the circuit, state and explain the change, if any, to the voltmeter reading.

.....

.....

.....

..... [2]

[Total: 11]

1 - (9702/23_Summer_2017_Q3) - *Electric Fields, Particle & Nuclear Physics*

(a) Define *electric field strength*.

.....

.....[1]

(b) An electron is accelerated from point A to point B by a uniform electric field, as illustrated in Fig. 3.1.

Fig. 3.1

The distance between A and B is 12 mm. The velocity of the electron at A is 2.5 km s^{-1} and at B is 18 Mm s^{-1}.

Calculate

(i) the acceleration of the electron,

acceleration = ...m s^{-2} [2]

(ii) the change in kinetic energy of the electron,

change in kinetic energy = ...J [3]

(iii) the electric field strength.

electric field strength = ... $V m^{-1}$ [3]

(c) An α-particle moves from A to B in the electric field in **(b)**.

Describe and explain how the change in the kinetic energy of the α-particle compares with that of the electron. Numerical values are not required.

.....

.....

.....

.....

.....[3]

2 - (9702/21_Summer_2017_Q7) - *Particle & Nuclear Physics*

(a) Use the quark model to show that

(i) the charge on a proton is $+e$,

.....[1]

(ii) the charge on a neutron is zero.

.....[1]

(b) A nucleus of $^{90}_{38}Sr$ decays by the emission of a β^- particle. A nucleus of $^{64}_{29}Cu$ decays by the emission of a β^+ particle.

(i) In Fig. 7.1, state the nucleon number and proton number for the nucleus produced in each of these decay processes.

	nucleus formed by β^- decay	nucleus formed by β^+ decay
nucleon number		
proton number		

Fig. 7.1 [1]

(ii) State the name of the force responsible for β decay.

.....[1]

(iii) State the names of the leptons produced in each of the decay processes.

β^- decay: .....

β^+ decay: .....

[1]

3 - (9702/23_Summer_2017_Q7) - *Particle & Nuclear Physics*

(a) The following particles are used to describe the structure of an atom.

electron neutron proton quark

Underline the fundamental particles in the above list. [1]

(b) The following equation represents the decay of a nucleus of $^{60}_{27}Co$ to form nucleus Q by β^- emission.

$$^{60}_{27}Co \rightarrow {}^{A}_{B}Q + \beta^- + x$$

(i) Complete Fig. 7.1.

	value
A	
B	

Fig. 7.1

[1]

(ii) State the name of the particle x.

.....[1]

4 - (9702/22_Summer_2017_Q8) - *Particle & Nuclear Physics*

(a) Describe **two** differences between the decay of a nucleus that emits a β^- particle and the decay of a nucleus that emits a β^+ particle.

1. .....

.....

2. .....

.....

[2]

(b) In a simple quark model there are three types of quark. State the composition of the proton and of the neutron in terms of these three quarks.

proton: .....

neutron: .....

[1]

5 - (9702/22_Winter_2017_Q7) - *Particle & Nuclear Physics*

A stationary nucleus X decays by emitting a β^+ particle to form a nucleus of carbon-13 ($^{13}_{6}C$). An incomplete equation to represent this decay is

$$X \rightarrow {}^{13}_{6}C + \beta^+.$$

(a) State the name of the class (group) of particles that includes β^+.

.....[1]

(b) For nucleus X, state the number of

protons, ...

neutrons. ..... [1]

(c) The carbon-13 nucleus has a mass of 2.2×10^{-26} kg. Its kinetic energy as a result of the decay process is 0.80 MeV.

Calculate the speed of this nucleus.

speed = ... $m\,s^{-1}$ [3]

(d) Explain why the sum of the kinetic energies of the carbon-13 nucleus and the β^+ particle cannot be equal to the total energy released by the decay process.

.....

.....[1]

6 - (9702/23_Winter_2017_Q7) - *Particle & Nuclear Physics*

(a) A nucleus X decays by emitting a β^+ particle to form a new nucleus, $^{23}_{11}Na$.

State the number of nucleons and the number of neutrons in nucleus X.

number of nucleons = ...

number of neutrons = ...
[2]

(b) State one similarity and one difference between a β^+ particle and a β^- particle.

similarity: .....

difference: .....
[2]

7 - (9702/21_Winter_2017_Q8) - *Particle & Nuclear Physics*

A neutron within a nucleus decays to produce a proton, a β^- particle and an (electron) antineutrino.

$$n \rightarrow p + \beta^- + \bar{\nu}$$

(a) Use the quark composition of the neutron to show that the neutron has no charge.

[3]

(b) Complete Fig. 8.1 by giving appropriate values of the charge and the mass of the proton, the β^- particle and the (electron) antineutrino.

	proton	β^- particle	antineutrino
charge			
mass			

Fig. 8.1

[2]

8 - (9702/22_Summer_2018_Q7) - *Particle & Nuclear Physics*

A stationary nucleus X decays to form nucleus Y, as shown by the equation

$$X \rightarrow Y + \beta^- + \bar{\nu}.$$

(a) In the above equation, draw a circle around all symbols that represent a lepton. [1]

(b) State the name of the particle represented by the symbol $\bar{\nu}$.

.....[1]

(c) Energy is released during the decay process. State the form of the energy that is gained by nucleus Y.

.....[1]

(d) By comparing the compositions of X and Y, state and explain whether they are isotopes.

.....

.....

.....[2]

(e) The quark composition of one nucleon in X is changed during the emission of a β^- particle. Describe this change to the quark composition.

.....

.....[1]

9 - (9702/23_Summer_2018_Q7) - *Particle & Nuclear Physics*

A graph of nucleon number *A* against proton number *Z* is shown in Fig. 7.1.

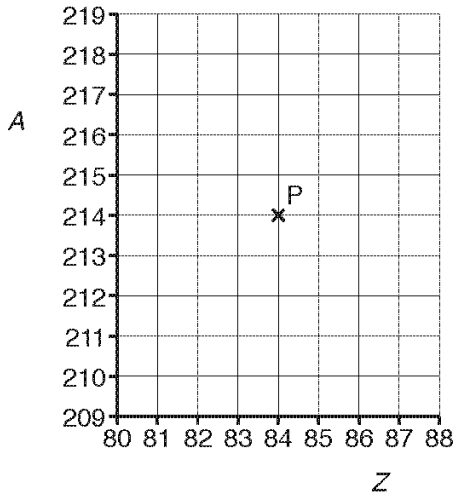


Fig. 7.1

The graph shows a cross (labelled P) that represents a nucleus P.

Nucleus P decays by emitting an α particle to form a nucleus Q.
Nucleus Q then decays by emitting a β^- particle to form a nucleus R.

(a) On Fig. 7.1, use a cross to represent

(i) nucleus Q (label this cross Q), [1]

(ii) nucleus R (label this cross R). [1]

(b) State the name of the class (group) of particles that includes the β^- particle.

.....[1]

(c) The quark composition of one nucleon in Q is changed during the emission of the β^- particle. Describe this change to the quark composition.

.....

.....[1]

10 - (9702/21_Winter_2018_Q5) - *Electric Fields, Particle & Nuclear Physics, Kinematics*

(a) State what is meant by an *electric field*.

.....

..... [1]

(b) A particle of mass m and charge q is in a uniform electric field of strength E. The particle has acceleration a due to the field.

Show that

$$a = \frac{Eq}{m}.$$

[2]

(c) A stationary nucleus X decays by emitting an α-particle to form a nucleus of plutonium, $^{240}_{94}Pu$, as shown.

$$X \longrightarrow {}^{240}_{94}Pu + \alpha$$

(i) Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...

number of neutrons = ...

[2]

(ii) The total mass of the plutonium nucleus and the α-particle is less than that of nucleus X. Explain this difference in mass.

.....

.....

.....

..... [2]

(iii) The plutonium nucleus and the α-particle are both accelerated by the same uniform electric field.

Use the expression in **(b)** to determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particle}}{\text{acceleration of the plutonium nucleus}}.$$

ratio = ... [2]

11 - (9702/23_Winter_2018_Q5) - *Electric Fields, Particle & Nuclear Physics*

A particle of mass m and charge q is in a uniform electric field of strength E. The particle has acceleration a due to the field.

(a) Show that

$$\frac{q}{m} = \frac{a}{E}.$$

[2]

(b) The particle has a charge of $4e$ where e is the elementary charge. The electric field strength is $3.5 \times 10^4\,\mathrm{V\,m^{-1}}$. The acceleration of the particle is $1.5 \times 10^{12}\,\mathrm{m\,s^{-2}}$.

Use the expression in **(a)** to show that the mass of the particle is 9.0 u.

[2]

(c) The particle is a nucleus. State the number of protons and the number of neutrons in the nucleus.

number of protons = ...

number of neutrons = ...

[1]

(d) A second nucleus that is an isotope of the nucleus in **(c)** is in the same uniform electric field.

State and explain whether the electric field produces, for the two nuclei, the same magnitudes of

(i) force,

.....

.....[1]

(ii) acceleration.

.....

.....[1]

12 - (9702/22_Winter_2018_Q8) - *Particle & Nuclear Physics*

(a) In the following list, underline all particles that are leptons.

antineutrino positron proton quark [1]

(b) A stationary nucleus of magnesium-27, $^{27}_{12}Mg$, decays by emitting a β^- particle and γ radiation. An incomplete equation to represent this decay is

$$^{27}_{12}Mg \rightarrow X + \beta^- + \gamma.$$

(i) State the nucleon number and the proton number of nucleus X.

nucleon number = ...

proton number = ...
[2]

(ii) State the name of the interaction that gives rise to this decay.

.....[1]

(iii) State **two** possible reasons why the sum of the kinetic energy of the β^- particle and the energy of the γ radiation is less than the total energy released during the decay of the magnesium nucleus.

1. .....

.....

2. .....

.....
[2]

13 - (9702/22_Summer_2019_Q6) - *Electric Fields, Particle & Nuclear Physics*

(a) State what is meant by a *field line* (*line of force*) in an electric field.

.....

.....[1]

(b) An electric field has two different regions X and Y. The field strength in X is less than that in Y. Describe a difference between the pattern of field lines (lines of force) in X and in Y.

.....

.....[1]

(c) A particle P has a mass of 0.15 u and a charge of $-1e$, where e is the elementary charge.

(i) Particle P and an α-particle are in the same uniform electric field. Calculate the ratio

$$\frac{\text{magnitude of acceleration of particle P}}{\text{magnitude of acceleration of } \alpha\text{-particle}}.$$

ratio = ... [3]

(ii) Particle P is a hadron composed of only two quarks. One of them is a down (d) quark.

By considering charge, determine a possible type (flavour) of the other quark. Explain your working.

.....

.....[3]

14 - (9702/21_Summer_2019_Q7) - *Particle & Nuclear Physics*

(a) One of the results of the α-particle scattering experiment is that a very small minority of the α-particles are scattered through angles greater than 90°.

State what may be inferred about the structure of the atom from this result.

.....

.....

.....

.....[2]

(b) A hadron has an overall charge of $+e$, where e is the elementary charge. The hadron contains three quarks. One of the quarks is a strange (s) quark.

(i) State the charge, in terms of e, of the strange (s) quark.

charge = ... [1]

(ii) The other two quarks in the hadron have the same charge as each other.

By considering charge, determine a possible type (flavour) of the other two quarks. Explain your working.

.....

.....[2]

15 - (9702/23_Summer_2019_Q7) - *Particle & Nuclear Physics*

A sample of a radioactive substance may decay by the emission of either α-radiation or β-radiation and/or γ-radiation.

State the type of radiation, one in each case, that:

(a) consists of leptons

.....[1]

(b) contains quarks

.....[1]

(c) cannot be deflected by an electric field

.....[1]

(d) has a continuous range of energies, rather than discrete values of energy.

.....[1]

16 - (9702/21_Winter_2019_Q7) - *Particle & Nuclear Physics*

(a) The decay of a nucleus $^{35}_{18}Ar$ by β^+ emission is represented by

$$^{35}_{18}Ar \rightarrow X + \beta^+ + Y.$$

A nucleus X and two particles, β^+ and Y, are produced by the decay.

State:

(i) the proton number and the nucleon number of nucleus X

proton number = ...

nucleon number = ...
[1]

(ii) the name of the particle represented by the symbol Y.

..... [1]

(b) A hadron consists of two down quarks and one strange quark.

Determine, in terms of the elementary charge *e*, the charge of this hadron.

charge = ... [2]

17 - (9702/22_Winter_2019_Q7) - *Particle & Nuclear Physics*

A nucleus of plutonium-238 ($^{238}_{94}Pu$) decays by emitting an α-particle to produce a new nucleus X and 5.6 MeV of energy. The decay is represented by

$$^{238}_{94}Pu \rightarrow X + \alpha + 5.6\,MeV.$$

(a) Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...

number of neutrons = ...
[2]

(b) Calculate the number of plutonium-238 nuclei that must decay in a time of 1.0 s to produce a power of 0.15 W.

number = ... [2]

18 - (9702/23_Winter_2019_Q7) - *Particle & Nuclear Physics*

A stationary nucleus of a radioactive isotope X decays by emitting an α-particle to produce a nucleus of neptunium-237 and 5.5 MeV of energy. The decay is represented by

$$X \rightarrow {}^{237}_{93}Np + \alpha + 5.5\,MeV.$$

(a) Calculate the number of protons and the number of neutrons in a nucleus of X.

number of protons = ...

number of neutrons = ...
[2]

(b) Explain why the energy transferred to the α-particle as kinetic energy is less than the 5.5 MeV of energy released in the decay process.

.....

..... [1]

(c) A sample of X is used to produce a beam of α-particles in a vacuum. The number of α-particles passing a fixed point in the beam in a time of 30 s is 6.9×10^{11}.

(i) Calculate the average current produced by the beam of α-particles.

current = ... A [2]

(ii) Determine the total power, in W, that is produced by the decay of 6.9×10^{11} nuclei of X in a time of 30 s.

power = ... W [2]

19 – (9702/21_Summer_2020_Q6) – *Electric Fields, Particle & Nuclear Physics*

(a) Two horizontal metal plates are separated by a distance of 2.0 cm in a vacuum, as shown in Fig. 6.1.

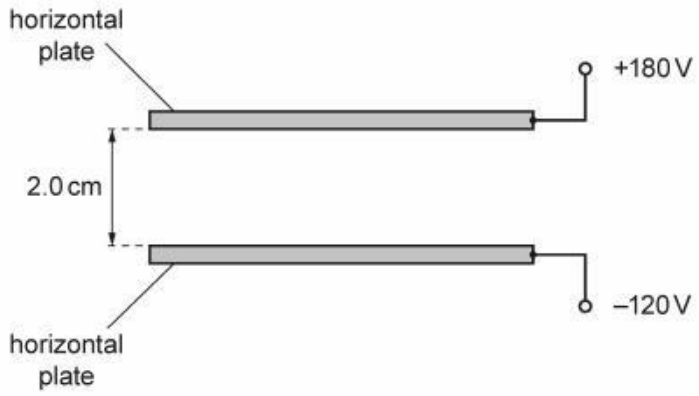


Fig. 6.1

The top plate has an electric potential of +180 V and the bottom plate has an electric potential of –120 V.

(i) Determine the magnitude of the electric field strength between the plates.

electric field strength = ... $N C^{-1}$ [2]

(ii) State the direction of the electric field.

..... [1]

(b) An uncharged atom of uranium-238 ($^{238}_{92}U$) has a change made to its number of orbital electrons. This causes the atom to change into a new particle (ion) X that has an overall charge of +2*e*, where *e* is the elementary charge.

(i) Determine the number of protons, neutrons and electrons in the particle (ion) X.

number of protons = ...

number of neutrons = ...

number of electrons = ...

[3]

(ii) The particle (ion) X is in the electric field in **(a)** at a point midway between the plates.

Determine the magnitude of the electric force acting on X.

force = ... N [2]

(iii) The nucleus of uranium-238 ($^{238}_{92}U$) decays in stages, by emitting α-particles and β^- particles, to form a nucleus of thorium-230 ($^{230}_{90}Th$).

Calculate the total number of α-particles and the total number of β^- particles that are emitted during the decay of uranium-238 to thorium-230.

number of α-particles = ...

number of β^- particles = ...
[2]

20 - (9702/22_Summer_2020_Q7) - *Particle & Nuclear Physics*

(a) A nucleus of an element X decays by emitting a β^+ particle to produce a nucleus of potassium-39 ($^{39}_{19}K$) and a neutrino. The decay is represented by

$$^{Q}_{S}X \rightarrow {}^{39}_{19}K + {}^{P}_{R}\beta^+ + {}^{0}_{0}\nu.$$

(i) State the number represented by each of the following letters.

P .....

Q .....

R .....

S .....

[2]

(ii) State the name of the interaction (force) that gives rise to β^+ decay.

..... [1]

(b) A hadron is composed of three identical quarks and has a charge of +2*e*, where *e* is the elementary charge.

Determine a possible type (flavour) of the quarks.
Explain your working.

.....

..... [2]

21 - (9702/23_Summer_2020_Q7) - *Electric Fields, Particle & Nuclear Physics*

A potential difference is applied between two horizontal metal plates that are a distance of 6.0 mm apart in a vacuum, as shown in Fig. 7.1.

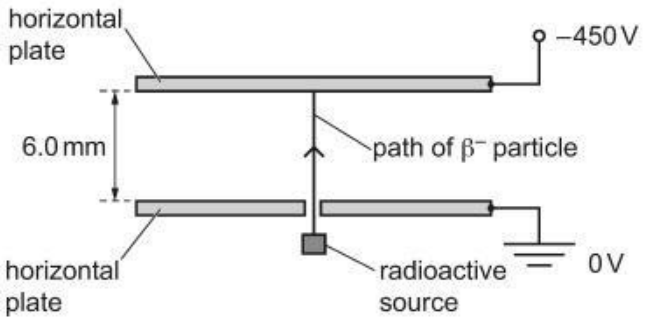


Fig. 7.1

The top plate has a potential of −450 V and the bottom plate is earthed. Assume that there is a uniform electric field produced between the plates.

A radioactive source emits a β^- particle that travels through a hole in the bottom plate and along a vertical path until it reaches the top plate.

(a) (i) Determine the magnitude and the direction of the electric force acting on the β^- particle as it moves between the plates.

magnitude of force = ... N

direction of force .....

[4]

(ii) Calculate the work done by the electric field on the β^- particle for its movement from the bottom plate to the top plate.

work done = ... J [2]

(b) The β^- particle is emitted from the source with a kinetic energy of 3.4×10^{-16} J.

Calculate the speed at which the β^- particle is emitted.

speed = ... $m\,s^{-1}$ [2]

(c) The β^- particle is produced by the decay of a neutron.

(i) Complete the equation below to represent the decay of the neutron.

$$^{1}_{0}n \rightarrow {}^{0}_{-1}\beta^- + \text{.....} + \text{.....}$$

[2]

(ii) State the name of the group (class) of particles that includes:

1. neutrons

.....

2. β^- particles.

.....

[2]

22 - (9702/22_Winter_2020_Q7) - *Electric Fields, Particle & Nuclear Physics*

(a) State a similarity and a difference between an up quark and an up antiquark.

similarity: .....

difference: .....

[2]

(b) Fig. 7.1 shows an electron in an electric field, in a vacuum, at an instant when the electron is stationary.

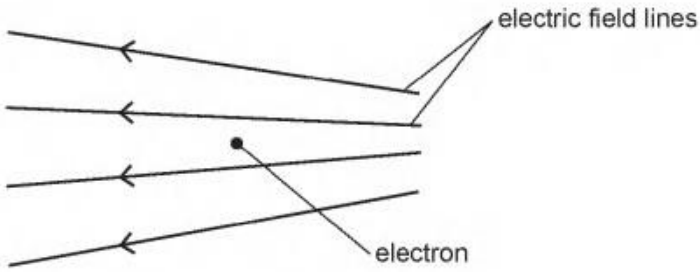


Fig. 7.1

(i) On Fig. 7.1, draw an arrow to show the direction of the electric force acting on the stationary electron. [1]

(ii) The electric field causes the electron to move from its initial position.

Describe and explain the acceleration of the electron due to the field, as the electron moves through the field.

.....

.....

.....

..... [2]

(iii) A stationary α-particle is now placed in the same electric field at the same initial position that was occupied by the electron.

Compare the initial electric force acting on the α-particle with the initial electric force that acted on the electron.

.....

.....

.....

..... [2]

[Total: 7]

23 - (9702/23_Winter_2020_Q7) - *Electric Fields, Particle & Nuclear Physics*

Two vertical metal plates are separated by a distance *d* in a vacuum, as shown in Fig. 7.1.

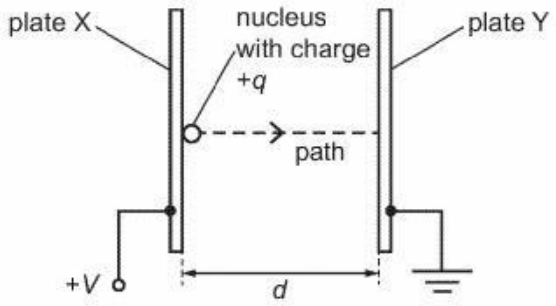


Fig. 7.1 (not to scale)

The potential difference (p.d.) between the plates is *V*. A nucleus with charge +*q* is initially at rest on plate X. The nucleus is accelerated by the uniform electric field from plate X along a horizontal path to plate Y.

(a) State expressions, in terms of some or all of *d*, *q* and *V*, for:

(i) the magnitude of the electric field strength

electric field strength = ... [1]

(ii) the magnitude of the electric force acting on the nucleus

force = ... [1]

(iii) the kinetic energy of the nucleus when it reaches plate Y.

kinetic energy = ... [1]

(b) State the change, if any, in the kinetic energy of the nucleus on reaching plate Y when the following separate changes are made.

(i) The distance *d* is halved, but the p.d. *V* remains the same.

..... [1]

(ii) The nucleus is replaced by a different nucleus that is an isotope of the original nucleus with fewer neutrons.

..... [1]

(c) The nucleus is carbon-14 ($^{14}_{6}C$). This nucleus decays to form a new nucleus by releasing a β^- particle and only one other particle of negligible mass.

(i) Calculate the nucleon number and the proton number of the **new** nucleus.

nucleon number = ...

proton number = ...
[1]

(ii) State the name of the particle of negligible mass.

..... [1]

[Total: 7]

24 - (9702/21_Winter_2020_Q8) - *Particle & Nuclear Physics*

(a) State a similarity and a difference between a down quark and a down antiquark.

similarity: .....

difference: .....

[2]

(b) For a nucleus of aluminium-25 ($^{25}_{13}Al$):

(i) state the number of protons and the number of neutrons

number of protons = ...

number of neutrons = ...
[1]

(ii) show that the charge is 2.1×10^{-18} C.

[1]

(c) The nucleus in **(b)** is moved along a straight line from point A to point B in a uniform horizontal electric field in a vacuum, as shown in Fig. 8.1.

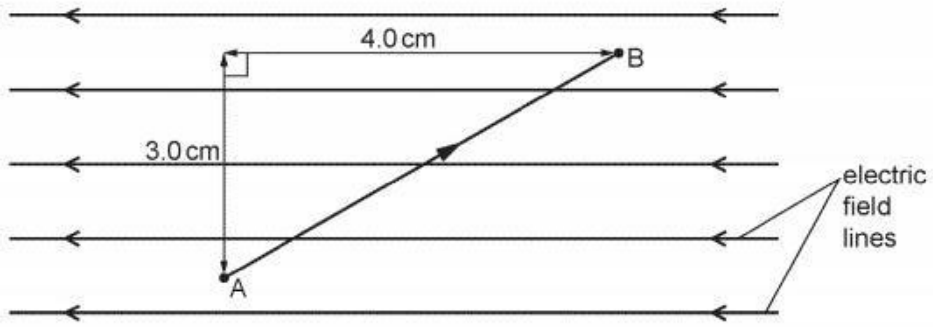


Fig. 8.1

The electric field strength is $11\,kV\,m^{-1}$.

Calculate the work done to move the charge from A to B.

work done = ... J [3]

[Total: 7]

25 - (9702/21_Summer_2021_Q6) - *Particle & Nuclear Physics*

(a) A proton in a nucleus decays to form a neutron and a β^+ particle.

(i) State the name of another lepton that is produced in the decay.

..... [1]

(ii) State the name of the interaction (force) that gives rise to this decay.

..... [1]

(iii) State which of the three particles (proton, neutron or β^+ particle) has the largest ratio of charge to mass.

..... [1]

(iv) Use the quark model to show that the charge on the proton is $+e$, where e is the elementary charge.

[2]

(v) The quark composition of the proton is changed during the decay.

Describe the change to the quark composition.

.....

..... [1]

(b) A nucleus X ($^{12}_{6}X$) and a nucleus Y ($^{16}_{8}Y$) are accelerated by the same uniform electric field.

(i) Determine the ratio

$$\frac{\text{electric force acting on nucleus X}}{\text{electric force acting on nucleus Y}}.$$

ratio = ... [2]

(ii) Determine the ratio

$$\frac{\text{acceleration of nucleus X due to the field}}{\text{acceleration of nucleus Y due to the field}}.$$

ratio = ... [1]

(iii) Nucleus X is at rest in the uniform electric field at time $t = 0$.

The field causes nucleus X to accelerate so that it moves through the field.

On Fig. 6.1, sketch the variation with time t of the acceleration a of nucleus X due to the field.

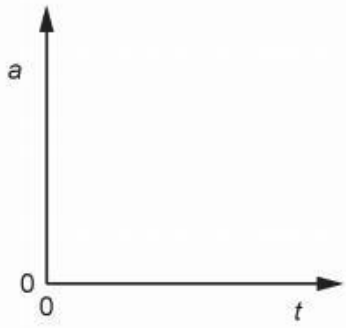


Fig. 6.1

[1]

26 - (9702/22_Summer_2021_Q6) - *Particle & Nuclear Physics*

(a) One of the results of the α-particle scattering experiment is that a very small minority of the α-particles are scattered through angles greater than 90°.

State what may be inferred about the structure of the atom from this result.

.....

.....

.....

..... [2]

(b) An α-particle is made up of other particles. One of these particles is a proton.

State and explain whether a proton is a fundamental particle.

.....

..... [1]

(c) A radioactive source produces a beam of α-particles in a vacuum. The average current produced by the beam is 6.9×10^{-9} A.

Calculate the average number of α-particles passing a fixed point in the beam in a time of 1.0 minute.

number = ... [3]

(d) The α-particles in the vacuum in **(c)** enter a uniform electric field. The α-particles enter the field with their velocity in the same direction as the field.

State and explain whether the magnitude of the acceleration of an α-particle due to the field decreases, increases or stays constant as the α-particle moves through the field.

.....

.....

..... [2]

(e) A nucleus X is an isotope of a nucleus Y. The mass of nucleus X is greater than that of Y.

Both of the nuclei are in the same uniform electric field.

State and explain whether the magnitude of the electric force acting on nucleus X is greater than, less than or the same as that acting on nucleus Y.

.....

.....

..... [2]

27 - (9702/23_Summer_2021_Q6) - *Particle & Nuclear Physics*

(a) State the quark composition of:

(i) a proton

..... [1]

(ii) a neutron

..... [1]

(iii) an alpha-particle.

.....

..... [2]

(b) In the alpha-particle scattering experiment, alpha-particles were directed at a thin gold foil.

State what may be inferred from:

(i) the observation that most alpha-particles pass through the foil

..... [1]

(ii) the observation that some alpha-particles are scattered through angles greater than 90°.

.....

.....

..... [2]

(c) A proton and an alpha-particle are moving in the same uniform electric field.

Determine the ratio

$$\frac{\text{acceleration of proton due to the electric field}}{\text{acceleration of alpha-particle due to the electric field}}.$$

ratio = ... [2]

28 - (9702/21_Winter_2021_Q6) - *Particle & Nuclear Physics*

(a) Complete Table 6.1 to show the masses (in terms of the unified atomic mass unit u) and charges (in terms of the elementary charge *e*) of α, β^+ and β^- particles.

Table 6.1

	mass / u	charge / *e*
α-particle		
β^+ particle		
β^- particle		

[4]

(b) Carbon-14 is radioactive and decays by emission of β^- particles.

(i) Nuclei do not contain β^- particles.

Explain the origin of the β^- particle that is emitted from the nucleus during β^- decay.

.....

.....

..... [1]

(ii) State the change in the quark composition of a carbon-14 nucleus when it emits a β^- particle.

..... [1]

(iii) Suggest why the β^- particles are emitted with a range of different energies.

.....

.....

.....

..... [2]

29 – (9702/22_Winter_2021_Q7) – *Particle & Nuclear Physics*

A stationary nucleus P of mass 243 u decays by emitting an α-particle of mass 4 u to form a different nucleus Q, as illustrated in Fig. 7.1.

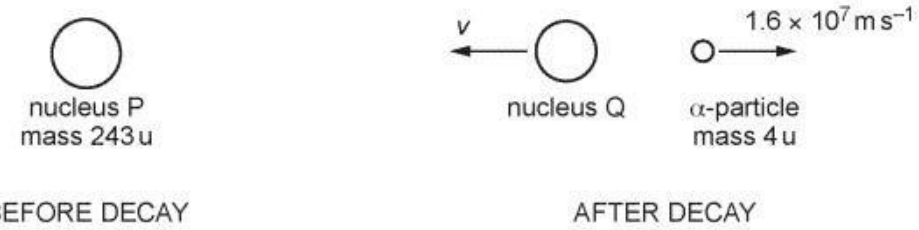


Fig. 7.1

The initial speed of the α-particle is $1.6 \times 10^7\,\text{m s}^{-1}$.

(a) Use the principle of conservation of momentum to explain why the initial velocities of nucleus Q and the α-particle must be in opposite directions.

.....

.....

.....

..... [2]

(b) Determine the initial speed v of nucleus Q.

v = ... m s^{-1} [2]

(c) Calculate the initial kinetic energy, in MeV, of the α-particle.

kinetic energy = ... MeV [3]

(d) A graph of number of neutrons N against proton number Z is shown in Fig. 7.2.

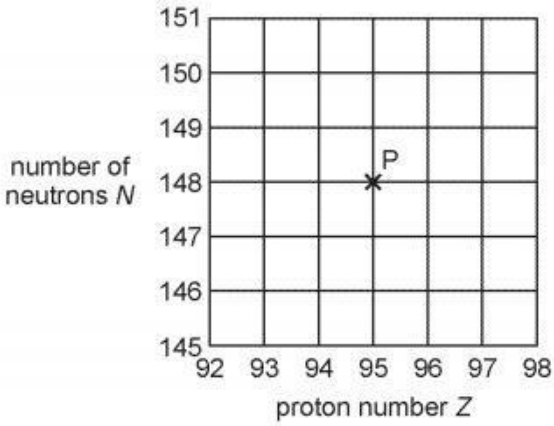


Fig. 7.2

The graph shows a cross that represents nucleus P.

A nucleus R has a nucleon number of 242 and is an isotope of nucleus P.

Nucleus R decays by emitting a β^- particle to form a different nucleus S.

(i) On Fig. 7.2, draw a cross to represent:

1. nucleus R (label this cross R)

2. nucleus S (label this cross S).

[2]

(ii) State the name of the other lepton, in addition to the β^- particle, that is emitted during the decay of nucleus R.

..... [1]

30 - (9702/21_Summer_2022_Q7) - *Particle & Nuclear Physics*

(a) An unstable nucleus $^{A}_{Z}X$ decays by emitting a β^- particle.

(i) Determine quantitatively the changes, if any, in *A* and *Z* when X decays.

change in *A* = ...

change in *Z* = ...
[2]

(ii) In addition to the β^- particle, another lepton is emitted during the decay.

State the name of the other lepton that is emitted.

..... [1]

(b) A particle P is composed of an up quark (u) and a down antiquark ($\bar{d}$).

(i) Calculate the charge *q* of particle P in terms of *e*, where *e* is the elementary charge.

Show your working.

q = ... *e* [2]

(ii) Particle P belongs to **two** classes (groups) of particles.

State the names of these two classes.

1 .....

2 .....
[2]

[Total: 7]

31 - (9702/22_Summer_2022_Q7) - *Particle & Nuclear Physics*

(a) A nucleus of caesium-137 ($^{137}_{55}Cs$) decays by emitting a β^- particle to produce a nucleus of an element X and an antineutrino. The decay is represented by

$$^{137}_{55}Cs \rightarrow {}^{Q}_{S}X + {}^{P}_{R}\beta^- + {}^{0}_{0}\bar{\nu}.$$

(i) State the number represented by each of the following letters.

P .....

Q .....

R .....

S .....

[2]

(ii) State the name of the class (group) of particles that includes the β^- particle and the antineutrino.

..... [1]

(b) A particle Y has a quark composition of ddd where d represents a down quark.

A particle Z has a quark composition of $\bar{u}$d where $\bar{u}$ represents an up antiquark.

(i) Show that the charges of particles Y and Z are equal.

[2]

(ii) State and explain which particle is a meson and which particle is a baryon.

meson: .....

.....

baryon: .....

.....

[2]

[Total: 7]

32 - (9702/23_Summer_2022_Q7) - *Particle & Nuclear Physics*

(a) Fluorine-18 ($^{18}_{9}F$) is an isotope that decays to an isotope of oxygen (O) by the emission of a β^+ particle.

(i) Complete the nuclear equation for the decay, including all the particles involved.

$$^{18}_{9}F \rightarrow$$

[3]

(ii) A quark in the fluorine-18 nucleus changes flavour during the decay. State this change of flavour.

..... quark to ..... quark. [1]

(b) A hadron has a charge of –2*e*, where *e* is the elementary charge.

(i) State and explain whether the hadron is a meson or a baryon.

.....

.....

..... [2]

(ii) State a possible quark composition for the hadron.

.....

..... [1]

[Total: 7]

33 - (9702/21_Winter_2022_Q6) - *Particle & Nuclear Physics*

(a) A lepton is an example of a fundamental particle.

State what is meant by fundamental particle.

.....

..... [1]

(b) A lambda particle Λ^0 is a hadron that consists of an up (u) quark, a down (d) quark and a strange (s) quark.

Show that the charge on the Λ^0 particle is zero.

[2]

(c) The Λ^0 particle is unstable. It can decay into a neutron (n) and a pion (π^0) as shown by

$$\Lambda^0 \rightarrow n + \pi^0.$$

The π^0 particle consists of an up quark and an up antiquark.

(i) Compare the properties of an up quark and an up antiquark.

.....

.....

..... [2]

(ii) Explain why the neutron is classed as a baryon and the π^0 particle is classed as a meson.

.....

.....

..... [2]

34 - (9702/23_Winter_2022_Q6) - *Particle & Nuclear Physics*

(a) The nuclide $^{14}_{6}C$ (carbon-14) is unstable and undergoes β^- decay, emitting a high-energy electron and an antineutrino to form a new nuclide X. The equation for this decay is shown.

$$^{14}_{6}C \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}X + \,^{\cdots\cdots}_{\cdots\cdots}e^- + \,^{0}_{0}\bar{\nu}$$

Complete the equation. [2]

(b) **(i)** State the equation for β^- decay in terms of the fundamental particles involved.

[1]

(ii) Use your equation from **(b)(i)** to show how charge is conserved in β^- decay.

[1]

(c) Neutrinos were first proposed to exist more than 20 years before they were directly detected, in order to explain a particular experimental observation about β-decay.

(i) State an observation about β-decay that is explained by the existence of neutrinos.

.....

.....

..... [1]

(ii) Suggest how the existence of neutrinos explains the observation in **(c)(i)**.

.....

.....

..... [1]

35 - (9702/22_Winter_2022_Q7) - *Particle & Nuclear Physics*

(a) Describe the structure of an **atom** of uranium-238, $^{238}_{92}U$.

.....

.....

..... [2]

(b) The decay of uranium-238 is shown by the equation

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + X.$$

For nucleus X, calculate the ratio, in $C\,kg^{-1}$, of

$$\frac{\text{charge}}{\text{mass}}.$$

ratio = ... $C\,kg^{-1}$ [3]

(c) Two particles P and Q each consist of three quarks. These quarks are up (u) or down (d) quarks.

Particle P has no overall charge.

Particle Q has an overall charge of +2*e*, where *e* is the elementary charge.

State the quark composition of:

(i) particle P

..... [1]

(ii) particle Q.

..... [1]

36 - (9702/21_Summer_2023_Q8) - *Particle & Nuclear Physics*

An isolated stationary nucleus X decays by emitting an α-particle to form a nucleus Y.

Nucleus Y and nucleus Z are isotopes of the same element.

(a) By comparing the number of protons in each nucleus, state and explain whether the charge of nucleus Y is less than, greater than or the same as the charge of:

(i) nucleus Z

.....

..... [1]

(ii) nucleus X.

.....

.....

..... [2]

(b) Use the principle of conservation of momentum to explain why nucleus Y cannot be stationary immediately after the decay of nucleus X.

.....

.....

.....

..... [2]

37 - (9702/22_Summer_2023_Q8) - *Particle & Nuclear Physics*

(a) Nucleus P and nucleus Q are isotopes of the same element.

Nucleus Q is unstable and emits a β^- particle to form nucleus R.

(i) For nuclei P and Q, compare:

- the number of protons

.....

- the number of neutrons.

.....
[2]

(ii) When nucleus Q decays to form nucleus R, the quark composition of a nucleon changes.

State the change to the quark composition of the nucleon.

..... [1]

(iii) State the name of another particle that must be emitted from nucleus Q in addition to the β^- particle.

..... [1]

(b) A hadron consists of two charm quarks and one bottom quark.

Determine, in terms of the elementary charge *e*, the charge of the hadron.

charge = ... *e* [2]

38 - (9702/23_Summer_2023_Q7) - *Particle & Nuclear Physics*

(a) Table 7.1 shows incomplete data for three flavours (types) of quark. The elementary charge is *e*.

Table 7.1

flavour	quark		antiquark	
	symbol	charge / *e*	symbol	charge / *e*
up	u	$+\frac{2}{3}$	$\bar{u}$	
down	d		$\bar{d}$	
charm	c		$\bar{c}$	

Complete Table 7.1 by inserting the missing charges. [2]

(b) Using the symbols given in Table 7.1, state a possible quark combination for the following hadrons:

(i) a neutral baryon

..... [1]

(ii) a meson with a charge of +*e*.

..... [1]

(c) Quarks are fundamental particles.

Electrons are in another group (class) of fundamental particle.

(i) State the name of this group.

..... [1]

(ii) State the name of another particle in this group.

..... [1]

39 - (9702/21_Winter_2023_Q7) - *Particle & Nuclear Physics*

(a) The results of the α-particle scattering experiment led to the development of the nuclear model for the atom.

State the results that suggested that most of the mass of the atom is concentrated in a very small region and most of the atom is empty space.

.....

.....

.....

..... [2]

(b) State the composition of γ-radiation.

..... [1]

(c) Table 7.1 lists the names of three particles and possible classifications for them.

Table 7.1

particle name	classification		
	baryon	hadron	lepton
neutrino			
neutron			
positron			

Complete Table 7.1 by placing ticks (✓) in the boxes to indicate the classifications that apply to each particle. [2]

(d) The discovery of a particle with an unusual charge was an important step in the development of the theory of quarks. The particle is a hadron with a mass of 2.19×10^{-27} kg and a charge of $+2e$, where e is the elementary charge.

(i) Calculate the mass, in u, of the particle. Give your answer to three significant figures.

mass = ... u [1]

(ii) Determine a possible quark composition of a hadron with a charge of $+2e$.
Explain your reasoning.

[2]

40 - (9702/22_Winter_2023_Q7) - *Particle & Nuclear Physics*

(a) In the following list, underline **all** the particles that are **not** fundamental.

antineutrino baryon nucleon positron [1]

(b) A nucleus of thorium-230 ($^{230}_{90}Th$) decays in stages, by emitting α-particles and β^- particles, to form a nucleus of lead-206 ($^{206}_{82}Pb$).

Determine the total number of α-particles and the total number of β^- particles that are emitted during the sequence of decays that form the nucleus of lead-206 from the nucleus of thorium-230.

number of α-particles = ...

number of β^- particles = ...
[2]

(c) A meson has a charge of $-1e$, where e is the elementary charge. The quark composition of the meson includes a charm antiquark.

State and explain a possible flavour (type) of the other quark in the meson.

.....

..... [2]

41 – (9702/23_Winter_2023_Q8) – *Particle & Nuclear Physics*

(a) The nuclide $^{23}_{12}Mg$ is an isotope of magnesium that undergoes β^+ decay to form a new nuclide X according to the equation

$$^{23}_{12}Mg \rightarrow \,^{\cdots\cdots}_{\cdots\cdots}X + \,^{\cdots\cdots}_{\cdots\cdots}\beta^+ + \,^{0}_{0}\nu.$$

Four numbers are missing from the equation.

(i) For the nuclide $^{23}_{12}Mg$, state what is represented by the numbers 23 and 12.

23 represents: .....

12 represents: .....
[2]

(ii) Complete the equation by inserting the missing numbers. [2]

(iii) State the name of the group (class) of fundamental particles to which the positron and neutrino belong.

..... [1]

(b) A radioactive source emits particles from its nuclei when it decays.
Fig. 8.1 shows, for the source, the variation with kinetic energy of the number of particles emitted.

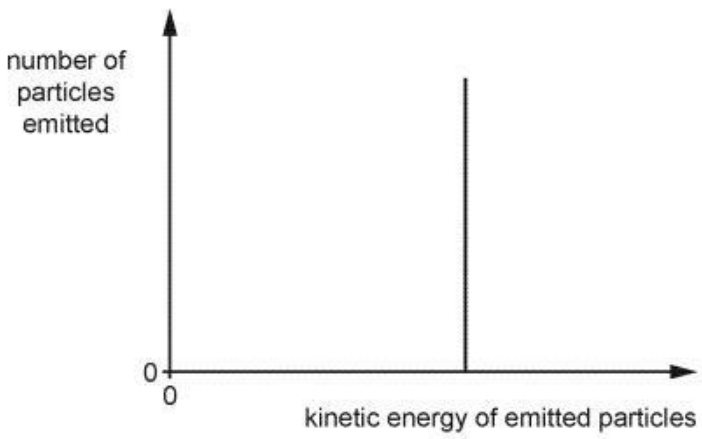


Fig. 8.1

State how Fig. 8.1 shows that these nuclei do **not** undergo beta-decay.

.....

..... [1]

ANSWERS

1 – (9702/21_Summer_2017_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)	(stress =) force / area or kg m s^{-2} / m^2
	= kg m^{-1} s^{-2}
(b)(i)	$0.58 = 2\pi \times [(4 \times 0.500 \times 0.600^3) / (E \times 0.0300 \times 0.00500^3)]^{0.5}$
	$E = [4\pi^2 \times 4 \times 0.500 \times (0.600)^3] / [(0.58)^2 \times 0.0300 \times (0.00500)^3]$
	$= 1.35 \times 10^{10}$ (Pa)
	= 14 (13.5) GPa
(b)(ii)1.	(accuracy determined by) the closeness of the value(s)/measurement(s) to the true value
	(precision determined by) the range of the values/measurements
(b)(ii)2.	l is (cubed so) 3 × (percentage/fractional) uncertainty **and** T is (squared so) 2 × (percentage / fractional) uncertainty **and** (so) l contributes more

2 – (9702/22_Summer_2017_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)	kelvin, mole, ampere, candela *any two*
(b)	use of resistivity = RA / l **and** $V = IR$ (to give $\rho = VA / Il$)
	units of V: (work done / charge) kg m^2 s^{-2} (A s)$^{-1}$
	units of resistivity: (kg m^2 s^{-3} A^{-1} A^{-1} m) = kg m^3 s^{-3} A^{-2}
	or
	use of $R = \rho L / A$ and $P = I^2R$ (gives $\rho = PA / I^2L$)
	units of P: kg m^2 s^{-3}
	units of resistivity: (kg m^2 s^{-3} × m^2) / (A^2 × m) = kg m^3 s^{-3} A^{-2}
(c)(i)	$\rho = (RA / l)$
	$= (0.03 \times 1.5 \times 10^{-6}) / 2.5$ $(= 1.8 \times 10^{-8})$
	= 18 nΩ m
(c)(ii)	**1.** precision is determined by the range in the measurements/values/readings/data/results
	2. metre rule measures to ± 1 mm and micrometer to ± 0.01 mm (so there is less (percentage) uncertainty/random error)

3 - (9702/23_Summer_2017_Q1) - *Physical Quantities & Units*

(a)(i)	R = 7(.0) N
(a)(ii)	R = 13 N
(b)(i)	forces resolved: 18 sin 65° (vertical) **and** 55 + 18 cos 65° (horizontal) **or** scale drawing: correct triangle drawn for forces
	$F = [(18 \sin 65°)^2 + (55 + 18 \cos 65°)^2]^{1/2}$ = 65 (64.7) N **or** scale drawing: scale given, length of resultant given correctly, ± 1 N
(b)(ii)	angle = $\tan^{-1}$ [18 sin 65° / (55 + 18 cos 65°)] = $\tan^{-1}$ (16.3 / 62.6) **or** scale drawing: correct angle measured/direction correct on diagram below the 55 N force
	angle = 15 (14.6)° (below the 55 N force) **or** scale drawing: angle = 15° ± 1°
(c)	(resultant) force = mass × acceleration
	80 − 65 = 2.7a
	a = 5.6 m s^{-2} [5.7 if 64.7 N used from **(i)**]

4 - (9702/21_Winter_2017_Q1) - *Physical Quantities & Units, Kinematics, Dynamics*

(a)	units of F: kg m s^{-2}	**C1**
	units of ρ: kg m^{-3} **and** units of v: m s^{-1}	**C1**
	units of K: kg m s^{-2} / [kg m^{-3} (m s^{-1})^2] = m^2	**A1**
(b)(i)	$K\rho$ = 1.5 / 33^2	**C1**
	= 1.38 × 10^{-3} F_D = 1.38 × 10^{-3} × 25^2 **or** F_D / 1.5 = 25^2 / 33^2 F_D = 0.86 N	**A1**
(b)(ii)	a = (1.5 – 0.86) / (1.5 / 9.81) **or** a = 9.81 – [0.86 / (1.5 / 9.81)]	**C1**
	a = 4.2 m s^{-2}	**A1**
(c)	initial acceleration is g/9.81 (m s^{-2})/acceleration of free fall	**B1**
	acceleration decreases	**B1**
	final acceleration is zero	**B1**

5 - (9702/23_Winter_2017_Q1) - *Physical Quantities & Units*

(a)(i)	work (done) / time (taken) **or** energy (transferred) / time (taken)	**B1**
(a)(ii)	Correct substitution of base units of all quantities into any correct equation for power. Examples: ($P = E / t$ or W / t gives) kg m^2 s^{-2} / s = kg m^2 s^{-3} ($P = Fs / t$ or mgh / t gives) kg m s^{-2} m / s = kg m^2 s^{-3} ($P = ½mv^2 / t$ gives) kg (m s^{-1})^2 / s = kg m^2 s^{-3} ($P = Fv$ gives) kg m s^{-2} m s^{-1} = kg m^2 s^{-3} ($P = VI$ gives) kg m^2 s^{-2} A^{-1} s^{-1} A = kg m^2 s^{-3}	**A1**
(b)(i)	units of A: m^2 **and** units of T: K	**C1**
	units of k: kg m^2 s^{-3} / m^2 K^4 = kg s^{-3} K^{-4}	**A1**
(b)(ii)	curve from the origin with increasing gradient	**B1**

6 – (9702/21_Summer_2018_Q1) – *Physical Quantities & Units, Kinematics*

(a)	a scalar has magnitude (only)	**B1**
	a vector has magnitude and direction	**B1**
(b)	power: scalar temperature: scalar momentum: vector *(two correct 1 mark, all three correct 2 marks)*	**B2**
(c)(i)	arrow labelled R in a direction from 5° to 20° north of west	**B1**
(c)(ii)	$v^2 = 28^2 + 95^2 - (2 \times 28 \times 95 \times \cos 115°)$ **or** $v^2 = [(95 + 28\cos 65°)^2 + (28\sin 65°)^2]$	**C1**
	$v = 110\ \text{ms}^{-1}$ ($109.8\ \text{ms}^{-1}$)	**A1**
	or (scale diagram method)	
	triangle of velocities drawn	**(C1)**
	$v = 110\ \text{ms}^{-1}$ (allow 108–112 ms^{-1})	**(A1)**

7 – (9702/22_Summer_2018_Q1) – *Physical Quantities & Units*

(a)	rate of change of momentum	**B1**
(b)	kg ms^{-2}	**A1**
(c)	units for Q: As **and** for *r*: m	**C1**
	units for ε = (As × As)/($\text{kg ms}^{-2} \times \text{m}^2$) $= \text{A}^2\text{kg}^{-1}\text{m}^{-3}\text{s}^4$	**A1**

8 – (9702/23_Winter_2018_Q1) – *Physical Quantities & Units, Forces, Density & Pressure, Deformation Of Solids*

(a)	current temperature (**allow** amount of substance, luminous intensity) *any two correct answers, 1 mark each*	**B2**
(b)(i)	$W = 2 \times (150 \times \sin 17°)$ **or** $2 \times (150 \times \cos 73°)$	**C1**
	$W = 88\ \text{N}$	**A1**
(b)(ii)	**1.** $\sigma = F/A$	**C1**
	$= 150/(7.5 \times 10^{-6})$ $= 2.0 \times 10^7\ \text{Pa}$	**A1**
	2. $\varepsilon = \sigma / E$	**C1**
	$= 2.0 \times 10^7/(2.1 \times 10^{11})$ $= 9.5 \times 10^{-5}$	**A1**

9 – (9702/22_Winter_2018_Q2) – *Physical Quantities & Units, Forces, Density & Pressure*

(a)	ampere kelvin (**allow** mole, candela) *any two correct answers, 1 mark each*	B2
(b)(i)	frictional (force)/friction	B1
(b)(ii)	$W\cos 31° \times 3.0$ **or** 90×6.0	C1
	$W\cos 31° \times 3.0 = 90 \times 6.0$ $W = 210\,N$	A1
(b)(iii)	$X = 90\sin 31°$ $= 46\,N$	A1

10 – (9702/21_Summer_2019_Q1) – *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a)	(velocity =) change in displacement / time (taken)	B1
(b)(i)	$k = [1.29 \times (3.3 \times 10^2)^2] / 9.9 \times 10^4$	C1
	$= 1.4$	A1
(b)(ii)	percentage uncertainty = (3 × 2) + 4 + 2 (= 12%) **or** fractional uncertainty = (0.03 × 2) + 0.04 + 0.02 (= 0.12)	C1
	$\Delta k = 0.12 \times 1.42$ $= 0.17$ (*allow to 1 significant figure*)	C1
	$k = 1.4 \pm 0.2$	A1

11 – (9702/23_Summer_2019_Q1) – *Current Of Electricity, Physical Quantities & Units*

(a)(i)	potential difference / current	B1
(a)(ii)	$R = 4.0 \times 10^9\ (\Omega)$	C1
	$I = 0.60 / 4.0 \times 10^9 = 1.5 \times 10^{-10}$ (A) $I = 150\,pA$	A1
(b)	units of energy: $kg\,m^2\,s^{-2}$	C1
	units of charge: A s	C1
	units of potential difference: ($kg\,m^2\,s^{-2}$ / A s =) $kg\,m^2\,A^{-1}\,s^{-3}$	A1

12 – (9702/21_Winter_2019_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)(i)	mass in range 1–20 g	A1
(a)(ii)	wavelength in range 1×10^{-8} m to 4×10^{-7} m	A1
(b)(i)	$T = 2\pi \times (200 \times 10^{-3} / 25)^{0.5}$ $= 0.56$ s	A1
(b)(ii)	percentage uncertainty = (2% + 8%) / 2 (= 5%) **or** fractional uncertainty = (0.02+0.08) / 2 (= 0.05)	C1
	$\Delta T = 0.56 \times 0.05$ $= 0.028$ (s)	C1
	$T = (0.56 \pm 0.03)$ s	A1

13 – (9702/22_Winter_2019_Q1) – *Physical Quantities & Units*

(a)	scalar quantity has (only) magnitude	B1
	vector quantity has magnitude and direction	B1
(b)(i)	$E = F / Q$	C1
	$= \text{kg m s}^{-2} / \text{A s} = \text{kg m A}^{-1} \text{s}^{-3}$	A1
(b)(ii)	$b = Q / x^2 E$ $= \text{A s} / \text{m}^2 \text{kg m A}^{-1} \text{s}^{-3}$	C1
	$= \text{A}^2 \text{s}^4 \text{kg}^{-1} \text{m}^{-3}$	A1

14 – (9702/21_Summer_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)	(work =) force × displacement	C1
	units: $\text{kg m s}^{-2} \times \text{m} = \text{kg m}^2 \text{s}^{-2}$	A1
(b)(i)	units of Q: As	C1
	units of C: $\text{kg}^{-1} \text{m}^{-2} \text{A}^2 \text{s}^4$	A1
(b)(ii)	**1.** e.g. reading scale from different angles (wrongly) interpolating between scale readings/divisions	B1
	2. e.g. zero error wrongly calibrated scale	B1

15 – (9702/22_Summer_2020_Q1) – *Physical Quantities & Units*

(a)	(velocity =) change in displacement / time (taken)	B1
(b)	units of F: kg m s^{-2}	C1
	units of k: $\text{kg m s}^{-2} / [\text{m}^2 \times (\text{m s}^{-1})^2]$ $= \text{kg m}^{-3}$	A1
(c)	$P = Fv$	C1
	$4.8 \times 10^4 = 0.24 \times 5.1 \times v^3$	C1
	$v = 34 \text{ m s}^{-1}$	A1

16 – (9702/23_Summer_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)	similarity: both have magnitude	B1
	difference: distance is a scalar/does not have direction **or** displacement is a vector/has direction	B1
(b)(i)	the measurements have a small range	B1
(b)(ii)	the (average of the) measurements is not close to the true value	B1

17 – (9702/23_Winter_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)(i)	wavelength = 8.5×10^{-5} m	A1
(a)(ii)	$f = v / \lambda$ **or** c / λ	C1
	$= 3.0 \times 10^{8} / 8.5 \times 10^{-5}$ (= 3.5×10^{12}) = 3.5 THz	A1
(a)(iii)	infrared	B1
(b)	(implied) percentage uncertainty in I = 4% **or** (implied) fractional uncertainty in I = 0.04	C1
	percentage uncertainty in E = 5% + (4% × 2) = 13%	A1

18 – (9702/22_Summer_2021_Q1) – *Physical Quantities & Units, Forces, Density & Pressure*

(a)	acceleration: vector electrical resistance: scalar momentum: vector *1 mark for two correct, 2 marks for all three correct*	B2
(b)	resultant force (in any direction) is zero	B1
	resultant torque/moment (about any point) is zero	B1
(c)(i)	upthrust = $\rho g(\Delta)h \times A$	C1
	$= (1.00 \times 10^{3} \times 9.81 \times 0.190) \times 0.0230$ = 42.9 N	A1
(c)(ii)	(T =) 43 – 28 = 15 (N) **or** (T =) 42.9 – 28 = 14.9 or 15 (N)	A1
(c)(iii)	$\sigma = F / A$ **or** T / A	C1
	$= 15 / (3.2 \times 10^{-6})$ $= 4.7 \times 10^{6}$ Pa	A1
(c)(iv)	upthrust (on cylinder) increases (and weight constant)	B1
	tension/stress increases and (so) strain energy increases	B1

19 – (9702/23_Summer_2021_Q1) – *Physical Quantities & Units*

(a)(i)	two correct scalar quantities e.g. time, mass, distance, temperature	B1
	two correct vector quantities e.g. force, acceleration, velocity, displacement	B1
(a)(ii)	magnitude	B1
	unit	B1
(b)(i)	north component of velocity = 11 m s^{-1}	A1
	east component of velocity = 7.5 m s^{-1}	A1
(b)(ii)	velocity = 7.5 – 2.7 = 4.8 m s^{-1}	A1
(b)(iii)	velocity = $\sqrt{(11^2 + 4.8^2)}$	C1
	= 12 m s^{-1}	A1
(b)(iv)	angle = $\tan^{-1}$ (4.8 / 11)	C1
	= 24°	A1

20 – (9702/22_Winter_2021_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)	10^{12}	B1
	pico (p)	B1
(b)	ampere and metre both underlined (and no other units underlined)	B1
(c)(i)	percentage uncertainty = 3.5 + (3.0 × 2) + 2.5 + 2.0	C1
	= 14%	A1
(c)(ii)	absolute uncertainty = $4.1 \times 10^{-7} \times 14 / 100$ $= 6 \times 10^{-8}\ \Omega\,m$	A1

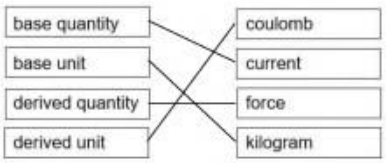
21 – (9702/22_Summer_2022_Q1) – *Physical Quantities & Units*

(a)	only ampere and kilogram underlined	B1
(b)(i)	percentage uncertainty = 2.1 + 0.6 + (1.5 × 2)	C1
	= 5.7%	A1
(b)(ii)	absolute uncertainty = (5.7 / 100) × 8.245×10^9 (= 4.7×10^8 Pa or 0.47×10^9 Pa)	C1
	$E = (8.2 \pm 0.5) \times 10^9$ Pa	A1

22 – (9702/23_Summer_2022_Q1) – *Physical Quantities & Units*

(a)	$\rho = m / V$	C1
	$V = (4/3) \times \pi \times r^3$ $= (4/3) \times \pi \times (3.42/2)^3$ (= 20.9 cm^3)	C1
	$\rho = 67 / 20.9$ = 3.2 g cm^{-3}	A1
(b)	$\%\rho = \%m + 3 \times \%d$ = [(2 / 67) × 100] + [3 × (0.02 / 3.42) × 100]	C1
	= 3.0% + 3 × 0.58% = 4.7% or 5%	A1

23 – (9702/21_Winter_2022_Q1) – *Physical Quantities & Units*

(a)	 any two joined correctly	C1
	all four joined correctly	A1
(b)(i)	the measurements have a small range	B1
(b)(ii)	(average of the) measurements not close to the true value	B1
(c)(i)	percentage uncertainty = (3 + 5 + 4) / 2	C1
	= 6%	A1
(c)(ii)	absolute uncertainty = (6 / 100) × 15.0 = 0.9 m s^{-1}	A1

24 – (9702/21_Summer_2023_Q1) – *Physical Quantities & Units*

(a)(i)	work done per unit time	B1
(a)(ii)	($P = W / t$ gives) units: kg m^2 s^{-2} / s = kg m^2 s^{-3}	B1
(b)	($I = P / A$ so) units of I: kg m^2 s^{-3} / m^2 or kg s^{-3}	C1
	units of f: s^{-1} **and** units of A: m **and** units of v: m s^{-1}	C1
	units of k: kg s^{-3} / [(s^{-1})^2 m^2 m s^{-1}] = kg m^{-3}	A1

25 – (9702/22_Summer_2023_Q1) – *Physical Quantities & Units*

(a)(i)	force / area (normal to the force)	B1
(a)(ii)	($p = F / A$ so units are) kg m s^{-2} / m^2 = kg m^{-1} s^{-2}	A1
(b)	unit of R: m **and** unit of t: s **and** unit of L: m	C1
	unit of ρ: kg m^{-3} **or** $\rho = m / V$	C1
	base units of k: (kg m^{-1} s^{-2} × m^4 × kg m^{-3} × s) / (kg × m) = kg m^{-1} s^{-1}	A1
(c)	R contributes 4 × 2% **or** 8% (and L contributes 2%) so R contributes more (to the percentage uncertainty in k)	B1

26 – (9702/23_Summer_2023_Q1) – *Physical Quantities & Units, Kinematics*

(a)	$t = \sqrt{(2s / g)}$ $= \sqrt{[(2 \times 36) / 9.81]}$	C1
	= 2.7 s	A1
(b)	• reaction time between hearing the splash and stopping the stop-watch • the sound (of the splash) takes time to reach the student **or** the stone hits the water at a different time to the sound being heard **or** the sound (of the splash) has to travel to the student • the student might not let go of the stone from ground level • the student might not let go of the stone and start the stop-watch at the same time • stop-watch may not be properly calibrated / has a zero error • (local value of) g is not (exactly) 9.81 (m s^{-2}) • stone given initial velocity / initial velocity not zero • stone does not fall (exactly) vertically / in a straight line *Any three points, 1 mark each*	B3
(c)	precise: results are close together / have little scatter	B1
	not accurate: the values are not close to / 50% different / (very) different from the true value	B1

27 – (9702/21_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)	scalar and vector have magnitude	B1
	vector has direction (and scalar does not have direction)	B1
(b)(i)	$r = [(3 \times 28) / 4\pi]^{1/3}$ $= 1.9$ cm	A1
(b)(ii)	percentage uncertainty in $V = (0.5 / 28) \times 100$ (= 1.79%)	C1
	percentage uncertainty in $r = 1.79 / 3$ = 0.6%	A1

28 – (9702/22_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a)	only electric current **and** time underlined	B1
(b)	initial speed / velocity is zero	B1
	(non-zero magnitude of) acceleration is constant / uniform (and in a straight line)	B1
(c)(i)	• magnitude of acceleration at $t = 8.0$ s is less than that at $t = 14.0$ s	B1
	• direction of acceleration at $t = 8.0$ s is opposite to that at $t = 14.0$ s	B1
(c)(ii)	a = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / (\Delta)t$	C1
	a = e.g. $(20 + 10) / 12$ **or** $(0 + 10) / 4$ **or** $(20 - 0) / (12 - 4)$ $a = 2.5$ m s^{-2}	A1
(c)(iii)	displacement $= [½ \times (12 - 4) \times 20] - [½ \times 4 \times 10]$ **or** displacement $= (-10 \times 12) + (½ \times 2.5 \times 12^2)$ **or** displacement $= (20 \times 12) - (½ \times 2.5 \times 12^2)$ **or** displacement $= ½ \times (20 - 10) \times 12$	C1
	displacement = 60 m	A1

29 – (9702/23_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)	charge **and** power only ticked	B1
(b)(i)	$\%D = 0.4\%$ **and** $\%L = 0.6\%$	A1
(b)(ii)	$\rho = (4 \times 0.247) / [\pi \times (26.2 \times 10^{-3})^2 \times 0.162]$	C1
	$\rho = 2.83 \times 10^3$ kg m^{-3}	A1
(b)(iii)	percentage uncertainty $= 0.4 + (2 \times 0.4) + 0.6$	C1
	= 1.8%	A1

1 - (9702/21_Summer_2017_Q1) - *Physical Quantities & Units, Measurement Techniques*

(a)	(stress =) force / area or kg m s^{-2} / m^2
	= kg m^{-1} s^{-2}
(b)(i)	$0.58 = 2\pi \times [(4 \times 0.500 \times 0.600^3) / (E \times 0.0300 \times 0.00500^3)]^{0.5}$
	$E = [4\pi^2 \times 4 \times 0.500 \times (0.600)^3] / [(0.58)^2 \times 0.0300 \times (0.00500)^3]$
	$= 1.35 \times 10^{10}$ (Pa)
	= 14 (13.5) GPa
(b)(ii)1.	(accuracy determined by) the closeness of the value(s)/measurement(s) to the true value
	(precision determined by) the range of the values/measurements
(b)(ii)2.	l is (cubed so) 3 × (percentage/fractional) uncertainty **and** T is (squared so) 2 × (percentage / fractional) uncertainty **and** (so) l contributes more

2 - (9702/22_Summer_2017_Q1) - *Physical Quantities & Units, Measurement Techniques*

(a)	kelvin, mole, ampere, candela *any two*
(b)	use of resistivity = RA / l **and** $V = IR$ (to give $\rho = VA / Il$)
	units of V: (work done / charge) kg m^2 s^{-2} (A s)$^{-1}$
	units of resistivity: (kg m^2 s^{-3} A^{-1} A^{-1} m) = kg m^3 s^{-3} A^{-2}
	or
	use of $R = \rho L / A$ and $P = I^2R$ (gives $\rho = PA / I^2L$)
	units of P: kg m^2 s^{-3}
	units of resistivity: (kg m^2 s^{-3} × m^2) / (A^2 × m) = kg m^3 s^{-3} A^{-2}
(c)(i)	$\rho = (RA / l)$
	$= (0.03 \times 1.5 \times 10^{-6}) / 2.5$ $(= 1.8 \times 10^{-8})$
	= 18 nΩ m
(c)(ii)	**1.** precision is determined by the range in the measurements/values/readings/data/results
	2. metre rule measures to ± 1 mm and micrometer to ± 0.01 mm (so there is less (percentage) uncertainty/random error)

3 - (9702/22_Winter_2017_Q1) - *Measurement Techniques*

(a)(i)	micrometer (screw gauge)/digital calipers	B1
(a)(ii)	take several readings (and average)	M1
	along the wire **or** around the circumference	A1
(b)(i)	$\sigma = 4 \times 25 / [\pi \times (0.40 \times 10^{-3})^2] = 1.99 \times 10^8$ N m^{-2} **or** $\sigma = 25 / [\pi \times (0.20 \times 10^{-3})^2] = 1.99 \times 10^8$ N m^{-2}	A1
(b)(ii)	$\%F = 2\%$ **and** $\%d = 5\%$ **or** $\Delta F / F = \frac{0.5}{25}$ **and** $\Delta d / d = \frac{0.02}{0.4}$	C1
	$\%\sigma = 2\% + (2 \times 5\%)$ **or** $\%\sigma = [0.02 + (2 \times 0.05)] \times 100$ $\%\sigma = 12\%$	A1
(b)(iii)	absolute uncertainty $= (12/100) \times 1.99 \times 10^8$ $= 2.4 \times 10^7$	C1
	$\sigma = 2.0 \times 10^8 \pm 0.2 \times 10^8$ N m^{-2} **or** $2.0 \pm 0.2 \times 10^8$ N m^{-2}	A1

4 - (9702/23_Summer_2018_Q1) - *Measurement Techniques*

(a)(i)	zero error **or** wrongly calibrated scale	B1
(a)(ii)	reading scale from different angles **or** wrongly interpolating between scale readings/divisions	B1
(b)(i)	$P = V^2/R$ **or** $P = VI$ <u>and</u> $V = IR$	C1
	$P = 5.0^2/125$ **or** 5.0×0.04 **or** $(0.04)^2 \times 125$ $= 0.20$ W	A1
(b)(ii)	$\%V = 2\%$ **or** $\Delta V / V = 0.02$	C1
	$\%P = (2 \times 2\%) + 3\%$ **or** $\%P = (2 \times 0.02 + 0.03) \times 100$ $= 7\%$	A1
(b)(iii)	absolute uncertainty in $P = (7/100) \times 0.20$ $= 0.014$	C1
	power $= 0.20 \pm 0.01$ W **or** $(2.0 \pm 0.1) \times 10^{-1}$ W	A1

5 - (9702/21_Summer_2019_Q1) - *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a)	(velocity =) change in displacement / time (taken)	B1
(b)(i)	$k = [1.29 \times (3.3 \times 10^2)^2] / 9.9 \times 10^4$	C1
	$= 1.4$	A1
(b)(ii)	percentage uncertainty $= (3 \times 2) + 4 + 2$ (= 12%) **or** fractional uncertainty $= (0.03 \times 2) + 0.04 + 0.02$ (= 0.12)	C1
	$\Delta k = 0.12 \times 1.42$ $= 0.17$ (*allow to 1 significant figure*)	C1
	$k = 1.4 \pm 0.2$	A1

6 – (9702/22_Summer_2019_Q1) – *Measurement Techniques*

(a)	absolute uncertainty = (1.6 / 100) × 0.0125 = 2×10^{-4} m	A1
(b)(i)	p = (4 × 0.38) / (π × 0.0125^2) = 3100 N m^{-2}	A1
(b)(ii)	percentage uncertainty = 2.8 + (2 × 1.6) (= 6%) **or** fractional uncertainty = 0.028 + (2 × 0.016) (= 0.06)	C1
	absolute uncertainty = 0.06 × 3100 = 190 N m^{-2} (*allow to 1 significant figure*)	A1

7 – (9702/21_Winter_2019_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)(i)	mass in range 1–20 g	A1
(a)(ii)	wavelength in range 1×10^{-8} m to 4×10^{-7} m	A1
(b)(i)	$T = 2\pi \times (200 \times 10^{-3} / 25)^{0.5}$ = 0.56 s	A1
(b)(ii)	percentage uncertainty = (2% + 8%) / 2 (= 5%) **or** fractional uncertainty = (0.02+0.08) / 2 (= 0.05)	C1
	ΔT = 0.56 × 0.05 = 0.028 (s)	C1
	T = (0.56 ± 0.03) s	A1

8 – (9702/21_Summer_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)	(work =) force × displacement	C1
	units: kg m s^{-2} × m = kg m^2 s^{-2}	A1
(b)(i)	units of Q: As	C1
	units of C: kg^{-1} m^{-2} A^2 s^4	A1
(b)(ii)	**1.** e.g. reading scale from different angles (wrongly) interpolating between scale readings/divisions	B1
	2. e.g. zero error wrongly calibrated scale	B1

9 – (9702/23_Summer_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)	similarity: both have magnitude	B1
	difference: distance is a scalar/does not have direction **or** displacement is a vector/has direction	B1
(b)(i)	the measurements have a small range	B1
(b)(ii)	the (average of the) measurements is not close to the true value	B1

10 – (9702/23_Winter_2020_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)(i)	wavelength = 8.5×10^{-5} m	A1
(a)(ii)	$f = v / \lambda$ **or** c / λ	C1
	$= 3.0 \times 10^{8} / 8.5 \times 10^{-5}$ ($= 3.5 \times 10^{12}$) = 3.5 THz	A1
(a)(iii)	infrared	B1
(b)	(implied) percentage uncertainty in I = 4% **or** (implied) fractional uncertainty in I = 0.04	C1
	percentage uncertainty in E = 5% + (4% × 2) = 13%	A1

11 – (9702/21_Summer_2021_Q1) – *Measurement Techniques, Forces, Density & Pressure*

(a)	mass / volume	B1
(b)(i)	absolute uncertainty = 4.0 × (5 / 100) = (±) 0.2 cm	B1
(b)(ii)	percentage uncertainty = 2 + 4 + (5 × 2)	C1
	= (±) 16%	A1
(c)	$p = F / A$ **or** $p = W / A$	C1
	$p = (19.5 \times 10^{-3} \times 9.81) / (4.0 \times 10^{-2})^2$	C1
	= 120 Pa	A1

12 – (9702/21_Winter_2021_Q1) – *Measurement Techniques, Forces, Density & Pressure*

(a)	mass / volume	B1
(b)(i)	(vernier/digital) calipers	B1
(b)(ii)	percentage uncertainty = (0.0004 / 0.0420) × 100 = 1%	A1
(c)(i)	kg m^{-3} = kg × m^{n} / m **or** kg m^{-3} = kg × m^{n} × m^{-1}	M1
	$-3 = n - 1$ and (so) $n = -2$	A1
(c)(ii)	$(\Delta\rho / \rho) = (\Delta M / M) + 2(\Delta r / r) + (\Delta L / L)$	C1
	percentage uncertainty = [(0.001 / 1.072) + 2 × (0.0004 / 0.0420) + (0.0001 / 0.1242)] (× 100)	C1
	= 0.09% + 2 × 0.95% + 0.08% = 2%	A1
(c)(iii)	$\rho = (1.072 \times 0.0420^{-2}) / (2.094 \times 0.1242)$ = 2337 (kg m^{-3})	C1
	$\Delta\rho = 0.021 \times 2337$ = 49 (kg m^{-3})	C1
	ρ = (2340 ± 50) kg m^{-3}	A1

13 - (9702/22_Winter_2021_Q1) - *Physical Quantities & Units, Measurement Techniques*

(a)	10^{12}	B1
	pico (p)	B1
(b)	ampere and metre both underlined (and no other units underlined)	B1
(c)(i)	percentage uncertainty = 3.5 + (3.0 × 2) + 2.5 + 2.0	C1
	= 14%	A1
(c)(ii)	absolute uncertainty = $4.1 \times 10^{-7} \times 14 / 100$ = $6 \times 10^{-8}\ \Omega\,m$	A1

14 - (9702/23_Winter_2022_Q1) - *Measurement Techniques*

(a)	(SI base unit of α =) $m^3\,s^{-1} \times m / m^4 = s^{-1}$	A1
(b)	(percentage uncertainty =) 3 + 4 + 2 × 4 = 15 (%)	A1
(c)	$\alpha = QL / r^4$ $= 2.72 \times 10^{-8} \times 2.5 \times 10^{-2} / (7.1 \times 10^{-5})^4$ $= 2.7 \times 10^7$	C1
	absolute uncertainty = $0.15 \times [2.7 \times 10^7]$ = 0.4×10^7	C1
	$\alpha = (2.7 \pm 0.4) \times 10^7\ s^{-1}$	A1

15 - (9702/21_Winter_2022_Q2) - *Measurement Techniques*

(a)(i)	$t = 1.8 / 4.9$ = 0.37 s	A1
(a)(ii)	$v = u + at$ $= 9.81 \times 0.37$	C1
	$= 3.6\ m\,s^{-1}$	A1
(a)(iii)	$v^2 = 3.6^2 + 4.9^2$	C1
	$v = 6.1\ m\,s^{-1}$	A1
	$\theta = \tan^{-1}(3.6 / 4.9)$ = 36°	A1
(b)(i)	$\rho = m / V$	C1
	$V = \frac{4}{3}\pi r^3$	C1
	$\rho = 0.017 / [\frac{4}{3}\pi \times (0.016 / 2)^3]$ $= 7900\ kg\,m^{-3}$	A1
(b)(ii)	$(E =)\ ½mv^2$	C1
	$(E =)\ ½ \times 0.017 \times 4.9^2 = 0.20$ (J)	A1

(b)(iii)	$k = F / x$ **or** k = gradient	C1
	e.g. $k = 6.4 / 10 \times 10^{-2}$ $= 64\ \text{N m}^{-1}$ (*allow 63–65 N m⁻¹*)	A1
(b)(iv)	$E = ½kx^2$ **or** $E = ½Fx$ **and** $F = kx$	C1
	$x_0 = [(2 \times 0.20) / 64]^{0.5}$ $= 0.079\ \text{m}$ or $0.080\ \text{m}$	A1
(c)(i)	same elastic potential energy / same (initial) kinetic energy and (polystyrene ball has) smaller mass (so greater speed) **or** same (average) force and (polystyrene ball has) smaller mass, (so greater average acceleration so greater speed)	B1
(c)(ii)	(for the polystyrene ball there is) less (average vertical) acceleration / smaller (average vertical component of) resultant force (so takes longer time to reach ground)	B1

16 – (9702/21_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques*

(a)	scalar and vector have magnitude	B1
	vector has direction (and scalar does not have direction)	B1
(b)(i)	$r = [(3 \times 28) / 4\pi]^{1/3}$ $= 1.9\ \text{cm}$	A1
(b)(ii)	percentage uncertainty in $V = (0.5 / 28) \times 100$ (= 1.79%)	C1
	percentage uncertainty in $r = 1.79 / 3$ = 0.6%	A1

17 – (9702/22_Winter_2023_Q1) – *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a)	only electric current **and** time underlined	B1
(b)	initial speed / velocity is zero	B1
	(non-zero magnitude of) acceleration is constant / uniform (and in a straight line)	B1
(c)(i)	• magnitude of acceleration at $t = 8.0$ s is less than that at $t = 14.0$ s	B1
	• direction of acceleration at $t = 8.0$ s is opposite to that at $t = 14.0$ s	B1
(c)(ii)	a = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / (\Delta)t$	C1
	a = e.g. $(20 + 10) / 12$ **or** $(0 + 10) / 4$ **or** $(20 - 0) / (12 - 4)$ $a = 2.5\ \text{m s}^{-2}$	A1
(c)(iii)	displacement $= [½ \times (12 - 4) \times 20] - [½ \times 4 \times 10]$ **or** displacement $= (-10 \times 12) + (½ \times 2.5 \times 12^2)$ **or** displacement $= (20 \times 12) - (½ \times 2.5 \times 12^2)$ **or** displacement $= ½ \times (20 - 10) \times 12$	C1
	displacement = 60 m	A1

18 - (9702/23_Winter_2023_Q1) - *Physical Quantities & Units, Measurement Techniques*

(a)	charge **and** power only ticked	B1
(b)(i)	$\%D = 0.4\%$ **and** $\%L = 0.6\%$	A1
(b)(ii)	$\rho = (4 \times 0.247) / [\pi \times (26.2 \times 10^{-3})^2 \times 0.162]$	C1
	$\rho = 2.83 \times 10^3\ \text{kg m}^{-3}$	A1
(b)(iii)	percentage uncertainty $= 0.4 + (2 \times 0.4) + 0.6$	C1
	$= 1.8\%$	A1

1 - (9702/22_Summer_2017_Q2) - *Kinematics, Work, Energy & Power*

(a)	rate of change of displacement **or** change in displacement/time taken
(b)(i)	$s = ut + ½at^2$
	$t = [(2 \times 1.25) / 9.81]^{1/2}$ (= 0.5048 s)
	or
	$v^2 = u^2 + 2as$ $v_{vert} = (2 \times 9.81 \times 1.25)^{1/2}$ (= 4.95)
	$t = [2s / (u + v)] = 2 \times 1.25 / 4.95$ (= 0.5048 s)
	$v = d / t = 1.5 / 0.50(48)$ $= 3.0\ (2.97)\ \text{m s}^{-1}$
(b)(ii)	vertical velocity $= at$ $= 9.81 \times 0.5048$ (= 4.95) [using $t = 0.50$ gives 4.9]
	velocity $= [(v_h)^2 + (v_v)^2]^{1/2}$
	$= [(2.97)^2 + (4.95)^2]^{1/2}$ $= 5.8\ (5.79)$ [using $t = 0.50$ leads to 5.7]
	direction (= $\tan^{-1}$ 4.95/2.97) = 59°
(b)(iii)	kinetic energy $= ½mv^2$
	$= ½ \times 0.45 \times (5.8)^2$ $= 7.6\ (7.57)$ J [using $t = 0.50$ leads to 7.3 J]

(b)(iv)	potential energy $= mgh$
	$= (0.45 \times 9.81 \times 1.25)$ $= 5.5\ (5.52)$ J
(c)	there is KE of the ball at the start/leaving table **or** the ball has an initial/constant horizontal velocity **or** the ball has velocity at start/leaving table

2 - (9702/23_Summer_2017_Q2) - *Kinematics, Dynamics*

(a)	(resultant) force is proportional/equal to the rate of change of momentum
(b)(i)	change in momentum $= m(v_2 - v_1)$ $= 0.84 \times (8.8 - 4.2)$
	$= 3.9\ (3.86)\ \text{kg m s}^{-1}$
(b)(ii)	$F = (3.9 / 4.0) = 0.97\ (0.965)$ N
(c)(i)	change in momentum for A: $0.84 \times (4.7 - 8.8) = -3.4\ (3.44)$ change in momentum for B: $0.73 \times (4.7 - 0) = 3.4\ (3.43)$
	change in momentum for B is equal and opposite to A
(c)(ii)	change in momentum equal (for A and B)
	force is change in momentum / time and time (of collision) is the same hence force on A and B equal and opposite as for Newton's third law
(c)(iii)	inelastic as relative speed of approach not equal to relative speed of separation

3 - (9702/21_Winter_2017_Q1) - *Physical Quantities & Units, Kinematics, Dynamics*

(a)	units of F: $kg\,m\,s^{-2}$	C1
	units of ρ: $kg\,m^{-3}$ **and** units of v: $m\,s^{-1}$	C1
	units of K: $kg\,m\,s^{-2} / [kg\,m^{-3} (m\,s^{-1})^2]$ $= m^2$	A1
(b)(i)	$K\rho = 1.5 / 33^2$	C1
	$= 1.38 \times 10^{-3}$ $F_D = 1.38 \times 10^{-3} \times 25^2$ **or** $F_D / 1.5 = 25^2 / 33^2$ $F_D = 0.86\,N$	A1
(b)(ii)	$a = (1.5 - 0.86) / (1.5 / 9.81)$ **or** $a = 9.81 - [0.86 / (1.5 / 9.81)]$	C1
	$a = 4.2\,m\,s^{-2}$	A1
(c)	initial acceleration is g/9.81 ($m\,s^{-2}$)/acceleration of free fall	B1
	acceleration decreases	B1
	final acceleration is zero	B1

4 - (9702/21_Winter_2017_Q2) - *Kinematics*

(a)	$30\,m\,s^{-1} = 108\,km\,h^{-1}$ **or** $100\,km\,h^{-1} = 28\,m\,s^{-1}$ **and** so exceeds speed limit	B1
(b)	acceleration = gradient **or** $\Delta v / (\Delta) t$ **or** $(v - u) / t$	C1
	e.g. acceleration = (24 – 20) / 12 [other points on graph line may be used] $= 0.33\,m\,s^{-2}$	A1
(c)	distance travelled by Q = ½ × 12 × 30 (= 180 m)	C1
	distance travelled by P = ½ × (20 + 24) × 12 (= 264 m)	C1
	distance between cars = 264 – 180 = 84 m	A1
(d)	$30 - 24 = 6\,m\,s^{-1}$ 'extra' time $T = 84/6$ (= 14 s) **or** $180 + 30T = 264 + 24T$ 'extra' time $T = 84/6$ (= 14 s)	C1
	$t = 12 + 14 = 26$ s	A1

5 - (9702/22_Winter_2017_Q3) - *Kinematics, Dynamics, Forces, Density & Pressure*

(a)	$p = 1000 \times 9.81 \times 7.0 \times 10^{-2}$ **or** $1000 \times 9.81 \times 1.9 \times 10^{-2}$	C1
	$\Delta p = 1000 \times 9.81 \times (7.0 \times 10^{-2} - 1.9 \times 10^{-2})$ **or** 686 – 186 = 500 Pa	A1
(b)	$F = pA$ **or** $(\Delta)F = \Delta p \times A$	C1
	upthrust = $500 \times (5.1 \times 10^{-2})^2 = 1.3$ N **or** upthrust = $(686 - 186) \times (5.1 \times 10^{-2})^2 = 1.3$ N **or** upthrust = $1000 \times 9.81 \times 5.1 \times 10^{-2} \times (5.1 \times 10^{-2})^2 = 1.3$ N	A1
(c)	force = 4.0 – 1.3 = 2.7 N	A1

(d)	extension/x/e = 2.7 / 30	C1
	= 0.09 (m) or 9 (cm)	C1
	height above surface = 9 – 7 = 2 cm	A1
(e)(i)	mass = 4.0 / 9.81	C1
	acceleration = 2.7 / (4.0 / 9.81) = 6.6 m s^{-2}	A1
(e)(ii)	viscous force increases (and then becomes constant)	M1
	(weight and upthrust constant so) acceleration decreases (to zero)	A1

6 – (9702/21_Summer_2018_Q1) – *Physical Quantities & Units, Kinematics*

(a)	a scalar has magnitude (only)	B1
	a vector has magnitude and direction	B1
(b)	power: scalar temperature: scalar momentum: vector *(two correct 1 mark, all three correct 2 marks)*	B2
(c)(i)	arrow labelled R in a direction from 5° to 20° north of west	B1
(c)(ii)	$v^2 = 28^2 + 95^2 - (2 \times 28 \times 95 \times \cos 115°)$ or $v^2 = [(95 + 28\cos 65°)^2 + (28\sin 65°)^2]$	C1
	v = 110 m s^{-1} (109.8 m s^{-1})	A1
	or (scale diagram method)	
	triangle of velocities drawn	(C1)
	v = 110 m s^{-1} (allow 108–112 m s^{-1})	(A1)

7 – (9702/21_Summer_2018_Q2) – *Dynamics, Kinematics, Work, Energy & Power*

(a)	a body continues at (rest or) constant velocity unless acted upon by a resultant force	B1
(b)(i)1.	from 0–2 s, distance = ½ × 2 × 6.8 (= 6.8 m) and from 2–3 s, distance = ½ × 1 × 3.4 (= 1.7 m)	C1
	magnitude of displacement = 5.1 m	A1
	direction of displacement is down(wards)	B1
(b)(i)2.	$(\Delta E) = mg\Delta h$ or $(E) = mgh$ or $(E) = Wh$	C1
	$(\Delta)E = 15 \times 5.1$ = (–) 77 J	A1
(b)(ii)	$a = (v - u) / t$ or a = gradient or $a = dv/dt$	C1
	a = 3.4 m s^{-2}	A1
(b)(iii)	$T - W = ma$ or $T - mg = ma$	C1
	T = 15 + (15 / 9.81) × 3.4 = 20 N or 20.2 N	A1
(b)(iv)	$E = F / A\varepsilon$ or $E = \sigma/\varepsilon$ and $\sigma = F / A$	C1
	$\varepsilon = 20 / (2.8 \times 10^{-5} \times 1.7 \times 10^{11})$	C1
	$= 4.2 \times 10^{-6}$	A1
(b)(v)	block is in equilibrium/has no resultant force	B1
	block could be stationary (or have constant velocity/speed) (so no, not possible to deduce)	B1

8 - (9702/22_Summer_2018_Q2) - *Kinematics, Dynamics*

(a)	sum/total momentum (of a system of bodies) is constant **or** sum/total momentum before = sum/total momentum after	**M1**
	for an isolated system **or** no (resultant) external force	**A1**
(b)(i)	(p =) mv **or** ($3.0M \times 7.0$) **or** ($2.0M \times 6.0$) **or** ($1.5M \times 8.0$)	**C1**
	$3.0M \times 7.0 = 2.0M \times 6.0\sin\theta + 1.5M \times 8.0\sin\theta$	**C1**
	$\theta = 61°$	**A1**
	or (vector triangle method)	
	momentum vector triangle drawn	**(C1)**
	$\theta = 61°$ (*2 marks for* ±1°, *1 mark for* ±2°)	**(A2)**
	or (use of cosine rule)	
	$p = mv$ **or** ($3.0M \times 7.0$) **or** ($2.0M \times 6.0$) **or** ($1.5M \times 8.0$)	**(C1)**
	$(21M)^2 = (12M)^2 + (12M)^2 - (2 \times 12M \times 12M \times \cos 2\theta)$	**(C1)**
	$\theta = 61°$	**(A1)**
(b)(ii)	(E =) $\frac{1}{2}mv^2$	**C1**
	ratio = $(\frac{1}{2} \times 2.0M \times 6.0^2) / (\frac{1}{2} \times 1.5M \times 8.0^2)$ = 0.75	**A1**

9 - (9702/21_Summer_2018_Q3) - *Kinematics, Dynamics*

(a)	mass is the property (of a body/object) resisting changes in motion **or** mass is the quantity of matter (in a body)	**B1**
(b)(i)	force on A (by B) equal and opposite to force on B (by A) **or** both A and B exert equal and opposite forces on each other	**B1**
	force is rate of change of momentum and time (of contact) is same	**B1**
(b)(ii)	$p = mv$ **or** $3M \times 0.40$ **or** $M \times 0.25$ **or** $3M \times 0.2$ **or** Mv	**C1**
	$(3M \times 0.40) - (M \times 0.25) = (3M \times 0.2) + Mv$	**C1**
	$v = (3 \times 0.40) - 0.25 - (3 \times 0.2)$ $= 0.35\,\text{ms}^{-1}$	**A1**
(b)(iii)	1. relative speed of approach = 0.40 + 0.25 $= 0.65\,\text{ms}^{-1}$	**A1**
	2. relative speed of separation = 0.35 – 0.20 $= 0.15\,\text{ms}^{-1}$	**A1**
(b)(iv)	(relative) speed of separation not equal to/less than (relative) speed of approach **or** answers (to (b)(iii) are) not equal **and** so inelastic collision	**B1**

10 – (9702/22_Summer_2018_Q3) – *Kinematics, Dynamics, Waves*

(a)	time = 12 s	**A1**
(b)	distance (up slope) = ½ × 12 × 18 (= 108)	**C1**
	distance (down slope) = ½ × 12 × 6 (= 36)	**C1**
	displacement from A = 108 – 36 = 72 m	**A1**
(c)	$v = u + at$ **or** a = gradient **or** $a = \Delta v / (\Delta)t$	**C1**
	$a = 6 / 12 = 0.50\ (\text{ms}^{-2})$ *(other points from the line may be used)*	**A1**
	or	
	$v^2 = u^2 + 2as$ **and** $u = 0$ **or** $v^2 = 2as$	**(C1)**
	$a = 6.0^2 / (2 \times 36) = 0.50\ (\text{ms}^{-2})$	**(A1)**
	or	
	$s = ut + ½at^2$ **and** $u = 0$ **or** $s = ½at^2$	**(C1)**
	$a = 2 \times 36 / 12^2 = 0.50\ (\text{ms}^{-2})$	**(A1)**
	or	
	$s = vt - ½at^2$	**(C1)**
	$a = 2 \times (6 \times 12 - 36) / 12^2 = 0.50\ (\text{ms}^{-2})$	**(A1)**

(d)(i)	$F = 70 \times 0.50$ (= 35)	**C1**
	frictional force = 80 – 35 = 45 N	**A1**
(d)(ii)	$\sin\theta = 80 / (70 \times 9.81)$	**C1**
	$\theta = 6.7°$	**A1**
(e)(i)	$f_0 = (900 \times 340) / (340 + 12)$	**C1**
	= 870 Hz	**A1**
(e)(ii)	speed/velocity (of sledge) decreases and (so) frequency increases	**B1**

11 - (9702/23_Summer_2018_Q3) - *Kinematics, Dynamics, Work, Energy & Power*

(a)	$v = u + at$ $v = 9.6 - (9.81 \times 0.37) = 6.0\,\text{m s}^{-1}$	**A1**
(b)	$s = ½ \times (9.6 + 6.0) \times 0.37$ **or** $6.0^2 = 9.6^2 - (2 \times 9.81 \times s)$ **or** $s = (9.6 \times 0.37) - (½ \times 9.81 \times 0.37^2)$ **or** $s = (6.0 \times 0.37) + (½ \times 9.81 \times 0.37^2)$	**C1**
	$s = 2.9\,\text{m}$	**A1**
(c)(i)	$(\Delta)E = mg(\Delta)h$	**C1**
	$\Delta E = 0.056 \times 9.81 \times 2.9$ $= 1.6\,\text{J}$	**A1**
(c)(ii)	$E = ½mv^2$	**C1**
	$\Delta E = ½ \times 0.056 \times (6.0^2 - 3.8^2)$ $= 0.60\,\text{J}$	**A1**
(d)	force on ball (by ceiling) <u>equal</u> to force on ceiling (by ball)	**M1**
	and opposite (in direction)	**A1**
(e)	$(p =)\ mv$ **or** 0.056×6.0 **or** 0.056×3.8	**C1**
	change in momentum $= 0.056 \times (6.0 + 3.8)$ $= 0.55\,\text{N s}$	**A1**

(f)	resultant force = 0.55 / 0.085 (= 6.47 N)	**C1**
	force by ceiling $= 6.47 - (0.056 \times 9.81)$ $= 5.9\,\text{N}$	**A1**

12 – (9702/21_Winter_2018_Q1) – *Kinematics, Work, Energy & Power*

(a)(i)	distance in a specified direction (from a point)	**B1**
(a)(ii)	change in velocity / time (taken)	**B1**
(b)(i)	vertical component of velocity = $(5.5^2 - 4.6^2)^{1/2} = 3.0\ (\text{ms}^{-1})$ **or** $5.5\cos\theta = 4.6$ (so $\theta = 33.2°$) **and** $5.5\sin 33.2° = 3.0\ (\text{ms}^{-1})$	**A1**
(b)(ii)	$s = ut + ½at^2$ $0 = (3.0 \times t) - (½ \times 9.81 \times t^2)$ **or** $v = u + at$ $-3.0 = 3.0 - 9.81t$	**C1**
	$t = 0.61$ s	**A1**
(b)(iii)	$d = 4.6 \times 0.61$ $= 2.8$ m	**A1**
(b)(iv)	$E = ½mv^2$	**C1**
	ratio = $(½ \times m \times 4.6^2) / (½ \times m \times 5.5^2)$ **or** ratio = $(½ \times m \times 5.5^2 - m \times 9.81 \times 0.459) / (½ \times m \times 5.5^2)$	**C1**
	ratio = 0.70	**A1**
(c)	straight line from positive value of v_y at $t = 0$ to negative value of v_y	**M1**
	straight line ends at $t = T$ and final magnitude of v_y greater than initial magnitude of v_y	**A1**

13 – (9702/22_Winter_2018_Q1) – *Kinematics, Work, Energy & Power*

(a)	$v_x = (6.0^2 - 4.8^2)^{1/2} = 3.6\ (\text{ms}^{-1})$ **or** $6.0\sin\theta = 4.8$ (so $\theta = 53.1°$) **and** $v_x = 6.0\cos 53.1° = 3.6\ (\text{ms}^{-1})$	**A1**
(b)(i)	straight line from (0, 4.8) to (0.49, 0)	**M1**
	straight line continues with same slope to (0.98, –4.8) (labelled Y)	**A1**
(b)(ii)	a horizontal line	**M1**
	from (0, 3.6) to (0.98, 3.6) (labelled X)	**A1**
(c)	$s = ut + ½at^2$ $= (4.8 \times 0.49) + (½ \times -9.81 \times 0.49^2)$ **or** $s = ½(u + v)t$ **or** area under graph $= ½ \times (4.8 + 0) \times 0.49$ **or** $s = vt - ½at^2$ $= ½ \times 9.81 \times 0.49^2$ **or** $v^2 = u^2 + 2as$ $s = 4.8^2 / (2 \times 9.81)$	**C1**
	$s = 1.2$ m	**A1**

(d)	$(\Delta)E = mg(\Delta)h$	C1
	$E = ½mv^2$	C1
	ratio = $(½ \times m \times 3.6^2) / (m \times 9.81 \times 1.2)$ **or** ratio = $[(½ \times m \times 6.0^2) - (m \times 9.81 \times 1.2)] / (m \times 9.81 \times 1.2)$ **or** ratio = $(½ \times m \times 3.6^2) / (½ \times m \times 4.8^2)$	C1
	ratio = 0.56	A1
(e)	(force due to) air resistance acts in opposite direction to the velocity **or** (with air resistance, average) resultant force is larger (than weight)	B1

14 – (9702/21_Winter_2018_Q5) – *Electric Fields, Particle & Nuclear Physics, Kinematics*

(a)	region (of space) where a force acts on a (stationary) charge	B1
(b)	$E = F / Q$	B1
	$F = ma$ **and** (so) $a = \frac{Eq}{m}$	A1
(c)(i)	protons = 96	A1
	neutrons = 148	A1
(c)(ii)	mass-energy is conserved/mass change is 'seen' as energy	B1
	energy released as gamma (radiation)/KE of α/KE of Pu	B1
(c)(iii)	ratio $= \frac{2}{4} \times \frac{240}{94}$ **or** ratio $= \frac{2 \times 1.60 \times 10^{-19}}{4 \times 1.66 \times 10^{-27}} \times \frac{240 \times 1.66 \times 10^{-27}}{94 \times 1.60 \times 10^{-19}}$	C1
	ratio = 1.3	A1

15 – (9702/21_Summer_2019_Q1) – *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a)	(velocity =) change in displacement / time (taken)	B1
(b)(i)	$k = [1.29 \times (3.3 \times 10^2)^2] / 9.9 \times 10^4$	C1
	= 1.4	A1
(b)(ii)	percentage uncertainty = $(3 \times 2) + 4 + 2$ (= 12%) **or** fractional uncertainty = $(0.03 \times 2) + 0.04 + 0.02$ (= 0.12)	C1
	$\Delta k = 0.12 \times 1.42$ = 0.17 (*allow to 1 significant figure*)	C1
	$k = 1.4 \pm 0.2$	A1

16 – (9702/22_Summer_2019_Q2) – *Kinematics, Dynamics, Electric Fields*

(a)	(resultant) force proportional/equal to/is rate of change of momentum	B1
(b)(i)	distance = area under graph **or** $s = ½ (u + v) t$ $= ½ \times (9 + 13) \times 10$ **or** $s = ut + ½at^2$ $= (9 \times 10) + (½ \times 0.40 \times 10^2)$ **or** $s = vt – ½at^2$ $= (13 \times 10) – (½ \times 0.40 \times 10^2)$ **or** $v^2 = u^2 + 2as$ $13^2 = 9^2 + (2 \times 0.40 \times s)$	C1
	distance = 110 m	A1

(b)(ii)	**1.** a = gradient **or** $a = (v – u) / t$ **or** $a = \Delta v / (\Delta)t$ e.g. $a = (14 – 9) / 12.5$ **or** $(13 – 9) / 10$	C1
	$a = 0.40$ m s^{-2}	A1
	2. resultant force $= 850 \times 0.40$ $= 340$ N	A1
	3. (F =) 510 + 440 + 340 = 1300 (N)	A1
	4. $P = Fv$	C1
	$= 1300 \times 13$ $= 1.7 \times 10^4$ W	A1
(c)	$E = \sigma / \varepsilon$	C1
	$E = (F / A) / (\Delta L / L)$ **or** $E = FL / A\Delta L$	C1
	$\Delta L = (480 \times 0.48) / (3.0 \times 10^{-4} \times 2.2 \times 10^{11})$ $= 3.5 \times 10^{-6}$ m	A1
(d)	$f_o = f_s v / (v – v_s)$ $480 = f_s \times 340 / (340 – 14)$	C1
	$f_s = 460$ Hz	A1

17 – (9702/21_Winter_2019_Q2) – *Kinematics, Dynamics, Electric Fields*

(a)	the (two) plates are vertical (and separated)	B1
	left plate positively charged **and** right plate negatively charged/earthed **or** right plate negatively charged **and** left plate positively charged/earthed	B1
(b)	$F = Eq$	C1
	$= 1.3 \times 10^4 \times 3.7 \times 10^{-9}$ $= 4.8 \times 10^{-5}$ N	A1
(c)	$F^2 = (4.8 \times 10^{-5})^2 + (5.4 \times 10^{-5})^2$ so $F = 7.2 \times 10^{-5}$ N **or** $F = [(4.8 \times 10^{-5})^2 + (5.4 \times 10^{-5})^2]^{0.5}$ so $F = 7.2 \times 10^{-5}$ N	A1
(d)	electric force is constant (because field strength/E is constant)	B1
	weight is constant (and so resultant force constant)	B1
(e)(i)	$m = 5.4 \times 10^{-5} / 9.81$ ($= 5.5 \times 10^{-6}$)	C1
	$a = 7.2 \times 10^{-5} / (5.5 \times 10^{-6})$ $= 13$ m s^{-2}	A1
(e)(ii)	$v^2 = u^2 + 2as$ $v^2 = 2 \times 13 \times 0.58$	C1
	$v = 3.9$ m s^{-1}	A1

18 – (9702/22_Winter_2019_Q2) – *Kinematics*

(a)	change in velocity / time (taken)	A1
(b)(i)	weight ≫ (force due to) air resistance **or** (force due to) air resistance is negligible compared to weight	B1
(b)(ii)	$s = ut + ½at^2$ $0.280 = ½ \times 9.81 \times t^2$	C1
	$t = 0.24$ s	A1

(b)(iii)	total distance fallen = 0.280 + 0.080 = 0.360 $0.360 = ½ \times 9.81 \times t^2$ $t = 0.27$ s	C1
	time taken = 0.27 – 0.24 = 0.03 s	A1
	or	
	$v = 9.81 \times 0.239$ **or** $(2 \times 9.81 \times 0.280)^{0.5}$ **or** $(2 \times 0.280) / 0.239$ $= 2.34$ (m s^{-1})	(C1)
	$0.080 = 2.34t + ½ \times 9.81 \times t^2$ solving quadratic equation gives $t = 0.03$ s *allow any correct method using equations of uniform accelerated motion*	(A1)
(c)	(average) resultant force/acceleration/speed/velocity (of low-density ball) is less	B1
	(so) time interval is longer	B1

19 – (9702/23_Winter_2019_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a)	(work done =) force × distance moved in direction of force	B1
(b)(i)	**1.** acceleration = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / t$	C1
	e.g. $a = 2.4 / 3.0$ $= 0.80\ \text{m s}^{-2}$	A1
	2. tension in cable = $(13.0 + 2.0) \times 10^3$	C1
	work done $= 15 \times 10^3 \times (3.0 \times 2.4)$ $= 1.1 \times 10^5$ J	A1
(b)(ii)	power = Fv	C1
	$v = 2.0\ (\text{m s}^{-1})$	C1
	input power $= (1.6 \times 10^4 \times 2.0) / 0.67$ $= 4.8 \times 10^4$ W	A1
(b)(iii)	work is done against friction so (increase in) GPE is less (than work done by motor) **or** energy is lost or transferred or converted to heat/thermal energy due to friction or resistance force **or** work is done lifting the cable so GPE is less	A1

20 – (9702/23_Winter_2019_Q3) – *Kinematics, Electric Fields*

(a)(i)	mass	B1
(a)(ii)	charge	B1
(b)(i)	$E = V/d$ **or** $E = F/q$	C1
	$F = (1.2 \times 10^3 \times 4.2 \times 10^{-9}) / 3.6 \times 10^{-2}$	C1
	$= 1.4 \times 10^{-4}$ N	A1
(b)(ii)	$W = mg$	C1
	$= 5.9 \times 10^{-6} \times 9.81$ resultant force $= 1.4 \times 10^{-4} - (5.9 \times 10^{-6} \times 9.81)$	C1
	$a = F/m$	C1
	$a = [1.4 \times 10^{-4} - (5.9 \times 10^{-6} \times 9.81)] / [5.9 \times 10^{-6}] = 14\ \text{m s}^{-2}$	A1
(b)(iii)	**1.** $s = ut + ½at^2$ $1.8 \times 10^{-2} = ½ \times 14 \times t^2$	C1
	$t = 0.051$ s	A1
	2. $p = 0.75 \times 0.051$ $= 0.038$ m	A1

21 – (9702/21_Summer_2020_Q2) – *Kinematics, Dynamics*

(a)	(resultant) force proportional to rate of change of momentum	B1
(b)(i)	arrow drawn vertically downwards from point X	B1
(b)(ii)	$s = ut + ½at^2$ $h = ½ \times 9.81 \times 0.81^2$	C1
	$= 3.2$ m	A1
(b)(iii)	$d = 5.4 \times 0.81$ $= 4.4$ m	A1
(c)(i)	downward pointing arrow labelled weight	B1
	upward pointing arrow labelled air resistance	B1
(c)(ii)	air resistance increases	B1
	weight constant **or** resultant force decreases	B1
	(so) acceleration decreases	B1
(c)(iii)	gravitational potential energy to thermal/internal energy	B1

22 – (9702/22_Summer_2020_Q2) – *Kinematics, Dynamics*

(a)(i)	area = $ut + ½(v - u)t$ **or** area = $vt - ½(v - u)t$ **or** area = $½(u + v)t$	A1
(a)(ii)	displacement	A1
(b)(i)	$u = 15 \sin 60°$ (= 13 m s^{-1})	C1
	$t = 15 \sin 60° / 9.81$	C1
	$= 1.3$ s	A1
(b)(ii)	the force in the horizontal direction is zero	B1
(b)(iii)	(velocity =) $15 \cos 60° = 7.5$ (m s^{-1}) **or** (velocity =) $15 \sin 30° = 7.5$ (m s^{-1})	A1
(c)(i)	$p = mv$ **or** 0.40×7.5 **or** 0.40×4.3	C1
	$\Delta p = 0.40\ (7.5 + 4.3)$ $= 4.7$ kg m s^{-1}	A1
(c)(ii)	force = $4.7 / 0.12$ **or** $0.40 \times [(7.5 + 4.3) / 0.12]$ $= 39$ N	A1

23 - (9702/23_Summer_2020_Q2) - *Kinematics, Dynamics*

(a)	a body continues at (rest or) constant velocity unless acted upon by a resultant force	B1
(b)(i)	distance = [½ × (2.0 + 4.4) × 3.0] + [4.4 × 2.0]	C1
	= 9.6 + 8.8 = 18 m	A1
(b)(ii)	$a = (v - u) / t$ **or** gradient **or** $\Delta v / (\Delta)t$	C1
	e.g. $a = (4.4 - 2.0) / 3.0 = 0.80\ \text{m s}^{-2}$	A1
(b)(iii)	**1.** force = 240 cos 28° **or** 240 sin 62° = 210 N	A1
	2. resultant force = 89 × 0.80 (= 71.2 N)	C1
	R = 210 – 71 = 140 N	A1
(b)(iv)	$T \sin 45° = mg$	C1
	T = (89 × 9.81) / sin 45° = 1200 N	A1

24 - (9702/22_Winter_2020_Q1) - *Motion In A Circle, Kinematics*

(a)	density and temperature indicated as scalars	B1
	acceleration and momentum indicated as vectors	B1
(b)(i)	decelerates **or** speed/velocity decreases	B1
(b)(ii)	speed = $(\Delta)d / (\Delta)t$ **or** gradient	C1
	= e.g. (0.56 – 0.20) / 1.5 = $0.24\ \text{m s}^{-1}$	A1
(c)	displacement is zero (so) average velocity is zero	B1

25 - (9702/21_Winter_2020_Q2) - *Kinematics, Work, Energy & Power*

(a)	constant gradient	B1
(b)	(displacement until 0.20 s =) ½ × 1.96 × 0.20 (= 0.196 m) **or** (displacement after 0.20 s =) ½ × 6.86 × 0.70 (= 2.401 m)	C1
	height = 2.401 – 0.196	C1
	= 2.2 m (*alternative methods are possible using equations of uniformly accelerated motion*)	A1
(c)	$(\Delta)E = mg(\Delta)h$ **or** $W(\Delta)h$	C1
	$(\Delta)E$ = 0.86 × 2.2 = 1.9 J	A1
(d)	curved line from the origin	M1
	gradient of curved line decreases and is zero at t = 0.20 s only	A1
(e)	acceleration (of free fall) is unchanged/is not dependent on mass <u>and</u> (so) no effect	B1

26 – (9702/22_Winter_2020_Q2) – *Kinematics, Dynamics, Forces, Density & Pressure*

(a)(i)	$(\Delta)p = \rho g(\Delta)h$ $520 = 1000 \times 9.81 \times h$	C1
	$h = 0.053$ m	A1
(a)(ii)	(upthrust =) $(\Delta)p \times A$ $= (\Delta)p \times \pi(d/2)^2$ **or** $(\Delta)p \times \pi r^2$	C1
	$= 520 \times \pi(0.031/2)^2 = 0.39$ (N)	A1
(a)(iii)	$T = 0.84 - 0.39$ $= 0.45$ N	A1
(b)(i)	$a = (v - u)/t$ **or** $(\Delta)v/(\Delta)t$ **or** gradient	C1
	$=$ e.g. $8.0 \times 10^{-2}/2.0$ $= 4.0 \times 10^{-2}$ m s^{-2}	A1
(b)(ii)	distance = $(½ \times 2.5 \times 0.10) + (½ \times 1.5 \times 0.10)$ **or** $(½ \times 4.0 \times 0.10)$ (= 0.20 (m))	C1
	depth = 0.32 – 0.20 = 0.12 m	A1
(c)(i)	viscous (force)	B1
(c)(ii)	viscous force increases (with speed/time/depth)	B1
	(so) acceleration decreases	B1

27 – (9702/23_Winter_2020_Q3) – *Kinematics, Dynamics*

(a)	$s = ½at^2$	C1
	$57 = ½ \times 9.81 \times t^2$ **and** $t = 3.4$ (s)	A1
(b)	horizontal distance = 41×3.4 = 140 m	A1
(c)	$(\text{displacement})^2 = 57^2 + 140^2$	C1
	displacement = $(57^2 + 140^2)^{0.5}$ = 150 m	A1
(d)	straight line from the origin with positive gradient	B1
(e)	$(1480 - m) \times 0.340 = m \times 41.0$	C1
	$m = 12.2$ kg	A1
	or	
	$m_c 0.34 = m_b 41$ **and** $m_c + m_b = 1480$	(C1)
	$m_c = (41/0.34)m_b$ $(41/0.34)m_b + m_b = 1480$ $m_b = 12.2$ kg	(A1)
(f)	acceleration (of free fall) is unchanged/is not dependent on mass	M1
	(so) no change (to the graph)	A1

28 – (9702/22_Summer_2021_Q2) – *Kinematics, Dynamics*

(a)	$v^2 = u^2 + 2as$ $u^2 = 8.7^2 - (2 \times 9.81 \times 1.5)$	C1
	$u = 6.8\ \text{m s}^{-1}$	A1
(b)	(magnitude of) force on ball (by ground) equal to force on ground (by ball)	B1
	(direction of) force on ball (by ground) opposite to force on ground (by ball)	B1
(c)(i)	(p =) 0.059×8.7 **or** 0.059×5.4	C1
	change in momentum = 0.059 (8.7 + 5.4) = 0.83 N s	A1
(c)(ii)	resultant force = 0.83 / 0.091 **or** 0.059 [(8.7 + 5.4) / 0.091] = 9.1 N	A1
(c)(iii)	(W =) 0.059×9.81	C1
	(W =) 0.58 (N) force = 9.1 + 0.58 = 9.7 N	A1
(d)	straight line with a positive gradient and starting from a non-zero value of speed at $t = 0$ and ending when $t = T$	B1
(e)	air resistance increases	B1
	resultant force/acceleration decreases so gradient (of curve) decreases	B1

29 – (9702/23_Summer_2021_Q2) – *Kinematics*

(a)	change in velocity / time (taken)	B1
(b)(i)	air resistance increases (with speed/with time)	B1
	resultant force decreases (as speed increases/with time) so acceleration decreases (as speed increases/with time)	B1
	when air resistance equals the weight the speed/velocity/v becomes constant	B1
(b)(ii)	speed = $36\ \text{m s}^{-1}$	A1
(b)(iii)	height given by area under the curve	C1
	height = 950 m *Round to two significant figures and award 2 marks for a value in the range 920–980 m and 1 mark for a value in the range 900–910 m or 990–1000 m.*	A2
(b)(iv)	line starting at (0, 9.8)	B1
	curve with negative gradient between $t = 0$ and $t = 20$ s	B1
	line showing zero acceleration between $t = 20$ s and $t = 30$ s	B1

30 – (9702/21_Winter_2021_Q2) – *Kinematics, Work, Energy & Power*

(a)	mass × velocity	B1
(b)(i)	kinetic energy = $\frac{1}{2}mv^2$	C1
	= $\frac{1}{2} \times 0.24 \times 2.3^2$	C1
	= 0.63 J	A1
(b)(ii)	change in momentum = $\frac{1}{2} \times 240 \times 5.0 \times 10^{-3}$	C1
	= 0.60 N s	A1
(b)(iii)	(change in velocity of Y) = 0.60 / 0.12 (= 5.0 m s^{-1})	C1
	final velocity of Y = 5.0 – 2.3 = 2.7 m s^{-1}	A1
	or	
	(final momentum of Y) = 0.60 – 0.12 × 2.3 (= 0.324 N s)	(C1)
	final velocity of Y = 0.324 / 0.12 = 2.7 m s^{-1}	(A1)
(c)	sloping straight line from (0, 0) to t = 3.0 ms **and** another straight line continuous with the first from t = 3.0 ms to (5.0, 0)	B1
	lines showing maximum force of magnitude 240 N	B1
	lines wholly in the negative F region of the graph	B1

31 – (9702/23_Winter_2021_Q3) – *Kinematics*

(a)	change in displacement / time (taken)	B1
(b)	by calculation: $v^2 = 42^2 + 23^2 - (2 \times 42 \times 23 \times \cos 54°)$ **or** $v^2 = (42 - 23 \cos 54°)^2 + (23 \sin 54°)^2$ **or** $v^2 = (42 - 23 \sin 36°)^2 + (23 \cos 36°)^2$	C1
	v = 34 m s^{-1}	A1
	or	
	by scale diagram: triangle of vector velocities drawn	(C1)
	v = 34 m s^{-1} (*allow* ± 1 m s^{-1} *if scale diagram used*)	(A1)
(c)(i)	$(\Delta)E = mg(\Delta)h$ **or** $(\Delta)E = W(\Delta)h$	C1
	h = 6100 / 46 (= 133 m)	C1
	θ = sin^{-1} (133 / 280) = 28°	A1
(c)(ii)	force = 6100 / 280 **or** 46 sin 28°	C1
	= 22 N	A1
(d)	$v_{(s)}$ = 280 / 14 (= 20 m s^{-1})	C1
	$f_o = f_s\, v / (v - v_s)$ f_s = 450 × (340 – 20) / 340	C1
	= 420 Hz	A1

32 - (9702/21_Summer_2022_Q1) - *Kinematics*

(a)	change in displacement / time (taken)	B1
(b)(i)	(displacement =) area under graph	C1
	(at t = 4.0 s) v = (–) 2.4	C1
	height = ½ × 2.5 × 4.0 – ½ × 1.5 × 2.4 = 3.2 m	A1
(b)(ii)	change in momentum = 7.5 (–4.0 – 2.4)	C1
	= (–) 48 N s	A1
(b)(iii)	$W = \Delta p / (\Delta)t$ **or** $\Delta mv / (\Delta)t$	C1
	= 48 / 4.0 = 12 N	A1
	or	
	$W = ma$ **or** mg **or** $m(v - u) / t$	(C1)
	= 7.5 × 1.6 **or** 7.5 × (4 + 2.4) / 4.0 = 12 N	(A1)
(c)	speed/velocity decreases so viscous force decreases	B1
	viscous force decreases (and weight constant) so resultant force decreases	B1

33 - (9702/22_Summer_2022_Q2) - *Kinematics*

(a)	$T \sin 68° + 32 = 280$	C1
	T = 270 N	A1
(b)(i)	$F = \rho g V$ $V = 280 / (1.0 \times 10^3 \times 9.81)$ = 0.029 m^3	A1
(b)(ii)	$\rho = (32 / 9.81) / 0.029$	C1
	= 110 kg m^{-3}	A1

(c)	$(\Delta)E = mg(\Delta)h$ **or** $(\Delta)E = W(\Delta)h$	C1
	$(\Delta)h = (-)\ 77 / 32$	C1
	$(\Delta)h = (-)\ 2.4$ final height = 6.2 – 2.4 = 3.8 m	A1
(d)(i)	$T = kx$ where k is a constant **or** $T = (EA / L)x$ where A is (cross-sectional) area, E is Young modulus, L is (original/unstretched) length	B1
(d)(ii)	$E = \frac{1}{2}kx^2$ **or** $E = \frac{1}{2}Fx$ **and** $F = kx$	C1
	$E = 0.65 \times 2^2$ = 2.6 J	A1
	or	
	$E = \frac{1}{2}Fx$ $0.65 = \frac{1}{2} \times 270 \times x$ and so $x = 4.8 \times 10^{-3}$ m $k = F / x = 270 / 4.8 \times 10^{-3}$ $= 5.6 \times 10^4$	(C1)
(d)(ii)	final $E = \frac{1}{2} \times 540 \times 9.6 \times 10^{-3}$ **or** $E = \frac{1}{2} \times (270 \times 2) \times (4.8 \times 10^{-3} \times 2)$ **or** $E = \frac{1}{2} \times 5.6 \times 10^4 \times (9.6 \times 10^{-3})^2$ = 2.6 J	(A1)

34 – (9702/23_Summer_2022_Q2) – *Kinematics*

(a)	(time =) displacement / velocity	C1
	(time =) 70.0 / 65.0 cos 4.30° = 1.08 (s)	A1
(b)	$s = ut + ½at^2$ $= (65 \times \sin 4.30° \times 1.08) – (0.5 \times 9.81 \times 1.08^2)$	C1
	$s = -0.46$ (m)	C1
	height above ground = 1.66 – 0.46 = 1.2 m	A1
(c)	GPE has decreased	M1
	(total energy conserved so) KE has increased	A1

35 – (9702/22_Summer_2022_Q3) – *Kinematics*

(a)	$v^2 = u^2 + 2as$ $s = 5.6^2 / (2 \times 9.81)$	C1
	(max height =) $3.1 + 5.6^2 / (2 \times 9.81) = 4.7$ (m)	A1
(b)	$s = ut + \frac{1}{2}at^2$ $4.7 = \frac{1}{2} \times 9.81 \times t^2$	C1
	$t = 0.98$ s	A1
(c)	line drawn from a non-zero speed at $t = 0$ to a greater speed at $t = T$	B1
	a single sloping straight line drawn from $t = 0$ to $t = T$	B1
	line starts with a positive non-zero value of v and ends with a negative non-zero value of v	B1
(d)	acceleration (of the ball)	B1
(e)(i)	(magnitudes of accelerations are) equal / same	B1
(e)(ii)	(speeds are) equal / same	B1

36 – (9702/23_Summer_2022_Q3) – *Kinematics*

(a)	(velocity =) change in displacement / time	B1
(b)(i)	a = 2400 / 1200 = 2.0 m s^{-2}	A1
(b)(ii)	straight line from the origin with positive gradient (labelled A)	M1
	ending at (20, 40)	A1
(c)(i)	line starting at origin (with the same gradient as A) and beneath A at all points	B1
	gradient decreasing to zero	B1
	straight horizontal line from $t = 12$ s and ending at $t = 20$ s (and labelled B)	B1
(c)(ii)	the velocity/speed will increase	B1
	to a new terminal/constant/maximum velocity/speed	B1
	or	
	the car has an acceleration	(B1)
	to a new (higher) terminal/constant/maximum velocity/speed	(B1)

37 – (9702/21_Summer_2023_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a)(i)	(component =) 4.8 sin 30° = 2.4 (N)	A1
(a)(ii)	(8.2 × 0.50) **or** (W × 0.60) **or** (0.30 × 0.80) **or** (2.4 × 1.2)	C1
	(8.2 × 0.50) = (W × 0.60) + (0.30 × 0.80) + (2.4 × 1.2)	C1
	W = 1.6 N	A1
(a)(iii)	force = 4.8 cos 30° = 4.2 N	A1
(b)	$E = ½Fx$	C1
	0.32 = ½ × 8.2 × x x = 0.078 m	A1

(c)(i)	$((\Delta)E) = mg(\Delta)h$ **or** $W(\Delta)h$	C1
	$= 0.30 \times 0.090$ $= 0.027$ J	A1
(c)(ii)	$E = ½mv^2$	C1
	$E = 0.044 - 0.027$ (= 0.017)	C1
	$v^2 = (2 \times 0.017) / (0.30 / 9.81)$ (where v = speed at A) $v = 1.1$ m s^{-1}	A1
	or	
	$E = ½mv^2$	(C1)
	$0.044 = ½ \times (0.30 / 9.81) \times v^2$ (where v = speed at B) ($v^2 = 2.88$) $v^2 = u^2 + 2as$ (where u = speed at A) $2.88 = u^2 + 2 \times 9.81 \times 0.090$	(C1)
	$u = 1.1$ m s^{-1}	(A1)
(c)(iii)	(gravitational / resultant) force / weight is vertical	B1
(c)(iv)	straight line with positive gradient starting from non-zero value of v_Y at time t_A to a time t_B	B1

38 – (9702/22_Summer_2023_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a)	the point where (all) the weight (of the object) is taken to act	B1
(b)(i)	(54×0.45) **or** (2.4×0.95) **or** $(T \sin 30° \times 1.3)$	C1
	$(54 \times 0.45) = (2.4 \times 0.95) + (T \sin 30° \times 1.3)$	C1
	$T = 34$ N	A1
(b)(ii)	resultant moment $= (54 \times 0.45) - (2.4 \times 0.95)$ **or** $(34 \sin 30° \times 1.3)$ $= 22$ N m	A1
(c)(i)	$(\Delta)E = mg(\Delta)h$ **or** $W(\Delta)h$	C1
	$= 2.4 \times 1.8$ $= 4.3$ J	A1

(c)(ii)	$E = \frac{1}{2}mv^2$	C1
	$= \frac{1}{2} \times (2.4 / 9.81) \times 3.4^2$ $= 1.4$ J (at X)	C1
	kinetic energy at Y $= 4.3 + 1.4$ $= 5.7$ J	A1
	or	
	$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 + mg(\Delta)h$	(C1)
	$v^2 = 3.4^2 + 2 \times 9.81 \times 1.8$ $v^2 = 46.9$ so $v = 6.85$ (m s^{-1}) KE $= \frac{1}{2} \times (2.4 / 9.81) \times 6.85^2$	(C1)
	$= 5.7$ J	(A1)
(c)(iii)	no variation **or** acceleration is (always) vertically downwards	B1
(c)(iv)	horizontal straight line at a non-zero value of velocity	B1

39 – (9702/22_Summer_2023_Q3) – *Dynamics, Kinematics*

(a)(i)	rate of change of momentum	B1
(a)(ii)	change in momentum = (1.4 – 0.80) × 3.0	C1
	= 1.8 kg m s^{-1}	A1
(b)(i)	resultant force (on block) is zero	B1
	(so) velocity is constant	B1
(b)(ii)	$P = Fv$ **or** $P = Fs / t$	C1
	$v = 2.0 / 0.80$ (= 2.5 m s^{-1})	C1
	distance = 2.5 × 3.0 = 7.5 m	A1
	or	
	$P = W / t$ **or** $P = Fs / t$	(C1)
	$W = 2.0 \times 3.0$ (= 6.0 J)	(C1)
	distance = 6.0 / 0.80 = 7.5 m	(A1)
(c)	0 to 3.0 s: upward sloping straight line from the origin.	B1
	3.0 to 6.0 s: horizontal line at non-zero value of momentum with no 'step change' in momentum at 3.0 s	B1

40 – (9702/23_Summer_2023_Q1) – *Physical Quantities & Units, Kinematics*

(a)	$t = \sqrt{(2s/g)}$ $= \sqrt{[(2 \times 36)/9.81]}$	C1
	$= 2.7$ s	A1
(b)	• reaction time between hearing the splash and stopping the stop-watch • the sound (of the splash) takes time to reach the student **or** the stone hits the water at a different time to the sound being heard **or** the sound (of the splash) has to travel to the student • the student might not let go of the stone from ground level • the student might not let go of the stone and start the stop-watch at the same time • stop-watch may not be properly calibrated / has a zero error • (local value of) g is not (exactly) 9.81 (m s^{-2}) • stone given initial velocity / initial velocity not zero • stone does not fall (exactly) vertically / in a straight line *Any three points, 1 mark each*	B3
(c)	precise: results are close together / have little scatter	B1
	not accurate: the values are not close to / 50% different / (very) different from the true value	B1

41 – (9702/21_Winter_2023_Q3) – *Kinematics*

(a)	displacement	A1
(b)(i)	a = gradient **or** $a = \Delta v/(\Delta)t$ **or** $a = (v - u)/t$	C1
	e.g. $a = (0.30 - 0.12)/(0.35 - 0.15)$ $a = 0.90$ m s^{-2}	A1
(b)(ii)	$(0.25 \times 0.48) + (0.75 \times 0.12) = (0.25\,v) + (0.75 \times 0.30)$ **or** $(0.48 - 0.12) = (0.30 - v)$ **or** $(½ \times 0.25 \times 0.48^2) + (½ \times 0.75 \times 0.12^2) = (½ \times 0.25 \times v^2) + (½ \times 0.75 \times 0.30^2)$	C1
	$v = (-)0.060$ m s^{-1}	A1
	direction: to the left / from the right / opposite to (its) initial velocity / opposite to (initial / final) velocity of B	B1
(c)	sketch: horizontal line from (0, 0.48) to (0.15, 0.48)	B1
	horizontal line from (0.35, –0.06) to (0.5, –0.06)	B1
	straight line between (0.15, 0.48) and (0.35, –0.06)	B1

42 - (9702/22_Winter_2023_Q1) - *Physical Quantities & Units, Measurement Techniques, Kinematics*

(a)	only electric current **and** time underlined	B1
(b)	initial speed / velocity is zero	B1
	(non-zero magnitude of) acceleration is constant / uniform (and in a straight line)	B1
(c)(i)	• magnitude of acceleration at t = 8.0 s is less than that at t = 14.0 s	B1
	• direction of acceleration at t = 8.0 s is opposite to that at t = 14.0 s	B1
(c)(ii)	a = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / (\Delta)t$	C1
	a = e.g. (20 + 10) / 12 **or** (0 + 10) / 4 **or** (20 – 0) / (12 – 4) $a = 2.5\ \text{m s}^{-2}$	A1
(c)(iii)	displacement = [½ × (12 – 4) × 20] – [½ × 4 × 10] **or** displacement = (–10 × 12) + (½ × 2.5 × 12^2) **or** displacement = (20 × 12) – (½ × 2.5 × 12^2) **or** displacement = ½ × (20 – 10) × 12	C1
	displacement = 60 m	A1

43 - (9702/23_Winter_2023_Q2) - *Kinematics*

(a)(i)	(time / t =) 9(.0) / 9.5 = 0.95 (s)	A1
(a)(ii)	(u_V) = 9.5 tan 38° **or** 9.5 / tan 52° **or** 9.5 = u cos 38° **and** u_V = u sin 38° **or** 9.5 = u cos 38° **and** $u_V = (u^2 - 9.5^2)^{½}$	C1
	$u_V = 7.4\ \text{m s}^{-1}$	A1
(a)(iii)	$s = ut + ½at^2$ (h =) 7.4 × 0.95 – ½ × 9.81 × 0.95^2	C1
	h = 2.6 m	A1
(b)	(collision is) inelastic	B1

1 - (9702/21_Summer_2017_Q2) - *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

(a)	resultant force (in any direction) is zero
	resultant torque/moment (about any point) is zero
(b)(i)	$a = (v - u) / t$ **or** gradient **or** $\Delta v / (\Delta)t$
	e.g. $a = (8.8 - 4.6) / (7.0 - 4.0) = 1.4\ \text{m s}^{-2}$
(b)(ii)	$s = 4.6 \times 4 + [(8.8 + 4.6) / 2] \times 3$
	$= 18.4 + 20.1$ $= 39\ (38.5)$ m
(b)(iii)	$\Delta E = ½ \times 95\ [(8.8)^2 - (4.6)^2]$
	$= 3678 - 1005$ $= 2700\ (2673)$ J
(b)(iv)1.	weight = 95×9.81 (= 932 N)
	vertical tension force = 280 sin 25° **or** 280 cos 65° (=118.3 N)
	$F = 932 + 118$ $= 1100\ (1050)$ N
(b)(iv)2.	horizontal tension force = 280 cos 25° **or** 280 sin 65° (= 253.8 N)
	resultant force = 95×1.4 (= 133 N)
	$133 = 253.8 - R$ $R = 120\ (120.8)$ N

2 - (9702/23_Summer_2017_Q2) - *Kinematics, Dynamics*

(a)	(resultant) force is proportional/equal to the rate of change of momentum
(b)(i)	change in momentum $= m(v_2 - v_1)$ $= 0.84 \times (8.8 - 4.2)$
	$= 3.9\ (3.86)\ \text{kg m s}^{-1}$
(b)(ii)	$F = (3.9 / 4.0) = 0.97\ (0.965)$ N
(c)(i)	change in momentum for A: $0.84 \times (4.7 - 8.8) = -3.4\ (3.44)$ change in momentum for B: $0.73 \times (4.7 - 0) = 3.4\ (3.43)$
	change in momentum for B is equal and opposite to A
(c)(ii)	change in momentum equal (for A and B)
	force is change in momentum / time and time (of collision) is the same hence force on A and B equal and opposite as for Newton's third law
(c)(iii)	inelastic as relative speed of approach not equal to relative speed of separation

3 - (9702/22_Summer_2017_Q4) - *Dynamics*

(a)	a body/mass/object continues (at rest or) at constant/uniform velocity unless acted on by a resultant force
(b)(i)	initial momentum = final momentum $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
	$0.60 \times 100 - 0.80 \times 200 = -0.40 \times 100 + v \times 200$ $v = (-)\ 0.3(0)\ \text{m s}^{-1}$
(b)(ii)	<u>kinetic</u> energy is not conserved/is lost (but) <u>total</u> energy is conserved/constant **or** some of the (initial) <u>kinetic</u> energy is transformed into other forms of energy

4 – (9702/21_Winter_2017_Q1) – *Physical Quantities & Units, Kinematics, Dynamics*

(a)	units of F: $kg\,m\,s^{-2}$	C1
	units of ρ: $kg\,m^{-3}$ **and** units of v: $m\,s^{-1}$	C1
	units of K: $kg\,m\,s^{-2} / [kg\,m^{-3} (m\,s^{-1})^2]$ $= m^2$	A1
(b)(i)	$K\rho = 1.5 / 33^2$	C1
	$= 1.38 \times 10^{-3}$ $F_D = 1.38 \times 10^{-3} \times 25^2$ **or** $F_D / 1.5 = 25^2 / 33^2$ $F_D = 0.86\,N$	A1
(b)(ii)	$a = (1.5 - 0.86) / (1.5 / 9.81)$ **or** $a = 9.81 - [0.86 / (1.5 / 9.81)]$	C1
	$a = 4.2\,m\,s^{-2}$	A1
(c)	initial acceleration is g/9.81 ($m\,s^{-2}$)/acceleration of free fall	B1
	acceleration decreases	B1
	final acceleration is zero	B1

5 – (9702/22_Winter_2017_Q3) – *Kinematics, Dynamics, Forces, Density & Pressure*

(a)	$p = 1000 \times 9.81 \times 7.0 \times 10^{-2}$ **or** $1000 \times 9.81 \times 1.9 \times 10^{-2}$	C1
	$\Delta p = 1000 \times 9.81 \times (7.0 \times 10^{-2} - 1.9 \times 10^{-2})$ **or** 686 – 186 $= 500\,Pa$	A1
(b)	$F = pA$ **or** $(\Delta)F = \Delta p \times A$	C1
	upthrust = $500 \times (5.1 \times 10^{-2})^2 = 1.3\,N$ **or** upthrust = $(686 - 186) \times (5.1 \times 10^{-2})^2 = 1.3\,N$ **or** upthrust = $1000 \times 9.81 \times 5.1 \times 10^{-2} \times (5.1 \times 10^{-2})^2 = 1.3\,N$	A1
(c)	force = 4.0 – 1.3 $= 2.7\,N$	A1

(d)	extension/x/e = 2.7 / 30	C1
	= 0.09 (m) **or** 9 (cm)	C1
	height above surface = 9 – 7 = 2 cm	A1
(e)(i)	mass = 4.0 / 9.81	C1
	acceleration = 2.7 / (4.0 / 9.81) $= 6.6\,m\,s^{-2}$	A1
(e)(ii)	viscous force <u>increases</u> (and then becomes constant)	M1
	(weight and upthrust constant so) acceleration decreases (to zero)	A1

6 – (9702/23_Winter_2017_Q3) – *Dynamics*

(a)	sum/total momentum (of system of bodies) is constant **or** sum/total momentum before = sum/total momentum after	**M1**
	for an isolated system/no (resultant) external force	**A1**
(b)(i)	$p = mv$	**C1**
	$(4.0 \times 6.0 \times \sin\theta) - (12 \times 3.5 \times \sin 30°) = 0$ **or** $(m_A v_A \times \sin\theta) - (m_B v_B \times \sin 30°) = 0$	**M1**
	$\theta = 61°$	**A1**

(b)(ii)	shows the horizontal momentum component of ball A or of ball B as $(4.0 \times 6.0 \times \cos\theta)$ **or** $(12 \times 3.5 \times \cos 30°)$	**C1**
	$(4.0 \times 6.0 \times \cos 61°) + (12 \times 3.5 \times \cos 30°) = 4.0v$ so $v = 12\ (\text{ms}^{-1})$	**A1**
(b)(iii)	initial E_K $(= ½ \times 4.0 \times 12^2) = 290\ (288)$ (J)	**M1**
	final E_K $(= ½ \times 4.0 \times 6.0^2 + ½ \times 12 \times 3.5^2) = 150\ (145.5)$ (J)	**M1**
	(initial E_K > final E_K) so inelastic [both M1 marks required to award this mark]	**A1**

7 – (9702/21_Summer_2018_Q2) – *Dynamics, Kinematics, Work, Energy & Power*

(a)	a body continues at (rest or) constant velocity unless acted upon by a resultant force	**B1**
(b)(i)1.	from 0–2 s, distance = $½ \times 2 \times 6.8$ (= 6.8 m) **and** from 2–3 s, distance = $½ \times 1 \times 3.4$ (= 1.7 m)	**C1**
	magnitude of displacement = 5.1 m	**A1**
	direction of displacement is down(wards)	**B1**
(b)(i)2.	$(\Delta E) = mg\Delta h$ **or** $(E) = mgh$ **or** $(E) = Wh$	**C1**
	$(\Delta)E = 15 \times 5.1$ $= (–)\ 77$ J	**A1**
(b)(ii)	$a = (v - u) / t$ **or** a = gradient **or** $a = dv/dt$	**C1**
	$a = 3.4\ \text{ms}^{-2}$	**A1**
(b)(iii)	$T - W = ma$ **or** $T - mg = ma$	**C1**
	$T = 15 + (15 / 9.81) \times 3.4 = 20$ N or 20.2 N	**A1**
(b)(iv)	$E = F / A\varepsilon$ **or** $E = \sigma / \varepsilon$ and $\sigma = F / A$	**C1**
	$\varepsilon = 20 / (2.8 \times 10^{-5} \times 1.7 \times 10^{11})$	**C1**
	$= 4.2 \times 10^{-6}$	**A1**
(b)(v)	block is in equilibrium/has no resultant force	**B1**
	block could be stationary (or have constant velocity/speed) (so no, not possible to deduce)	**B1**

8 - (9702/22_Summer_2018_Q2) - *Kinematics, Dynamics*

(a)	sum/total momentum (of a system of bodies) is constant **or** sum/total momentum before = sum/total momentum after	**M1**
	for an isolated system **or** no (resultant) external force	**A1**
(b)(i)	(p =) mv **or** ($3.0M \times 7.0$) **or** ($2.0M \times 6.0$) **or** ($1.5M \times 8.0$)	**C1**
	$3.0M \times 7.0 = 2.0M \times 6.0\sin\theta + 1.5M \times 8.0\sin\theta$	**C1**
	$\theta = 61°$	**A1**
	or (vector triangle method)	
	momentum vector triangle drawn	**(C1)**
	$\theta = 61°$ (*2 marks for* ±1°, *1 mark for* ±2°)	**(A2)**
	or (use of cosine rule)	
	$p = mv$ **or** ($3.0M \times 7.0$) **or** ($2.0M \times 6.0$) **or** ($1.5M \times 8.0$)	**(C1)**
	$(21M)^2 = (12M)^2 + (12M)^2 - (2 \times 12M \times 12M \times \cos 2\theta)$	**(C1)**
	$\theta = 61°$	**(A1)**
(b)(ii)	(E =) $\frac{1}{2}mv^2$	**C1**
	ratio = $(\frac{1}{2} \times 2.0M \times 6.0^2) / (\frac{1}{2} \times 1.5M \times 8.0^2)$ = 0.75	**A1**

9 - (9702/21_Summer_2018_Q3) - *Kinematics, Dynamics*

(a)	mass is the property (of a body/object) resisting changes in motion **or** mass is the quantity of matter (in a body)	**B1**
(b)(i)	force on A (by B) equal and opposite to force on B (by A) **or** both A and B exert equal and opposite forces on each other	**B1**
	force is rate of change of momentum and time (of contact) is same	**B1**
(b)(ii)	$p = mv$ **or** $3M \times 0.40$ **or** $M \times 0.25$ **or** $3M \times 0.2$ **or** Mv	**C1**
	$(3M \times 0.40) - (M \times 0.25) = (3M \times 0.2) + Mv$	**C1**
	$v = (3 \times 0.40) - 0.25 - (3 \times 0.2)$ $= 0.35\,\text{ms}^{-1}$	**A1**
(b)(iii)	1. relative speed of approach = 0.40 + 0.25 $= 0.65\,\text{ms}^{-1}$	**A1**
	2. relative speed of separation = 0.35 – 0.20 $= 0.15\,\text{ms}^{-1}$	**A1**
(b)(iv)	(relative) speed of separation not equal to/less than (relative) speed of approach **or** answers (to (b)(iii) are) not equal **and** so inelastic collision	**B1**

10 - (9702/22_Summer_2018_Q3) - *Kinematics, Dynamics, Waves*

(a)	time = 12 s	**A1**
(b)	distance (up slope) = ½ × 12 × 18 (= 108)	**C1**
	distance (down slope) = ½ × 12 × 6 (= 36)	**C1**
	displacement from A = 108 – 36 = 72 m	**A1**
(c)	$v = u + at$ **or** a = gradient **or** $a = \Delta v / (\Delta)t$	**C1**
	$a = 6 / 12 = 0.50$ (ms^{-2}) *(other points from the line may be used)*	**A1**
	or	
	$v^2 = u^2 + 2as$ **and** $u = 0$ **or** $v^2 = 2as$	**(C1)**
	$a = 6.0^2 / (2 \times 36) = 0.50$ (ms^{-2})	**(A1)**
	or	
	$s = ut + ½at^2$ **and** $u = 0$ **or** $s = ½at^2$	**(C1)**
	$a = 2 \times 36 / 12^2 = 0.50$ (ms^{-2})	**(A1)**
	or	
	$s = vt - ½at^2$	**(C1)**
	$a = 2 \times (6 \times 12 - 36) / 12^2 = 0.50$ (ms^{-2})	**(A1)**

(d)(i)	$F = 70 \times 0.50$ (= 35)	**C1**
	frictional force = 80 – 35 = 45 N	**A1**
(d)(ii)	$\sin\theta = 80 / (70 \times 9.81)$	**C1**
	$\theta = 6.7°$	**A1**
(e)(i)	$f_0 = (900 \times 340) / (340 + 12)$	**C1**
	= 870 Hz	**A1**
(e)(ii)	speed/velocity (of sledge) decreases and (so) frequency increases	**B1**

11 – (9702/23_Summer_2018_Q3) – *Kinematics, Dynamics, Work, Energy & Power*

(a)	$v = u + at$ $v = 9.6 - (9.81 \times 0.37) = 6.0\,\text{m s}^{-1}$	A1
(b)	$s = ½ \times (9.6 + 6.0) \times 0.37$ **or** $6.0^2 = 9.6^2 - (2 \times 9.81 \times s)$ **or** $s = (9.6 \times 0.37) - (½ \times 9.81 \times 0.37^2)$ **or** $s = (6.0 \times 0.37) + (½ \times 9.81 \times 0.37^2)$	C1
	$s = 2.9\,\text{m}$	A1
(c)(i)	$(\Delta)E = mg(\Delta)h$	C1
	$\Delta E = 0.056 \times 9.81 \times 2.9$ $= 1.6\,\text{J}$	A1
(c)(ii)	$E = ½mv^2$	C1
	$\Delta E = ½ \times 0.056 \times (6.0^2 - 3.8^2)$ $= 0.60\,\text{J}$	A1
(d)	force on ball (by ceiling) <u>equal</u> to force on ceiling (by ball)	M1
	and opposite (in direction)	A1
(e)	$(p =)\ mv$ **or** 0.056×6.0 **or** 0.056×3.8	C1
	change in momentum $= 0.056 \times (6.0 + 3.8)$ $= 0.55\,\text{N s}$	A1

(f)	resultant force = 0.55 / 0.085 (= 6.47 N)	C1
	force by ceiling $= 6.47 - (0.056 \times 9.81)$ $= 5.9\,\text{N}$	A1

12 – (9702/22_Summer_2018_Q5) – *Forces, Density & Pressure, Dynamics, Work, Energy & Power*

(a)	$\rho = m / V$	C1
	$= (560 / 9.81) / (1.2 \times 0.018)$ $= 2600\,\text{kg m}^{-3}$	A1
(b)	$(\Delta)p = 940 \times 9.81 \times 1.2$	C1
	(upthrust =) $940 \times 9.81 \times 1.2 \times 0.018 = 200\,\text{N}$	A1
(c)(i)	tension $= 560 - 200$ $= 360\,\text{N}$	A1
(c)(ii)	$P = Fv$	C1
	$= 360 \times 0.020$ $= 7.2\,\text{W}$	A1
(d)(i)	upthrust decreases	B1
	tension (in wire) increases	M1
	power (output of motor) increases	A1
(d)(ii)	there is work done (on the cylinder) by the upthrust **or** GPE of oil decreases (as it fills the space left by cylinder and so total energy is conserved)	B1

13 – (9702/21_Winter_2018_Q2) – *Dynamics*

(a)	(p =) mv **or** 4.0×45 **or** 2.0×85 **or** $89v$	C1
	$(4.0 \times 45) - (2.0 \times 85) = 89\,v$ $v = 0.11\,\text{ms}^{-1}$	A1
(b)(i)	**1.** speed of approach = $47\,\text{ms}^{-1}$ **and** **2.** speed of separation = 0	A1
(b)(ii)	speed of separation less than/not equal to speed of approach **and** so inelastic collision	A1
(c)	force is equal to rate of change of momentum	B1
	force on ball (by block) equal and opposite to force on block (by ball) so rates of change of momentum are equal and opposite	B1
	or	
	force on ball (by block) equal and opposite to force on block (by ball)	(B1)
	force is equal to rate of change of momentum so rates of change of momentum are equal and opposite	(B1)

14 – (9702/23_Winter_2018_Q2) – *Dynamics, Work, Energy & Power*

(a)	energy (of a mass/body/object) due to motion/speed/velocity	B1
(b)(i)	$E = ½mv^2$	C1
	$480 = ½ \times m \times 80^2$ so $m = 0.15\,\text{kg}$	A1
(b)(ii)	**1.** $E = mgh$ **or** $\Delta E = mg\Delta h$	C1
	$= 0.15 \times 9.81 \times 210$ $= 310\,\text{J}$	A1
	2. work done $= 480 - 310$ $= 170\,\text{J}$	A1
(b)(iii)	work done = Fs	C1
	force $= 170/210$ $= 0.81\,\text{N}$	A1
(b)(iv)	curved line from positive value on v-axis to (T, 0)	M1
	magnitude of gradient decreases	A1
(b)(v)	as shell rises force decreases and as shell falls force increases	B1
	as shell rises force is downward and as shell falls force is upward	B1
	or	
	as shell rises the force decreases and is downward	(B1)
	as shell falls the force increases and is upward	(B1)

15 - (9702/22_Winter_2018_Q3) - *Dynamics*

(a)	sum/total momentum (of a system of bodies) is constant **or** sum/total momentum before = sum/total momentum after	**M1**
	for an isolated system **or** no (resultant) external force	**A1**
(b)(i)	$m = \rho V$	**C1**
	$= 1.3 \times \pi \times 0.045^2 \times 1.8 \times 2.0 = 0.030$ (kg)	**A1**
(b)(ii)	**1.** $(\Delta)p = (\Delta)mv$	**C1**
	$= 0.030 \times 1.8$ $= 0.054$ N s	**A1**
	2. $F = 0.054/2.0$ **or** $0.030 \times 1.8/2.0$ $= 0.027$ N	**A1**
(b)(iii)	force on air (by propeller) equal to force on propeller (by air)	**M1**
	and opposite (in direction)	**A1**
(b)(iv)	resultant force $= 0.20 \times 0.075$ (= 0.015 N) frictional force $= 0.027 - 0.015$	**C1**
	$= 0.012$ N	**A1**

16 - (9702/23_Winter_2018_Q3) - *Dynamics*

(a)	(resultant) force proportional/equal to rate of change of momentum	**B1**
(b)(i)	$\rho = m / V$	**C1**
	$V = \pi \times (7.5 \times 10^{-3})^2 \times 13 \times 0.2$ (= 4.59×10^{-4} m^3) $m = \pi \times (7.5 \times 10^{-3})^2 \times 13 \times 0.2 \times 1000 = 0.46$ kg	**A1**
(b)(ii)	**1.** $(\Delta)p = (\Delta m)v$	**C1**
	$(\Delta)p = 0.46 \times 13$ $= 6.0$ N s	**A1**
	2. $F = 6.0/0.20$ $= 30$ N	**A1**
(b)(iii)	force on water (by rocket/nozzle) equal to force on rocket/nozzle (by water)	**M1**
	in the opposite direction	**A1**
(b)(iv)	**1.** mass = 0.40 + 0.70 – 0.46 = 0.64 kg	**A1**
	2. acceleration = $[30 - (0.64 \times 9.81)]/0.64$ **or** $30/0.64 - 9.81$	**C1**
	$= 37$ m s^{-2}	**A1**

17 – (9702/21_Summer_2019_Q2) – *Dynamics*

(a)	(momentum =) mass × velocity	B1
(b)(i)	time = 40 ms	A1
(b)(ii)	**1.** (the magnitude of the acceleration is) constant	B1
	2. (the magnitude of the acceleration is) zero	B1
(c)	$F = \Delta p / (\Delta)t$ **or** F = gradient	C1
	e.g. $F = 0.50 / 40 \times 10^{-3}$ $= 13$ N	A1
(d)	horizontal line from (0, 0.40) to (60, 0.40)	B1
	straight line from (60, 0.40) to (100, –0.10)	B1
	horizontal line from (100, –0.10) to (160, –0.10)	B1

18 – (9702/22_Summer_2019_Q2) – *Kinematics, Dynamics, Electric Fields*

(a)	(resultant) force proportional/equal to/is rate of change of momentum	B1
(b)(i)	distance = area under graph **or** $s = ½ (u + v) t$ $= ½ \times (9 + 13) \times 10$ **or** $s = ut + ½at^2$ $= (9 \times 10) + (½ \times 0.40 \times 10^2)$ **or** $s = vt – ½at^2$ $= (13 \times 10) – (½ \times 0.40 \times 10^2)$ **or** $v^2 = u^2 + 2as$ $13^2 = 9^2 + (2 \times 0.40 \times s)$	C1
	distance = 110 m	A1

(b)(ii)	**1.** a = gradient **or** $a = (v – u) / t$ **or** $a = \Delta v / (\Delta)t$ e.g. $a = (14 – 9) / 12.5$ **or** $(13 – 9) / 10$	C1
	$a = 0.40$ m s^{-2}	A1
	2. resultant force $= 850 \times 0.40$ $= 340$ N	A1
	3. (F =) 510 + 440 + 340 = 1300 (N)	A1
	4. $P = Fv$	C1
	$= 1300 \times 13$ $= 1.7 \times 10^4$ W	A1
(c)	$E = \sigma / \varepsilon$	C1
	$E = (F / A) / (\Delta L / L)$ **or** $E = FL / A\Delta L$	C1
	$\Delta L = (480 \times 0.48) / (3.0 \times 10^{-4} \times 2.2 \times 10^{11})$ $= 3.5 \times 10^{-6}$ m	A1
(d)	$f_o = f_s v / (v – v_s)$ $480 = f_s \times 340 / (340 – 14)$	C1
	$f_s = 460$ Hz	A1

19 – (9702/23_Summer_2019_Q3) – *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

(a)	$P = Fv$	C1
	$P = 8.9 \cos 30° \times 0.60$ $= 4.6$ W	A1
(b)	$p = F / A$	C1
	$F = 8.9 \sin 30° + (0.24 \times 9.81)$ $(= 6.80$ N$)$	C1
	$A = 6.80 / 3500$ $= 1.9 \times 10^{-3}$ m^2	A1
(c)(i)	upwards/up	B1
(c)(ii)	the Earth/planet	B1

20 – (9702/21_Winter_2019_Q2) – *Kinematics, Dynamics, Electric Fields*

(a)	the (two) plates are <u>vertical</u> (and separated)	B1
	left plate positively charged **and** right plate negatively charged/earthed **or** right plate negatively charged **and** left plate positively charged/earthed	B1
(b)	$F = Eq$	C1
	$= 1.3 \times 10^4 \times 3.7 \times 10^{-9}$ $= 4.8 \times 10^{-5}$ N	A1
(c)	$F^2 = (4.8 \times 10^{-5})^2 + (5.4 \times 10^{-5})^2$ so $F = 7.2 \times 10^{-5}$ N **or** $F = [(4.8 \times 10^{-5})^2 + (5.4 \times 10^{-5})^2]^{0.5}$ so $F = 7.2 \times 10^{-5}$ N	A1
(d)	electric force is constant (because field strength/E is constant)	B1
	weight is constant (and so resultant force constant)	B1
(e)(i)	$m = 5.4 \times 10^{-5} / 9.81$ $(= 5.5 \times 10^{-6})$	C1
	$a = 7.2 \times 10^{-5} / (5.5 \times 10^{-6})$ $= 13$ m s^{-2}	A1
(e)(ii)	$v^2 = u^2 + 2as$ $v^2 = 2 \times 13 \times 0.58$	C1
	$v = 3.9$ m s^{-1}	A1

21 – (9702/23_Winter_2019_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a)	(work done =) force × distance moved in direction of force	B1
(b)(i)	**1.** acceleration = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / t$	C1
	e.g. a = 2.4 / 3.0 = 0.80 m s^{-2}	A1
	2. tension in cable = (13.0 + 2.0) × 10^3	C1
	work done = 15 × 10^3 × (3.0 × 2.4) = 1.1 × 10^5 J	A1
(b)(ii)	power = Fv	C1
	v = 2.0 (m s^{-1})	C1
	input power = (1.6 × 10^4 × 2.0) / 0.67 = 4.8 × 10^4 W	A1
(b)(iii)	work is done against friction so (increase in) GPE is less (than work done by motor) **or** energy is lost or transferred or converted to heat/thermal energy due to friction or resistance force **or** work is done lifting the cable so GPE is less	A1

22 – (9702/21_Winter_2019_Q3) – *Waves, Dynamics*

(a)	$\rho = m / V$	C1
	$V = \pi \times (0.16 / 2)^2 \times 7.6 \times 3.0$ (= 0.458 m^3)	C1
	$m = \pi \times (0.16 / 2)^2 \times 7.6 \times 3.0 \times 1.2$ = 0.55 kg	A1
(b)(i)	Δp = 0.55 × 7.6 = 4.2 N s	A1
(b)(ii)	F = 4.2 / 3.0 **or** 0.55 × 7.6 / 3.0 = 1.4 N	A1
(c)(i)	F = 1.4 N	A1
(c)(ii)	Newton's third law (of motion)	B1
(d)	2 × 1.4 = m × 9.81 m = 0.29 kg	A1
(e)	the density of air is less at high altitude	B1
(f)	$f_o = f_s v / (v - v_s)$ = 3000 × 340 / (340 – 22)	C1
	= 3200 Hz	A1

23 – (9702/22_Winter_2019_Q3) – *Dynamics*

(a)	force on body A (by body B) is equal (in magnitude) to force on body B (by body A)	B1
	force on body A (by body B) is opposite (in direction) to force on body B (by body A)	B1
(b)(i)	$m_X \times 5v$ **or** $(m_X + m_Y) \times v$	C1
	$m_X \times 5v = (m_X + m_Y) \times v$ (so) $m_Y / m_X = 4$	A1
(b)(ii)	$(E =)\ ½mv^2$	C1
	ratio $= [½ \times (m_X + m_Y) \times v^2] / [½ \times m_X \times (5v)^2]$	C1
	$= 0.2$	A1
(b)(iii)	ratio = 1	A1
(c)(i)	**1.** (magnitude of resultant force is) zero	B1
	2. (magnitude of resultant force is) constant	B1
	(direction of resultant force is) opposite to the momentum	B1
(c)(ii)	horizontal line from (0 ms, 0 squares) ending at (20 ms, 0 squares)	B1
	straight line from (20 ms, 0 squares) ending at (40 ms, 4.0 squares [= 4.0 cm vertically])	B1
	horizontal line from (40 ms, 4.0 squares) ending at (60 ms, 4.0 squares)	B1

24 – (9702/23_Winter_2019_Q4) – *Dynamics, Deformation Of Solids*

(a)(i)	$p = mv$	C1
	$= 0.2(00) \times 6.(00) \times \sin 60(.0)°$ **or** $0.2(00) \times 6.(00) \times \cos 30(.0)°$ $= 1.04\ \text{kg m s}^{-1}$	A1
(a)(ii)	$0.300 \times v_x \times \sin 60.0° = 1.04$ $v_x = 4.00\ \text{m s}^{-1}$	A1
(a)(iii)	$0.30 \times 4.0 \times \cos 60°$ **or** $0.20 \times 6.0 \times \cos 60°$ **or** $(0.30 + 0.20)v$ **or** $0.50v$	C1
	$0.30 \times 4.0 \times \cos 60° + 0.20 \times 6.0 \times \cos 60° = (0.30 + 0.20)v$ **or** $0.50v$ so $v = 2.4\ \text{m s}^{-1}$	A1
(b)(i)	$E = ½mv^2$	C1
	$½ \times 0.50 \times 2.4^2 = ½ \times 72 \times x^2$	C1
	$x = 0.20\ \text{m}$	A1
(b)(ii)	**1.** straight line from the origin sloping upwards	B1
	2. line drawn from a positive value of E_k at $x = 0$ to a positive value of x at $E_k = 0$	M1
	line has an increasing downwards slope	A1

25 – (9702/21_Summer_2020_Q2) – *Kinematics, Dynamics*

(a)	(resultant) force proportional to rate of change of momentum	B1
(b)(i)	arrow drawn vertically downwards from point X	B1
(b)(ii)	$s = ut + ½at^2$ $h = ½ \times 9.81 \times 0.81^2$	C1
	$= 3.2$ m	A1
(b)(iii)	$d = 5.4 \times 0.81$ $= 4.4$ m	A1
(c)(i)	downward pointing arrow labelled weight	B1
	upward pointing arrow labelled air resistance	B1
(c)(ii)	air resistance increases	B1
	weight constant **or** resultant force decreases	B1
	(so) acceleration decreases	B1
(c)(iii)	gravitational potential energy to thermal/internal energy	B1

26 – (9702/22_Summer_2020_Q2) – *Kinematics, Dynamics*

(a)(i)	area = $ut + ½(v - u)t$ **or** area = $vt - ½(v - u)t$ **or** area = $½(u + v)t$	A1
(a)(ii)	displacement	A1
(b)(i)	$u = 15 \sin 60°$ (= 13 m s^{-1})	C1
	$t = 15 \sin 60° / 9.81$	C1
	$= 1.3$ s	A1
(b)(ii)	the force in the horizontal direction is zero	B1
(b)(iii)	(velocity =) $15 \cos 60° = 7.5$ (m s^{-1}) **or** (velocity =) $15 \sin 30° = 7.5$ (m s^{-1})	A1
(c)(i)	$p = mv$ **or** 0.40×7.5 **or** 0.40×4.3	C1
	$\Delta p = 0.40\ (7.5 + 4.3)$ $= 4.7$ kg m s^{-1}	A1
(c)(ii)	force = $4.7 / 0.12$ **or** $0.40 \times [(7.5 + 4.3) / 0.12]$ $= 39$ N	A1

27 – (9702/23_Summer_2020_Q2) – *Kinematics, Dynamics*

(a)	a body continues at (rest or) constant velocity unless acted upon by a resultant force	B1
(b)(i)	distance = [½ × (2.0 + 4.4) × 3.0] + [4.4 × 2.0]	C1
	= 9.6 + 8.8 = 18 m	A1
(b)(ii)	$a = (v - u) / t$ **or** gradient **or** $\Delta v / (\Delta)t$	C1
	e.g. $a = (4.4 - 2.0) / 3.0 = 0.80\ \text{m s}^{-2}$	A1
(b)(iii)	**1.** force = 240 cos 28° **or** 240 sin 62° = 210 N	A1
	2. resultant force = 89 × 0.80 (= 71.2 N)	C1
	R = 210 – 71 = 140 N	A1
(b)(iv)	$T \sin 45° = mg$	C1
	T = (89 × 9.81) / sin 45° = 1200 N	A1

28 – (9702/22_Winter_2020_Q2) – *Kinematics, Dynamics, Forces, Density & Pressure*

(a)(i)	$(\Delta)p = \rho g(\Delta)h$ $520 = 1000 \times 9.81 \times h$	C1
	h = 0.053 m	A1
(a)(ii)	(upthrust =) $(\Delta)p \times A$ $= (\Delta)p \times \pi(d / 2)^2$ **or** $(\Delta)p \times \pi r^2$	C1
	$= 520 \times \pi(0.031 / 2)^2 = 0.39$ (N)	A1
(a)(iii)	$T = 0.84 - 0.39$ = 0.45 N	A1
(b)(i)	$a = (v - u) / t$ **or** $(\Delta)v / (\Delta)t$ **or** gradient	C1
	= e.g. $8.0 \times 10^{-2} / 2.0$ $= 4.0 \times 10^{-2}\ \text{m s}^{-2}$	A1
(b)(ii)	distance = (½ × 2.5 × 0.10) + (½ × 1.5 × 0.10) **or** (½ × 4.0 × 0.10) (= 0.20 (m))	C1
	depth = 0.32 – 0.20 = 0.12 m	A1
(c)(i)	viscous (force)	B1
(c)(ii)	viscous force increases (with speed/time/depth)	B1
	(so) acceleration decreases	B1

29 - (9702/21_Winter_2020_Q3) - *Dynamics*

(a)	(force =) rate of change of momentum	B1
(b)(i)	$E = ½mv^2$ **or** $½ \times 0.062 \times 3.8^2$ **or** $½ \times 0.062 \times 1.7^2$	C1
	loss of KE $= ½ \times 0.062 \times (3.8^2 - 1.7^2)$ $= 0.36$ J	A1
(b)(ii)	$p = mv$ **or** 0.062×3.8 **or** 0.062×1.7	C1
	change in momentum $= 0.062 \times (1.7 + 3.8)$ $= 0.34$ N s	A1
(b)(iii)	(average resultant force =) $0.34 / 0.081 = 4.2$ (N) **or** (average resultant force =) $0.062 \times (1.7 + 3.8) / 0.081 = 4.2$ (N)	A1
(b)(iv)	**1.** average force $= 4.2 + (0.062 \times 9.81)$ $= 4.8$ N	A1
	2. average force = 4.8 N	A1

30 - (9702/23_Winter_2020_Q3) - *Kinematics, Dynamics*

(a)	$s = ½at^2$	C1
	$57 = ½ \times 9.81 \times t^2$ **and** $t = 3.4$ (s)	A1
(b)	horizontal distance $= 41 \times 3.4$ $= 140$ m	A1
(c)	$(\text{displacement})^2 = 57^2 + 140^2$	C1
	displacement $= (57^2 + 140^2)^{0.5}$ $= 150$ m	A1
(d)	straight line from the origin with positive gradient	B1
(e)	$(1480 - m) \times 0.340 = m \times 41.0$	C1
	$m = 12.2$ kg	A1
	or	
	$m_c 0.34 = m_b 41$ **and** $m_c + m_b = 1480$	(C1)
	$m_c = (41 / 0.34)m_b$ $(41 / 0.34)m_b + m_b = 1480$ $m_b = 12.2$ kg	(A1)
(f)	acceleration (of free fall) is unchanged/is not dependent on mass	M1
	(so) no change (to the graph)	A1

31 – (9702/22_Summer_2021_Q2) – *Kinematics, Dynamics*

(a)	$v^2 = u^2 + 2as$ $u^2 = 8.7^2 - (2 \times 9.81 \times 1.5)$	C1
	$u = 6.8\ \text{m s}^{-1}$	A1
(b)	(magnitude of) force on ball (by ground) equal to force on ground (by ball)	B1
	(direction of) force on ball (by ground) opposite to force on ground (by ball)	B1
(c)(i)	(p =) 0.059×8.7 **or** 0.059×5.4	C1
	change in momentum = 0.059 (8.7 + 5.4) = 0.83 N s	A1
(c)(ii)	resultant force = 0.83 / 0.091 **or** 0.059 [(8.7 + 5.4) / 0.091] = 9.1 N	A1
(c)(iii)	(W =) 0.059×9.81	C1
	(W =) 0.58 (N) force = 9.1 + 0.58 = 9.7 N	A1
(d)	straight line with a positive gradient and starting from a non-zero value of speed at $t = 0$ and ending when $t = T$	B1
(e)	air resistance increases	B1
	resultant force/acceleration decreases so gradient (of curve) decreases	B1

32 – (9702/21_Summer_2021_Q3) – *Dynamics, Forces, Density & Pressure*

(a)	solid straight line drawn between centre of sphere at X and at Y	B1
(b)	$p = mv$ **or** $0.72 = mv$	C1
	$E = ½mv^2$ **or** $0.86 = ½mv^2$	C1
	(m =) $0.72^2 / (2 \times 0.86) = 0.30$ (kg) **or** $v = 2E_K / p$ $v = (0.86 \times 2) / 0.72 = 2.4$ (to 2 s.f.) $m = 0.72 / 2.4 = 0.30$ (kg)	A1
(c)	$(\Delta)E = mg(\Delta)h$	C1
	$h = 0.86 / (0.30 \times 9.81)$ = 0.29 m	A1
(d)	$\cos\theta = (0.93 - 0.29) / 0.93$ so $\theta = 47°$	A1
(e)	moment = $(0.30 \times 9.81) \times 0.93 \times (\sin 47°$ **or** $\cos 43°)$ **or** moment = $(0.30 \times 9.81) \times [0.93^2 - (0.93 - 0.29)^2]^{0.5}$	C1
	= 2.0 N m	A1

(f)	there is a <u>resultant</u> force (acting on sphere) **or** there is a <u>resultant</u> moment (about P acting on pendulum) (so) not in equilibrium	B1

33 – (9702/21_Summer_2022_Q2) – *Dynamics*

(a)	point where (all) the weight (of the object) is taken to act	B1
(b)(i)	moments about P are: ($F \times 1.10$), (44.0×0.60) and (3.0×2.90) *1 mark for any one correct moment and 2 marks for two correct moments*	C2
	($F \times 1.10$) = (44.0×0.60) + (3.0×2.90) F = 32 N	A1
(b)(ii)	force = 32 + 44 + 3 = 79 N	A1
(c)(i)	($F = \rho g V$) $V = 2.5 / (1100 \times 9.81)$ ($= 2.32 \times 10^{-4}$)	C1
	$V = (4/3)\pi r^3$	C1
	$r = [(3 \times 2.32 \times 10^{-4}) / 4\pi]^{1/3}$ r = 0.038 m	A1
(c)(ii)	resultant moment = 2.5×2.9 = 7.3 N m **or** resultant moment = $F \times 1.1 - (44 \times 0.6 + 0.5 \times 2.9)$ = 7.3 N m (allow 7.2 N m or 7.4 N m from rounded values of F)	A1
	direction: anticlockwise	A1

34 – (9702/22_Summer_2022_Q4) – *Dynamics*

(a)	sum/total momentum before = sum/total momentum after **or** sum/total momentum (of a system of objects) is constant	M1
	if no (resultant) external force/for a closed system	A1
(b)(i)	($3.0 \times 4.0 \times \cos\theta$) **or** ($2.5 \times 4.8 \times \cos\theta$) **or** ($5.5 \times 3.7$)	C1
	($3.0 \times 4.0 \times \cos\theta$) + ($2.5 \times 4.8 \times \cos\theta$) = ($5.5 \times 3.7$)	C1
	$\theta = 32°$	A1
(b)(ii)	(initial $E_K = \frac{1}{2} \times 3.0 \times 4.0^2 + \frac{1}{2} \times 2.5 \times 4.8^2$ =) 53 (J) **or** (final $E_K = \frac{1}{2} \times 5.5 \times 3.7^2$ =) 38 (J)	C1
	values of initial E_K and final E_K both correct **and** inelastic stated	A1

35 - (9702/23_Winter_2022_Q2) - *Dynamics*

(a)(i)	(e.g. a =) [16.5 – 0] / [0.30 – 0] = 55 (m s^{-2})	A1
(a)(ii)	(F =) $T - W$	A1
(a)(iii)	$ma = T - mg$ m = 16 / (55 + 9.81)	C1
	m = 0.25 kg	A1
(b)(i)	$s = ut + ½at^2$ **or** $v^2 = u^2 + 2as$ **or** $s = vt - ½at^2$ **or** $s = ½(u + v)t$ **or** s = area under graph $s = ½ \times 55 \times 0.30^2$ **or** $s = 16.5^2 / (2 \times 55)$ **or** $s = 16.5 \times 0.30 - ½ \times 55 \times 0.30^2$ **or** $s = ½ \times 16.5 \times 0.30$	C1
	s = 2.5 m	A1
(b)(ii)	u = 16.5 (m s^{-1})	C1
	$v^2 = u^2 + 2as$ $v^2 = 16.5^2 + 2 \times 9.81 \times 2.5$	C1
	v = 18 m s^{-1}	A1

36 - (9702/21_Summer_2023_Q2) - *Kinematics, Dynamics, Work, Energy & Power*

(a)(i)	(component =) 4.8 sin 30° = 2.4 (N)	A1
(a)(ii)	(8.2 × 0.50) **or** (W × 0.60) **or** (0.30 × 0.80) **or** (2.4 × 1.2)	C1
	(8.2 × 0.50) = (W × 0.60) + (0.30 × 0.80) + (2.4 × 1.2)	C1
	W = 1.6 N	A1
(a)(iii)	force = 4.8 cos 30° = 4.2 N	A1
(b)	$E = ½Fx$	C1
	0.32 = ½ × 8.2 × x x = 0.078 m	A1

(c)(i)	$((\Delta)E) = mg(\Delta)h$ **or** $W(\Delta)h$	C1
	$= 0.30 \times 0.090$ $= 0.027$ J	A1
(c)(ii)	$E = ½mv^2$	C1
	$E = 0.044 - 0.027$ (= 0.017)	C1
	$v^2 = (2 \times 0.017) / (0.30 / 9.81)$ (where v = speed at A) $v = 1.1$ m s^{-1}	A1
	or	
	$E = ½mv^2$	(C1)
	$0.044 = ½ \times (0.30 / 9.81) \times v^2$ (where v = speed at B) ($v^2 = 2.88$) $v^2 = u^2 + 2as$ (where u = speed at A) $2.88 = u^2 + 2 \times 9.81 \times 0.090$	(C1)
	$u = 1.1$ m s^{-1}	(A1)
(c)(iii)	(gravitational / resultant) force / weight is vertical	B1
(c)(iv)	straight line with positive gradient starting from non-zero value of v_Y at time t_A to a time t_B	B1

37 – (9702/21_Summer_2023_Q3) – *Dynamics, Forces, Density & Pressure*

(a)	(resultant) force (on an object) is proportional to / equal to the rate of change of momentum	B1
(b)(i)	resultant force = e.g. 6.0 / 4.0 = 1.5 N	A1
(b)(ii)	force X = 1.5 + 2.0 = 3.5 N	A1
(c)	from t = 0 to t = 4.0 s: horizontal line at any non-zero value of X	B1
	from t = 0 to t = 4.0 s: horizontal line at X = 3.5 N	B1
	from t = 4.0 s to t = 6.0 s: horizontal line at X = 2.0 N	B1

38 – (9702/22_Summer_2023_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a)	the point where (all) the weight (of the object) is taken to act	B1
(b)(i)	(54×0.45) **or** (2.4×0.95) **or** $(T \sin 30° \times 1.3)$	C1
	$(54 \times 0.45) = (2.4 \times 0.95) + (T \sin 30° \times 1.3)$	C1
	$T = 34$ N	A1
(b)(ii)	resultant moment = $(54 \times 0.45) - (2.4 \times 0.95)$ **or** $(34 \sin 30° \times 1.3)$ = 22 N m	A1
(c)(i)	$(\Delta)E = mg(\Delta)h$ **or** $W(\Delta)h$	C1
	$= 2.4 \times 1.8$ $= 4.3$ J	A1

(c)(ii)	$E = \frac{1}{2}mv^2$	C1
	$= \frac{1}{2} \times (2.4 / 9.81) \times 3.4^2$ $= 1.4$ J (at X)	C1
	kinetic energy at Y $= 4.3 + 1.4$ $= 5.7$ J	A1
	or	
	$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 + mg(\Delta)h$	(C1)
	$v^2 = 3.4^2 + 2 \times 9.81 \times 1.8$ $v^2 = 46.9$ so $v = 6.85$ (m s^{-1}) KE $= \frac{1}{2} \times (2.4 / 9.81) \times 6.85^2$	(C1)
	$= 5.7$ J	(A1)
(c)(iii)	no variation **or** acceleration is (always) vertically downwards	B1
(c)(iv)	horizontal straight line at a non-zero value of velocity	B1

39 – (9702/22_Summer_2023_Q3) – *Dynamics, Kinematics*

(a)(i)	rate of change of momentum	B1
(a)(ii)	change in momentum = (1.4 – 0.80) × 3.0	C1
	= 1.8 kg m s^{-1}	A1
(b)(i)	resultant force (on block) is zero	B1
	(so) velocity is constant	B1
(b)(ii)	$P = Fv$ **or** $P = Fs / t$	C1
	$v = 2.0 / 0.80$ (= 2.5 m s^{-1})	C1
	distance = 2.5 × 3.0 = 7.5 m	A1
	or	
	$P = W / t$ **or** $P = Fs / t$	(C1)
	$W = 2.0 \times 3.0$ (= 6.0 J)	(C1)
	distance = 6.0 / 0.80 = 7.5 m	(A1)
(c)	0 to 3.0 s: upward sloping straight line from the origin.	B1
	3.0 to 6.0 s: horizontal line at non-zero value of momentum with no 'step change' in momentum at 3.0 s	B1

40 – (9702/22_Summer_2023_Q4) – *Dynamics, Work, Energy & Power*

(a)	Hooke's (law)	B1
(b)	$k = F / x$ **or** k = gradient	C1
	= e.g. 12.0 / (0.240 – 0.08) = 75 N m^{-1}	A1
(c)	$E = \frac{1}{2}Fx$ **or** $E = \frac{1}{2}kx^2$ **or** E = area under graph	C1
	$E = \frac{1}{2} \times 6.0 \times 0.080$ **or** $\frac{1}{2} \times 75 \times 0.08^2$ = 0.24 J	A1

41 – (9702/23_Summer_2023_Q3) – *Dynamics*

(a)	sum / total momentum before = sum / total momentum after **or** sum / total momentum (of a system of objects) is constant	M1
	if no (resultant) external force / for an isolated system	A1
(b)(i)	$3m \times 4 = m \times v \sin\theta$ ($v \sin\theta = 12$)	C1
	$2m \times 6 = m \times v \cos\theta$ ($v \cos\theta = 12$)	C1
	therefore $\sin\theta = \cos\theta$ **or** $\tan\theta = 1$ $\theta = 45°$	A1
(b)(ii)	$mv \times \cos 45° = 12m$ **or** $mv \times \sin 45° = 12m$ **or** $(mv)^2 = (3m \times 4)^2 + (2m \times 6)^2$	C1
	$v = 17$ m s^{-1}	A1
(c)(i)	(chemical energy) = 0.0050 × 700 = 3.5 (J) **or** (chemical energy) = 5.0 × 0.700 = 3.5 (J)	A1

(c)(ii)	$E = ½mv^2$	C1
	total $E = (0.5 \times 3m \times 4^2) + (0.5 \times 2m \times 6^2) + (0.5 \times m \times 17^2)$	C1
	$3.5 = 204m$ $m = 0.017$ kg	A1

42 – (9702/23_Summer_2023_Q6) – *Dynamics, Forces, Density & Pressure*

(a)	(Young modulus =) stress / strain	B1
(b)(i)	unstretched length = 1.9980 m	A1
(b)(ii)	stress $= F / A$	C1
	$= 30 / 9.5 \times 10^{-7}$ $= 3.2 \times 10^7$ Pa	A1
	strain = 0.0050 / 1.9980 $= 2.5 \times 10^{-3}$	A1

43 – (9702/21_Winter_2023_Q2) – *Work, Energy & Power, Dynamics*

(a)(i)	arrow upwards (↑) **and** labelled upthrust / U arrow downwards (↓) **and** labelled weight / W / mg arrow downwards (↓) **and** labelled tension / T *1 mark: One or two correctly labelled arrows* *2 marks: Three correctly labelled arrows*	B2
(a)(ii)	$U = T + W$ **or** upthrust = tension + weight	C1
	$\rho Vg = T + W$ $V = [(4.00 \times 10^2) + (3.39 \times 10^4)] / (1.23 \times 9.81)$	C1
	$V = 2.84 \times 10^3\ m^3$	A1
(a)(iii)	$m = W / g$ **or** $a = F / m$	C1
	$a = (4.00 \times 10^2) / [(3.39 \times 10^4) / 9.81)]$	C1
	$a = 0.12\ m\ s^{-2}$	A1
(b)	there is air resistance (which increases with speed)	B1
	(average) resultant force is less (than weight)	B1
	(average) acceleration is less (than g / 9.81, so speed is less than 100 m s^{-1})	B1
(c)(i)	(extension =) $2.5 \times 2.4 \times 10^{-5} = 6.0 \times 10^{-5}$ (m)	A1

(c)(ii)	$E_{(P)} = ½ Fx$ **or** $E_{(P)} = ½ kx^2$ **and** $F = kx$	C1
	$E_{(P)} = ½ \times 4.00 \times 10^2 \times 6.0 \times 10^{-5}$ **or** $E_{(P)} = ½ \times 6.7 \times 10^6 \times (6.0 \times 10^{-5})^2$ $E_{(P)} = 0.012$ J	A1
(c)(iii)	longer extension **or** smaller spring constant	M1
	elastic potential energy is greater	A1

44 – (9702/22_Winter_2023_Q2) – *Dynamics*

(a)	$65 = \rho gV$ **or** $65 = mg$ **and** $m = \rho V$	C1
	$\rho = 65 / (9.81 \times 7.5)$ $= 0.88\ kg\ m^{-3}$	A1
(b)(i)	acceleration = 9.8 m s^{-2}	A1
(b)(ii)	air resistance (acting on sphere) increases	B1
	resultant force (on sphere) decreases	B1
	(magnitude of) acceleration decreases	B1
(c)	$F = ma$ $= 4.0 \times 1.9$ (= 7.6 N)	C1
	resistive force = $(4.0 \times 9.81) - (4.0 \times 1.9)$ = 32 N	A1

45 - (9702/22_Winter_2023_Q4) - *Dynamics*

(a)(i)	component of momentum = 0.25 × 3.7 × sin 27°	C1
	= 0.42 N s	A1
(a)(ii)	$m_{(Z)}$ × 5.5 × sin 44° = 0.42 **or** $m_{(Z)}$ × 5.5 × sin 44° = 0.25 × 3.7 × sin 27° m_Z = 0.11 kg	A1
(a)(iii)	magnitudes: equal	B1
	directions: opposite	B1
(b)	4 + 6 = 2 + v v = 8 m s^{-1}	A1

46 - (9702/23_Winter_2023_Q3) - *Dynamics, Work, Energy & Power*

(a)	resultant force (in any direction) is zero	B1
	resultant moment / torque (about any point) is zero	B1
(b)(i)	$F = \rho V g$ V = 93 000 / (1.2 × 9.81) = 7900 m^3	A1
(b)(ii)	weight = 93 000 + 3(.0) × 10^3	C1
	m = (93 000 + 3.0 × 10^3) / 9.81 = 9800 kg	A1
(c)(i)	$(\Delta p) = F(\Delta)t$ **or** $F = \Delta p / (\Delta)t$ **or** F = rate of change of momentum **or** $F = m(v - u) / t$	C1
	Δp = 2800 × 0.50 = 1400 kg m s^{-1}	A1
(c)(ii)	$(\Delta p =)\ mv$	C1
	v = 1400 / 64 = 22 m s^{-1}	A1

(c)(iii)	$E_K = ½mv^2$	C1
	= ½ × 64 × 22^2 = 15 000 J	A1
	or	
	$E_K = p^2 / 2m$	(C1)
	= 1400^2 / (2 × 64) = 15 000 J	(A1)

1 - (9702/21_Summer_2017_Q2) - *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

(a)	resultant force (in any direction) is zero
	resultant torque/moment (about any point) is zero
(b)(i)	$a = (v - u) / t$ **or** gradient **or** $\Delta v / (\Delta)t$
	e.g. $a = (8.8 - 4.6) / (7.0 - 4.0) = 1.4\ \text{m s}^{-2}$
(b)(ii)	$s = 4.6 \times 4 + [(8.8 + 4.6) / 2] \times 3$
	$= 18.4 + 20.1$ $= 39\ (38.5)$ m
(b)(iii)	$\Delta E = ½ \times 95\ [(8.8)^2 - (4.6)^2]$
	$= 3678 - 1005$ $= 2700\ (2673)$ J
(b)(iv)1.	weight = 95×9.81 (= 932 N)
	vertical tension force = 280 sin 25° **or** 280 cos 65° (=118.3 N)
	$F = 932 + 118$ $= 1100\ (1050)$ N
(b)(iv)2.	horizontal tension force = 280 cos 25° **or** 280 sin 65° (= 253.8 N)
	resultant force = 95×1.4 (= 133 N)
	$133 = 253.8 - R$ $R = 120\ (120.8)$ N

2 - (9702/21_Summer_2017_Q3) - *Forces, Density & Pressure*

(a)	$\rho = m / V$
	$V = \pi d^2 L / 4$ **or** $\pi r^2 L$
	weight = $2.7 \times 10^3 \times \pi\ (1.2 \times 10^{-2})^2 \times 5.0 \times 10^{-2} \times 9.81 = 0.60$ N
(b)(i)	the point from where (all) the weight (of a body) seems to act
(b)(ii)	$W \times 12$
	$(0.25 \times 8) + (0.6 \times 38)$
	$W = (2 + 22.8) / 12$ $= 2.1\ (2.07)$ N
(c)(i)	pressure changes with depth (in water) **or** pressure on bottom (of cylinder) different from pressure on top
	pressure on bottom of cylinder <u>greater than</u> pressure on top **or** force (up) on bottom of cylinder <u>greater than</u> force (down) on top
(c)(ii)	anticlockwise moment reduced and reducing the weight of X reduces clockwise moment **or** anticlockwise moment reduced so clockwise moment now greater than (total) anticlockwise moment

3 - (9702/22_Winter_2017_Q2) - *Forces, Density & Pressure*

(a)	force × perpendicular distance (of line of action of force) to/from a point	B1
(b)(i)	$2.4r$ or $(1.2 \times 2r)$ or $(1.2r + 1.2r)$	A1
(b)(ii)	(anticlockwise moment =) $6.0 \times r/2 \times \sin\theta$	C1
	$6.0 \times r/2 \times \sin\theta = 2.4r$ $\theta = 53°$	A1
(b)(iii)	6.0 N	A1

4 - (9702/23_Winter_2017_Q2) - *Forces, Density & Pressure, Work, Energy & Power*

(a)	$\rho = m / V$ or $\rho = m / Ah$	B1
	$p = F / A$ or $p = W / A$	B1
	$p = [\rho Ahg] / A$ or $p = [\rho Vg] / [V / h]$ (so) $p = \rho gh$	A1

(b)(i)	1. weight/gravitational (force) upthrust (force)/buoyancy (force) drag/viscous/frictional (force)/fluid resistance/resistance	B1
	2. weight = upthrust + viscous (force)	B1
(b)(ii)	• decrease in (gravitational) potential energy (of sphere) due to decrease in height (since $E_p = mgh$) • increase in thermal energy due to work done against viscous force/drag • loss/change of (total) E_p equal to gain/change in thermal energy *Any 2 points.*	B2
(c)(i)	atmospheric pressure = $9.1(0) \times 10^4$ Pa	A1
(c)(ii)	$(\Delta)p = \rho g(\Delta)h$ $(9.15 - 9.10) \times 10^4 = \rho \times 9.81 \times (0.17 - 0.10)$	C1
	$\rho = 730\ (728)$ kg m^{-3}	A1

5 - (9702/22_Winter_2017_Q3) - *Kinematics, Dynamics, Forces, Density & Pressure*

(a)	$p = 1000 \times 9.81 \times 7.0 \times 10^{-2}$ or $1000 \times 9.81 \times 1.9 \times 10^{-2}$	C1
	$\Delta p = 1000 \times 9.81 \times (7.0 \times 10^{-2} - 1.9 \times 10^{-2})$ or $686 - 186$ $= 500$ Pa	A1
(b)	$F = pA$ or $(\Delta)F = \Delta p \times A$	C1
	upthrust = $500 \times (5.1 \times 10^{-2})^2 = 1.3$ N or upthrust = $(686 - 186) \times (5.1 \times 10^{-2})^2 = 1.3$ N or upthrust = $1000 \times 9.81 \times 5.1 \times 10^{-2} \times (5.1 \times 10^{-2})^2 = 1.3$ N	A1
(c)	force = $4.0 - 1.3$ $= 2.7$ N	A1

(d)	extension/x/e = 2.7 / 30	C1
	= 0.09 (m) or 9 (cm)	C1
	height above surface = 9 – 7 = 2 cm	A1
(e)(i)	mass = 4.0 / 9.81	C1
	acceleration = 2.7 / (4.0 / 9.81) = 6.6 m s^{-2}	A1
(e)(ii)	viscous force increases (and then becomes constant)	M1
	(weight and upthrust constant so) acceleration decreases (to zero)	A1

6 – (9702/23_Summer_2018_Q2) – *Forces, Density & Pressure, Work, Energy & Power, Waves*

(a)(i)	(work =) force × distance moved in the direction of the force	B1
(b)(i)	$\rho = m / V$	C1
	= (20 / 9.81) / (4/3 × π × 0.16^3) = 120 kg m^{-3}	A1
(b)(ii)	the pressure on the lower surface (of sphere) is greater than the pressure on the upper surface (of sphere)	B1
(b)(iii)	a = (170 – 20) / (20 / 9.81)	C1
	= 74 m s^{-2}	A1
(b)(iv)	D = 170 – 20 (= 150)	C1
	810 × (0.16^2) × v^2 = 150	C1
	v = 2.7 m s^{-1}	A1
(b)(v)	4870 = (4850 × v) / (v – 6.30)	C1
	v = 1530 m s^{-1}	A1

7 – (9702/22_Summer_2018_Q5) – *Forces, Density & Pressure, Dynamics, Work, Energy & Power*

(a)	$\rho = m / V$	C1
	= (560 / 9.81) / (1.2 × 0.018) = 2600 kg m^{-3}	A1
(b)	(Δ)p = 940 × 9.81 × 1.2	C1
	(upthrust =) 940 × 9.81 × 1.2 × 0.018 = 200 N	A1
(c)(i)	tension = 560 – 200 = 360 N	A1
(c)(ii)	$P = Fv$	C1
	= 360 × 0.020 = 7.2 W	A1
(d)(i)	upthrust decreases	B1
	tension (in wire) increases	M1
	power (output of motor) increases	A1
(d)(ii)	there is work done (on the cylinder) by the upthrust or GPE of oil decreases (as it fills the space left by cylinder and so total energy is conserved)	B1

8 - (9702/23_Winter_2018_Q1) - *Physical Quantities & Units, Forces, Density & Pressure, Deformation Of Solids*

(a)	current temperature (**allow** amount of substance, luminous intensity) *any two correct answers, 1 mark each*	**B2**
(b)(i)	$W = 2 \times (150 \times \sin 17°)$ **or** $2 \times (150 \times \cos 73°)$	**C1**
	$W = 88$ N	**A1**
(b)(ii)	**1.** $\sigma = F/A$	**C1**
	$= 150/(7.5 \times 10^{-6})$ $= 2.0 \times 10^{7}$ Pa	**A1**
	2. $\varepsilon = \sigma / E$	**C1**
	$= 2.0 \times 10^{7}/(2.1 \times 10^{11})$ $= 9.5 \times 10^{-5}$	**A1**

9 - (9702/22_Winter_2018_Q2) - *Physical Quantities & Units, Forces, Density & Pressure*

(a)	ampere kelvin (**allow** mole, candela) *any two correct answers, 1 mark each*	**B2**
(b)(i)	frictional (force)/friction	**B1**
(b)(ii)	$W\cos 31° \times 3.0$ **or** 90×6.0	**C1**
	$W\cos 31° \times 3.0 = 90 \times 6.0$ $W = 210$ N	**A1**
(b)(iii)	$X = 90 \sin 31°$ $= 46$ N	**A1**

10 - (9702/22_Summer_2019_Q3) - *Forces, Density & Pressure, Work, Energy & Power*

(a)	the point where (all) the weight (of the body) is taken to act	**B1**
(b)(i)	vertical component $= 54 \sin 35°$ $= 31$ N	**A1**
(b)(ii)	the (line of action of the) force (at B) passes through (point) A **or** the (line of action of the) force (at B) has zero (perpendicular) distance from (point) A	**B1**
(b)(iii)	$54 \sin 35° \times 0.68$ **or** $54 \cos 35° \times 0.68$ **or** $W \times 0.34$	**C1**
	$54 \sin 35° \times 0.68 + 54 \cos 35° \times 0.68 = W \times 0.34$ so $W = 150$ (N)	**A1**
(b)(iv)	total vertical force $= 150 - 31$ $= 120$ N	**A1**
(c)	$(\Delta)E = mg(\Delta)h$	**C1**
	$E = ½mv^2$	**C1**
	ratio $= (m \times 9.81 \times 4.8)/(½ \times m \times 9.2^2)$ **or** $(9.81 \times 4.8)/(½ \times 9.2^2)$	**C1**
	$= 1.1$	**A1**

11 – (9702/23_Summer_2019_Q3) – *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

(a)	$P = Fv$	C1
	$P = 8.9 \cos 30° \times 0.60$ $= 4.6$ W	A1
(b)	$p = F / A$	C1
	$F = 8.9 \sin 30° + (0.24 \times 9.81)$ $(= 6.80$ N)	C1
	$A = 6.80 / 3500$ $= 1.9 \times 10^{-3}$ m^2	A1
(c)(i)	upwards/up	B1
(c)(ii)	the Earth/planet	B1

12 – (9702/23_Winter_2019_Q1) – *Forces, Density & Pressure*

(a)	base units: kg m s^{-2} × m = kg m^2 s^{-2}	A1
(b)(i)	distance of COG from P (= GP) = 17 cos 45° – 4.0 **or** $(144.5)^{½}$ – 4.0 (= 8.0 cm)	C1
	moment = $0.15 \times 8.0 \times 10^{-2}$ = 1.2×10^{-2} N m	A1
(b)(ii)	(line of action of) weight acts through pivot/P **or** distance between (line of action of) weight and pivot/P is zero	B1
	(so) weight does not have a moment about pivot/P	B1

13 – (9702/22_Winter_2019_Q4) – *Forces, Density & Pressure*

(a)(i)	(vertically) upwards/up	B1
(a)(ii)	increases (with time/velocity/depth)	B1
(b)(i)	for a body in (rotational) equilibrium	B1
	<u>sum/total</u> of clockwise moments about a point = <u>sum/total</u> of anticlockwise moments about the (same) point	B1
(b)(ii)	$(F_B \times 5.0)$ **or** (380×2.5) **or** (750×1.6)	C1
	$(F_B \times 5.0) = (380 \times 2.5) + (750 \times 1.6)$ $F_B = 430$ N	A1
(b)(iii)	taking moments about C: $(380 \times 2.5) = 750 \times (2.0 - x)$	C1
	$(2.0 - x) = 1.3$ $x = 0.7$ m	A1
	or	
	moments may be taken about other points, e.g. about D: $(380 \times 4.5) + (750 \times x) = 1130 \times 2.0$	(C1)
	$x = 0.7$ m	(A1)

14 – (9702/21_Summer_2020_Q3) – *Forces, Density & Pressure, Work, Energy & Power*

(a)	resultant force (in any direction) is zero	B1
	resultant torque/moment (about any point) is zero	B1
(b)(i)	**1.** $T \sin 53° = 2.4$ $T = 3.0$ N	A1
	2. $F = T \cos 53°$ **or** $F^2 = T^2 - 2.4^2$ $F = 1.8$ N	A1
(b)(ii)	$\sigma = T / A$ **or** $\sigma = F / A$	C1
	$A = \pi d^2 / 4$ **or** $A = \pi r^2$	C1
	$\sigma = 3.0 \times 4 / [\pi \times (0.50 \times 10^{-3})^2]$ $= 1.5 \times 10^7$ Pa	A1
(c)(i)	$h = 75 - 75 \sin 53° = 15$ cm	A1
(c)(ii)	$(\Delta)E = mg(\Delta)h$ **or** $(\Delta)E = W(\Delta)h$	C1
	$(\Delta)E = 2.4 \times 15 \times 10^{-2}$ $= 0.36$ J	A1
(c)(iii)	$E = ½mv^2$	B1
	$0.36 = ½ \times (2.4 / 9.81) \times v^2$	C1
	$v = 1.7$ m s^{-1}	A1

15 – (9702/23_Summer_2020_Q3) – *Forces, Density & Pressure, Deformation Of Solids*

(a)	for a body in (rotational) equilibrium	B1
	sum/total of clockwise moments about a point = sum/total of anticlockwise moments about the (same) point	B1
(b)(i)	$(W \times 0.45)$ **or** (19×1.3) **or** $(W \times 1.85)$ **or** (22×2.6)	C1
	$(W \times 0.45) + (19 \times 1.3) + (W \times 1.85) = (22 \times 2.6)$ so $W = 14$ N	A1
(b)(ii)	magnitude = 19 + 14 + 14 – 22 = 25 N	A1
	direction: vertically upwards	A1
(c)(i)	the extension is zero when the force is zero	B1
	graph is a straight line and (so) Hooke's law obeyed	B1
(c)(ii)	$k = F / x$ **or** k = gradient	C1
	e.g. $k = 60 / (1.00 - 0.25)$ $k = 80$ N m^{-1}	A1
(c)(iii)	area shaded below graph line between $L = 0.25$ m and $L = 0.75$ m	B1

16 – (9702/21_Winter_2020_Q1) – *Forces, Density & Pressure*

(a)(i)	force × perpendicular distance (of line of action of force to the point)	B1
(a)(ii)	units: kg m s^{-2} m = kg m^2 s^{-2}	A1
(b)	$W = \rho Vg$ **or** $W = \rho ALg$	C1
	$A = 5.2 / (790 \times 2.4 \times 9.81)$ $(= 2.8 \times 10^{-4}\ (m^2))$	C1
	$= 2.8 \times 10^2$ mm^2	A1
(c)(i)	(component =) 5.2 sin 56° = 4.3 (N) **or** 5.2 cos 34° = 4.3 (N)	A1
(c)(ii)	$(T \times 2.4)$ **or** (4.3×1.2) **or** (4.6×1.8)	C1
	$(T \times 2.4) + (4.3 \times 1.2) = (4.6 \times 1.8)$	C1
	$T = 1.3$ N	A1

17 – (9702/22_Winter_2020_Q2) – *Kinematics, Dynamics, Forces, Density & Pressure*

(a)(i)	$(\Delta)p = \rho g(\Delta)h$ $520 = 1000 \times 9.81 \times h$	C1
	$h = 0.053$ m	A1
(a)(ii)	(upthrust =) $(\Delta)p \times A$ $= (\Delta)p \times \pi(d/2)^2$ **or** $(\Delta)p \times \pi r^2$	C1
	$= 520 \times \pi(0.031/2)^2 = 0.39$ (N)	A1
(a)(iii)	$T = 0.84 - 0.39$ $= 0.45$ N	A1
(b)(i)	$a = (v - u)/t$ **or** $(\Delta)v/(\Delta)t$ **or** gradient	C1
	= e.g. $8.0 \times 10^{-2} / 2.0$ $= 4.0 \times 10^{-2}$ m s^{-2}	A1
(b)(ii)	distance = $(½ \times 2.5 \times 0.10) + (½ \times 1.5 \times 0.10)$ **or** $(½ \times 4.0 \times 0.10)$ (= 0.20 (m))	C1
	depth = 0.32 – 0.20 = 0.12 m	A1
(c)(i)	viscous (force)	B1
(c)(ii)	viscous force increases (with speed/time/depth)	B1
	(so) acceleration decreases	B1

18 - (9702/23_Winter_2020_Q2) - *Forces, Density & Pressure*

(a)	point where (all) the weight (of the body)	M1
	is considered/seems to act	A1
(b)(i)	horizontal component of force = 38 cos 60° **or** 38 sin 30° = 19 N	A1
(b)(ii)	($T \times 1.2$) **or** (19×0.9) **or** 17	C1
	($T \times 1.2$) = (19×0.9) T = 14 N	A1
(b)(iii)	F = 45 + 38 sin 60° = 78 N	A1

19 - (9702/22_Winter_2020_Q4) - *Forces, Density & Pressure*

(a)	(component =) 96 sin 38° = 59 (N) **or** 96 cos 52° = 59 (N)	A1
(b)	(45×2.9) **or** ($T \times 1.8$) **or** (59×1.5)	C1
	(45×2.9) = ($T \times 1.8$) + (59×1.5)	C1
	T = 23 N	A1

20 - (9702/21_Summer_2021_Q1) - *Measurement Techniques, Forces, Density & Pressure*

(a)	mass / volume	B1
(b)(i)	absolute uncertainty = $4.0 \times (5 / 100)$ = (±) 0.2 cm	B1
(b)(ii)	percentage uncertainty = 2 + 4 + (5×2)	C1
	= (±) 16%	A1
(c)	$p = F / A$ **or** $p = W / A$	C1
	$p = (19.5 \times 10^{-3} \times 9.81) / (4.0 \times 10^{-2})^2$	C1
	= 120 Pa	A1

21 – (9702/22_Summer_2021_Q1) – *Physical Quantities & Units, Forces, Density & Pressure*

(a)	acceleration: vector electrical resistance: scalar momentum: vector *1 mark for two correct, 2 marks for all three correct*	B2
(b)	resultant force (in any direction) is zero	B1
	resultant torque/moment (about any point) is zero	B1
(c)(i)	upthrust = $\rho g(\Delta)h \times A$	C1
	= $(1.00 \times 10^3 \times 9.81 \times 0.190) \times 0.0230$ = 42.9 N	A1
(c)(ii)	(T =) 43 – 28 = 15 (N) **or** (T =) 42.9 – 28 = 14.9 or 15 (N)	A1
(c)(iii)	$\sigma = F / A$ **or** T / A	C1
	= $15 / (3.2 \times 10^{-6})$ = 4.7×10^6 Pa	A1
(c)(iv)	upthrust (on cylinder) increases (and weight constant)	B1
	tension/stress increases and (so) strain energy increases	B1

22 – (9702/21_Summer_2021_Q3) – *Dynamics, Forces, Density & Pressure*

(a)	solid straight line drawn between centre of sphere at X and at Y	B1
(b)	$p = mv$ **or** $0.72 = mv$	C1
	$E = ½mv^2$ **or** $0.86 = ½mv^2$	C1
	(m =) $0.72^2 / (2 \times 0.86)$ = 0.30 (kg) **or** $v = 2E_K / p$ $v = (0.86 \times 2) / 0.72$ = 2.4 (to 2 s.f.) m = 0.72 / 2.4 = 0.30 (kg)	A1
(c)	$(\Delta)E = mg(\Delta)h$	C1
	$h = 0.86 / (0.30 \times 9.81)$ = 0.29 m	A1
(d)	$\cos\theta = (0.93 - 0.29) / 0.93$ so $\theta = 47°$	A1
(e)	moment = $(0.30 \times 9.81) \times 0.93 \times (\sin 47°$ **or** $\cos 43°)$ **or** moment = $(0.30 \times 9.81) \times [0.93^2 - (0.93 - 0.29)^2]^{0.5}$	C1
	= 2.0 N m	A1

(f)	there is a <u>resultant</u> force (acting on sphere) **or** there is a <u>resultant</u> moment (about P acting on pendulum) (so) not in equilibrium	B1

23 – (9702/23_Summer_2021_Q3) – *Forces, Density & Pressure*

(a)	force × distance	M1
	perpendicular distance of (line of action of) force from the point	A1
(b)(i)	distance moved by pointer = 123 – 86 (= 37 mm)	C1
	(extension =) 37 × (1.8 / 52.6) = 1.3 (mm) **or** sin or tan θ = 37 / 526 (so θ = 4.0° so extension =) sin or tan θ × 18 = 1.3 (mm)	A1
(b)(ii)	moment = $0.472 \times 9.81 \times 6.2 \times 10^{-2}$	C1
	= 0.29 N m	A1
(b)(iii)	$(\Delta)F \times 1.8 \times 10^{-2} = 0.29$	C1
	ΔF = 16 N	A1
(b)(iv)	$k = F / x$	C1
	= $16 / (1.3 \times 10^{-3})$ = 1.2×10^{4} N m^{-1}	A1

24 – (9702/21_Winter_2021_Q1) – *Measurement Techniques, Forces, Density & Pressure*

(a)	mass / volume	B1
(b)(i)	(vernier/digital) calipers	B1
(b)(ii)	percentage uncertainty = (0.0004 / 0.0420) × 100 = 1%	A1
(c)(i)	kg m^{-3} = kg × m^{n} / m **or** kg m^{-3} = kg × m^{n} × m^{-1}	M1
	–3 = n – 1 and (so) n = –2	A1
(c)(ii)	$(\Delta\rho / \rho) = (\Delta M / M) + 2(\Delta r / r) + (\Delta L / L)$	C1
	percentage uncertainty = [(0.001 / 1.072) + 2 × (0.0004 / 0.0420) + (0.0001 / 0.1242)] (× 100)	C1
	= 0.09% + 2 × 0.95% + 0.08% = 2%	A1
(c)(iii)	$\rho = (1.072 \times 0.0420^{-2}) / (2.094 \times 0.1242)$ = 2337 (kg m^{-3})	C1
	$\Delta\rho = 0.021 \times 2337$ = 49 (kg m^{-3})	C1
	ρ = (2340 ± 50) kg m^{-3}	A1

25 – (9702/23_Winter_2021_Q1) – *Forces, Density & Pressure*

(a)	$m = \rho V$ **or** ρAL	C1
	$W = mg$	C1
	(A =) 24 / (9.81 × 850 × 0.18) = 0.016 (m^2)	A1
	or	
	$P = F / A$	(C1)
	$P = \rho gh$	(C1)
	(A =) 24 / (9.81 × 850 × 0.18) = 0.016 (m^2)	(A1)
(b)(i)	(upthrust =) 24 + 8(.0) = 32 (N)	A1
(b)(ii)	$(\Delta)p$ = 32 / 0.016 (= 2000)	C1
	$(\Delta)p = \rho g(\Delta)h$ ρ = 2000 / (9.81 × 0.17)	C1
	= 1200 kg m^{-3}	A1
(c)(i)	$E = ½Fx$ **or** $E = ½kx^2$ **or** E = area under graph	C1
	$(\Delta)E$ = (½ × 8.0 × 0.40) – (½ × 4.0 × 0.20) **or** (½ × 20 × 0.40^2) – (½ × 20 × 0.20^2) **or** ½ × (4.0 + 8.0) × 0.20	C1
	= 1.2 J	A1
(c)(ii)	length = 30 cm	A1

26 – (9702/22_Winter_2022_Q2) – *Forces, Density & Pressure*

(a)	$F = \rho gV$ 0.071 = 1.2 × 9.81 × V	C1
	(V = 6.03 × 10^{-3} m^3) 4/3 × π × r^3 = 6.03 × 10^{-3} r = 0.11 m	A1
(b)	m = 0.053 / 9.81 (= 5.4 × 10^{-3} kg)	C1
	F = 0.071 – 0.053 (= 0.018 N)	C1
	a = (0.071 – 0.053) / (0.053 / 9.81) = 3.3 m s^{-2}	A1
(c)(i)	$v^2 = u^2 + 2as$ $3.6^2 = (-1.4)^2 + 2 \times 9.81 \times s$ **or** $3.6^2 = 1.4^2 + 2 \times 9.81 \times s$	C1
	s = 0.56 m	A1
(c)(ii)	single straight line from any positive non-zero value of v at t = 0 to any negative non-zero value of v at $t = T$	B1
	line starting at (0, 1.4) and ending at (T, –3.6)	B1

27 – (9702/22_Winter_2022_Q3) – *Forces, Density & Pressure*

(a)	point where (all) the weight (of an object) is taken to act	B1
(b)(i)	vertical component = 45 sin 37° = 27 N	A1
(b)(ii)	the magnitudes of the three moments about A are (23 × 0.48), (27 × 0.56) and (W × 0.76) correct magnitude of any one moment about A	C1
	correct magnitudes of any two moments about A	C1
	(23 × 0.48) + (W × 0.76) = 27 × 0.56 W = 5.4 N	A1
(b)(iii)	horizontal component = 45 cos 37° = 36 N	A1
(b)(iv)	decrease	B1
(b)(v)	$\sigma = F / A$	C1
	$\sigma = F / \pi r^2$ or $4F / \pi d^2$ so $\sigma = 5.3 \times 10^7 \times \pi r^2 / \pi (3r)^2$ $= 5.3 \times 10^7 / 9$ $= 5.9 \times 10^6$ Pa	A1

28 – (9702/23_Winter_2022_Q3) – *Forces, Density & Pressure*

(a)	sum of CW moments = sum of ACW moments	M1
	about the same point for (an object in rotational) equilibrium	A1
(b)	moment = 0.3(0) × 0.29 cos 40° **or** 0.3(0) × 0.222	C1
	= 0.067 N m	A1
(c)(i)	$k = F / x$ **or** k = gradient	C1
	e.g. $k = 21 / 10 \times 10^{-3}$ $k = 2100$ N m^{-1}	A1
(c)(ii)	$V_{(sphere)} = \frac{4}{3} \times \pi \times (0.0480)^3$	C1
	$F = \rho g V$ (upthrust =) $1000 \times 9.81 \times (\frac{4}{3} \times \pi \times (0.048)^3) \times 0.26(0) = 1.18$ (N)	A1
(c)(iii)	1.18 × 0.29 **or** 0.30 × 0.29 **or** F × 0.017	C1
	(1.18 × 0.29) = (0.30 × 0.29) + (F × 0.017) F = 15 N	A1

(c)(iv)	$E_{(P)} = ½kx^2$ **or** $E_{(P)} = ½Fx$	C1
	$x = F / k = 15 / 2100$ **or** x determined from graph for F = 15.0 N $E_P = ½ \times 2100 \times (15 / 2100)^2$ **or** $E_P = ½ \times 15 \times (15 / 2100)$ E_P = 0.054 J	A1
(d)	the <u>sphere</u> has gained gravitational potential energy	B1

29 – (9702/21_Summer_2023_Q3) – *Dynamics, Forces, Density & Pressure*

(a)	(resultant) force (on an object) is proportional to / equal to the rate of change of momentum	B1
(b)(i)	resultant force = e.g. 6.0 / 4.0 = 1.5 N	A1
(b)(ii)	force X = 1.5 + 2.0 = 3.5 N	A1
(c)	from t = 0 to t = 4.0 s: horizontal line at any non-zero value of X	B1
	from t = 0 to t = 4.0 s: horizontal line at X = 3.5 N	B1
	from t = 4.0 s to t = 6.0 s: horizontal line at X = 2.0 N	B1

30 – (9702/21_Summer_2023_Q4) – *Forces, Density & Pressure*

(a)	$\rho = m / V$ **or** $\rho = m / Ah$	B1
	$p = F / A$ **or** $p = W / A$	B1
	appropriate algebra leading to $p = \rho gh$ e.g. $p = \rho Ahg / A$ **or** $\rho Vg / A$ **or** $\rho Vg / (Vlh)$ **and** (so) $p = \rho gh$	B1
(b)	there is atmospheric / air pressure	B1
(c)	$\Delta p = \rho g \Delta h$ e.g. $(9.66 - 9.60) \times 10^4 / 8.0 \times 10^{-2} = \rho \times 9.81$	C1
	ρ = 760 – 770 kg m^{-3}	A1
(d)	$F = \rho gV$ $= 760 \times 9.81 \times 3.7 \times 10^{-4} \times 4.0 \times 10^{-2}$ (= 0.11 N)	C1
	tension = 0.53 – 0.11 = 0.42 N	A1
	or	
	$F = (\Delta)p \times A$ $= (9.63 - 9.60) \times 10^4 \times 3.7 \times 10^{-4}$ (= 0.11 N)	(C1)
	tension = 0.53 – 0.11 = 0.42 N	(A1)

31 – (9702/23_Summer_2023_Q2) – *Forces, Density & Pressure*

(a)	$F = 1050 \times 9.81 \times 0.21V$ **or** $W = \rho \times 9.81 \times V$	C1
	$0.21V \times 1050 (\times 9.81) = V (\times 9.81) \times \rho$ ρ = 220 kg m^{-3}	A1
(b)(i)	$F = 1050 \times 9.81 \times V$ **or** $W = 220 \times 9.81 \times V$	C1
	$(V \times 1050 \times 9.81) - (V \times 220 \times 9.81) = (V \times 220) \times a$	C1
	a = 37 m s^{-2}	A1
(b)(ii)	the (downward) drag / viscous force increases (with speed)	M1
	resultant force decreases (as upthrust and weight remain the same)	M1
	acceleration decreases (as its velocity increases)	A1

32 – (9702/23_Summer_2023_Q6) – *Dynamics, Forces, Density & Pressure*

(a)	(Young modulus =) stress / strain	B1
(b)(i)	unstretched length = 1.9980 m	A1
(b)(ii)	stress = F / A	C1
	= $30 / 9.5 \times 10^{-7}$ = 3.2×10^{7} Pa	A1
	strain = 0.0050 / 1.9980 = 2.5×10^{-3}	A1

1 – (9702/21_Summer_2017_Q2) – *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

(a)	resultant force (in any direction) is zero
	resultant torque/moment (about any point) is zero
(b)(i)	$a = (v - u) / t$ **or** gradient **or** $\Delta v / (\Delta)t$
	e.g. $a = (8.8 - 4.6) / (7.0 - 4.0) = 1.4\,\text{m s}^{-2}$
(b)(ii)	$s = 4.6 \times 4 + [(8.8 + 4.6) / 2] \times 3$
	$= 18.4 + 20.1$
	$= 39\ (38.5)$ m
(b)(iii)	$\Delta E = ½ \times 95\ [(8.8)^2 - (4.6)^2]$
	$= 3678 - 1005$
	$= 2700\ (2673)$ J
(b)(iv)1.	weight = 95×9.81 (= 932 N)
	vertical tension force = 280 sin 25° **or** 280 cos 65° (=118.3 N)
	$F = 932 + 118$
	$= 1100\ (1050)$ N
(b)(iv)2.	horizontal tension force = 280 cos 25° **or** 280 sin 65° (= 253.8 N)
	resultant force = 95×1.4 (= 133 N)
	$133 = 253.8 - R$
	$R = 120\ (120.8)$ N

2 – (9702/22_Summer_2017_Q2) – *Kinematics, Work, Energy & Power*

(a)	rate of change of displacement **or** change in displacement/time taken
(b)(i)	$s = ut + ½at^2$
	$t = [(2 \times 1.25) / 9.81]^{1/2}$ (= 0.5048 s)
	or
	$v^2 = u^2 + 2as$
	$v_{vert} = (2 \times 9.81 \times 1.25)^{1/2}$ (= 4.95)
	$t = [2s / (u + v)] = 2 \times 1.25 / 4.95$ (= 0.5048 s)
	$v = d / t = 1.5 / 0.50(48)$
	$= 3.0\ (2.97)\,\text{m s}^{-1}$
(b)(ii)	vertical velocity $= at$
	$= 9.81 \times 0.5048$ (= 4.95) [using $t = 0.50$ gives 4.9]
	velocity $= [(v_h)^2 + (v_v)^2]^{1/2}$
	$= [(2.97)^2 + (4.95)^2]^{1/2}$
	$= 5.8\ (5.79)$ [using $t = 0.50$ leads to 5.7]
	direction (= $\tan^{-1}$ 4.95/2.97) = 59°
(b)(iii)	kinetic energy $= ½mv^2$
	$= ½ \times 0.45 \times (5.8)^2$
	$= 7.6\ (7.57)$ J [using $t = 0.50$ leads to 7.3 J]

(b)(iv)	potential energy = mgh
	= (0.45 × 9.81 × 1.25) = 5.5 (5.52) J
(c)	there is KE of the ball at the start/leaving table **or** the ball has an initial/constant horizontal velocity **or** the ball has velocity at start/leaving table

3 – (9702/23_Winter_2017_Q2) – *Forces, Density & Pressure, Work, Energy & Power*

(a)	$\rho = m / V$ or $\rho = m / Ah$	**B1**
	$p = F / A$ or $p = W / A$	**B1**
	$p = [\rho Ahg] / A$ or $p = [\rho Vg] / [V / h]$ (so) $p = \rho gh$	**A1**

(b)(i)	1. weight/gravitational (force) upthrust (force)/buoyancy (force) drag/viscous/frictional (force)/fluid resistance/resistance	**B1**
	2. weight = upthrust + viscous (force)	**B1**
(b)(ii)	• decrease in (gravitational) potential energy (of sphere) due to decrease in height (since $E_p = mgh$) • increase in thermal energy due to work done against viscous force/drag • loss/change of (total) E_p equal to gain/change in thermal energy *Any 2 points.*	**B2**
(c)(i)	atmospheric pressure = 9.1(0) × 10^4 Pa	**A1**
(c)(ii)	$(\Delta)p = \rho g(\Delta)h$ $(9.15 - 9.10) \times 10^4 = \rho \times 9.81 \times (0.17 - 0.10)$	**C1**
	ρ = 730 (728) kg m^{-3}	**A1**

4 – (9702/21_Summer_2018_Q2) – *Dynamics, Kinematics, Work, Energy & Power*

(a)	a body continues at (rest or) constant velocity unless acted upon by a resultant force	B1
(b)(i)1.	from 0–2 s, distance = ½ × 2 × 6.8 (= 6.8 m) **and** from 2–3 s, distance = ½ × 1 × 3.4 (= 1.7 m)	C1
	magnitude of displacement = 5.1 m	A1
	direction of displacement is down(wards)	B1
(b)(i)2.	$(\Delta E) = mg\Delta h$ **or** $(E) = mgh$ **or** $(E) = Wh$	C1
	$(\Delta)E = 15 \times 5.1$ $= (-)\ 77\,\text{J}$	A1
(b)(ii)	$a = (v - u)/t$ **or** a = gradient **or** $a = dv/dt$	C1
	$a = 3.4\,\text{ms}^{-2}$	A1
(b)(iii)	$T - W = ma$ **or** $T - mg = ma$	C1
	$T = 15 + (15/9.81) \times 3.4 = 20\,\text{N}$ or $20.2\,\text{N}$	A1
(b)(iv)	$E = F/A\varepsilon$ **or** $E = \sigma/\varepsilon$ <u>and</u> $\sigma = F/A$	C1
	$\varepsilon = 20/(2.8 \times 10^{-5} \times 1.7 \times 10^{11})$	C1
	$= 4.2 \times 10^{-6}$	A1
(b)(v)	block is in equilibrium/has no resultant force	B1
	block could be stationary (or have constant velocity/speed) (so no, not possible to deduce)	B1

5 – (9702/23_Summer_2018_Q2) – *Forces, Density & Pressure, Work, Energy & Power, Waves*

(a)(i)	(work =) force × distance moved in the direction of the force	B1
(b)(i)	$\rho = m/V$	C1
	$= (20/9.81)/(4/3 \times \pi \times 0.16^3)$ $= 120\,\text{kgm}^{-3}$	A1
(b)(ii)	the pressure on the lower surface (of sphere) is greater than the pressure on the upper surface (of sphere)	B1
(b)(iii)	$a = (170 - 20)/(20/9.81)$	C1
	$= 74\,\text{ms}^{-2}$	A1
(b)(iv)	$D = 170 - 20$ (= 150)	C1
	$810 \times (0.16^2) \times v^2 = 150$	C1
	$v = 2.7\,\text{ms}^{-1}$	A1
(b)(v)	$4870 = (4850 \times v)/(v - 6.30)$	C1
	$v = 1530\,\text{ms}^{-1}$	A1

6 - (9702/23_Summer_2018_Q3) - *Kinematics, Dynamics, Work, Energy & Power*

(a)	$v = u + at$ $v = 9.6 - (9.81 \times 0.37) = 6.0\,\text{m s}^{-1}$	A1
(b)	$s = ½ \times (9.6 + 6.0) \times 0.37$ **or** $6.0^2 = 9.6^2 - (2 \times 9.81 \times s)$ **or** $s = (9.6 \times 0.37) - (½ \times 9.81 \times 0.37^2)$ **or** $s = (6.0 \times 0.37) + (½ \times 9.81 \times 0.37^2)$	C1
	$s = 2.9\,\text{m}$	A1
(c)(i)	$(\Delta)E = mg(\Delta)h$	C1
	$\Delta E = 0.056 \times 9.81 \times 2.9$ $= 1.6\,\text{J}$	A1
(c)(ii)	$E = ½mv^2$	C1
	$\Delta E = ½ \times 0.056 \times (6.0^2 - 3.8^2)$ $= 0.60\,\text{J}$	A1
(d)	force on ball (by ceiling) <u>equal</u> to force on ceiling (by ball)	M1
	and opposite (in direction)	A1
(e)	$(p =)\ mv$ **or** 0.056×6.0 **or** 0.056×3.8	C1
	change in momentum $= 0.056 \times (6.0 + 3.8)$ $= 0.55\,\text{N s}$	A1

(f)	resultant force = 0.55 / 0.085 (= 6.47 N)	C1
	force by ceiling $= 6.47 - (0.056 \times 9.81)$ $= 5.9\,\text{N}$	A1

7 - (9702/22_Summer_2018_Q5) - *Forces, Density & Pressure, Dynamics, Work, Energy & Power*

(a)	$\rho = m / V$	C1
	$= (560 / 9.81) / (1.2 \times 0.018)$ $= 2600\,\text{kg m}^{-3}$	A1
(b)	$(\Delta)p = 940 \times 9.81 \times 1.2$	C1
	(upthrust =) $940 \times 9.81 \times 1.2 \times 0.018 = 200\,\text{N}$	A1
(c)(i)	tension $= 560 - 200$ $= 360\,\text{N}$	A1
(c)(ii)	$P = Fv$	C1
	$= 360 \times 0.020$ $= 7.2\,\text{W}$	A1
(d)(i)	upthrust decreases	B1
	tension (in wire) increases	M1
	power (output of motor) increases	A1
(d)(ii)	there is work done (on the cylinder) by the upthrust **or** GPE of oil decreases (as it fills the space left by cylinder and so total energy is conserved)	B1

8 – (9702/21_Winter_2018_Q1) – *Kinematics, Work, Energy & Power*

(a)(i)	distance in a specified direction (from a point)	**B1**
(a)(ii)	change in velocity / time (taken)	**B1**
(b)(i)	vertical component of velocity = $(5.5^2 - 4.6^2)^{1/2} = 3.0\ (\text{ms}^{-1})$ **or** $5.5\cos\theta = 4.6$ (so $\theta = 33.2°$) **and** $5.5\sin 33.2° = 3.0\ (\text{ms}^{-1})$	**A1**
(b)(ii)	$s = ut + ½at^2$ $0 = (3.0 \times t) - (½ \times 9.81 \times t^2)$ **or** $v = u + at$ $-3.0 = 3.0 - 9.81t$	**C1**
	$t = 0.61$ s	**A1**
(b)(iii)	$d = 4.6 \times 0.61$ $= 2.8$ m	**A1**
(b)(iv)	$E = ½mv^2$	**C1**
	ratio = $(½ \times m \times 4.6^2) / (½ \times m \times 5.5^2)$ **or** ratio = $(½ \times m \times 5.5^2 - m \times 9.81 \times 0.459) / (½ \times m \times 5.5^2)$	**C1**
	ratio = 0.70	**A1**
(c)	straight line from positive value of v_y at $t = 0$ to negative value of v_y	**M1**
	straight line ends at $t = T$ and final magnitude of v_y greater than initial magnitude of v_y	**A1**

9 – (9702/22_Winter_2018_Q1) – *Kinematics, Work, Energy & Power*

(a)	$v_x = (6.0^2 - 4.8^2)^{1/2} = 3.6\ (\text{ms}^{-1})$ **or** $6.0\sin\theta = 4.8$ (so $\theta = 53.1°$) **and** $v_x = 6.0\cos 53.1° = 3.6\ (\text{ms}^{-1})$	**A1**
(b)(i)	straight line from (0, 4.8) to (0.49, 0)	**M1**
	straight line continues with same slope to (0.98, –4.8) (labelled Y)	**A1**
(b)(ii)	a horizontal line	**M1**
	from (0, 3.6) to (0.98, 3.6) (labelled X)	**A1**
(c)	$s = ut + ½at^2$ $= (4.8 \times 0.49) + (½ \times -9.81 \times 0.49^2)$ **or** $s = ½(u + v)t$ **or** area under graph $= ½ \times (4.8 + 0) \times 0.49$ **or** $s = vt - ½at^2$ $= ½ \times 9.81 \times 0.49^2$ **or** $v^2 = u^2 + 2as$ $s = 4.8^2 / (2 \times 9.81)$	**C1**
	$s = 1.2$ m	**A1**

(d)	$(\Delta)E = mg(\Delta)h$	C1
	$E = ½mv^2$	C1
	ratio = $(½ \times m \times 3.6^2) / (m \times 9.81 \times 1.2)$ or ratio = $[(½ \times m \times 6.0^2) – (m \times 9.81 \times 1.2)] / (m \times 9.81 \times 1.2)$ or ratio = $(½ \times m \times 3.6^2) / (½ \times m \times 4.8^2)$	C1
	ratio = 0.56	A1
(e)	(force due to) air resistance acts in opposite direction to the velocity or (with air resistance, average) resultant force is larger (than weight)	B1

10 – (9702/23_Winter_2018_Q2) – *Dynamics, Work, Energy & Power*

(a)	energy (of a mass/body/object) due to motion/speed/velocity	B1
(b)(i)	$E = ½mv^2$	C1
	$480 = ½ \times m \times 80^2$ so $m = 0.15$ kg	A1
(b)(ii)	1. $E = mgh$ or $\Delta E = mg\Delta h$	C1
	$= 0.15 \times 9.81 \times 210$ $= 310$ J	A1
	2. work done = 480 – 310 = 170 J	A1
(b)(iii)	work done = Fs	C1
	force = 170 / 210 = 0.81 N	A1
(b)(iv)	curved line from positive value on v-axis to (T, 0)	M1
	magnitude of gradient decreases	A1
(b)(v)	as shell rises force decreases and as shell falls force increases	B1
	as shell rises force is downward and as shell falls force is upward	B1
	or	
	as shell rises the force decreases and is downward	(B1)
	as shell falls the force increases and is upward	(B1)

11 – (9702/21_Winter_2018_Q3) – *Work, Energy & Power*

(a)(i)	work (done) / time (taken)	B1
(a)(ii)	energy of a mass due to its position in a gravitational field	B1
(b)(i)	$P = Fv$	C1
	$= 2.0 \times 10^3 \times 45$ $= 9.0 \times 10^4$ W	A1
(b)(ii)	**1.** $W = (2.0 \times 10^3) \times (45 \times 3.0 \times 60)$ **or** $W = 9.0 \times 10^4 \times 3.0 \times 60$	C1
	$W = 1.6 \times 10^7$ J	A1
	2. $(\Delta)E_P = mg(\Delta)h$	C1
	$= 1200 \times 9.81 \times 3.3 \times 3.0 \times 60$ $= 7.0 \times 10^6$ J	A1
	3. $W = 1.6 \times 10^7 - 7.0 \times 10^6$ $= 9.0 \times 10^6$ J	A1
(b)(iii)	force $= (9.0 \times 10^6) / (45 \times 3.0 \times 60)$ $= 1.1 \times 10^3$ N	A1
(b)(iv)	constant velocity so no resultant force	B1
	no resultant force so in equilibrium	B1

12 – (9702/23_Summer_2019_Q2) – *Work, Energy & Power*

(a)(i)	**1.** $W = mas$	B1
	2. $s = (v^2 - u^2) / 2a$	B1
(a)(ii)	W/work equals energy transferred/gain or change in kinetic energy	B1
	W (= mas) = $ma(v^2 - u^2) / 2a$ leading to $W = m(v^2 - u^2) / 2$ (so KE = ½mv^2)	B1
(b)(i)	**1.** solid curved line drawn from X to Y along path of ball and labelled D	B1
	2. solid straight line drawn from X to Y and labelled S	B1
(b)(ii)	$(\Delta)E = mg(\Delta)h$	C1
	$4.5 = (0.040 \times 9.81 \times h) + (½ \times 0.040 \times 9.5^2)$	C1
	$h = 6.9$ m	A1
(b)(iii)	line with a negative gradient starting from a non-zero value of kinetic energy when the vertical height is zero	M1
	straight line ends at a non-zero value of kinetic energy when the vertical height is h	A1

13 – (9702/21_Summer_2019_Q3) – *Deformation Of Solids, Work, Energy & Power*

(a)(i)	$E = ½Fx$ **or** $E = ½kx^2$ **or** E = area under graph	C1
	$E = ½ \times 4.0 \times 0.32 = 0.64$ J **or** $E = ½ \times 12.5 \times (0.32)^2 = 0.64$ J	A1
(a)(ii)	$E = mgh$ **or** $E = Wh$ $= 2.5 \times 0.32$	C1
	$= 0.80$ J	A1
(b)(i)	kinetic energy $= 0.80 - 0.64$ $= 0.16$ J	A1
(b)(ii)	$E = ½mv^2$ $0.16 = ½ \times (2.5 / 9.81) \times v^2$	C1
	$v = 1.1$ m s^{-1}	A1

14 – (9702/22_Summer_2019_Q3) – *Forces, Density & Pressure, Work, Energy & Power*

(a)	the point where (all) the weight (of the body) is taken to act	B1
(b)(i)	vertical component = 54 sin 35° = 31 N	A1
(b)(ii)	the (line of action of the) force (at B) passes through (point) A **or** the (line of action of the) force (at B) has zero (perpendicular) distance from (point) A	B1
(b)(iii)	54 sin 35° × 0.68 **or** 54 cos 35° × 0.68 **or** W × 0.34	C1
	54 sin 35° × 0.68 + 54 cos 35° × 0.68 = W × 0.34 so W = 150 (N)	A1
(b)(iv)	total vertical force = 150 – 31 = 120 N	A1
(c)	$(\Delta)E = mg(\Delta)h$	C1
	$E = ½mv^2$	C1
	ratio = (m × 9.81 × 4.8) / (½ × m × 9.2²) **or** (9.81 × 4.8) / (½ × 9.2²)	C1
	= 1.1	A1

15 – (9702/23_Summer_2019_Q3) – *Dynamics, Forces, Density & Pressure, Work, Energy & Power*

(a)	$P = Fv$	C1
	P = 8.9 cos 30° × 0.60 = 4.6 W	A1
(b)	$p = F / A$	C1
	F = 8.9 sin 30° + (0.24 × 9.81) (= 6.80 N)	C1
	A = 6.80 / 3500 = 1.9 × 10⁻³ m²	A1
(c)(i)	upwards/up	B1
(c)(ii)	the Earth/planet	B1

16 – (9702/23_Winter_2019_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a)	(work done =) force × distance moved in direction of force	B1
(b)(i)	**1.** acceleration = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / t$	C1
	e.g. a = 2.4 / 3.0 = 0.80 m s⁻²	A1
	2. tension in cable = (13.0 + 2.0) × 10³	C1
	work done = 15 × 10³ × (3.0 × 2.4) = 1.1 × 10⁵ J	A1
(b)(ii)	power = Fv	C1
	v = 2.0 (m s⁻¹)	C1
	input power = (1.6 × 10⁴ × 2.0) / 0.67 = 4.8 × 10⁴ W	A1
(b)(iii)	work is done against friction so (increase in) GPE is less (than work done by motor) **or** energy is lost or transferred or converted to heat/thermal energy due to friction or resistance force **or** work is done lifting the cable so GPE is less	A1

17 – (9702/21_Winter_2019_Q4) – *Work, Energy & Power, Deformation Of Solids*

(a)	$k = F / x$ **or** k = gradient	C1
	e.g. $k = 4.0 / 0.050$ $k = 80\ \text{N m}^{-1}$	A1
(b)	$E = ½Fx$ **or** $E = ½kx^2$ **or** E = area under graph	C1
	$(\Delta)E = (½ \times 3.2 \times 0.040) – (½ \times 1.2 \times 0.015) = 0.055$ J **or** $(\Delta)E = (½ \times 80 \times 0.040^2) – (½ \times 80 \times 0.015^2) = 0.055$ J **or** $(\Delta)E = ½ \times (1.2 + 3.2) \times 0.025 = 0.055$ J	A1
(c)	$(\Delta)E = mg(\Delta)h$	C1
	$= 0.122 \times 9.81 \times (0.120 – 0.095)$ $= 0.030$ J	A1
	or	
	$(\Delta)E = W \times (\Delta)h$	(C1)
	$= 1.2 \times 0.025$ $= 0.030$ J	(A1)

(d)(i)	$E = 0.055 – 0.030$ $= 0.025$ J	A1
(d)(ii)	$E = ½mv^2$	C1
	$v = [(2 \times 0.025) / 0.122]^{0.5}$ $= 0.64\ \text{m s}^{-1}$	A1

18 – (9702/21_Summer_2020_Q3) – *Forces, Density & Pressure, Work, Energy & Power*

(a)	resultant force (in any direction) is zero	B1
	resultant torque/moment (about any point) is zero	B1
(b)(i)	**1.** $T \sin 53° = 2.4$ $T = 3.0$ N	A1
	2. $F = T \cos 53°$ **or** $F^2 = T^2 – 2.4^2$ $F = 1.8$ N	A1
(b)(ii)	$\sigma = T / A$ **or** $\sigma = F / A$	C1
	$A = \pi d^2 / 4$ **or** $A = \pi r^2$	C1
	$\sigma = 3.0 \times 4 / [\pi \times (0.50 \times 10^{-3})^2]$ $= 1.5 \times 10^7$ Pa	A1
(c)(i)	$h = 75 – 75 \sin 53° = 15$ cm	A1
(c)(ii)	$(\Delta)E = mg(\Delta)h$ **or** $(\Delta)E = W(\Delta)h$	C1
	$(\Delta)E = 2.4 \times 15 \times 10^{-2}$ $= 0.36$ J	A1
(c)(iii)	$E = ½mv^2$	B1
	$0.36 = ½ \times (2.4 / 9.81) \times v^2$	C1
	$v = 1.7\ \text{m s}^{-1}$	A1

19 - (9702/22_Summer_2020_Q3) - *Work, Energy & Power*

(a)	(work done =) force × displacement in direction of the force	B1
(b)(i)	**1.** $(\Delta)E = mg(\Delta)h$	C1
	$= 0.42 \times 9.81 \times 78$ $= 320$ J	A1
	2. $E = ½mv^2$	C1
	$(\Delta)E = ½ \times 0.42 \times 23^2$ $= 110$ J	A1
(b)(ii)	work done = 320 – 110 (= 210 N)	C1
	average resistive force = 210 / 78 = 2.7 N	A1
(c)	downward sloping line from (0, *g*) to a non-zero value on the time axis	M1
	line is curved with a gradient that becomes less negative **and** the line meets *t*-axis at time $t < T$	A1

20 - (9702/21_Winter_2020_Q2) - *Kinematics, Work, Energy & Power*

(a)	constant gradient	B1
(b)	(displacement until 0.20 s =) ½ × 1.96 × 0.20 (= 0.196 m) **or** (displacement after 0.20 s =) ½ × 6.86 × 0.70 (= 2.401 m)	C1
	height = 2.401 – 0.196	C1
	= 2.2 m (*alternative methods are possible using equations of uniformly accelerated motion*)	A1
(c)	$(\Delta)E = mg(\Delta)h$ **or** $W(\Delta)h$	C1
	$(\Delta)E = 0.86 \times 2.2$ = 1.9 J	A1
(d)	curved line from the origin	M1
	gradient of curved line decreases and is zero at $t = 0.20$ s only	A1
(e)	acceleration (of free fall) is unchanged/is not dependent on mass <u>and</u> (so) no effect	B1

21 – (9702/22_Winter_2020_Q3) – *Work, Energy & Power, Deformation Of Solids*

(a)(i)	$F = kx$	C1
	$F_1 = 800 \times 0.045$ $= 36$ N	A1
(a)(ii)	(E =) $\frac{1}{2}kx^2$ **or** $\frac{1}{2}Fx$ **or** area under graph	C1
	$\frac{1}{2} \times 800 \times (0.045)^2$ **or** $\frac{1}{2} \times 36 \times 0.045 = 0.81$ (J)	A1
(b)(i)	efficiency = $(0.72 / 0.81) \times 100$ = 89%	A1
(b)(ii)	$E = \frac{1}{2}mv^2$	C1
	$p = mv$	C1
	$0.72 = \frac{1}{2} \times 0.020 \times v^2$ and $p = 0.020 \times v$ $p = 0.17$ N s	A1
(c)(i)	$(\Delta)E = mg(\Delta)h$	C1
	$h = 0.60 / (0.020 \times 9.81) = 3.1$ m	A1
(c)(ii)	$F = (0.72 - 0.60) / 3.1$	C1
	= 0.039 N	A1
(c)(iii)	resultant force on ball is less (than that with air resistance) so time (taken) is more (than T)	B1

22 – (9702/23_Winter_2020_Q4) – *Work, Energy & Power, Deformation Of Solids*

(a)	compression/extension is proportional to force (provided limit of proportionality is not exceeded)	B1
(b)	(E) = $\frac{1}{2}Fx$ **or** $\frac{1}{2}kx^2$ **or** area under graph	C1
	$= \frac{1}{2} \times 8 \times 16 \times 10^{-2} = 0.64$ (J) **or** $= \frac{1}{2} \times 50 \times (16 \times 10^{-2})^2 = 0.64$ (J)	A1
(c)(i)	(E) = $\frac{1}{2}mv^2$	C1
	$0.64 = \frac{1}{2} \times 0.076 \times v^2$ $v = 4.1$ m s^{-1}	A1
(c)(ii)	$(\Delta)(E) = mg(\Delta)h$	C1
	$= 0.076 \times 9.81 \times 0.24$ (= 0.18 (J))	C1
	kinetic energy = 0.64 – 0.18 = 0.46 J	A1
(c)(iii)	$v = 4.1$ m s^{-1}	A1
(d)	$W = Fs$	C1
	$d = 0.30 + (2\pi \times 0.12) + 0.25$ (= 1.3 m)	C1
	$F = 0.23 / 1.3$ = 0.18 N	A1

23 – (9702/21_Summer_2021_Q2) – *Work, Energy & Power*

(a)(i)	$P = Fv$	C1
	$= 18 \times 1.4$ $= 25\ \text{W}$	A1
(a)(ii)	$a = F / m$	C1
	$a = 18 / 72 = 0.25\ (\text{m s}^{-2})$ $t = 1.4 / 0.25$	C1
	$= 5.6\ \text{s}$	A1
(b)(i)	$a = (54 - 18) / 72$ **or** $36 / 72\ (= 0.50\ \text{m s}^{-2})$	C1
	$v^2 = 2 \times 0.50 \times 9.5$	C1
	$v = 3.1\ \text{m s}^{-1}$	A1
(b)(ii)	$W = 54 \times 9.5$ $= 510\ \text{J}$	A1
(b)(iii)	curved line from the origin	M1
	gradient of line increases	A1
(c)	(force due to) air resistance increases/changes/not constant **or** air resistance increases with speed	B1

24 – (9702/22_Summer_2021_Q3) – *Work, Energy & Power*

(a)	$(\Delta)E = mg(\Delta)h$ **or** $W(\Delta)h$	C1
	$= 330 \times (4.0 - 1.1)$ $= 960\ \text{J}$	A1
(b)	(work =) $960 - 540$ $(= 420\ \text{J})$	C1
	distance moved = $(960 - 540) / 52$ $= 8.1\ \text{m}$	A1
(c)(i)	$E = ½mv^2$	C1
	$540 = ½ \times (330 / 9.81) \times v^2$ $v = 5.7\ \text{m s}^{-1}$	A1
(c)(ii)	speed = horizontal component of velocity $= 5.7 \times \cos 41°$	C1
	$= 4.3\ \text{m s}^{-1}$	A1

25 – (9702/21_Winter_2021_Q2) – *Kinematics, Work, Energy & Power*

(a)	mass × velocity	B1
(b)(i)	kinetic energy = $\frac{1}{2}mv^2$	C1
	= $\frac{1}{2} \times 0.24 \times 2.3^2$	C1
	= 0.63 J	A1
(b)(ii)	change in momentum = $\frac{1}{2} \times 240 \times 5.0 \times 10^{-3}$	C1
	= 0.60 N s	A1
(b)(iii)	(change in velocity of Y) = 0.60 / 0.12 (= 5.0 m s^{-1})	C1
	final velocity of Y = 5.0 – 2.3 = 2.7 m s^{-1}	A1
	or	
	(final momentum of Y) = 0.60 – 0.12 × 2.3 (= 0.324 N s)	(C1)
	final velocity of Y = 0.324 / 0.12 = 2.7 m s^{-1}	(A1)
(c)	sloping straight line from (0, 0) to t = 3.0 ms **and** another straight line continuous with the first from t = 3.0 ms to (5.0, 0)	B1
	lines showing maximum force of magnitude 240 N	B1
	lines wholly in the negative F region of the graph	B1

26 – (9702/23_Winter_2021_Q2) – *Work, Energy & Power*

(a)	force × displacement in the direction of the force	B1
(b)	units: kg m s^{-2} × m = kg m^2 s^{-2}	A1
(c)	T_1: K and T_2: K	C1
	A: m^2 and t: s and L: m	C1
	c = (kg m^2 s^{-2} m) / (m^2 K s) = kg m s^{-3} K^{-1}	A1

27 – (9702/21_Winter_2021_Q3) – *Work, Energy & Power*

(a)(i)	$\sigma = F / xy$	B1
(a)(ii)	$\varepsilon = (z - w) / w$	B1
(a)(iii)	$E = \sigma / \varepsilon$	C1
	$= Fw / xy(z - w)$	A1
(b)(i)	extension = 2.2 mm (*allow* 2.0–2.4 mm)	A1
(b)(ii)	strain energy = area under graph/line **or** $\frac{1}{2}Fx$ **or** $\frac{1}{2}kx^2$	C1
	= $\frac{1}{2} \times 120 \times 1.4 \times 10^{-3}$ **or** $\frac{1}{2} \times 8.6 \times 10^4 \times (1.4 \times 10^{-3})^2$	C1
	= 0.084 J	A1
(b)(iii)	(some of the) deformation of the wire is plastic/permanent/not elastic **or** wire goes past the elastic limit/enters plastic region	B1
	energy (that cannot be recovered) is dissipated as thermal energy/becomes internal energy	B1

28 – (9702/22_Winter_2021_Q3) – *Work, Energy & Power*

(a)	work (done) / time (taken)	B1
(b)(i)	zero / 0 J	A1
(b)(ii)	work done = 440 × 25 = 1.1×10^4 J	A1
(c)(i)	$(\Delta)E_{(P)} = mg(\Delta)h$	C1
	$h = 4.8 \times 10^4 / (1700 \times 9.81)$ = 2.9 m	A1
(c)(ii)	$\theta = \sin^{-1}(2.9/25)$ = 6.7°	A1
(d)	work done = $4.8 \times 10^4 + 1.1 \times 10^4$ (= 5.9×10^4 J)	C1
	time = $5.9 \times 10^4 / 1.7 \times 10^4$ = 3.5 s	A1

29 – (9702/21_Summer_2022_Q3) – *Work, Energy & Power*

(a)(i)	work (done) / time (taken)	B1
(a)(ii)	$W = Fx$ **or** $E = Fx$	B1
	$(P =)\ Fx/t = Fv$ **or** $P = Fvt/t = Fv$	B1
(b)(i)	$T = 430 \sin 11°$ **or** $430 \cos 79°$	C1
	= 82 N	A1
(b)(ii)	speed = 56 / 82 = 0.68 m s^{-1}	A1
(b)(iii)	no change in kinetic energy (of block)	B1
(b)(iv)	(input power) = 56 / 0.80 (= 70 W)	C1
	time taken = $1.2 \times 10^3 / 70$ = 17 s	A1
	or	
	(useful energy) = 1200 × 80 / 100 (= 960 J)	(C1)
	time taken = 960 / 56 = 17 s	(A1)

30 – (9702/23_Summer_2022_Q4) – *Work, Energy & Power*

(a)	work (done) = force × displacement	M1
	(force = mg and distance = Δh) (so) work (done) = $mg\Delta h$ and work = $\Delta E_{(P)}$ (so $\Delta E_{(P)} = mg\Delta h$)	A1
(b)	gravitational potential (energy) to heat/thermal (energy)	B1
(c)(i)	$P = mg(\Delta)h / (\Delta)t$ **or** Fv	C1
	$P = (0.60 \times 9.81 \times 1.4) / 4.0$ **or** $0.60 \times 9.81 \times (1.4 / 4.0)$ = 2.1 W	A1
(c)(ii)	$P = I^2R$ **or** IV **or** V^2 / R	C1
	$= 0.09^2 \times 47$ **or** 0.09×4.23 **or** $4.23^2 / 47$ = 0.38 W	A1
(c)(iii)	efficiency = P_{out} / P_{in} (× 100) **or** E_{out} / E_{in} (× 100)	C1
	= 0.38 / 2.1 (× 100) **or** 0.38 × 4.0 / 2.1 × 4.0 (× 100) = 0.18 **or** 18%	A1

31 – (9702/22_Winter_2022_Q1) – *Work, Energy & Power*

(a)	force × displacement in the direction of the force	B1
(b)	$P = Fs / t$ $= (\text{kg m s}^{-2} \times \text{m}) / \text{s}$	C1
	$= \text{kg m}^2 \text{ s}^{-3}$	A1
(c)(i)	$84 \times 10^3 = v^3 \times 0.56$	C1
	$v = 53 \text{ m s}^{-1}$	A1
(c)(ii)	percentage uncertainty = (5% + 7%) / 3 (= 4%) **or** fractional uncertainty = (0.05 + 0.07) / 3 (= 0.04)	C1
	absolute uncertainty = 0.04 × 53 $= (\pm) 2 \text{ m s}^{-1}$	A1

32 – (9702/21_Winter_2022_Q3) – *Work, Energy & Power*

(a)(i)	work done per unit time	B1
(a)(ii)	$W = Fs$	B1
	$P = Fs / t$ and (so) $P = Fv$	B1
(b)	(F =) $130 \times 10^3 / 25 = 5200$ (N)	A1
(c)(i)	(component of weight =) $mg \sin\theta$	A1
(c)(ii)	F (along slope due to weight) = $36\,000 \times 9.81 \times \sin 1.4°$ (= 8600 N)	C1
	(total) $F = 5200 + 36\,000 \times 9.81 \times \sin 1.4°$ (= 13 800 N)	C1
	$P = 13\,800 \times 25$ $= 350 \times 10^3$ (W) = 350 kW	A1

33 – (9702/21_Summer_2023_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a)(i)	(component =) 4.8 sin 30° = 2.4 (N)	A1
(a)(ii)	(8.2 × 0.50) **or** (W × 0.60) **or** (0.30 × 0.80) **or** (2.4 × 1.2)	C1
	(8.2 × 0.50) = (W × 0.60) + (0.30 × 0.80) + (2.4 × 1.2)	C1
	W = 1.6 N	A1
(a)(iii)	force = 4.8 cos 30° = 4.2 N	A1
(b)	$E = ½Fx$	C1
	0.32 = ½ × 8.2 × x x = 0.078 m	A1

(c)(i)	((Δ)E) = mg(Δ)h **or** W(Δ)h	C1
	= 0.30 × 0.090 = 0.027 J	A1
(c)(ii)	$E = ½mv^2$	C1
	E = 0.044 – 0.027 (= 0.017)	C1
	v^2 = (2 × 0.017) / (0.30 / 9.81) (where v = speed at A) v = 1.1 m s^{-1}	A1
	or	
	$E = ½mv^2$	(C1)
	0.044 = ½ × (0.30 / 9.81) × v^2 (where v = speed at B) (v^2 = 2.88) $v^2 = u^2 + 2as$ (where u = speed at A) 2.88 = u^2 + 2 × 9.81 × 0.090	(C1)
	u = 1.1 m s^{-1}	(A1)
(c)(iii)	(gravitational / resultant) force / weight is vertical	B1
(c)(iv)	straight line with positive gradient starting from non-zero value of v_Y at time t_A to a time t_B	B1

34 – (9702/22_Summer_2023_Q2) – *Kinematics, Dynamics, Work, Energy & Power*

(a)	the point where (all) the weight (of the object) is taken to act	B1
(b)(i)	(54 × 0.45) **or** (2.4 × 0.95) **or** (T sin 30° × 1.3)	C1
	(54 × 0.45) = (2.4 × 0.95) + (T sin 30° × 1.3)	C1
	T = 34 N	A1
(b)(ii)	resultant moment = (54 × 0.45) – (2.4 × 0.95) **or** (34 sin 30° × 1.3) = 22 N m	A1
(c)(i)	(Δ)E = mg(Δ)h **or** W(Δ)h	C1
	= 2.4 × 1.8 = 4.3 J	A1

(c)(ii)	$E = \frac{1}{2}mv^2$	C1
	$= \frac{1}{2} \times (2.4 / 9.81) \times 3.4^2$ $= 1.4$ J (at X)	C1
	kinetic energy at Y $= 4.3 + 1.4$ $= 5.7$ J	A1
	or	
	$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 + mg(\Delta)h$	(C1)
	$v^2 = 3.4^2 + 2 \times 9.81 \times 1.8$ $v^2 = 46.9$ so $v = 6.85$ (m s^{-1}) KE $= \frac{1}{2} \times (2.4 / 9.81) \times 6.85^2$	(C1)
	$= 5.7$ J	(A1)
(c)(iii)	no variation **or** acceleration is (always) vertically downwards	B1
(c)(iv)	horizontal straight line at a non-zero value of velocity	B1

35 – (9702/22_Summer_2023_Q4) **–** *Dynamics, Work, Energy & Power*

(a)	Hooke's (law)	B1
(b)	$k = F / x$ **or** k = gradient	C1
	= e.g. $12.0 / (0.240 - 0.08)$ $= 75$ N m^{-1}	A1
(c)	$E = \frac{1}{2}Fx$ **or** $E = \frac{1}{2}kx^2$ **or** E = area under graph	C1
	$E = \frac{1}{2} \times 6.0 \times 0.080$ **or** $\frac{1}{2} \times 75 \times 0.08^2$ $= 0.24$ J	A1

36 – (9702/21_Winter_2023_Q2) – *Work, Energy & Power, Dynamics*

(a)(i)	arrow upwards (↑) **and** labelled upthrust / U arrow downwards (↓) **and** labelled weight / W / mg arrow downwards (↓) **and** labelled tension / T *1 mark: One or two correctly labelled arrows* *2 marks: Three correctly labelled arrows*	B2
(a)(ii)	$U = T + W$ **or** upthrust = tension + weight	C1
	$\rho Vg = T + W$ $V = [(4.00 \times 10^2) + (3.39 \times 10^4)] / (1.23 \times 9.81)$	C1
	$V = 2.84 \times 10^3\ m^3$	A1
(a)(iii)	$m = W / g$ **or** $a = F / m$	C1
	$a = (4.00 \times 10^2) / [(3.39 \times 10^4) / 9.81)]$	C1
	$a = 0.12\ m\ s^{-2}$	A1
(b)	there is air resistance (which increases with speed)	B1
	(average) resultant force is less (than weight)	B1
	(average) acceleration is less (than g / 9.81, so speed is less than 100 m s^{-1})	B1
(c)(i)	(extension =) $2.5 \times 2.4 \times 10^{-5} = 6.0 \times 10^{-5}$ (m)	A1

(c)(ii)	$E_{(P)} = ½ Fx$ **or** $E_{(P)} = ½ kx^2$ **and** $F = kx$	C1
	$E_{(P)} = ½ \times 4.00 \times 10^2 \times 6.0 \times 10^{-5}$ **or** $E_{(P)} = ½ \times 6.7 \times 10^6 \times (6.0 \times 10^{-5})^2$ $E_{(P)} = 0.012$ J	A1
(c)(iii)	longer extension **or** smaller spring constant	M1
	elastic potential energy is greater	A1

37 – (9702/22_Winter_2023_Q3) – *Work, Energy & Power, Deformation Of Solids*

(a)	$E_{(P)} = ½kx^2$ **or** $E_{(P)} = ½Fx$ **and** $F = kx$	C1
	$0.048 = ½ \times k \times (2.1 \times 10^{-2})^2$ $k = 220\ N\ m^{-1}$	A1
(b)	$E_{(K)} = ½mv^2$	C1
	$0.048 = ½ \times 7.5 \times 10^{-3} \times v^2$ $v = 3.6\ m\ s^{-1}$	A1
(c)(i)	$(\Delta)E = mg(\Delta)h$	C1
	$0.039 = 7.5 \times 10^{-3} \times 9.81 \times (\Delta)h$ $\Delta h = 0.53$ m	A1
(c)(ii)	$F \times 0.53 = 0.048 - 0.039$	C1
	$F = 0.02$ N	A1
(d)	sketch: curved line from the origin	M1
	curved line has increasing gradient	A1

38 – (9702/23_Winter_2023_Q3) – *Dynamics, Work, Energy & Power*

(a)	resultant force (in any direction) is zero	B1
	resultant moment / torque (about any point) is zero	B1
(b)(i)	$F = \rho V g$ $V = 93\,000 / (1.2 \times 9.81)$ $= 7900\ \text{m}^3$	A1
(b)(ii)	weight = $93\,000 + 3(.0) \times 10^3$	C1
	$m = (93\,000 + 3.0 \times 10^3) / 9.81$ $= 9800\ \text{kg}$	A1
(c)(i)	$(\Delta p) = F(\Delta)t$ **or** $F = \Delta p / (\Delta)t$ **or** F = rate of change of momentum **or** $F = m(v - u) / t$	C1
	$\Delta p = 2800 \times 0.50$ $= 1400\ \text{kg m s}^{-1}$	A1
(c)(ii)	$(\Delta p =)\ mv$	C1
	$v = 1400 / 64$ $= 22\ \text{m s}^{-1}$	A1

(c)(iii)	$E_K = ½mv^2$	C1
	$= ½ \times 64 \times 22^2$ $= 15\,000\ \text{J}$	A1
	or	
	$E_K = p^2 / 2m$	(C1)
	$= 1400^2 / (2 \times 64)$ $= 15\,000\ \text{J}$	(A1)

1 – (9702/22_Winter_2020_Q1) – *Motion In A Circle, Kinematics*

(a)	density and temperature indicated as scalars	B1
	acceleration and momentum indicated as vectors	B1
(b)(i)	decelerates **or** speed/velocity decreases	B1
(b)(ii)	speed = $(\Delta)d / (\Delta)t$ **or** gradient	C1
	= e.g. (0.56 – 0.20) / 1.5 = 0.24 $m\,s^{-1}$	A1
(c)	displacement is zero (so) average velocity is zero	B1

1 - (9702/22_Summer_2017_Q3) - *Deformation Of Solids*

(a)	E = stress / strain or $(F / A) / (e / l)$
	= [gradient × 3.5] / [$\pi \times (0.19 \times 10^{-3})^2$] e.g. E = [{(40 – 5) / ([11.6 – 3.2] × 10^{-3})} × 3.5] / [$\pi \times (0.19 \times 10^{-3})^2$] or [4170 × 3.5] / [$\pi \times (0.19 \times 10^{-3})^2$]
	E (= 1.3 × 10^{11}) = 0.13 TPa (*allow answers in range 0.120–0.136 TPa*)
(b)	a larger range of F required or range greater than 35 N

2 - (9702/23_Summer_2017_Q4) - *Deformation Of Solids*

(a)	the straight line does not go through the origin/the force is not proportional to extension (so does not obey Hooke's law)
(b)	elastic potential energy
(c)	remove the force/masses and the spring returns to its original length if elastic
(d)	work done is represented by/linked to area under the line (× g)
	work = ½ (145 + 70) × 10^{-3} × 9.81 × 120 × 10^{-3}
	= 0.13 (0.127) J

3 - (9702/21_Winter_2017_Q4) - *Deformation Of Solids*

(a)	(strain =) extension / original length	B1
(b)(i)	$E = \sigma / \varepsilon$	C1
	maximum stress = 2.1 × 10^{11} × 4.0 × 10^{-4} = 8.4 × 10^{7} Pa	A1
(b)(ii)	$\sigma = F / A$	C1
	minimum area = 8.0 × 10^{3} / 8.4 × 10^{7} = 9.5 × 10^{-5} m^2	A1

4 - (9702/23_Summer_2018_Q4) - *Deformation Of Solids*

(a)	(Young modulus =) stress / strain	B1
(b)(i)	$k = F / \Delta L$ or 1 / gradient	C1
	= 90 × 10^{3} / (2 × 10^{-3}) (*or other point on line*) = 4.5 × 10^{7} N m^{-1}	A1
(b)(ii)	E = ½$F\Delta L$ or E = ½$k(\Delta L)^2$	C1
	= ½ × 90 × 10^{3} × 2 × 10^{-3} or ½ × 4.5 × 10^{7} × (2 × 10^{-3})^2	C1
	= 90 J	A1
(c)	straight line starting from (0, 150) and below original line	M1
	line ends at (90, 147)	A1

5 – (9702/23_Winter_2018_Q1) – *Physical Quantities & Units, Forces, Density & Pressure, Deformation Of Solids*

(a)	current temperature (**allow** amount of substance, luminous intensity) *any two correct answers, 1 mark each*	**B2**
(b)(i)	$W = 2 \times (150 \times \sin 17°)$ **or** $2 \times (150 \times \cos 73°)$	**C1**
	$W = 88$ N	**A1**
(b)(ii)	**1.** $\sigma = F/A$	**C1**
	$= 150/(7.5 \times 10^{-6})$ $= 2.0 \times 10^{7}$ Pa	**A1**
	2. $\varepsilon = \sigma / E$	**C1**
	$= 2.0 \times 10^{7}/(2.1 \times 10^{11})$ $= 9.5 \times 10^{-5}$	**A1**

6 – (9702/21_Summer_2019_Q3) – *Deformation Of Solids, Work, Energy & Power*

(a)(i)	$E = ½Fx$ **or** $E = ½kx^2$ **or** E = area under graph	**C1**
	$E = ½ \times 4.0 \times 0.32 = 0.64$ J **or** $E = ½ \times 12.5 \times (0.32)^2 = 0.64$ J	**A1**
(a)(ii)	$E = mgh$ **or** $E = Wh$ $= 2.5 \times 0.32$	**C1**
	$= 0.80$ J	**A1**
(b)(i)	kinetic energy $= 0.80 - 0.64$ $= 0.16$ J	**A1**
(b)(ii)	$E = ½mv^2$ $0.16 = ½ \times (2.5/9.81) \times v^2$	**C1**
	$v = 1.1$ m s^{-1}	**A1**

7 – (9702/21_Winter_2019_Q4) – *Work, Energy & Power, Deformation Of Solids*

(a)	$k = F/x$ **or** k = gradient	**C1**
	e.g. $k = 4.0/0.050$ $k = 80$ N m^{-1}	**A1**
(b)	$E = ½Fx$ **or** $E = ½kx^2$ **or** E = area under graph	**C1**
	$(\Delta)E = (½ \times 3.2 \times 0.040) - (½ \times 1.2 \times 0.015) = 0.055$ J **or** $(\Delta)E = (½ \times 80 \times 0.040^2) - (½ \times 80 \times 0.015^2) = 0.055$ J **or** $(\Delta)E = ½ \times (1.2 + 3.2) \times 0.025 = 0.055$ J	**A1**
(c)	$(\Delta)E = mg(\Delta)h$	**C1**
	$= 0.122 \times 9.81 \times (0.120 - 0.095)$ $= 0.030$ J	**A1**
	or	
	$(\Delta)E = W \times (\Delta)h$	**(C1)**
	$= 1.2 \times 0.025$ $= 0.030$ J	**(A1)**

(d)(i)	E = 0.055 – 0.030 = 0.025 J	A1
(d)(ii)	$E = ½mv^2$	C1
	v = [(2 × 0.025) / 0.122]$^{0.5}$ = 0.64 m s^{-1}	A1

8 – (9702/23_Winter_2019_Q4) – *Dynamics, Deformation Of Solids*

(a)(i)	$p = mv$	C1
	= 0.2(00) × 6.(00) × sin 60(.0)° **or** 0.2(00) × 6.(00) × cos 30(.0)° = 1.04 kg m s^{-1}	A1
(a)(ii)	0.300 × v_x × sin 60.0° = 1.04 v_x = 4.00 m s^{-1}	A1
(a)(iii)	0.30 × 4.0 × cos 60° **or** 0.20 × 6.0 × cos 60° **or** (0.30 + 0.20)v **or** 0.50v	C1
	0.30 × 4.0 × cos 60° + 0.20 × 6.0 × cos 60° = (0.30 + 0.20)v **or** 0.50v so v = 2.4 m s^{-1}	A1
(b)(i)	$E = ½mv^2$	C1
	½ × 0.50 × 2.4^2 = ½ × 72 × x^2	C1
	x = 0.20 m	A1
(b)(ii)	**1.** straight line from the origin sloping upwards	B1
	2. line drawn from a positive value of E_k at x = 0 to a positive value of x at E_k = 0	M1
	line has an increasing downwards slope	A1

9 – (9702/23_Summer_2020_Q3) – *Forces, Density & Pressure, Deformation Of Solids*

(a)	for a body in (rotational) equilibrium	B1
	sum/total of clockwise moments about a point = sum/total of anticlockwise moments about the (same) point	B1
(b)(i)	(W × 0.45) **or** (19 × 1.3) **or** (W × 1.85) **or** (22 × 2.6)	C1
	(W × 0.45) + (19 × 1.3) + (W × 1.85) = (22 × 2.6) so W = 14 N	A1
(b)(ii)	magnitude = 19 + 14 + 14 – 22 = 25 N	A1
	direction: vertically upwards	A1
(c)(i)	the extension is zero when the force is zero	B1
	graph is a straight line and (so) Hooke's law obeyed	B1
(c)(ii)	$k = F / x$ **or** k = gradient	C1
	e.g. k = 60 / (1.00 – 0.25) k = 80 N m^{-1}	A1
(c)(iii)	area shaded below graph line between L = 0.25 m and L = 0.75 m	B1

10 - (9702/22_Summer_2020_Q5) - *Deformation Of Solids, Current Of Electricity*

(a)	Hooke's (law)	B1
(b)(i)	$\sigma = F / A$	C1
	$= 36 / (4.1 \times 10^{-7})$ $= 8.8 \times 10^{7}$ Pa	A1
(b)(ii)	Young modulus = σ / ε **or** $F / A\varepsilon$	C1
	$\varepsilon = 8.8 \times 10^{7} / (1.7 \times 10^{11})$ $= 5.2 \times 10^{-4}$	A1
(c)	$R = \rho L / A$	C1
	$\Delta R = \rho \Delta x / A$ $= 3.7 \times 10^{-7} \times 0.12 \times 10^{-3} / (4.1 \times 10^{-7})$	C1
	$= 1.1 \times 10^{-4}\ \Omega$	A1
(d)	remove the force/F and wire returns to original length	B1

11 - (9702/22_Winter_2020_Q3) - *Work, Energy & Power, Deformation Of Solids*

(a)(i)	$F = kx$	C1
	$F_1 = 800 \times 0.045$ $= 36$ N	A1
(a)(ii)	(E =) $\frac{1}{2}kx^2$ **or** $\frac{1}{2}Fx$ **or** area under graph	C1
	$\frac{1}{2} \times 800 \times (0.045)^2$ **or** $\frac{1}{2} \times 36 \times 0.045 = 0.81$ (J)	A1
(b)(i)	efficiency = $(0.72 / 0.81) \times 100$ = 89%	A1
(b)(ii)	$E = \frac{1}{2}mv^2$	C1
	$p = mv$	C1
	$0.72 = \frac{1}{2} \times 0.020 \times v^2$ and $p = 0.020 \times v$ $p = 0.17$ N s	A1
(c)(i)	$(\Delta)E = mg(\Delta)h$	C1
	$h = 0.60 / (0.020 \times 9.81) = 3.1$ m	A1
(c)(ii)	$F = (0.72 - 0.60) / 3.1$	C1
	$= 0.039$ N	A1
(c)(iii)	resultant force on ball is less (than that with air resistance) so time (taken) is more (than T)	B1

12 - (9702/21_Winter_2020_Q4) - *Deformation Of Solids*

(a)(i)	(stress =) force / cross-sectional area	B1
(a)(ii)	(strain =) extension / original length	B1
(b)(i)	$E = FL / Ax$	C1
	$= GL / A$	A1
(b)(ii)	straight line from origin above the original line	M1
	line ends at point (4 small squares, F_1)	A1
(b)(iii)	1. shaded area below the graph line and between the two vertical dashed lines	B1
	2. remove the force/F/F_2 and the wire goes back to original length/zero extension	B1
(b)(iv)	values have a large range	B1

13 – (9702/23_Winter_2020_Q4) – *Work, Energy & Power, Deformation Of Solids*

(a)	compression/extension is proportional to force (provided limit of proportionality is not exceeded)	B1
(b)	$(E) = ½Fx$ **or** $½kx^2$ **or** area under graph	C1
	$= ½ \times 8 \times 16 \times 10^{-2} = 0.64$ (J) **or** $= ½ \times 50 \times (16 \times 10^{-2})^2 = 0.64$ (J)	A1
(c)(i)	$(E) = ½mv^2$	C1
	$0.64 = ½ \times 0.076 \times v^2$ $v = 4.1\ \text{m s}^{-1}$	A1
(c)(ii)	$(\Delta)(E) = mg(\Delta)h$	C1
	$= 0.076 \times 9.81 \times 0.24$ (= 0.18 (J))	C1
	kinetic energy = 0.64 – 0.18 = 0.46 J	A1
(c)(iii)	$v = 4.1\ \text{m s}^{-1}$	A1
(d)	$W = Fs$	C1
	$d = 0.30 + (2\pi \times 0.12) + 0.25$ (= 1.3 m)	C1
	$F = 0.23 / 1.3$ = 0.18 N	A1

14 – (9702/21_Summer_2022_Q4) – *Deformation Of Solids*

(a)	$k = F / \Delta L$ **or** F / x **or** gradient	C1
	= e.g. 30 / (0.60 – 0.20) $= 75\ \text{N m}^{-1}$	A1
(b)	$E = \frac{1}{2}F\Delta L$ **or** $\frac{1}{2}Fx$ **or** $\frac{1}{2}k(\Delta L)^2$ **or** $\frac{1}{2}kx^2$ **or** area under graph	C1
	$= \frac{1}{2} \times 15 \times 0.20$ **or** $\frac{1}{2} \times 75 \times 0.20^2$	C1
	= 1.5 J	A1

15 – (9702/22_Winter_2023_Q3) – *Work, Energy & Power, Deformation Of Solids*

(a)	$E_{(P)} = ½kx^2$ **or** $E_{(P)} = ½Fx$ **and** $F = kx$	C1
	$0.048 = ½ \times k \times (2.1 \times 10^{-2})^2$ $k = 220\ \text{N m}^{-1}$	A1
(b)	$E_{(K)} = ½mv^2$	C1
	$0.048 = ½ \times 7.5 \times 10^{-3} \times v^2$ $v = 3.6\ \text{m s}^{-1}$	A1
(c)(i)	$(\Delta)E = mg(\Delta)h$	C1
	$0.039 = 7.5 \times 10^{-3} \times 9.81 \times (\Delta)h$ $\Delta h = 0.53\ \text{m}$	A1
(c)(ii)	$F \times 0.53 = 0.048 - 0.039$	C1
	$F = 0.02\ \text{N}$	A1
(d)	sketch: curved line from the origin	M1
	curved line has increasing gradient	A1

16 – (9702/23_Winter_2023_Q4) – *Deformation Of Solids*

(a)(i)	spring constant	B1
(a)(ii)	area represents the work done (to extend the wire)	B1
	work done (to extend the wire) is equal to elastic potential energy	B1
(b)(i)	$x_G = 0.39\ \text{mm}$ **and** $x_H = 0.29\ \text{mm}$	A1
(b)(ii)	$E = ½Fx$ **or** $E = ½kx^2$ **and** $F = kx$ **or** E = area under graph	C1
	for G: $E = ½ \times 2.0 \times (0.39 \times 10^{-3})$ **or** $½ \times 5.1 \times 10^3 \times (0.39 \times 10^{-3})^2$ for H: $E = ½ \times 2.0 \times (0.29 \times 10^{-3})$ **or** $½ \times 6.9 \times 10^3 \times (0.29 \times 10^{-3})^2$ $E_P = 3.9 \times 10^{-4} + 2.9 \times 10^{-4}$ $= 6.8 \times 10^{-4}\ \text{J}$	A1
(b)(iii)	$E = FL / Ax$ **or** stress / strain = FL / Ax	C1
	$A_G / A_H = 1 \times (0.29 \times 10^{-3}) / [1.5 \times (0.39 \times 10^{-3})]$	C1
	ratio = 0.50	A1

1 – (9702/22_Winter_2022_Q4) – *Ideal Gases*

(a)	$E = ½mv^2$	C1
	$= ½ \times 0.25 \times 2.3^2$ $= 0.66$ J	A1
(b)	$E = ½kx^2$ **or** $E = ½Fx$ **and** $F = kx$	C1
	$x = [(2 \times 0.66) / 420]^{0.5}$ $= 0.056$ m	A1
	or	
	$E = ½kx^2$	(C1)
	$½mv^2 = ½kx^2$ $x = (0.25 \times 2.3^2 / 420)^{0.5}$ $= 0.056$ m	(A1)
(c)(i)	(p =) 0.25×2.3 **or** 0.25×1.5	C1
	change in momentum = 0.25 (2.3 + 1.5) = 0.95 N s	A1
(c)(ii)	resultant force = 0.95 / 0.086 or $0.25 \times (2.3 + 1.5) / 0.086$ = 11 N	A1
(d)	curved line from the origin with an increasing gradient	B1

1 – (9702/21_Summer_2017_Q5) – *Waves*

(a)	observed frequency is different to source frequency when source moves relative to observer
(b)	360 = (400 × 340) / (340 ± v)
	v = 38 (37.8) m s^{-1}
	away (from the observer)

2 – (9702/22_Summer_2017_Q5) – *Waves, Superposition*

(a)	frequency is the number of vibrations/oscillations per unit time **or** the number of wavefronts passing a point per unit time
(b)	vibrations/oscillation of the air particles are parallel to the direction of it (the direction of travel of the sound wave)
(c)(i)	T = 2(.0) (ms)
	f = 500 Hz
(c)(ii)	**1.** amplitude increases (time) period decreases **2.** amplitude decreases (time) period increases *any 3 points*

3 – (9702/21_Winter_2017_Q3) – *Waves, Superposition*

(a)(i)	in a stationary wave energy is not transferred **or** in a progressive wave energy is transferred	**B1**
(a)(ii)	in a stationary wave (adjacent) particles are in phase **or** in a progressive wave (adjacent) particles are out of phase/have a phase difference/not in phase	**B1**
(b)(i)	(position where) maximum amplitude	**B1**
(b)(ii)	distance = 0.10 m	**B1**
(b)(iii)	**1.** λ = 0.60/1.5 = 0.40 m	**A1**
	2. $v = f\lambda$	**C1**
	f = 340/0.40 = 850 Hz	**A1**
(b)(iv)	λ = 2 × 0.60 **or** λ = 3 × 0.40 **or** f = 850/3	**C1**
	f = 280 (283) Hz	**A1**

4 – (9702/22_Winter_2017_Q4) – *Waves, Superposition*

(a)	(two) waves travelling (at same speed) in opposite directions overlap	B1
	waves (are same type and) have same frequency/wavelength	B1
(b)(i)	5	A1
(b)(ii)	$T = 1/40$ (= 2.5×10^{-2})	C1
	time taken = $2.5 \times 10^{-2}/2$ = 1.3×10^{-2} s (1.25×10^{-2} s)	A1
(b)(iii)	180°	A1
(b)(iv)	$v = f\lambda$	C1
	$\lambda = 2.0/2.5$ (= 0.80 m) $v = 0.80 \times 40$ = 32 m s^{-1}	A1

5 – (9702/23_Winter_2017_Q4) – *Waves, Superposition*

(a)	displacement of particles/vibration(s)/oscillation(s) is parallel to/along the direction of energy/propagation	B1
(b)	period = 1 / 800 (= 1.25×10^{-3} s)	C1
	time-base setting = $1.25 \times 10^{-3}/2.5$	C1
	= 5.0×10^{-4} s cm^{-1}	A1
(c)(i)	$I \propto A^2$	C1
	$(I_X/I_Y =)\ [r_Y/r_X]^2 = [A_X/A_Y]^2$	C1
	ratio A_Y/A_X = 120 / 30 = 4.0	A1

(c)(ii)	**1.** $v = f\lambda$	C1
	minimum $\lambda = 330/(800 + 16) = 0.40$ m	A1
	2. $f_o/f_s = v/(v - v_s)$ $816/800 = 330/(330 - v_s)$	C1
	$v_s = 6.5$ m s^{-1}	A1

6 – (9702/23_Summer_2018_Q2) – *Forces, Density & Pressure, Work, Energy & Power, Waves*

(a)(i)	(work =) force × distance moved in the direction of the force	B1
(b)(i)	$\rho = m / V$	C1
	$= (20/9.81)/(4/3 \times \pi \times 0.16^3)$ $= 120\,\text{kgm}^{-3}$	A1
(b)(ii)	the pressure on the lower surface (of sphere) is greater than the pressure on the upper surface (of sphere)	B1
(b)(iii)	$a = (170 - 20)/(20/9.81)$	C1
	$= 74\,\text{ms}^{-2}$	A1
(b)(iv)	$D = 170 - 20$ (= 150)	C1
	$810 \times (0.16^2) \times v^2 = 150$	C1
	$v = 2.7\,\text{ms}^{-1}$	A1
(b)(v)	$4870 = (4850 \times v)/(v - 6.30)$	C1
	$v = 1530\,\text{ms}^{-1}$	A1

7 – (9702/22_Summer_2018_Q3) – *Kinematics, Dynamics, Waves*

(a)	time = 12 s	A1
(b)	distance (up slope) = ½ × 12 × 18 (= 108)	C1
	distance (down slope) = ½ × 12 × 6 (= 36)	C1
	displacement from A = 108 – 36 = 72 m	A1
(c)	$v = u + at$ **or** a = gradient **or** $a = \Delta v / (\Delta) t$	C1
	$a = 6 / 12 = 0.50\,(\text{ms}^{-2})$ *(other points from the line may be used)*	A1
	or	
	$v^2 = u^2 + 2as$ **and** $u = 0$ **or** $v^2 = 2as$	(C1)
	$a = 6.0^2 / (2 \times 36) = 0.50\,(\text{ms}^{-2})$	(A1)
	or	
	$s = ut + ½at^2$ **and** $u = 0$ **or** $s = ½at^2$	(C1)
	$a = 2 \times 36 / 12^2 = 0.50\,(\text{ms}^{-2})$	(A1)
	or	
	$s = vt - ½at^2$	(C1)
	$a = 2 \times (6 \times 12 - 36) / 12^2 = 0.50\,(\text{ms}^{-2})$	(A1)

(d)(i)	$F = 70 \times 0.50$ (= 35)	C1
	frictional force = 80 – 35 = 45 N	A1
(d)(ii)	$\sin\theta = 80/(70 \times 9.81)$	C1
	$\theta = 6.7°$	A1
(e)(i)	$f_0 = (900 \times 340)/(340 + 12)$	C1
	= 870 Hz	A1
(e)(ii)	speed/velocity (of sledge) decreases and (so) frequency increases	B1

8 - (9702/21_Summer_2018_Q4) - *Waves, Superposition*

(a)(i)	time for one oscillation/one vibration/one cycle **or** time between adjacent wavefronts/points in phase **or** shortest time between two wavefronts/points in phase	**B1**
(a)(ii)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** minimum distance between two wavefronts **or** distance between two adjacent wavefronts **or** minimum distance between two points having the same displacement and moving in the same direction	**B1**
(b)(i)	$v = \lambda / T$ **or** $v = f\lambda$ <u>and</u> $f = 1/T$	**C1**
	$\lambda = 20 \times 0.60$ $= 12$ cm	**A1**
(b)(ii)	phase difference $= 360° \times (0.20/0.60)$ **or** $360° \times (0.40/0.60)$ $= 120°$ **or** $240°$	**A1**
(b)(iii)	$I \propto A^2$	**C1**
	$I_Q/I_P = A_Q^2/A_P^2$ $= 2.0^2/3.0^2$ $= 0.44$	**A1**
(b)(iv)	displacement $= 1.00 - 3.00$ $= -2.00$ mm	**A1**

9 - (9702/22_Summer_2018_Q4) - *Waves, Superposition*

(a)(i)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** <u>minimum</u> distance between two wavefronts **or** distance between two <u>adjacent</u> wavefronts	**B1**
(a)(ii)	(position where) maximum amplitude	**B1**
(b)(i)	$\lambda = 4 \times 0.045$ (= 0.18 (m) or 18 (cm))	**C1**
	$v = f\lambda$	**C1**
	$f = 340/0.18$ $= 1900$ Hz	**A1**
(b)(ii)	distance $= \lambda/2$ (= 0.09 (m) or 9 (cm))	**C1**
	time $= 0.09 / 0.0075$ $= 12$ s	**A1**
	or	
	$t = 4.5/0.75$ **and** $t = 13.5/0.75$	**(C1)**
	time $= 18 - 6$ $= 12$ s	**(A1)**

10 – (9702/21_Summer_2018_Q5) – *Waves, Superposition*

(a)(i)	waves spread at (each) slit/gap	B1
(a)(ii)	constant phase difference (between (each of) the waves)	B1
(b)(i)	$n\lambda = d\sin\theta$	B1
	$d\sin\theta$ is the same **and** $3\lambda_1 = 4\lambda_2$ so $\lambda_2 / \lambda_1 = 0.75$	A1
(b)(ii)	$\lambda_2 / \lambda_1 = 0.75$ and $\lambda_1 - \lambda_2 = 170$ $\lambda_1 = 680\,\text{nm}$	A1

11 – (9702/23_Summer_2018_Q5) – *Waves, Superposition*

(a)	intensity $\propto$ (amplitude)^2	B1
(b)(i)	$v = f\lambda$ **or** $c = f\lambda$	C1
	$f = 3.00 \times 10^8 / 0.060$ $= 5.0 \times 10^9\,\text{Hz}$	A1
(b)(ii)	(at X path) difference = 3λ	M1
	(at X phase) difference = 0 or 1080°	M1
	so intensity is at a maximum/it is an intensity maximum	A1
(b)(iii)	**1.** decrease in the distance between (adjacent intensity) maxima/minima	B1
	2. (intensity) maxima and minima exchange places	B1

12 – (9702/22_Winter_2018_Q4) – *Waves*

(a)	vibration(s)/oscillation(s) (of particles) parallel to direction of propagation of energy	B1
(b)(i)	phase difference = 180°	A1
(b)(ii)	$v = f\lambda$	C1
	$\lambda/2$ = 25 (cm) or 0.25 (m)	C1
	$f = 330/0.50$ $= 660\,\text{Hz}$	A1
(b)(iii)	(readings from graph =) 2.6 <u>and</u> 4.0	C1
	ratio = $(2.6/4.0)^{1/2}$ $= 0.81$	A1

13 – (9702/23_Winter_2018_Q4) – *Waves, Superposition*

(a)	graph with *x*-axis labelled 'distance' and wavelength/λ correctly shown	B1
	graph with *x*-axis labelled 'time' and period/*T* correctly shown	B1
	graph with *y*-axis labelled 'displacement' and amplitude/*A* correctly shown	B1
(b)(i)	wave (moves along string and) reflects at fixed point/Y/X/end/wall/boundary	B1
	the incident and reflected waves interfere/superpose	B1
(b)(ii)	100 / 40 **or** 2.5 (cycles/periods/*T*)	C1
	1. displacement = 0	B1
	2. distance = 130 mm	A1
(b)(iii)	**1.** $f = 1/40 \times 10^{-3}$ $= 25$ Hz	A1
	2. $v = f\lambda$ **or** $\lambda = vT$	C1
	$\lambda = 30/25$ **or** $30 \times 40 \times 10^{-3}$ (= 1.2 m)	C1
	distance $= 1.2 \times 1.5$ $= 1.8$ m	A1

14 – (9702/22_Summer_2019_Q4) – *Waves, Superposition*

(a)(i)	distance (in a specified direction of particle/point on wave) from the equilibrium position	B1
(a)(ii)	the maximum distance (of particle/point on wave) from the equilibrium position **or** the maximum displacement (of particle/point on wave)	B1
(b)	$I \propto A^2$	C1
	$I_R / I = (3.6 - 1.2)^2 / (1.2)^2$ resultant intensity = $4.0I$	A1
(c)(i)	as wave(s) pass through the slit(s)	B1
	wave(s) spread (into geometric shadow)	B1
(c)(ii)	$n\lambda = d \sin\theta$	C1
	$3\lambda = d \sin 90°$ **or** $3\lambda = d$	C1
	$d = 3 \times 630 \times 10^{-9}$ $= 1.9 \times 10^{-6}$ m	A1
(c)(iii)	wavelength of blue light is shorter (than 540 nm/630 nm/wavelengths of original light)	M1
	(so) third order diffraction maximum is produced	A1

15 – (9702/21_Summer_2019_Q5) – *Waves, Superposition*

(a)(i)	**1.** $N\lambda$	B1
	2. N / f	B1
(a)(ii)	v (= distance / time) = $N\lambda / (N / f)$ so $v = f\lambda$	B1
(b)	$T = 4.0 \times 0.20 = 0.80$ (ms) **or** 8.0×10^{-4} (s)	C1
	$f = 1 / 8.0 \times 10^{-4}$ $= 1300$ Hz	A1
(c)(i)	constant phase difference (between the waves)	B1
(c)(ii)	180°	A1
(c)(iii)	path difference $= 2\lambda$ **or** $S_1Y - S_2Y = 2\lambda$	C1
	distance $= 7.40 + (0.85 \times 2)$ $= 9.1$ m	A1

16 – (9702/23_Summer_2019_Q5) – *Waves, Superposition*

(a)	(incident) wave reflects at end/top of tube	B1
	(incident) wave and reflected wave interfere/superpose	B1
(b)	line has maximum value of amplitude at $h = 0$ and $h = 0.60$ m only	B1
	line has minimum/zero value of amplitude at $h = 0.30$ m only	B1
(c)(i)	vertical/along length of tube/along axis of tube	B1
(c)(ii)	phase difference = 0	A1
(d)	$v = f\lambda$	C1
	$v = 340 / (2 \times 0.60)$ $= 280$ Hz	A1
(e)	$f = 340 / 0.60$ $= 570$ Hz	A1

17 – (9702/21_Winter_2019_Q3) – *Waves, Dynamics*

(a)	$\rho = m / V$	C1
	$V = \pi \times (0.16 / 2)^2 \times 7.6 \times 3.0$ (= 0.458 m^3)	C1
	$m = \pi \times (0.16 / 2)^2 \times 7.6 \times 3.0 \times 1.2 = 0.55$ kg	A1
(b)(i)	$\Delta p = 0.55 \times 7.6$ $= 4.2$ N s	A1
(b)(ii)	$F = 4.2 / 3.0$ **or** $0.55 \times 7.6 / 3.0$ $= 1.4$ N	A1
(c)(i)	$F = 1.4$ N	A1
(c)(ii)	Newton's third law (of motion)	B1
(d)	$2 \times 1.4 = m \times 9.81$ $m = 0.29$ kg	A1
(e)	the density of air is less at high altitude	B1
(f)	$f_o = f_s v / (v - v_s)$ $= 3000 \times 340 / (340 - 22)$	C1
	$= 3200$ Hz	A1

18 – (9702/21_Winter_2019_Q5) – *Waves, Superposition*

(a)(i)	the dippers are connected to the same vibrator/motor	B1
(a)(ii)	(the overlapping waves have) similar/same amplitude	B1
(b)	any means of 'freezing' the pattern e.g. use a stroboscope/strobe	B1
(c)	$vT = \lambda$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$T = 0.060 / 0.40$ $= 0.15$ s	A1
(d)(i)	path difference = 3.0 cm	A1
(d)(ii)	phase difference = 180°	A1
(e)	line drawn joining points where only maxima are observed (i.e. through points where wavefronts intersect) of length at least 4 cm	B1

19 – (9702/22_Winter_2019_Q5) – *Waves, Superposition*

(a)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** minimum distance between two wavefronts **or** distance between two adjacent wavefronts	B1
(b)	(T =) 2.0×2.5 (= 5.0 ms) **or** $2.0 \times 2.5 \times 10^{-3}$ (= 5.0×10^{-3} s)	C1
	$f = 1 / (5.0 \times 10^{-3})$ $= 200$ Hz	A1
(c)(i)	(path difference =) $8.0 + (20.8^2 - 8.0^2)^{0.5} - 20.8 = 6.4$ (m)	A1
(c)(ii)	• path difference = 4λ • waves (meet at C) in phase • constructive interference (of waves) *any two points, one mark each*	B2
(c)(iii)	$v = 200 \times 1.6$ $= 320$ (m s^{-1})	C1
	$\Delta t = 6.4 / 320$ **or** $27.2 / 320 - 20.8 / 320$ $= 0.020$ s	A1
(c)(iv)	$3\lambda = 6.4$ $\lambda = 2.1$ m	A1

20 – (9702/23_Winter_2019_Q5) – *Waves, Superposition*

(a)(i)	(coherence means) constant phase difference (between waves)	B1
(a)(ii)	(interference is) the sum/addition/combination of the displacements of overlapping/meeting waves	B1
(b)(i)	$n\lambda = d \sin\theta$	C1
	$\lambda = \sin 51° / (2 \times 6.7 \times 10^5)$ $= 5.8 \times 10^{-7}$ m	A1
(b)(ii)	smaller angle (corresponding to second order maxima and so) shorter distance (between second order maxima spots)	B1

21 – (9702/21_Summer_2020_Q4) – *Waves, Superposition*

(a)(i)	vibrations (of particles) are parallel to direction of energy propagation	B1
(a)(ii)	waves meet/overlap (at a point)	B1
	(resultant) displacement is sum of individual displacements	B1
(b)(i)	$\lambda = ax / D$	C1
	$= (3.7 \times 10^{-4} \times 4.3 \times 10^{-3}) / 2.3$	C1
	$= 6.9 \times 10^{-7}$ (m) = 690 nm	A1
(b)(ii)	• no change to fringe separation/fringe width/number of fringes • bright fringes are darker • dark fringes are brighter *Any two marking points, 1 mark each*	B2

22 – (9702/22_Summer_2020_Q4) – *Waves, Superposition*

(a)	progressive waves transfer energy **or** stationary waves do not transfer energy	B1
(b)(i)	0.32 m	A1
(b)(ii)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$v = 0.32 / 0.020$ **or** 50×0.32 $= 16\ \text{m s}^{-1}$	A1
(b)(iii)	450° **or** 90°	A1
(b)(iv)	(P has) maximum downward displacement at 0.005 s	B1
	returns to original position/point (at 0.010 s)	B1
(c)(i)	(position where) zero amplitude	B1
(c)(ii)	2	A1
(c)(iii)	180°	A1
(c)(iv)	string drawn between X and Y with one antinode midway along the string	B1

23 – (9702/23_Summer_2020_Q4) – *Waves*

(a)(i)	frequency **or** period	B1
(a)(ii)	amplitude	B1
(b)	constant phase difference so coherent	B1
(c)	120°	B1
(d)	resultant displacement = 4.0 μm – 1.0 μm = 3.0 μm	B1
(e)	$I \propto A^2$	C1
	intensity of Z = $(2^2 / 4^2)\ I$ $= 0.25\ I$	A1
(f)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$330 = \lambda / 3.0 \times 10^{-3}$	C1
	$\lambda = 0.99$ m	A1

24 – (9702/21_Winter_2020_Q5) – *Waves*

(a)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$v = 8.0 \times 10^{-2} / 0.40$ $= 0.20\ \text{m s}^{-1}$	A1
(b)	$I \propto A^2$	C1
	ratio $= 2^2 / 4^2$	C1
	$= 0.25$	A1

25 – (9702/22_Winter_2020_Q5) – *Waves, Superposition*

(a)	$v = f\lambda$ **or** $c = f\lambda$	C1
	$f = 3.0 \times 10^8 / 0.040$	C1
	$= 7.5 \times 10^9$ (Hz) $= 7.5$ GHz	A1
(b)(i)	path difference = 0.020 m	A1
(b)(ii)	phase difference = 180°	A1
(c)	(intensity) increases	C1
	(intensity) increases by a factor of 4	A1
(d)(i)	minimum moves closer to the maximum **or** decrease in separation of maximum and minimum	B1
(d)(ii)	the maximum and minimum exchange places **or** the maximum becomes a minimum **and** the minimum becomes a maximum	B1

26 – (9702/23_Winter_2020_Q5) – *Waves, Superposition*

(a)(i)	$T = 2.0 \times 10^{-5} \times 6.0$ $(= 1.2 \times 10^{-4}\ \text{s})$	C1
	$f = 1 / (2.0 \times 10^{-5} \times 6.0)$ $= 8300$ Hz	A1
(a)(ii)	new trace shows the same period	B1
	new trace shows amplitude of 10 small squares	B1
(a)(iii)	(trace is a) vertical line	B1
(b)(i)	$n\lambda = d \sin\theta$	C1
	$\lambda = (3.4 \times 10^{-6} \times \sin 16°) / 2$ $= 4.7 \times 10^{-7}$ m	A1
(b)(ii)	$n = 3.4 \times 10^{-6}\ (\times \sin 90°) / 4.7 \times 10^{-7}$ or $2\ (\times \sin 90°) / \sin 16°$ (= 7.2 or 7.3)	C1
	highest order = 7	A1

27 – (9702/21_Summer_2021_Q4) – *Waves, Superposition*

(a)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** minimum distance between two wavefronts **or** distance between two adjacent wavefronts	B1
(b)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$T = 460 \times 10^{-9} / 3.00 \times 10^{8}$	C1
	$= 1.5 \times 10^{-15}$ s	A1
(c)	waves pass through/enter the slit(s)	B1
	waves spread (into geometric shadow)	B1
(d)(i)	$n\lambda = d \sin\theta$	C1
	$G = \sin\theta / \lambda$ $d = 4 / G$	A1
(d)(ii)	straight line from 400 nm to 700 nm that is always below printed line	M1
	straight line has smaller gradient than printed line and is 5 small squares high at wavelength of 700 nm	A1

28 – (9702/22_Summer_2021_Q4) – *Waves, Superposition*

(a)	time for one oscillation/vibration/cycle **or** time between adjacent wavefronts (passing the same point) **or** shortest time between two wavefronts (passing the same point)	B1
(b)	(when two or more) waves meet/overlap (at a point)	B1
	(resultant) displacement is sum of the individual displacements	B1
(c)(i)	microwave(s)	B1
(c)(ii)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1/T$	C1
	$T = 0.040 / 3.00 \times 10^{8}$	C1
	$= 1.33 \times 10^{-10}$ (s) $= 1.33 \times 10^{-10} / 10^{-12}$ (ps) $= 130$ ps	A1
(c)(iii)	$(1.380 - 1.240) / 0.040 = 3.5$ **or** $1.380 / 0.040 - 1.240 / 0.040 = 3.5$	A1
(c)(iv)	phase difference = 1260° **or** 180°	A1
(c)(v)	(always) zero	A1
(c)(vi)	increase in distance between (adjacent intensity) maxima/minima	A1

29 – (9702/21_Winter_2021_Q4) – *Waves*

(a)	oscillations (of particles) are parallel to (the direction of) energy transfer	B1
(b)(i)	(frequency varies as) vehicle moves relative to (stationary) observer	C1
	(vehicle) moving towards (observer) gives higher (observed) frequency (than 1.2 kHz) <u>and</u> (vehicle) moving away (from observer) gives lower (observed) frequency (than 1.2 kHz)	A1
(b)(ii)	Doppler effect	B1
(b)(iii)	position of vehicle labelled 'X' at top (12 o'clock) position on track	B1
(b)(iv)	position of vehicle labelled 'Y' at right-hand edge (3 o'clock) position on track	B1
(c)	maximum frequency = 1.40 (kHz) **or** 1.40×10^3 (Hz)	C1
	$1.40 = (1.2 \times 320) / (320 - v)$	C1
	$v = 46\ \text{m s}^{-1}$	A1
	or	
	minimum frequency = 1.05 (kHz) **or** 1.05×10^3 (Hz)	(C1)
	$1.05 = (1.2 \times 320) / (320 + v)$	(C1)
	$v = 46\ \text{m s}^{-1}$	(A1)

30 – (9702/22_Winter_2021_Q4) – *Waves*

(a)(i)	decrease(s)	B1
(a)(ii)	increase(s)	B1
(b)	$f_o = f_s\, v / (v + v_s)$ $= 925 \times 338 / (338 + 12)$	C1
	$= 893$ Hz	A1
(c)	distance $= (½ \times 2 \times 12) + (2 \times 12)$ $(= 36\ \text{m})$	C1
	time taken $= 36 / 338$ $= 0.11$ s	A1

31 – (9702/23_Winter_2021_Q5) – *Waves*

(a)	maximum displacement (of a point/particle on string/wave)	B1
(b)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$T = 690 \times 10^{-9} / 3.00 \times 10^8$	C1
	$= 2.3 \times 10^{-15}$ s	A1
(c)(i)	$\lambda = ax / D$	C1
	$G = x / D$ (so) $a = \lambda / G$	A1
(c)(ii)	straight line from origin always below printed line	M1
	line is half the height of printed line at maximum D	A1

32 - (9702/21_Winter_2022_Q4) - *Waves*

(a)(i)	oscillations are in a single direction, which is perpendicular to the direction of propagation (of the wave) **or** oscillations are in a single plane, which contains the direction of propagation (of the wave)	B1
(a)(ii)	light waves are transverse **and** sound waves are longitudinal	B1
(b)	$I = I_0 \cos^2\theta$	C1
	$\cos^2\theta = 1/4$ so $\cos\theta = 1/2$ $\theta = 60°$ or $120°$ or $240°$ or $300°$	C1
	angle of rotation = $(120° - 90°)$ or $(240° - 90°)$ or $(300° - 90°)$ $= 30°$ or $150°$ or $210°$ or $330°$	A1
(c)(i)	the waves have different amplitudes	B1
	cannot have resultant displacement that is always zero **or** cannot have (complete) destructive interference (at nodes) **or** (at nodes resultant) amplitude is the difference of the amplitudes	B1
(c)(ii)	$I \propto A^2$	C1
	$A^2 / A_0^2 = (I_0/4)/I_0$ $A = 0.5\,A_0$	C1
	maximum amplitude = $A_0 + 0.5\,A_0$ $= 1.5\,A_0$	A1

33 - (9702/23_Winter_2022_Q4) - *Waves*

(a)(i)	circles drawn around any two particles with seven (uncircled) particles in between	A1
(a)(ii)	curve has an initial negative displacement and initial amplitude same as original curve	B1
	curve has same amplitude as original curve throughout	B1
	curve has same wavelength as original curve throughout, with constant (non-zero) phase difference	B1
(a)(iii)	(to the) right / rightwards	A1
(b)	$\lambda = 2 \times 0.19$ $= 0.38$ m	C1
	$v = f\lambda$	C1
	$v = (16 \times 10^3) \times 0.38$ $v = 6100$ m s^{-1}	A1
(c)	$I \propto A^2$	C1
	$I = (1/2)^2 I_0$ intensity = $0.25\,I_0$	A1
(d)(i)	same frequency / wavelength / period	B1
(d)(ii)	• a stationary wave has nodes/antinodes (and a progressive wave does not) • a stationary wave does not transfer/propagate energy (and a progressive wave does transfer/propagate energy) • different points on a stationary wave have different amplitudes (and all points on a progressive wave have the same/constant amplitude) • stationary wave has adjacent particles that are in phase (and adjacent particles on progressive wave are out of phase) *Any two points, 1 mark each. Allow the reverse statement for each marking point.*	B2

34 – (9702/22_Winter_2022_Q5) – *Waves*

(a)	(they travel in) opposite directions	B1
(b)(i)	straight line from A to B, labelled P	B1
	line that is 'mirror image' of given line, labelled Q	B1
(b)(ii)	$\lambda = 0.80 / 2$ $(= 0.40\ \text{m})$	C1
	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$v = 0.40 / 0.016$ **or** 62.5×0.40 $= 25\ \text{m s}^{-1}$	A1
(c)(i)	$I_1 / I_0 = \cos^2 30°$	C1
	$= 0.75$	A1
(c)(ii)	$I_2 / I_1 = \cos^2 60°$ $I_2 / I_0 = \cos^2 30° \times \cos^2 60°$ **or** $0.75 \times \cos^2 60°$	C1
	$= 0.19$	A1

35 – (9702/22_Summer_2023_Q5) – *Waves*

(a)(i)	(they are) perpendicular	B1
(a)(ii)	(they are) parallel	B1
(b)(i)	$\lambda = v / f$	C1
	$= 340 / 1700$ $= 0.20\ \text{m}$	A1
(b)(ii)	$L = \frac{3}{4} \times \lambda = \frac{3}{4} \times 0.20$ $= 0.15\ \text{m}$	A1
(b)(iii)	$\lambda = 4 \times 0.15$ **or** 0.20×3 $= 0.60\ \text{m}$	A1
(c)(i)	$(I =)\ 8.5 \times \cos^2 35° = 5.7\ (\text{W m}^{-2})$	A1
(c)(ii)	$5.2 = 5.7 \cos^2 \theta$ $(\theta = 17°)$	C1
	$\alpha = 35° + 17°$ $= 52°$	A1

36 – (9702/23_Summer_2023_Q4) – *Waves*

(a)	the number of wavefronts/crests/troughs passing a fixed point per unit time **or** the number of oscillations per unit time (of source / point on wave / particle of medium)	B1
(b)(i)	$T = 4 \times 0.50 \times 10^{-3}$ $(= 2.0 \times 10^{-3}$ s)	C1
	$f = 1 / 2.0 \times 10^{-3}$ $= 500$ Hz	A1
(b)(ii)	amplitude $= 2.8 \times 0.20$ $= 0.56$ V	A1
(c)	period same as original trace	B1
	sinusoidal wave of constant amplitude less than 2.8 cm throughout	M1
	amplitude 1.4 cm	A1

(d)(i)	when (two or more) waves meet (at a point)	B1
	(resultant) displacement is the sum of the individual displacements	B1
(d)(ii)	node-to-node separation is $\lambda / 2$ **or** microphone moves through 3 node-to-node separations **or** $d = 1.5\lambda$	C1
	$\lambda = 1.05 / 1.5$ $= 0.70$ m	A1
(d)(iii)	$v = f \times \lambda$	C1
	$= 500 \times 0.70$ $= 350$ m s^{-1}	A1

37 – (9702/21_Winter_2023_Q5) – *Waves*

(a)	sketch: approximately horizontal line above horizontal dashed line from $t = 0$ to $t = t_1$ **and** approximately horizontal line below horizontal dashed line from $t = t_1$ to $t = t_2$	A1
(b)	$I = P / A$	C1
	$A = \pi \times 0.028^2$ **or** $\pi \times 2.8^2$ $(= 2.46 \times 10^{-3}$ **or** $24.6)$	C1
	$P = 4.7 \times 10^{-3} \times 2.46 \times 10^{-3}$ $= 1.2 \times 10^{-5}$ W	A1

38 – (9702/23_Winter_2023_Q5) – *Waves*

(a)(i)	cross labelled Y drawn: at any position where wavefronts cross **or** centrally in a 'diamond' shape formed between any adjacent wavefronts from A and B	**B1**
(a)(ii)	cross labelled Z drawn on a wavefront from one source at a point midway between adjacent wavefronts from the other source	**B1**
(b)(i)	$\lambda = ax / D$	**C1**
	$a = (2.9 \times 10^{-5} \times 140) / (1.2 \times 10^{-2})$	**C1**
	$= 0.34$ m	**A1**
(b)(ii)	infrared	**A1**

1 – (9702/21_Summer_2017_Q4) – *Superposition*

(a)	(two) waves travelling (at same speed) in opposite directions overlap
	waves (are same type and) have same frequency/wavelength
(b)(i)	λ = 12 / 250 (= 0.048 m)
	distance = 1.5 × 0.048 = 0.072 m
(b)(ii)	T = 1 / 250 = 0.004 (s) or 4 (ms)
	1. curve drawn is mirror image of that in Fig. 4.2 and labelled P
	2. horizontal line drawn between A and B and labelled Q

2 – (9702/22_Summer_2017_Q5) – *Waves, Superposition*

(a)	frequency is the number of vibrations/oscillations per unit time **or** the number of wavefronts passing a point per unit time
(b)	vibrations/oscillation of the air particles are parallel to the direction of it (the direction of travel of the sound wave)
(c)(i)	T = 2(.0) (ms)
	f = 500 Hz
(c)(ii)	**1.** amplitude increases (time) period decreases **2.** amplitude decreases (time) period increases *any 3 points*

3 – (9702/23_Summer_2017_Q5) – *Superposition*

(a)(i)	waves at the elements/slits
	waves spread (into the geometric shadow)
(a)(ii)	**1.** waves (from each element/slit) overlap/meet/superpose
	with a phase difference/path difference of zero
	2. phase difference is 360°/path difference of λ
(b)(i)	e.g. gradient = (0.40 – 0.32) / [(500 – 400) × 10^{-9}]
	= 8(.0) × 10^{5}
(b)(ii)	$d \sin\theta = n\lambda$ d = n / gradient
	= 2 / 8.0 × 10^{5} = 2.5 × 10^{-6} m
(b)(iii)	straight line drawn with lower gradient (about ½) and all points lower

4 – (9702/22_Summer_2017_Q6) – *Superposition*

(a)(i)	waves at (each) slit/aperture spread
	(into the geometric shadow) wave(s) overlap/superpose/sum/meet/intersect
(a)(ii)	there is not a constant phase difference/coherence (for two separate light source(s)) **or** waves/light from the double slit are coherent/have a constant phase difference
(b)	$x = \lambda D / a$
	$\lambda = (36 \times 10^{-3} \times 0.48 \times 10^{-3}) / (16 \times 2.4)$
	$= 4.5 \times 10^{-7}$ m
(c)(i)	no movement of the water/water is flat/no ripples/disturbance
	the path difference is 2.5λ **or** the phase difference is 900° **or** 5π rad
(c)(ii)	**1.** surface/water/P vibrates/ripples **and** as (waves from the two dippers) arrive in phase
	2. surface/water/P vibrates/ripples **and** as amplitudes/displacements are no longer equal/do not cancel

5 – (9702/21_Winter_2017_Q3) – *Waves, Superposition*

(a)(i)	in a stationary wave energy is not transferred **or** in a progressive wave energy is transferred	**B1**
(a)(ii)	in a stationary wave (adjacent) particles are in phase **or** in a progressive wave (adjacent) particles are out of phase/have a phase difference/not in phase	**B1**
(b)(i)	(position where) maximum amplitude	**B1**
(b)(ii)	distance = 0.10 m	**B1**
(b)(iii)	**1.** $\lambda = 0.60/1.5$ $= 0.40$ m	**A1**
	2. $v = f\lambda$	**C1**
	$f = 340/0.40$ $= 850$ Hz	**A1**
(b)(iv)	$\lambda = 2 \times 0.60$ **or** $\lambda = 3 \times 0.40$ **or** $f = 850/3$	**C1**
	$f = 280$ (283) Hz	**A1**

6 - (9702/22_Winter_2017_Q4) - *Waves, Superposition*

(a)	(two) waves travelling (at same speed) in opposite directions overlap	B1
	waves (are same type and) have same frequency/wavelength	B1
(b)(i)	5	A1
(b)(ii)	$T = 1/40$ (= 2.5×10^{-2})	C1
	time taken = $2.5 \times 10^{-2}/2$ = 1.3×10^{-2} s (1.25×10^{-2} s)	A1
(b)(iii)	180°	A1
(b)(iv)	$v = f\lambda$	C1
	$\lambda = 2.0/2.5$ (= 0.80 m) $v = 0.80 \times 40$ = 32 m s^{-1}	A1

7 - (9702/23_Winter_2017_Q4) - *Waves, Superposition*

(a)	displacement of particles/vibration(s)/oscillation(s) is parallel to/along the direction of energy/propagation	B1
(b)	period = 1 / 800 (= 1.25×10^{-3} s)	C1
	time-base setting = $1.25 \times 10^{-3}/2.5$	C1
	= 5.0×10^{-4} s cm^{-1}	A1
(c)(i)	$I \propto A^2$	C1
	$(I_X/I_Y =)\ [r_Y/r_X]^2 = [A_X/A_Y]^2$	C1
	ratio A_Y/A_X = 120 / 30 = 4.0	A1

(c)(ii)	**1.** $v = f\lambda$	C1
	minimum $\lambda = 330/(800 + 16) = 0.40$ m	A1
	2. $f_o/f_s = v/(v - v_s)$ $816/800 = 330/(330 - v_s)$	C1
	$v_s = 6.5$ m s^{-1}	A1

8 - (9702/21_Summer_2018_Q4) - *Waves, Superposition*

(a)(i)	time for one oscillation/one vibration/one cycle **or** time between adjacent wavefronts/points in phase **or** shortest time between two wavefronts/points in phase	**B1**
(a)(ii)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** minimum distance between two wavefronts **or** distance between two adjacent wavefronts **or** minimum distance between two points having the same displacement and moving in the same direction	**B1**
(b)(i)	$v = \lambda / T$ **or** $v = f\lambda$ <u>and</u> $f = 1/T$	**C1**
	$\lambda = 20 \times 0.60$ $= 12$ cm	**A1**
(b)(ii)	phase difference $= 360° \times (0.20/0.60)$ **or** $360° \times (0.40/0.60)$ $= 120°$ **or** $240°$	**A1**
(b)(iii)	$I \propto A^2$	**C1**
	$I_Q/I_P = A_Q^2/A_P^2$ $= 2.0^2/3.0^2$ $= 0.44$	**A1**
(b)(iv)	displacement $= 1.00 - 3.00$ $= -2.00$ mm	**A1**

9 - (9702/22_Summer_2018_Q4) - *Waves, Superposition*

(a)(i)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** <u>minimum</u> distance between two wavefronts **or** distance between two <u>adjacent</u> wavefronts	**B1**
(a)(ii)	(position where) maximum amplitude	**B1**
(b)(i)	$\lambda = 4 \times 0.045$ (= 0.18 (m) or 18 (cm))	**C1**
	$v = f\lambda$	**C1**
	$f = 340/0.18$ $= 1900$ Hz	**A1**
(b)(ii)	distance $= \lambda/2$ (= 0.09 (m) or 9 (cm))	**C1**
	time $= 0.09 / 0.0075$ $= 12$ s	**A1**
	or	
	$t = 4.5/0.75$ **and** $t = 13.5/0.75$	**(C1)**
	time $= 18 - 6$ $= 12$ s	**(A1)**

10 – (9702/21_Summer_2018_Q5) – *Waves, Superposition*

(a)(i)	waves spread at (each) slit/gap	**B1**
(a)(ii)	constant phase difference (between (each of) the waves)	**B1**
(b)(i)	$n\lambda = d\sin\theta$	**B1**
	$d\sin\theta$ is the same **and** $3\lambda_1 = 4\lambda_2$ so $\lambda_2 / \lambda_1 = 0.75$	**A1**
(b)(ii)	$\lambda_2 / \lambda_1 = 0.75$ and $\lambda_1 - \lambda_2 = 170$ $\lambda_1 = 680\,\text{nm}$	**A1**

11 – (9702/23_Summer_2018_Q5) – *Waves, Superposition*

(a)	intensity $\propto$ (amplitude)^2	**B1**
(b)(i)	$v = f\lambda$ **or** $c = f\lambda$	**C1**
	$f = 3.00 \times 10^8 / 0.060$ $= 5.0 \times 10^9\,\text{Hz}$	**A1**
(b)(ii)	(at X path) difference = 3λ	**M1**
	(at X phase) difference = 0 or 1080°	**M1**
	so intensity is at a maximum/it is an intensity maximum	**A1**
(b)(iii)	**1.** decrease in the distance between (adjacent intensity) maxima/minima	**B1**
	2. (intensity) maxima and minima exchange places	**B1**

12 – (9702/21_Winter_2018_Q4) – *Superposition*

(a)	when (two or more) waves meet (at a point)	**B1**
	(resultant) displacement is the sum of the individual displacements	**B1**
(b)(i)	constant phase difference (between the waves)	**B1**
(b)(ii)	**1.** phase difference = 360° **or** 0	**B1**
	2. path difference $= 1.5\lambda$ $= 1.5 \times 610$ $= 920\,\text{nm}$	**A1**
(b)(iii)	$\lambda = ax / D$	**C1**
	$x = 22/4$ (= 5.5 mm) **or** $22 \times 10^{-3}/4$ (= 5.5×10^{-3} m)	**C1**
	$a = (610 \times 10^{-9} \times 2.7)/(5.5 \times 10^{-3})$ $= 3.0 \times 10^{-4}\,\text{m}$	**A1**
(b)(iv)	shorter wavelength **and** (so) separation decreases	**B1**
(b)(v)	• no change to fringe separation/fringe width/number of fringes • bright fringes are brighter • dark fringes are unchanged *Any two of the above three points, 1 mark each.*	**B2**

13 – (9702/23_Winter_2018_Q4) – *Waves, Superposition*

(a)	graph with *x*-axis labelled 'distance' and wavelength/λ correctly shown	B1
	graph with *x*-axis labelled 'time' and period/*T* correctly shown	B1
	graph with *y*-axis labelled 'displacement' and amplitude/*A* correctly shown	B1
(b)(i)	wave (moves along string and) reflects at fixed point/Y/X/end/wall/boundary	B1
	the incident and reflected waves interfere/superpose	B1
(b)(ii)	100 / 40 **or** 2.5 (cycles/periods/*T*)	C1
	1. displacement = 0	B1
	2. distance = 130 mm	A1
(b)(iii)	**1.** $f = 1/40 \times 10^{-3}$ $= 25$ Hz	A1
	2. $v = f\lambda$ **or** $\lambda = vT$	C1
	$\lambda = 30/25$ **or** $30 \times 40 \times 10^{-3}$ (= 1.2 m)	C1
	distance $= 1.2 \times 1.5$ $= 1.8$ m	A1

14 – (9702/22_Winter_2018_Q5) – *Superposition*

(a)	$n\lambda = d\sin\theta$	C1
	$\lambda = 640 \times 10^{-9}$ (m)	C1
	$2 \times 640 \times 10^{-9} = 1.7 \times 10^{-6} \times \sin\theta$ so $\theta = 49(°)$	A1
(b)	$2 \times 640 \times 10^{-9} = 3 \times \lambda$ **or** $1.7 \times 10^{-6} \times \sin 49° = 3 \times \lambda$	C1
	$\lambda = 4.3 \times 10^{-7}$ m	A1

15 – (9702/22_Summer_2019_Q4) – *Waves, Superposition*

(a)(i)	distance (in a specified direction of particle/point on wave) from the equilibrium position	B1
(a)(ii)	the maximum distance (of particle/point on wave) from the equilibrium position **or** the maximum displacement (of particle/point on wave)	B1
(b)	$I \propto A^2$	C1
	$I_R / I = (3.6 - 1.2)^2 / (1.2)^2$ resultant intensity = $4.0I$	A1
(c)(i)	as wave(s) pass through the slit(s)	B1
	wave(s) spread (into geometric shadow)	B1
(c)(ii)	$n\lambda = d\sin\theta$	C1
	$3\lambda = d\sin 90°$ **or** $3\lambda = d$	C1
	$d = 3 \times 630 \times 10^{-9}$ $= 1.9 \times 10^{-6}$ m	A1
(c)(iii)	wavelength of blue light is shorter (than 540 nm/630 nm/wavelengths of original light)	M1
	(so) third order diffraction maximum is produced	A1

16 – (9702/21_Summer_2019_Q5) – *Waves, Superposition*

(a)(i)	**1.** $N\lambda$	B1
	2. N / f	B1
(a)(ii)	v (= distance / time) = $N\lambda / (N / f)$ so $v = f\lambda$	B1
(b)	$T = 4.0 \times 0.20 = 0.80$ (ms) **or** 8.0×10^{-4} (s)	C1
	$f = 1 / 8.0 \times 10^{-4}$ $= 1300$ Hz	A1
(c)(i)	constant phase difference (between the waves)	B1
(c)(ii)	180°	A1
(c)(iii)	path difference $= 2\lambda$ **or** $S_1Y - S_2Y = 2\lambda$	C1
	distance $= 7.40 + (0.85 \times 2)$ $= 9.1$ m	A1

17 – (9702/23_Summer_2019_Q5) – *Waves, Superposition*

(a)	(incident) wave reflects at end/top of tube	B1
	(incident) wave and reflected wave interfere/superpose	B1
(b)	line has maximum value of amplitude at $h = 0$ and $h = 0.60$ m only	B1
	line has minimum/zero value of amplitude at $h = 0.30$ m only	B1
(c)(i)	vertical/along length of tube/along axis of tube	B1
(c)(ii)	phase difference = 0	A1
(d)	$v = f\lambda$	C1
	$v = 340 / (2 \times 0.60)$ $= 280$ Hz	A1
(e)	$f = 340 / 0.60$ $= 570$ Hz	A1

18 – (9702/21_Winter_2019_Q5) – *Waves, Superposition*

(a)(i)	the dippers are connected to the same vibrator/motor	B1
(a)(ii)	(the overlapping waves have) similar/same amplitude	B1
(b)	any means of 'freezing' the pattern e.g. use a stroboscope/strobe	B1
(c)	$vT = \lambda$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$T = 0.060 / 0.40$ $= 0.15$ s	A1
(d)(i)	path difference = 3.0 cm	A1
(d)(ii)	phase difference = 180°	A1
(e)	line drawn joining points where only maxima are observed (i.e. through points where wavefronts intersect) of length at least 4 cm	B1

19 – (9702/22_Winter_2019_Q5) – *Waves, Superposition*

(a)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** minimum distance between two wavefronts **or** distance between two adjacent wavefronts	B1
(b)	(T =) 2.0×2.5 (= 5.0 ms) **or** $2.0 \times 2.5 \times 10^{-3}$ (= 5.0×10^{-3} s)	C1
	$f = 1 / (5.0 \times 10^{-3})$ = 200 Hz	A1
(c)(i)	(path difference =) $8.0 + (20.8^2 - 8.0^2)^{0.5} - 20.8 = 6.4$ (m)	A1
(c)(ii)	• path difference = 4λ • waves (meet at C) in phase • constructive interference (of waves) *any two points, one mark each*	B2
(c)(iii)	$v = 200 \times 1.6$ = 320 (m s^{-1})	C1
	$\Delta t = 6.4 / 320$ **or** $27.2 / 320 - 20.8 / 320$ = 0.020 s	A1
(c)(iv)	$3\lambda = 6.4$ $\lambda = 2.1$ m	A1

20 – (9702/23_Winter_2019_Q5) – *Waves, Superposition*

(a)(i)	(coherence means) constant phase difference (between waves)	B1
(a)(ii)	(interference is) the sum/addition/combination of the displacements of overlapping/meeting waves	B1
(b)(i)	$n\lambda = d \sin\theta$	C1
	$\lambda = \sin 51° / (2 \times 6.7 \times 10^5)$ $= 5.8 \times 10^{-7}$ m	A1
(b)(ii)	smaller angle (corresponding to second order maxima and so) shorter distance (between second order maxima spots)	B1

21 – (9702/21_Summer_2020_Q4) – *Waves, Superposition*

(a)(i)	vibrations (of particles) are parallel to direction of energy propagation	B1
(a)(ii)	waves meet/overlap (at a point)	B1
	(resultant) displacement is sum of individual displacements	B1
(b)(i)	$\lambda = ax / D$	C1
	$= (3.7 \times 10^{-4} \times 4.3 \times 10^{-3}) / 2.3$	C1
	$= 6.9 \times 10^{-7}$ (m) = 690 nm	A1
(b)(ii)	• no change to fringe separation/fringe width/number of fringes • bright fringes are darker • dark fringes are brighter *Any two marking points, 1 mark each*	B2

22 – (9702/22_Summer_2020_Q4) – *Waves, Superposition*

(a)	progressive waves transfer energy **or** stationary waves do not transfer energy	B1
(b)(i)	0.32 m	A1
(b)(ii)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$v = 0.32 / 0.020$ **or** 50×0.32 $= 16\ \text{m s}^{-1}$	A1
(b)(iii)	450° **or** 90°	A1
(b)(iv)	(P has) maximum downward displacement at 0.005 s	B1
	returns to original position/point (at 0.010 s)	B1
(c)(i)	(position where) zero amplitude	B1
(c)(ii)	2	A1
(c)(iii)	180°	A1
(c)(iv)	string drawn between X and Y with one antinode midway along the string	B1

23 – (9702/22_Winter_2020_Q5) – *Waves, Superposition*

(a)	$v = f\lambda$ **or** $c = f\lambda$	C1
	$f = 3.0 \times 10^8 / 0.040$	C1
	$= 7.5 \times 10^9$ (Hz) $= 7.5$ GHz	A1
(b)(i)	path difference = 0.020 m	A1
(b)(ii)	phase difference = 180°	A1
(c)	(intensity) increases	C1
	(intensity) increases by a factor of 4	A1
(d)(i)	minimum moves closer to the maximum **or** decrease in separation of maximum and minimum	B1
(d)(ii)	the maximum and minimum exchange places **or** the maximum becomes a minimum **and** the minimum becomes a maximum	B1

24 – (9702/23_Winter_2020_Q5) – *Waves, Superposition*

(a)(i)	$T = 2.0 \times 10^{-5} \times 6.0$ (= 1.2×10^{-4} s)	C1
	$f = 1 / (2.0 \times 10^{-5} \times 6.0)$ = 8300 Hz	A1
(a)(ii)	new trace shows the same period	B1
	new trace shows amplitude of 10 small squares	B1
(a)(iii)	(trace is a) vertical line	B1
(b)(i)	$n\lambda = d \sin\theta$	C1
	$\lambda = (3.4 \times 10^{-6} \times \sin 16°) / 2$ = 4.7×10^{-7} m	A1
(b)(ii)	$n = 3.4 \times 10^{-6} (\times \sin 90°) / 4.7 \times 10^{-7}$ or $2 (\times \sin 90°) / \sin 16°$ (= 7.2 or 7.3)	C1
	highest order = 7	A1

25 – (9702/21_Winter_2020_Q6) – *Superposition*

(a)	the waves (of the same type) move in opposite directions and overlap	B1
	the waves have the same (speed and) frequency/wavelength	B1
(b)(i)	zero amplitude	B1
(b)(ii)	distance = 6.0 × 4 = 24 cm	A1
(b)(iii)	180°	A1

26 – (9702/21_Summer_2021_Q4) – *Waves, Superposition*

(a)	distance moved by wavefront/energy during one cycle/oscillation/period (of source) **or** minimum distance between two wavefronts **or** distance between two adjacent wavefronts	B1
(b)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$T = 460 \times 10^{-9} / 3.00 \times 10^{8}$	C1
	= 1.5×10^{-15} s	A1
(c)	waves pass through/enter the slit(s)	B1
	waves spread (into geometric shadow)	B1
(d)(i)	$n\lambda = d \sin\theta$	C1
	$G = \sin\theta / \lambda$ $d = 4 / G$	A1
(d)(ii)	straight line from 400 nm to 700 nm that is always below printed line	M1
	straight line has smaller gradient than printed line and is 5 small squares high at wavelength of 700 nm	A1

27 - (9702/22_Summer_2021_Q4) - *Waves, Superposition*

(a)	time for one oscillation/vibration/cycle **or** time between adjacent wavefronts (passing the same point) **or** shortest time between two wavefronts (passing the same point)	B1
(b)	(when two or more) waves meet/overlap (at a point)	B1
	(resultant) displacement is sum of the individual displacements	B1
(c)(i)	microwave(s)	B1
(c)(ii)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1/T$	C1
	$T = 0.040 / 3.00 \times 10^8$	C1
	$= 1.33 \times 10^{-10}$ (s) $= 1.33 \times 10^{-10} / 10^{-12}$ (ps) = 130 ps	A1
(c)(iii)	(1.380 – 1.240) / 0.040 = 3.5 **or** 1.380 / 0.040 – 1.240 / 0.040 = 3.5	A1
(c)(iv)	phase difference = 1260° **or** 180°	A1
(c)(v)	(always) zero	A1
(c)(vi)	increase in distance between (adjacent intensity) maxima/minima	A1

28 - (9702/23_Summer_2021_Q4) - *Superposition*

(a)	(when two or more) waves meet/overlap (at a point)	B1
	(resultant) displacement is sum of the individual displacements	B1
(b)	intensity ∝ amplitude^2	C1
	maximum intensity = $9I$	A1
(c)(i)	$x = \lambda D / a$	C1
	$= (550 \times 10^{-9} \times 1.2) / (0.35 \times 10^{-3})$	C1
	$= 1.9 \times 10^{-3}$ m	A1
(c)(ii)	red light has longer wavelength (than 550 nm) so distance (between fringes) increases	B1

29 - (9702/22_Winter_2021_Q5) - *Superposition*

(a)	a (much) louder sound can be heard	B1
(b)	$v = f\lambda$	C1
	$\lambda = 340 / 530$ (= 0.64 m)	C1
	height = 0.64 / 4 = 0.16 m	A1
(c)	distance = 0.64 / 2 **or** 0.16 × 2 **or** (¾ × 0.64 – ¼ × 0.64) = 0.32 m	A1

30 - (9702/21_Summer_2022_Q5) - *Superposition*

(a)	wave(s) (travel along string and) reflect at fixed point / A / B / end	B1
	incident and reflected waves superpose / interfere **or** two waves travelling / with speed in opposite directions superpose / interfere	B1
(b)	line has an approximate sinusoidal shape with maximum downward displacement at P and zero displacement at each node	B1
(c)	$v = \lambda / T$ **or** $v = f\lambda$ **and** $f = 1 / T$	C1
	$\lambda = 35 \times 0.040$ **or** $35 / 25$ (= 1.4 m)	C1
	distance = 1.4 × 2.5 = 3.5 m	A1
(d)	(number of periods / cycles) (= t / T) = 0.060 / 0.040 (= 1.5)	C1
	amplitude = 72 / 6 = 12 mm	A1

31 - (9702/22_Summer_2022_Q5) - *Superposition*

(a)	constant phase difference (between the waves)	B1
(b)(i)	path difference = 1.5 × 660 = 990 nm	A1
(b)(ii)	phase difference = 360° × 1.5 = 540°	A1
(c)	$\lambda = ax / D$	C1
	$x = (660 \times 10^{-9} \times 1.8) / 0.44 \times 10^{-3}$	C1
	$= 2.7 \times 10^{-3}$ m	A1
(d)	bright fringes are brighter	B1
	no change to dark fringes	B1
	no change to (fringe) separation / (fringe) spacing	B1
(e)	(blue light has) shorter wavelength	M1
	(so) decrease (slit) separation	A1

32 - (9702/23_Summer_2022_Q5) - *Superposition*

(a)(i)	power = intensity × area	C1
	$= 1.3 \times 10^3 \times (\pi \times 0.055^2)$ = 12 W	A1
(a)(ii)	intensity = power / area $= 12 / (\pi \times 0.0015^2)$ $= 1.7 \times 10^6$ W m^{-2}	A1
(b)(i)	(λ =) v / f **or** c / f	C1
	(λ =) $3.0 \times 10^8 / 3.7 \times 10^{15} = 8.1 \times 10^{-8}$ (m)	A1
(b)(ii)	ultraviolet	A1

(b)(iii)	$d \sin\theta = n\lambda$ **or** $(1/N) \times \sin\theta = n\lambda$	C1
	$d = 1/2400 \times 10^3$ (m) $= 4.2 \times 10^{-7}$ (m) **or** $N = 2400 \times 10^3$ (m^{-1})	C1
	$n = 4.2 \times 10^{-7} \times \sin 90° / 8.1 \times 10^{-8}$ **or** $\sin 90° / 2400 \times 10^3 \times 8.1 \times 10^{-8}$ $n = 5.2$ or 5.1 **or** when $n = 5$, $\theta = 76.4°$ and when $n = 6$, $\sin\theta > 1$ (so) $n = 5$	B1
	number of maxima = $(2 \times 5) + 1$ $= 11$	A1
(b)(iv)	the wavelength has increased	M1
	(so) number of maxima decreases	A1

33 – (9702/21_Summer_2023_Q5) – *Superposition*

(a)(i)	infrared	B1
(a)(ii)	$v = f\lambda$ **or** $c = f\lambda$	C1
	$f = 3.0 \times 10^8 / 8.4 \times 10^{-6}$ $= 3.6 \times 10^{13}$ (Hz) $= 36$ THz	A1
(b)(i)	constant phase difference (between the waves) (with time)	B1
(b)(ii)	$\lambda = ax / D$	C1
	$x = 22/8$ **or** 2.75 (mm) **or** $22 \times 10^{-3}/8$ **or** 2.75×10^{-3} (m)	C1
	$a = (6.2 \times 10^{-7} \times 2.8) / (22 \times 10^{-3}/8)$ $= 6.3 \times 10^{-4}$ m	A1
(c)(i)	difference in distances $= 6.2 \times 10^{-7}/2$ $= 3.1 \times 10^{-7}$ m	A1
(c)(ii)	phase difference = 360°	A1

34 - (9702/21_Winter_2023_Q4) - *Superposition*

(a)	(when two or more) waves meet / overlap (at a point)	B1
	(resultant) displacement is the sum of the individual displacements	B1
(b)	$\lambda = ax / D$	C1
	$\lambda = [(0.65 \times 10^{-3}) \times (1.7 \times 10^{-3})] / 1.9$	C1
	$\lambda = 5.8 \times 10^{-7}$ m	A1
(c)(i)	waves are out of phase by a quarter of a cycle / period **or** when one wave has maximum/minimum displacement, the other wave has zero displacement	B1
(c)(ii)	(statement 2 is) not correct (because) waves do not have phase difference of 180° / not in antiphase **or** one wave has some displacement when other has no displacement **or** the displacements of the waves are not always equal and opposite	B1
(d)	more diffraction (of light/waves by slits) **or** light/waves are more spread (by slits) **or** light/waves (from slits) have less intensity	B1
	more (bright/dark) fringes **or** bright fringes are less bright / are dimmer / have lower intensity **or** no change to fringe spacing/separation/width	B1

35 - (9702/22_Winter_2023_Q5) - *Superposition*

(a)(i)	light intensity has maximum value at 0°, 180°, 360° and zero intensity at 90°, 270°	M1
	'sinusoidally-shaped' curve	A1
(a)(ii)	$4.2 = 7.6 \cos^2\theta$	C1
	$\theta = 42°$	A1
(b)	wave passes (through) an aperture **or** wave passes (by / through / around) an edge	B1
	wave spreads (into geometrical shadow)	B1
(c)(i)	$n\lambda = d \sin\theta$	C1
	$d = (3 \times 4.3 \times 10^{-7}) / \sin 68°$ $= 1.4 \times 10^{-6}$ m	A1
(c)(ii)	$1.4 \times 10^{-6} \times \sin 68° = 2 \times \lambda$ **or** $3 \times 4.3 \times 10^{-7} = 2 \times \lambda$	C1
	$\lambda = 6.5 \times 10^{-7}$ m	A1

36 - (9702/23_Winter_2023_Q6) - *Superposition*

(a)	$291 = 251 \times 340 / (340 - v_{(s)})$	C1
	$v_s = 47$ m s^{-1}	A1
(b)(i)	$I \propto A^2$	B1
(b)(ii)	sketch: line starts at (1.0, 1.0)	B1
	approximately straight line drawn with negative gradient and line ends at (4.0, 0.25)	B1

1 - (9702/23_Summer_2017_Q3) - *Electric Fields, Particle & Nuclear Physics*

(a)	force per unit (positive) charge
(b)(i)	$a = (v^2 - u^2) / 2s$
	$= [(18 \times 10^6)^2 - (2.5 \times 10^3)^2] / (2 \times 12 \times 10^{-3})$
	$= 1.3\ (1.35) \times 10^{16}\ \text{m s}^{-2}$
(b)(ii)	KE = $\frac{1}{2} mv^2$ **or** $\frac{1}{2} m(v^2 - u^2)$
	change in KE $= 0.5 \times 9.11 \times 10^{-31} \times [(18 \times 10^6)^2 - (2.5 \times 10^3)^2]$
	$= 1.5\ (1.48) \times 10^{-16}$ J
(b)(iii)	$E = F / e = ma / e$ **or** $eV = \Delta\text{KE}$ so $E = \Delta\text{KE} / (e \times d)$
	$E = (9.11 \times 10^{-31} \times 1.35 \times 10^{16}) / 1.60 \times 10^{-19}$ **or** $E = (1.48 \times 10^{-16}) / (12 \times 10^{-3} \times 1.60 \times 10^{-19})$
	$= 7.7\ (7.69) \times 10^4\ \text{V m}^{-1}$
(c)	charge on α opposite to electron/charge on α is positive
	ΔKE is negative/KE reduced
	charge of α greater/twice that of electron causes larger/twice ΔKE (in magnitude)

2 - (9702/22_Winter_2017_Q5) - *Electric Fields*

(a)	(coulomb is) ampere second	**B1**
(b)(i)	$E = V / d$ **or** $E = F / Q$	**C1**
	$F = VQ / d$ $F = (2.0 \times 10^2 \times 8.0 \times 10^{-19}) / 4.0 \times 10^{-2} = 4.0 \times 10^{-15}$ N	**A1**
(b)(ii)	arrow pointing to the left labelled 'electric force' **and** arrow pointing downwards labelled 'weight'	**B1**
(b)(iii)	**1.** resultant force $= \sqrt{[(3.9 \times 10^{-15})^2 + (4.0 \times 10^{-15})^2]}$	**C1**
	$= 5.6 \times 10^{-15}$ N	**A1**
	2. angle $= \tan^{-1} (3.9 \times 10^{-15} / 4.0 \times 10^{-15})$ $= 44°$	**A1**
(c)	downward sloping line from (0, 2.0)	**M1**
	magnitude of gradient of line increases with time and line ends at (T, 0)	**A1**

3 - (9702/23_Winter_2017_Q5) - *Electric Fields*

(a)	force <u>per</u> unit positive charge	**B1**
(b)(i)	$s = \frac{1}{2}at^2$	**C1**
	$a = (2 \times 0.045) / (1.5 \times 10^{-7})^2 = 4(.0) \times 10^{12}\ \text{m s}^{-2}$	**A1**
(b)(ii)	$F = 1.67 \times 10^{-27} \times 4.0 \times 10^{12} = 6.7\ (6.68) \times 10^{-15}$ N	**A1**
(b)(iii)	**1.** $E = F / Q$	**C1**
	$= 6.68 \times 10^{-15} / 1.6 \times 10^{-19}$ $= 4.2\ (4.18) \times 10^4\ \text{N C}^{-1}$	**A1**
	2. $E = V / d$	**C1**
	$V = 4.18 \times 10^4 \times 0.045$ $= 1.9 \times 10^3$ V	**A1**

(c)	$a = Eq / m$ **or** $F = ma$ **and** $F = Eq$	**C1**
	ratio $= \frac{(2 \times 1.6 \times 10^{-19}) \times (1.67 \times 10^{-27})}{(1.6 \times 10^{-19}) \times (4 \times 1.66 \times 10^{-27})}$ **or** $\frac{2 \times 1}{1 \times 4}$ $= 0.50$	**A1**

4 – (9702/21_Winter_2017_Q6) – *Electric Fields*

(a)	force <u>per</u> unit positive charge	**B1**
(b)(i)	$E_K = ½mv^2$	**C1**
	$2.4 \times 10^{-16} = ½ \times 1.7 \times 10^{-27} \times v^2$ $v = 5.3 \times 10^5\,ms^{-1}$	**A1**
(b)(ii)	work done $= 2.4 \times 10^{-16}$ J	**A1**
(b)(iii)	$W = Fs$	**C1**
	$F = 2.4 \times 10^{-16} / 15 \times 10^{-3}$ $= 1.6 \times 10^{-14}$ N	**A1**
(b)(iv)	$V = Fd / Q$ **or** $V = W / Q$ **or** $E = V / d$ **and** $E = F / Q$	**C1**
	$V = (1.6 \times 10^{-14} \times 15 \times 10^{-3}) / 1.6 \times 10^{-19}$ **or** $2.4 \times 10^{-16} / 1.6 \times 10^{-19}$	**C1**
	$= 1500$ V	**A1**
(b)(v)	straight line with positive gradient starting at the origin and going as far as $x = 15$ mm	**B1**

5 – (9702/21_Summer_2018_Q7) – *Electric Fields*

(a)	arrow pointing vertically down the page	**B1**
(b)	$E = ½mv^2$	**C1**
	$E = 460 \times 1.60 \times 10^{-19}$ $(= 7.36 \times 10^{-17}$ (J))	**C1**
	$v = [(2 \times 460 \times 1.60 \times 10^{-19}) / (9.11 \times 10^{-31})]^{½}$ $= 1.3 \times 10^7\,ms^{-1}$	**A1**
(c)	β^- particles have range of/different/various speeds/velocities/momenta/energies	**M1**
	so they follow different paths	**A1**

6 – (9702/21_Winter_2018_Q5) – *Electric Fields, Particle & Nuclear Physics, Kinematics*

(a)	region (of space) where a force acts on a (stationary) charge	B1
(b)	$E = F/Q$	B1
	$F = ma$ **and** (so) $a = \frac{Eq}{m}$	A1
(c)(i)	protons = 96	A1
	neutrons = 148	A1
(c)(ii)	mass-energy is conserved/mass change is 'seen' as energy	B1
	energy released as gamma (radiation)/KE of α/KE of Pu	B1
(c)(iii)	ratio $= \frac{2}{4} \times \frac{240}{94}$ **or** ratio $= \frac{2 \times 1.60 \times 10^{-19}}{4 \times 1.66 \times 10^{-27}} \times \frac{240 \times 1.66 \times 10^{-27}}{94 \times 1.60 \times 10^{-19}}$	C1
	ratio = 1.3	A1

7 – (9702/23_Winter_2018_Q5) – *Electric Fields, Particle & Nuclear Physics*

(a)	$E = F/Q$	M1
	$F = ma$ **and** (so) $q/m = a/E$	A1
(b)	$m = (4 \times 1.60 \times 10^{-19} \times 3.5 \times 10^{4}) / 1.5 \times 10^{12}$ (= 1.49×10^{-26} kg)	B1
	$= 1.49 \times 10^{-26} / 1.66 \times 10^{-27} = 9.0$ (u)	A1
(c)	protons: 4 **and** neutrons: 5	A1
(d)(i)	nuclei have the same charge and so same (magnitudes of) force	B1
(d)(ii)	nuclei have different masses and same force and so different (magnitudes of) acceleration	B1

8 – (9702/22_Summer_2019_Q2) – *Kinematics, Dynamics, Electric Fields*

(a)	(resultant) force proportional/equal to/is rate of change of momentum	B1
(b)(i)	distance = area under graph **or** $s = ½ (u + v) t$ $= ½ \times (9 + 13) \times 10$ **or** $s = ut + ½at^2$ $= (9 \times 10) + (½ \times 0.40 \times 10^2)$ **or** $s = vt - ½at^2$ $= (13 \times 10) - (½ \times 0.40 \times 10^2)$ **or** $v^2 = u^2 + 2as$ $13^2 = 9^2 + (2 \times 0.40 \times s)$	C1
	distance = 110 m	A1

(b)(ii)	**1.** a = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / (\Delta)t$ e.g. $a = (14 - 9) / 12.5$ **or** $(13 - 9) / 10$	C1
	$a = 0.40\ \text{m s}^{-2}$	A1
	2. resultant force $= 850 \times 0.40$ $= 340\ \text{N}$	A1
	3. $(F =)\ 510 + 440 + 340 = 1300\ (\text{N})$	A1
	4. $P = Fv$	C1
	$= 1300 \times 13$ $= 1.7 \times 10^4\ \text{W}$	A1
(c)	$E = \sigma / \varepsilon$	C1
	$E = (F / A) / (\Delta L / L)$ **or** $E = FL / A\Delta L$	C1
	$\Delta L = (480 \times 0.48) / (3.0 \times 10^{-4} \times 2.2 \times 10^{11})$ $= 3.5 \times 10^{-6}\ \text{m}$	A1
(d)	$f_o = f_s v / (v - v_s)$ $480 = f_s \times 340 / (340 - 14)$	C1
	$f_s = 460\ \text{Hz}$	A1

9 – (9702/21_Summer_2019_Q4) – *Electric Fields*

(a)(i)	$m = \rho \times V$	C1
	$= (4 / 3) \times \pi \times (1.2 \times 10^{-6})^3 \times 940 = 6.8 \times 10^{-15}\ (\text{kg})$	A1
(a)(ii)	minimum charge (on drop) is $1.6 \times 10^{-19}\ \text{C}$	B1
(b)(i)	$V = Ed$	C1
	$V = 2.1 \times 10^5 \times 8.0 \times 10^{-3}$ $= 1.7 \times 10^3\ \text{V}$	A1
(b)(ii)	constant velocity so no resultant force (so in equilibrium)	B1
(b)(iii)	$mg = Eq$ **or** $mg = (V / d)q$ **or** $F = mg$ **and** $F = Eq$	C1
	$q = (6.8 \times 10^{-15} \times 9.81) / 2.1 \times 10^5$ $= 3.2 \times 10^{-19}\ \text{C}$	A1
	sign of charge is negative	A1
(c)(i)	<u>electric</u> force decreases	B1
	weight > electric force **or** resultant force acts downwards	B1
(c)(ii)	(field line) separation increases	B1
(d)(i)	upthrust (force)	B1
(d)(ii)	air resistance/drag/viscous (force)	B1

10 – (9702/23_Summer_2019_Q4) – *Electric Fields*

(a)	straight (horizontal) lines **and** from the +0.90 kV plate/to the 0 V plate	B1
	(lines are) equally spaced	B1
(b)	weight/gravitational force **and** electric force	B1
(c)	$s = ½at^2$ **or** $s = ut + ½at^2$ **and** $u = 0$	C1
	$2.0 = ½ \times 9.81 \times t^2$ so $t = 0.64$ s	A1
(d)	$0.080 = ½ \times a \times 0.64^2$	C1
	$a = 0.39$ m s^{-2}	A1
(e)(i)	$E = (\Delta)V / (\Delta)d$	C1
	$E = 0.90 \times 10^3 / 0.12$ $= 7.5 \times 10^3$ N C^{-1}	A1
(e)(ii)	$ma = Eq$ **or** $F = ma$ **and** $F = Eq$	C1
	$q / m = 0.39 / 7.5 \times 10^3$ $= 5.2 \times 10^{-5}$ C kg^{-1}	A1
(f)(i)	no effect	B1
(f)(ii)	decreases/smaller	B1

11 – (9702/22_Summer_2019_Q6) – *Electric Fields, Particle & Nuclear Physics*

(a)	path/direction in which a (free) <u>positive</u> charge will move	B1
(b)	(lines) closer together in Y/further apart in X	B1
(c)(i)	$a = Eq / m$ **or** $F = Eq$ **and** $F = ma$	C1
	ratio $= (1e / 0.15\text{ u}) \times (4\text{ u} / 2e)$ **or** $1 / 0.15 \times 4 / 2$	C1
	ratio $= 13$	A1
(c)(ii)	down quark charge is $-(1 / 3)e$	C1
	$-(1 / 3)e + q = -1e$ so $q = -(2 / 3)e$	A1
	($-(2 / 3)e$ is) anti-up / $\bar{u}$ (quark) (*allow charm or top antiquark*)	B1

12 – (9702/21_Winter_2019_Q2) – *Kinematics, Dynamics, Electric Fields*

(a)	the (two) plates are vertical (and separated)	B1
	left plate positively charged **and** right plate negatively charged/earthed **or** right plate negatively charged **and** left plate positively charged/earthed	B1
(b)	$F = Eq$	C1
	$= 1.3 \times 10^4 \times 3.7 \times 10^{-9}$ $= 4.8 \times 10^{-5}$ N	A1
(c)	$F^2 = (4.8 \times 10^{-5})^2 + (5.4 \times 10^{-5})^2$ so $F = 7.2 \times 10^{-5}$ N **or** $F = [(4.8 \times 10^{-5})^2 + (5.4 \times 10^{-5})^2]^{0.5}$ so $F = 7.2 \times 10^{-5}$ N	A1
(d)	electric force is constant (because field strength/E is constant)	B1
	weight is constant (and so resultant force constant)	B1
(e)(i)	$m = 5.4 \times 10^{-5} / 9.81$ ($= 5.5 \times 10^{-6}$)	C1
	$a = 7.2 \times 10^{-5} / (5.5 \times 10^{-6})$ $= 13$ m s^{-2}	A1
(e)(ii)	$v^2 = u^2 + 2as$ $v^2 = 2 \times 13 \times 0.58$	C1
	$v = 3.9$ m s^{-1}	A1

13 – (9702/23_Winter_2019_Q3) – *Kinematics, Electric Fields*

(a)(i)	mass	B1
(a)(ii)	charge	B1
(b)(i)	$E = V/d$ **or** $E = F/q$	C1
	$F = (1.2 \times 10^3 \times 4.2 \times 10^{-9}) / 3.6 \times 10^{-2}$	C1
	$= 1.4 \times 10^{-4}$ N	A1
(b)(ii)	$W = mg$	C1
	$= 5.9 \times 10^{-6} \times 9.81$ resultant force $= 1.4 \times 10^{-4} - (5.9 \times 10^{-6} \times 9.81)$	C1
	$a = F/m$	C1
	$a = [1.4 \times 10^{-4} - (5.9 \times 10^{-6} \times 9.81)] / [5.9 \times 10^{-6}] = 14$ m s^{-2}	A1
(b)(iii)	**1.** $s = ut + ½at^2$ $1.8 \times 10^{-2} = ½ \times 14 \times t^2$	C1
	$t = 0.051$ s	A1
	2. $p = 0.75 \times 0.051$ $= 0.038$ m	A1

14 – (9702/21_Summer_2020_Q6) – *Electric Fields, Particle & Nuclear Physics*

(a)(i)	$E = \Delta V / \Delta d$	C1
	$E = (180 + 120) / (2.0 \times 10^{-2})$ $= 1.5 \times 10^4$ N C^{-1}	A1
(a)(ii)	vertically downwards	B1
(b)(i)	number of protons = 92	A1
	number of neutrons = 146	A1
	number of electrons = 90	A1
(b)(ii)	$F = EQ$	C1
	$= 1.5 \times 10^4 \times 2 \times 1.60 \times 10^{-19}$ $= 4.8 \times 10^{-15}$ N	A1
(b)(iii)	number of α-particles = 2	A1
	number of β^- particles = 2	A1

15 – (9702/23_Summer_2020_Q7) – *Electric Fields, Particle & Nuclear Physics*

(a)(i)	$E = V / d$ **or** $E = F / Q$	C1
	$F = (450 \times 1.60 \times 10^{-19}) / 6.0 \times 10^{-3}$	C1
	$= 1.2 \times 10^{-14}$ N	A1
	direction: vertically downwards	B1

(a)(ii)	work done = Fs **or** Fd **or** EQd	C1
	$= (-)1.2 \times 10^{-14} \times 6.0 \times 10^{-3}$ $= (-)7.2 \times 10^{-17}$ J	A1
	or	
	work done = VQ	(C1)
	$= (-)450 \times 1.60 \times 10^{-19}$ $= (-)7.2 \times 10^{-17}$ J	(A1)
(b)	$E = ½mv^2$	C1
	$3.4 \times 10^{-16} = ½ \times 9.11 \times 10^{-31} \times v^2$ $v = 2.7 \times 10^7$ m s^{-1}	A1
(c)(i)	^1_1p	A1
	$^0_{-1}V_{(e)}$	A1
(c)(ii)	**1.** hadrons	B1
	2. leptons	B1

16 - (9702/22_Winter_2020_Q7) - *Electric Fields, Particle & Nuclear Physics*

(a)	similarity: same/equal mass **or** same/equal (magnitude of) charge **or** both fundamental (particles)	B1
	difference: opposite (sign of) charge **or** one is matter and the other is antimatter	B1
(b)(i)	arrow points to the right	B1
(b)(ii)	(electric) field strength increases **or** (electric) force increases	B1
	acceleration increases	B1
(b)(iii)	force (on α-particle) has twice the magnitude (of force on electron)	B1
	force (on α-particle) is in opposite direction (to force on electron)	B1

17 - (9702/23_Winter_2020_Q7) - *Electric Fields, Particle & Nuclear Physics*

(a)(i)	electric field strength = V / d	B1
(a)(ii)	force = Vq / d	B1
(a)(iii)	kinetic energy = Vq	B1
(b)(i)	no change	B1
(b)(ii)	no change	B1
(c)(i)	nucleon number = 14 **and** proton number = 7	A1
(c)(ii)	(electron) antineutrino	B1

18 - (9702/22_Winter_2021_Q2) - *Electric Fields*

(a)(i)	$E = (\Delta)V / (\Delta)d$	C1
	$= 1340 / 1.4 \times 10^{-2}$ $= 9.6 \times 10^{4}$ N C^{-1}	A1
(a)(ii)	$F = Eq$ **or** $q(\Delta)V / (\Delta)d$	C1
	$q = 4.6 \times 10^{-14} / 9.6 \times 10^{4}$ **or** $4.6 \times 10^{-14} \times 1.4 \times 10^{-2} / 1340$ $= 4.8 \times 10^{-19}$ C	A1
	sign of charge: negative	B1
(b)(i)	(adjacent field) lines have same separation (for both patterns)	B1
	(direction of lines changes from) downwards to upwards	B1

(b)(ii)	resultant force $= 4.6 \times 10^{-14} + (9.6 \times 10^{4} \times 4.8 \times 10^{-19})$ $= 4.6 \times 10^{-14} + 4.6 \times 10^{-14}$ $= 9.2 \times 10^{-14}$ N	A1
(b)(iii)	(a =) F / m **or** $2W / m$ **or** $2g$	B1
	$a = 9.2 \times 10^{-14} / (4.6 \times 10^{-14} / 9.81) = 20$ (m s^{-2}) **or** $a = 2 \times 9.81 = 20$ (m s^{-2})	A1
(b)(iv)	$s = ut + ½at^2$ $(1.4 \times 10^{-2} / 2) = ½ \times 20 \times t^2$	C1
	$t = 2.6 \times 10^{-2}$ s	A1
(c)	line from (0, 0.7×10^{-2}) to a non-zero point on the t-axis	M1
	magnitude of gradient of line increases	A1

19 - (9702/23_Winter_2021_Q4) - *Electric Fields*

(a)	to the left/from the right/from B to A/opposite (direction) to (α-particle) velocity	B1
(b)	$v^2 = u^2 + 2as$ $s = (4.1 \times 10^{6})^2 / (2 \times 2.7 \times 10^{14})$	C1
	$= 0.031$ m	A1
(c)	$E = F / Q$ **or** $E = ma / Q$	C1
	$= (4 \times 1.66 \times 10^{-27} \times 2.7 \times 10^{14}) / (2 \times 1.60 \times 10^{-19})$	C1
	$= 5.6 \times 10^{6}$ V m^{-1}	A1
(d)	straight line with negative gradient that intercepts both the momentum and t axes	B1
(e)	force (on α-particle)	B1
(f)(i)	$E = ½mv^2$	C1
	$= ½ \times 9.11 \times 10^{-31} \times (4.1 \times 10^{6})^2$	C1
	$= 7.7 \times 10^{-18}$ J	A1
(f)(ii)	particles have opposite charges	B1
	(so) forces (on charges) are opposite (directions)	B1
	β^- has less/half the charge so less/half the force	B1
(f)(iii)	(electron) antineutrino	B1

1 - (9702/21_Summer_2017_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	volt / ampere
(b)(i)	$R_T = [1/3.0 + 1/6.0]^{-1} + 4.0$ (= 6.0 Ω)
	$I = 1.5 / 6.0$
	= 0.25 A
(b)(ii)	$V_B = 0.5$ V
	$I = 0.5 / 3.0$
	= 0.17 (0.167) A
(b)(iii)	$P = I^2R$ **or** VI **or** V^2/R
	ratio = $(0.167^2 \times 3.0) / (0.25^2 \times 4.0)$
	= 0.33
(c)(i)	vary/change/different radius/diameter/cross-sectional area (of wire)
(c)(ii)	$v = I / Ane$
	ratio $= \dfrac{(I_B / A_B)}{(I_C / A_C)}$ **or** $\dfrac{I_B}{I_C} \times \dfrac{A_C}{A_B}$
	($R \propto 1/A$ so) ratio $= \dfrac{I_B}{I_C} \times \dfrac{R_B}{R_C} = \dfrac{0.167}{0.25} \times \dfrac{3.0}{4.0}$
	= 0.50
(d)(i)	0.25 A to 0.13 (0.125) A **or** halved
(d)(ii)	no change

2 - (9702/23_Summer_2017_Q6) - *Current Of Electricity, D.c. Circuits*

(a)(i)	straight line through the origin
(a)(ii)	zero current for one direction (–ve V) up to zero or a few tenths of volt (+ve V)
	straight line positive gradient/increasing gradient (+ve V)
(b)(i)	**1.** current = 2.8 A
	2. 4(.0) A for each lamp
	current in circuit = 8(.0) A
(b)(ii)	use of $R = V / I$ with correct values of V from graph for each arrangement
	1. series resistance (= 2.1 + 2.1) = 4.2 or 4.3 Ω **or** (12 / 2.8) = 4.3 Ω
	2. parallel resistance 1.5 Ω (each lamp 3.0 Ω) **or** (12 / 8.0) = 1.5 Ω
(b)(iii)	power = IV **or** V^2 / R **or** I^2R
	ratio = $(2.8 \times 6.0) / (4.0 \times 12) = 0.35$

3 - (9702/21_Winter_2017_Q5) - *Current Of Electricity, D.c. Circuits*

(a)	$I_1 + I_2 = I_3$ [any subject]	**B1**
(b)	$E_1 + E_3 = I_1R_1 + I_3R_3 + I_3R_4$ [any subject]	**B1**
(c)	$E_1 - E_2 = I_1R_1 - I_2R_2$ [any subject]	**B1**

4 - (9702/22_Winter_2017_Q6) - *Current Of Electricity*

(a)	flow of charge carriers	B1
(b)(i)	$nALe$	B1
(b)(ii)	(t is time taken for electrons to move length L) $I = Q / t$	B1
	$I = nALe / t$ **or** $I = nALe / (L / v)$ **or** $I = nAvte / t$ **and** $I = nAve$	B1
(c)(i)	ratio = area at X / area at Y $= [\pi d^2 / 4] / [\pi(0.69d)^2 / 4]$ **or** $d^2 / (0.69d)^2$ **or** $1 / 0.69^2$	C1
	$= 2.1$	A1
(c)(ii)	**1.** $R = \rho L / A$ **or** $R / L \propto 1 / A$	C1
	resistance per unit length $= 1.7 \times 10^{-2} \times$ (area at X / area at Y) $= 1.7 \times 10^{-2} \times 2.1$ $= 3.6 \times 10^{-2}\ \Omega\,m^{-1}$	A1
	2. $P = I^2R$ **or** $P = V^2 / R$	C1
	$R = 3.6 \times 10^{-2} \times 3.0 \times 10^{-3}$ (= $1.08 \times 10^{-4}\ \Omega$) $P = 0.50^2 \times 1.08 \times 10^{-4}$ **or** $P = (5.4 \times 10^{-5})^2 / 1.08 \times 10^{-4}$ $= 2.7 \times 10^{-5}$ W	A1

(c)(iii)	(cross-sectional area decreases so) resistance increases	M1
	($P = I^2R$, so) power increases	A1

5 - (9702/23_Winter_2017_Q6) - *Current Of Electricity, D.c. Circuits*

(a)(i)	$P = VI$	C1
	$I = 30 / 120$ $= 0.25$ A	A1
(a)(ii)	$Q = 0.25 \times 3.0 \times 3600$ (= 2700)	C1
	number $= (0.25 \times 3.0 \times 3600) / 1.60 \times 10^{-19}$ $= 1.7 \times 10^{22}$	A1
(b)	$R = V / I$ **or** $R = P / I^2$ **or** $R = V^2 / P$	C1
	$= 120 / 0.25$ **or** $= 30 / 0.25^2$ **or** $= 120^2 / 30$ $= 480\ \Omega$	A1

(c)	$R = \rho l / A$	C1
	$A = (6.1 \times 10^{-7} \times 580 \times 10^{-3}) / 480$ (= 7.37×10^{-10})	C1
	$d = [(4 \times 7.37 \times 10^{-10}) / \pi]^{1/2}$ $= 3.1 \times 10^{-5}$ m	A1
(d)	temperature decreases and so resistance decreases	B1

6 - (9702/21_Winter_2017_Q7) - *Current Of Electricity, D.c. Circuits*

(a)	(the ohm is) volt / ampere	B1
(b)(i)	$R = \rho L / A$	C1
	ratio = $[\rho L / (\pi d^2 / 4)] / [0.028\rho \times 7.0L / (\pi(14d)^2 / 4)] = 1000$ or ratio = $14^2 / (0.028 \times 7) = 1000$	A1
(b)(ii)	same current (in connecting and filament wires) and the lamp/filament (wire) has greater resistance	B1
(b)(iii)	$P = V^2 / R$ or $P = VI$ or $P = I^2R$	C1
	(for filament wire) $R = 12^2 / 6.0$ or $R = 6.0 / 0.50^2$ or $R = 12 / 0.50$	C1
	(for filament wire) $R = 24\,\Omega$ (for connecting wire) $R = 24 / 1000$ $= 2.4 \times 10^{-2}\,\Omega$	A1
(b)(iv)	resistance of connecting wire increases	B1
	current in circuit/lamp/filament (wire) decreases or potential difference across lamp/filament (wire) decreases	M1
	(so) resistance of lamp/filament (wire) decreases	A1

7 - (9702/21_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	joule / coulomb	B1
(b)(i)	lamps have same p.d./lamps have p.d. of 2.7 V	B1
	current = 0.15 + 0.090 = 0.24 A	A1
(b)(ii)	$R = (4.5 - 2.7) / 0.24$ or $R_P = 18\,(\Omega)$ and $R_Q = 30\,(\Omega)$ $I / R_T = 1/18 + 1/30$ and so $R_T = 11.25$ $4.5 = 0.24 \times (R + 11.25)$	C1
	$R = 7.5\,\Omega$	A1

(b)(iii)	$R = \rho l / A$	C1
	$R_P / R_Q = [(2.7/0.15)/(2.7/0.09)]$ (= 0.60)	C1
	ratio = 0.60×2^2 = 2.4	A1
(b)(iv)	less p.d. across resistor/greater p.d. across P	B1
	greater current through P and so resistance (of P) increases	B1

8 - (9702/22_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a)(i)	sum of current(s) into junction = sum of current(s) out of junction or (algebraic) sum of current(s) at a junction is zero	B1
(a)(ii)	charge	B1
(b)(i)1.	$E = I^2Rt$ or $E = VIt$ or $E = (V^2/R)t$	C1
	$E = 2.5^2 \times 2.0 \times 5.0 \times 60$ or $5.0 \times 2.5 \times 5.0 \times 60$ or $(5.0^2/2.0) \times 5.0 \times 60$ $= 3800$ J	A1
(b)(i)2.	p.d. $= 8.0 - (2.0 \times 2.5)$ $= 3.0$ V	A1
(b)(ii)	$I_X = 3.0/15 = 0.20$ (A)	C1
	$I_Y = 2.5 - 0.20 = 2.3$ (A)	C1
	$R_Y = 3.0/2.3$ $= 1.3\,\Omega$	A1
	or	
	$R_T = 3.0/2.5 = 1.2\,(\Omega)$ or $(8.0/2.5) - 2.0 = 1.2\,(\Omega)$	(C1)
	$1/1.2 = 1/15 + 1/R_Y$	(C1)
	$R_Y = 1.3\,\Omega$	(A1)

(b)(iii)1.	Z has larger radius/diameter/(cross-sectional) area	B1
	Z has (material of) smaller resistivity/greater conductivity	B1
(b)(iii)2.	current/I (in battery) increases	M1
	($P = EI$ so) power/P (produced by battery) increases	A1

9 - (9702/23_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	$R = \rho L/A$	C1
	$3.0 = \rho/[\pi \times (0.48 \times 10^{-3}/2)^2]$	C1
	$\rho = 5.4 \times 10^{-7}\,\Omega$m	A1
(b)(i)	p.d. $= 5.0 - (2.0 \times 1.6)$ $= 1.8$V	A1
(b)(ii)1.	current in resistor $= 1.8/4.5$ (= 0.40 A)	C1
	current in wire $= 1.6 - 0.40$ (= 1.2 A)	C1
	$R_X = 1.8/1.2$ $= 1.5\,\Omega$	A1
	or	
	$R_T = 1.8/1.6$ or $(5.0/1.6) - 2.0$ (= 1.125 Ω)	(C1)
	$(1/1.125) = (1/4.5) + (1/R_X)$	(C1)
	$R_X = 1.5\,\Omega$	(A1)
(b)(ii)2.	length $= 1.5/3.0$ or $1.5 \times 1.8 \times 10^{-7}/(5.4 \times 10^{-7})$ $= 0.50$m	A1

10 - (9702/21_Winter_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	sum of e.m.f.(s) equal to sum of p.d.(s)	M1
	around a loop/around a closed circuit	A1
(b)(i)	current in variable resistor = (6.0 / 2.4) + (6.0 / 1.2) (= 7.5 A)	C1
	p.d. across variable resistor = 9.0 – 6.0 (= 3.0 V)	C1
	R = 3.0 / 7.5 = 0.40 Ω	A1
	or	
	$\frac{1}{R_T} = \frac{1}{2.4} + \frac{1}{1.2}$ R_T = 0.80 (Ω)	(C1)
	$\frac{3}{9} = \frac{R}{(R + 0.80)}$ or $\frac{3}{R} = \frac{6}{0.8}$	(C1)
	R = 0.40 Ω	(A1)
(b)(ii)	$P = V^2/R$ or $P = I^2R$ or $P = IV$	C1
	P = $6.0^2/24$ or $2.5^2 \times 2.4$ or 6.0×2.5 = 15 W	A1

(b)(iii)	1. $R = \frac{\rho L}{A}$	C1
	ratio = (2.4 / 1.2) × (3 / 1) = 6.0	A1
	2. ($I = nAvq$) I_X / I_Y = 2.5 / 5.0 or 1.2 / 2.4 or 0.5	C1
	ratio = (2.5 / 5.0) × (1 / 3) or (1.2 / 2.4) × (1 / 3) = 0.17	A1

11 - (9702/22_Winter_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	joule / coulomb	B1
(b)(i)	7.0 = (I × 5.2) + (I × 6.0) + 1.4	C1
	I = 0.50 A	A1
(b)(ii)	R = 1.4 / 0.50 = 2.8 Ω	A1
(b)(iii)	$P = EI$ or $P = VI$ or $P = I^2R$ or $P = V^2/R$	C1
	efficiency = [(0.50^2 × 6.0) / (7.0 × 0.50)] (×100) or efficiency = [(0.50 × 3.0) / (7.0 × 0.50)] (×100) or efficiency = [(3.0^2 / 6.0) / (7.0 × 0.50)] (×100)	C1
	efficiency = 43%	A1
(b)(iv)	$R = \rho l / A$	C1
	$\alpha = \rho / R$ = 3.7×10^{-7} / 6.0 = 6.2×10^{-8} m	A1

12 – (9702/23_Winter_2018_Q6) – *Current Of Electricity*

(a)	(coulomb is an) ampere second	B1
(b)	8.0×10^{-19} C and 1.6×10^{-18} C both underlined (and no others underlined)	B1
(c)	line drawn between (S, $1.00v_s$) and (T, $0.25v_s$)	M1
	line with decreasing magnitude of gradient	A1

13 – (9702/22_Winter_2018_Q7) – *Current Of Electricity*

(a)	*A*: (cross-sectional) area (of wire)	B1
	n: number of free electrons per unit volume **or** number density of free electrons	B1
(b)	line drawn between (X, v_s) and (Y, $4v_s$)	M1
	line has increasing gradient	A1

14 – (9702/23_Winter_2018_Q7) – *Current Of Electricity, D.c. Circuits*

(a)	sum of current(s) in(to) junction = sum of current(s) out of junction **or** (algebraic) sum of current(s) at a junction is zero	B1
(b)(i)	**1.** potential difference = 0	A1
	2. potential difference = 9.6 V	A1
(b)(ii)	for resistance in parallel: $(1 / R_T) = (1 / 400) + (1 / 400)$ $R_T = 200\,(\Omega)$	C1
	$V / 9.6 = 200 / 600$	C1
	$V = 3.2$ V	A1

15 – (9702/23_Summer_2019_Q1) – *Current Of Electricity, Physical Quantities & Units*

(a)(i)	potential difference / current	B1
(a)(ii)	$R = 4.0 \times 10^9\,(\Omega)$	C1
	$I = 0.60 / 4.0 \times 10^9 = 1.5 \times 10^{-10}$ (A) $I = 150$ pA	A1
(b)	units of energy: $kg\,m^2\,s^{-2}$	C1
	units of charge: A s	C1
	units of potential difference: $(kg\,m^2\,s^{-2} / A\,s =)\ kg\,m^2\,A^{-1}\,s^{-3}$	A1

16 - (9702/22_Summer_2019_Q5) - *Current Of Electricity, D.c. Circuits*

(a)	sum of e.m.f.(s) = sum of p.d.(s)	M1
	around a loop/around a closed circuit	A1
(b)(i)	**1.** $1/R = 1/R_1 + 1/R_2$ $1/R = 1/90 + 1/18$	C1
	$R = 15\,\Omega$	A1
	2. $I = V/R$	C1
	$I = 4.8/15$ **or** $I = 4.8/90 + 4.8/18$ $I = 0.32\,A$	A1
(b)(ii)	$E = V + Ir$ **or** $E = I(R + r)$	C1
	$5.6 = 4.8 + 0.32\,r$ so $r = 2.5\,(\Omega)$ **or** $5.6 = 0.32 \times (15 + r)$ so $r = 2.5\,(\Omega)$	A1
(b)(iii)	$P = EI$ **or** $P = VI$ **or** $P = I^2R$ **or** $P = V^2/R$	C1
	ratio $= (0.32^2 \times 2.5)/(5.6 \times 0.32)$ **or** $0.256/1.792$	C1
	$= 0.14$	A1

(c)	$7.2 - 5.6 - 2.5I - 3.5I = 0$	C1
	$I = 0.27\,A$	A1

17 - (9702/21_Summer_2019_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	energy is dissipated in the internal resistance	B1
(b)	$E = V + Ir$	B1
(c)(i)	(graph shows) maximum value of potential difference is 2.8 (V) **or** (graph shows) when current/I (from battery) is zero, V is 2.8 (V) / E	B1
(c)(ii)	r = (–)gradient **or** $r = (E - V)/I$ **or** substituted values from the graph for E, V and I	C1
	$r = 1.4\,\Omega$	A1
(d)(i)	$R = 2.1/0.50$ $= 4.2\,\Omega$	A1
(d)(ii)	number $= 0.50/1.60 \times 10^{-19}$ $= 3.1 \times 10^{18}$	A1
(d)(iii)	energy $= EIt$ **or** $P = EI$ **and** $P = W/t$	C1
	$(9.2 - 1.6) \times 10^3 = 2.8 \times 0.50 \times t$	C1
	$t = 5.4 \times 10^3\,s$	A1

18 – (9702/23_Summer_2019_Q6) – *Current Of Electricity, D.c. Circuits*

(a)	volt / ampere	B1
(b)(i)	**1.** $I = 1.8 + 0.60$ $= 2.4$ A	A1
	2. $(8.0 \times 0.60) = 1.8 \times (2.0 + R_Z)$	C1
	$R_Z = 0.67\ \Omega$	A1
	3. $E - (2.4 \times 1.5) = (0.60 \times 8.0)$ **or** $E - (2.4 \times 1.5) = 1.8 \times (2.0 + 0.67)$ **or** $E = 2.4 \times [1.5 + (8.0 \times 2.67) / (8.0 + 2.67)]$	C1
	$E = 8.4$ V	A1
(b)(ii)	**1.** $R = \rho L / A$ **or** $R \propto 1 / A$	C1
	ratio $= R_Y / R_X = 2.0 / 8.0$ $= 0.25$	A1
	2. $I \propto Av$ **or** $I_X / I_Y = A_X v_X / A_Y v_Y$	C1
	ratio $= (0.60 / 1.8) \times (1 / 0.25)$ $= 1.3$	A1

19 – (9702/21_Winter_2019_Q6) – *Current Of Electricity, D.c. Circuits*

(a)	work done / charge **or** energy (transferred from electrical to other forms) / charge	B1
(b)	for $V < 0.25$ V resistance is infinite/very high (as current is zero)	B1
	for $V > 0.25$ V resistance decreases (as V increases)	B1
(c)(i)	$R = V / I$	C1
	$= 0.75 / (15 \times 10^{-3})$	C1
	$= 50\ \Omega$	A1

(c)(ii)	**1.** $V_Y = 15 \times 10^{-3} \times 60$ (= 0.90 V)	C1
	$V_X = 2.0 - 0.90 - 0.75$ (= 0.35 V)	C1
	$R_X = 0.35 / (15 \times 10^{-3})$ $= 23\ \Omega$	A1
	or	
	total $R = 60 + 50 + R_X$	(C1)
	$60 + 50 + R_X = 2.0 / (15 \times 10^{-3})$	(C1)
	$R_X = 23\ \Omega$	(A1)
	2. $P = VI$ **or** $P = EI$ **or** $P = I^2R$ **or** $P = V^2 / R$	C1
	ratio $= \dfrac{(15 \times 10^{-3})^2 \times 60}{2.0 \times 15 \times 10^{-3}}$ **or** $\dfrac{0.90 \times 15 \times 10^{-3}}{2.0 \times 15 \times 10^{-3}}$ **or** $\dfrac{(0.90^2 / 60)}{2.0 \times 15 \times 10^{-3}}$ $= 0.45$	A1

20 - (9702/22_Winter_2019_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	sum of current(s) into junction = sum of current(s) out of junction **or** (algebraic) sum of current(s) at a junction is zero	B1
(b)(i)	$R = V / I$	C1
	$= 0.60 / 7.5 \times 10^{-3}$	C1
	$= 80\ \Omega$	A1
(b)(ii)	resistance decreases	B1
(c)(i)	$E = 0.60 + 0.30$ $= 0.90$ V	A1
(c)(ii)	(I =) 9.3 – 7.5	C1
	I = 1.8 (mA) **or** 1.8×10^{-3} (A) $R = 0.90 / 1.8 \times 10^{-3}$ $= 500\ \Omega$	A1
	or	
	total resistance = $0.90 / 9.3 \times 10^{-3} = 96.8\ (\Omega)$ total resistance of diode and X = $0.90 / 7.5 \times 10^{-3} = 120\ (\Omega)$ $1 / 96.8 = 1 / R + 1 / 120$	(C1)
	$R = 500\ \Omega$	(A1)

(c)(iii)	$P = VI$ **or** I^2R **or** V^2 / R	C1
	$= 0.60 \times 7.5 \times 10^{-3}$ **or** $(7.5 \times 10^{-3})^2 \times 80$ **or** $0.60^2 / 80$ $= 4.5 \times 10^{-3}$ W	A1
(c)(iv)	current = 2.5 mA	A1

21 - (9702/23_Winter_2019_Q6) - *Current Of Electricity, D.c. Circuits*

(a)(i)	$R = V / I$	C1
	resistance = (12 / 0.20) / 2 **or** 6 / 0.20 $= 30\ \Omega$	A1
(a)(ii)	$I = 0.50 - 0.20$ (= 0.30 A)	C1
	$R + 28 = 12 / 0.30$ (= 40 Ω) $R = 12\ \Omega$	A1

(b)	p.d. across lamp = 0.20 × 30 (= 6.0 V)	C1
	p.d. across R = 0.30 × 12 (= 3.6 V)	C1
	V_{XY} = 6.0 – 3.6 = 2.4 V	A1
	or	
	p.d. across lamp = 0.20 × 30 (= 6.0 V)	(C1)
	p.d. across 28 Ω resistor = 0.30 × 28 (= 8.4 V)	(C1)
	V_{XY} = 8.4 – 6.0 = 2.4 V	(A1)
(c)	$P = VI$ **or** $P = EI$ **or** $P = I^2R$ **or** $P = V^2/R$	C1
	ratio = (6.0 × 0.20) × 2 / (12 × 0.50) **or** 0.20 / 0.50 = 0.40	A1
(d)	no change to V across lamps, so power in lamps unchanged **or** current in battery/total current increases (and e.m.f. the same) so power produced by battery increases	B1
	both the above statements and so the ratio decreases	B1

22 – (9702/21_Summer_2020_Q5) – *Current Of Electricity, D.c. Circuits*

(a)(i)	$R = \rho L / A$	C1
	$A = (2.6 \times 10^{-8} \times 59) / 3.4 = 4.5 \times 10^{-7}$ m^2	A1
(a)(ii)	I = 1.8 / 3.4 = 0.53 A	A1
(a)(iii)	$I = Anvq$ $v = 0.53 / (4.5 \times 10^{-7} \times 6.1 \times 10^{28} \times 1.60 \times 10^{-19})$	C1
	$= 1.2 \times 10^{-4}$ m s^{-1}	A1
(b)(i)	(cross-sectional) area/A is less	M1
	(I, n, e the same so) average drift speed is greater	A1
(b)(ii)	(area is less so) more resistance/R	M1
	(I is the same, so) more power/P	A1
	or	
	($P = I^2\rho L / A$ so) $P \propto 1 / A$	(M1)
	(A is less so) more P	(A1)
(c)(i)	180 Ω and 90 Ω resistors shown connected in parallel	B1
(c)(ii)	resistors connected in parallel labelled as 180 Ω and 90 Ω **and** the other resistor labelled as 30 Ω	M1
	V_{OUT} or 8.0 V labelled across the two resistors in parallel	A1

23 – (9702/22_Summer_2020_Q5) – *Deformation Of Solids, Current Of Electricity*

(a)	Hooke's (law)	B1
(b)(i)	$\sigma = F / A$	C1
	$= 36 / (4.1 \times 10^{-7})$ $= 8.8 \times 10^{7}$ Pa	A1
(b)(ii)	Young modulus = σ / ε **or** $F / A\varepsilon$	C1
	$\varepsilon = 8.8 \times 10^{7} / (1.7 \times 10^{11})$ $= 5.2 \times 10^{-4}$	A1
(c)	$R = \rho L / A$	C1
	$\Delta R = \rho \Delta x / A$ $= 3.7 \times 10^{-7} \times 0.12 \times 10^{-3} / (4.1 \times 10^{-7})$	C1
	$= 1.1 \times 10^{-4}\ \Omega$	A1
(d)	remove the force/F and wire returns to original length	B1

24 – (9702/23_Summer_2020_Q6) – *Current Of Electricity*

(a)	A: cross-sectional area	B1
	n: number density of free electrons	B1
(b)	units of I: A **and** units of A: m^2 **and** units of v: $m\,s^{-1}$	B1
	units of e: $A / (m^2\,m^{-3}\,m\,s^{-1}) = A\,s$	A1
(c)	ratio $= A_Q / A_P$	C1
	$= [\pi r^2] / [\pi (2r^2)]$ $= 0.25$	A1

25 – (9702/22_Winter_2020_Q6) – *Current Of Electricity, D.c. Circuits*

(a)	$I = I_1 + I_2 + I_3$	B1
	$(V / R) = (V / R_1) + (V / R_2) + (V / R_3)$ **or** $(I / V) = (I_1 / V) + (I_2 / V) + (I_3 / V)$ **and** $1 / R = 1 / R_1 + 1 / R_2 + 1 / R_3$	B1
(b)(i)	current = 0.49 + 0.45 = 0.94 A	A1
(b)(ii)	$8.0 = (0.94 \times r) + (0.45 \times 16)$	C1
	$r = 0.85\ \Omega$	A1
(c)	$I = Anvq$ $v = (0.45 / 0.49) \times 2.1 \times 10^{-4}$	C1
	$= 1.9 \times 10^{-4}\ m\,s^{-1}$	A1
(d)	total/combined resistance decreases	B1
	(current in battery increases so terminal) potential difference decreases	B1

26 - (9702/23_Winter_2020_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	$\frac{\text{work (done) / energy (transferred from electrical to other forms)}}{\text{charge}}$	B1
(b)	$R = \rho L / A$	B1
	$V = LA$ **and** (so) $R = \rho V / A^2$ (with ρ and V constant)	B1
(c)	$E = IR + Ir$ **or** $E = I(R + r)$ **or** $E - Ir = IR$ **and** $R = (E / I) - r$	A1
(d)(i)	$P = I^2R$ **or** $P = IV$ **or** $P = V^2 / R$	C1
	$R = 5.4\ (\Omega)$ **or** $V = 10.8\ (V)$	C1
	$P = 2.0^2 \times 5.4$ $= 22\ W$	A1
(d)(ii)	**1.** $r = 0.60\ \Omega$	A1
	2. E = gradient	C1
	= e.g. 5.4 / 0.45 = 12 V	A1

27 - (9702/21_Winter_2020_Q7) - *Current Of Electricity, D.c. Circuits*

(a)	volt / ampere	B1
(b)	$R = \rho L / A$	C1
	$A = 460 \times 10^{-9} \times 2.5 / 3.2$	C1
	$= 3.6 \times 10^{-7}\ m^2$	A1
(c)(i)	energy is dissipated in the internal resistance/r	B1
(c)(ii)	$E = IR + Ir$ **or** $E = I(R + r)$	B1
(c)(iii)	$P = I^2R$ **or** $P = I^2r$	C1
	$I = E / 2r$ (so) $P = E^2 / 4r$	A1

28 - (9702/21_Summer_2021_Q5) - *Current Of Electricity, D.c. Circuits*

(a)	sum of e.m.f.(s) = sum of p.d.(s) **or** (algebraic) sum of e.m.f.(s) and p.d.(s) is zero	M1
	around a loop/around a closed circuit	A1
(b)(i)	$I = 1.8 / 0.90$ $= 2.0$ A	A1
(b)(ii)	$Q = It$	C1
	number = $(2.0 \times 45) / 1.60 \times 10^{-19}$ $= 5.6 \times 10^{20}$	A1
(b)(iii)	$4.0 = 1.8 + [2.0 \times (0.35 + R)]$ **or** $4.0 = 2.0 \times (0.90 + 0.35 + R)$	C1
	$R = 0.75\ \Omega$	A1
(c)(i)	$1.2 / 1.8 = 0.30 / L$	C1
	$L = 0.45$ m	A1
(c)(ii)	p.d. across XY decreases/p.d. across XP decreases	B1
	(so) P is moved towards Y/away from X/to the right	B1

29 - (9702/22_Summer_2021_Q5) - *Current Of Electricity, D.c. Circuits*

(a)	volt / ampere	B1
(b)	$R = \rho L / A$	B1
	$(A = V / L)$ (so) $R = \rho L^2 / V$ (with ρ and V constant so $R \propto L^2$)	B1
(c)(i)	$E = 2.4$ V	A1
(c)(ii)	$P = VI$ **or** I^2R **or** V^2 / R	C1
	$= 1.3 \times 5.0$ **or** $5.0^2 \times 0.26$ **or** $1.3^2 / 0.26$	C1
	$= 6.5$ W	A1
(c)(iii)	(–) internal resistance **or** (–) r	B1

30 - (9702/21_Winter_2021_Q5) - *Current Of Electricity*

(a)	sum of current(s) in = sum of current(s) out **or** (algebraic) sum of current(s) is zero	M1
	at a junction (in a circuit)	A1
(b)(i)	(current in R_4 or R_1 =) 0.30 + 0.30 (= 0.60 A)	B1
	(R =) 2.4 / 0.60 = 4.0 (Ω)	A1
	or	
	(p.d. across R_3 or R_2 =) 2.4 / 2 (= 1.2 V)	(B1)
	(R =) 1.2 / 0.30 = 4.0 (Ω)	(A1)
(b)(ii)	E = 2.4 + 2.4 + 1.2	C1
	= 6.0 V	A1
	or	
	total resistance = 10 (Ω)	(C1)
	E = 10 × 0.60 = 6.0 V	(A1)
(c)	total resistance increases	B1
	current decreases (in battery) so total power decreases	B1

(d)	resistivity = RA / L	C1
	= $4.0 \times \pi \times (240 \times 10^{-6})^2 / 0.67$	C1
	= 1.1×10^{-6} Ω m	A1

31 - (9702/23_Winter_2021_Q6) - *Current Of Electricity*

(a)	$R = \rho L / A$	C1
	(R =) $5(.0) \times 10^{-7} \times 2(.0) / 3.3 \times 10^{-7}$ = 3.0 Ω	A1
(b)(i)	I = 1.2 / 3.0 = 0.40 A	A1
(b)(ii)	r = (1.50 – 1.20) / 0.40 **or** 1.50 / 0.40 – 3.0	C1
	= 0.75 Ω	A1
(c)	E / 1.20 = 1.4 / 2.0	C1
	E = 0.84 V	A1
	or	
	R_{XP} = (1.4 / 2.0) × 3.0 (= 2.1 Ω) E = 2.1 × 0.40	(C1)
	E = 0.84 V	(A1)
(d)	(second wire has) larger resistance/resistance increases	M1
	p.d. across XY is larger/increases (for second wire) **or** p.d. across the (second) wire is larger/increases	M1
	(so) length XP (for second wire) is shorter	A1

32 - (9702/22_Summer_2022_Q6) - *Current Of Electricity*

(a)	$V = V_1 + V_2 + V_3$	B1
	$IR = IR_1 + IR_2 + IR_3$ **or** $(V/I) = (V_1/I) + (V_2/I) + (V_3/I)$ **and** $R = R_1 + R_2 + R_3$	B1
(b)(i)	$V/8.0 = 6.0 \times 10^3 / (4.0 \times 10^3 + 6.0 \times 10^3)$ **or** $I = 8.0/(4.0 \times 10^3 + 6.0 \times 10^3) = 8.0 \times 10^{-4}$ $V = 8.0 \times 10^{-4} \times 6.0 \times 10^3$	C1
	$V = 4.8$ V	A1
(b)(ii)	total resistance in parallel = 3.0×10^3 (Ω) **or** 3.0 (kΩ)	C1
	current = $8.0/(3.0 \times 10^3 + 6.0 \times 10^3)$ $= 8.9 \times 10^{-4}$ A	A1
(c)	thermistor resistance increases	B1
	(thermistor resistance increases so total resistance increases so) current decreases (in battery)	M1
	($P = EI$ and E constant so) power decreases	A1

33 - (9702/23_Summer_2022_Q6) - *Current Of Electricity*

(a)(i)	line passes through (0,0) and is in first and third quadrants only	M1
	gradient of line becoming less steep in both quadrants and roughly symmetrical	A1
(a)(ii)	(as I increases) the temperature (of the filament wire/lamp) increases	B1
	(as I / temperature / V increases) the resistance (of wire/lamp) increases	B1
	(as I / temperature / V increases the graph curves because) ratio V/I increases or ratio I/V decreases	B1
(b)	$R = \rho L / A$	C1
	$= (5.6 \times 10^{-8} \times 5.8) / 3.4 \times 10^{-8}$ $= 9.6\ \Omega$	A1
(c)		B4

position of switches		ammeter readings		
S_1	S_2	X / A	Y / A	Z / A
open	open	0	0	0
open	closed	1.0	**0**	**1.0**
closed	open	**2.0**	**2.0**	**0**
closed	closed	**3.0**	**2.0**	**1.0**

second row: both values correct (B1)

third row: all three values correct (B1)

fourth row: $X = Y + Z$ (any values) (B1)

all three values correct (B1)

34 - (9702/21_Winter_2022_Q5) - *Current Of Electricity*

(a)	current (through a conductor is directly) proportional to potential difference (across the conductor)	M1
	(provided that) temperature (of conductor remains) constant	A1
(b)(i)	(ratio of) V / I increases (as p.d. increases)	B1
(b)(ii)	(as p.d. increases, current increases so) temperature increases	B1
(c)(i)	$I = 1.55$ A	A1
(c)(ii)	$P = VI$ **or** $P = I^2R$ **or** $P = V^2 / R$	C1
	$= 6.0 \times 1.55 \times 2$ **or** $1.55^2 \times 3.87 \times 2$ **or** $(6.0^2 / 3.87) \times 2$ $= 19$ W	A1
(c)(iii)	$I = 1.78 - 1.55$ $(= 0.23$ A)	C1
	$R = 12.0 / 0.23$ $= 52\ \Omega$	A1
(d)	lamp P: p.d. across lamp decreases to zero so goes 'out'	B1
	lamp Q: p.d. across lamp increases to 12 V so gets brighter	B1

35 - (9702/23_Winter_2022_Q5) - *Current Of Electricity*

(a)	sum of e.m.f.(s) = sum of p.d.(s) **or** (algebraic) sum of e.m.f.(s) and p.d.(s) is zero	M1
	around a loop / around a closed circuit	A1
(b)(i)	$1 / r_{(T)} = 1 / 0.59 + 1 / 0.59 + 1 / 0.59$	B1
	$(r_{(T)} =)$ 0.197 (Ω) $(R =)$ $2.2 - 0.197 = 2.0\ \Omega$	A1
	or	
	$I = 1.5 / 2.2$ (= 0.68 A) **and** $i = 0.68 / 3$ (where I is the circuit current and i is the current from each cell)	(B1)
	$(E = IR + ir =)$ $1.5 = 0.68R + (0.68 / 3) \times 0.59$ **and** $R = 2.0\ \Omega$	(A1)

(b)(ii)	current = 1.5 / 2.2	C1
	= 0.68 A	A1
	or	
	p.d. across cell = p.d. across conductor $1.5 - 0.59I = 3I \times 2.0$ so $I = 0.228$ A (where I is current in cell) current = 3 × 0.228	(C1)
	= 0.68 A	(A1)
	or	
	current in conductor = 3 × current in cell $V / 2.0 = 3 \times (1.5 - V) / 0.59$ (where V is p.d. across conductor) $V = 1.37$ V current = 1.37 / 2.0	(C1)
	= 0.68 A	(A1)
(c)(i)	$R = \rho L / A$	C1
	$R = 4\rho L / \pi d^2$ (ρ and L are the same so) $R_A / R_B = 7.6^2 / 4.3^2$	C1
	= 3.1	A1

(c)(ii)	$I = Anvq$ and I, n, q are same / equal / constant	B1
	$\frac{v_A}{v_B} = \frac{A_B}{A_A} = \frac{d_B^2}{d_A^2}$ ratio = $7.6^2 / 4.3^2$ = 3.1	A1
(d)	combined internal resistance (of the cells) will be greater **or** total / circuit resistance (of circuit) greater (because a parallel resistance removed)	B1
	more 'lost volts' (inside each cell) **or** internal resistances take a greater share of total p.d. **or** conductor gets a smaller share of the total p.d. **or** current in conductor/total current decreases	M1
	(so) potential difference (across conductor) decreases	A1

36 – (9702/22_Winter_2022_Q6) – *Current Of Electricity*

(a)	energy transferred per (unit) charge (from electrical to other forms)	B1
(b)	same/equal current (in X and Y)	B1
	$P = I^2R$ (and $R_X > R_Y$) **or** $P = VI$ **and** $V_X > V_Y$	M1
	(so) X (dissipates more power)	A1
(c)(i)	$I = Q / t$	C1
	= 650 / 540 = 1.2 A	A1
(c)(ii)	$V = W / Q$ **or** W / It	C1
	= 4800 / 650 **or** 4800 / (1.2 × 540) = 7.4 V	A1
	or	
	$V = P / I$ **and** $P = W / t$	(C1)
	= 8.9 / 1.2 = 7.4 V	(A1)
(c)(iii)	I = 4.5 + 1.2 (= 5.7 A)	C1
	9.0 = 7.4 + 5.7r **or** 9.0 = 5.7 (1.3 + r) r = 0.28 Ω	A1

37 – (9702/21_Summer_2023_Q6) – *Current Of Electricity*

(a)	(number density =) $2.3 \times 10^{23} / (1.5 \times 10^{-6} \times 1.8) = 8.5 \times 10^{28}$ (m^{-3})	A1
(b)	$I = Q / t$ **or** $I = 172 / 2.5 \times 60$ **or** $I = 1.1(5)$	C1
	$I = nAvq$ $172 / (2.5 \times 60) = 1.5 \times 10^{-6} \times 8.5 \times 10^{28} \times v \times 1.6 \times 10^{-19}$	C1
	$v = 5.6 \times 10^{-5}$ m s^{-1}	A1

38 – (9702/21_Summer_2023_Q7) – *Current Of Electricity*

(a)	9.6 = 6.0 + (I × 5800) **or** 3.6 = I × 5800	C1
	$I = 6.2 \times 10^{-4}$ A	A1
(b)	9.6 = 6.2×10^{-4} × (3400 + 5800 + R) **or** 6.0 = 6.2×10^{-4} × (3400 + R)	C1
	$R = 6.3 \times 10^3$ Ω	A1
(c)	(ΔE =) 9.6 × 330 (= 3170 J)	C1
	final stored energy = 2.6×10^4 – 3170 = 2.3×10^4 J	A1
(d)(i)	decrease	B1
(d)(ii)	decrease	B1
(d)(iii)	increase	B1

39 - (9702/22_Summer_2023_Q6) - *Current Of Electricity*

(a)	temperature decreases (so) resistance decreases	B1
(b)(i)	current = V / R	A1
(b)(ii)	$I = Anvq$ $n = N / V$ **or** $n = N / AL$	C1
	$v = (V / R) / [(V / L)(N / V) e]$ **or** $(V / R) / [A (N / AL) e]$ $= VL / RNe$	A1
	or	
	$v = L / t$ $= L / (Q / I)$	(C1)
	$= LI / Q$ $= L(V / R) / Ne$ $= VL / RNe$	(A1)
(b)(iii)	time = distance / speed **or** Q / I $= L / (VL / RNe)$ **or** $Ne / (V / R)$ time = RNe / V	A1

40 - (9702/22_Summer_2023_Q7) - *Current Of Electricity*

(a)	$V / 9.0 = 1800 / (1800 + 1200)$	C1
	$V = 5.4$ V	A1
	or	
	$I = 9.0 / (1800 + 1200) = 3.0 \times 10^{-3}$ (A) $V = 3.0 \times 10^{-3} \times 1800$	(C1)
	$= 5.4$ V	(A1)
(b)(i)	$L / 1.2 = 5.4 / 9.0$ **or** $XZ / 1.2 = 5.4 / 9.0$	C1
	$L = 0.72$ m	A1
	or	
	$L / 1.2 = 1800 / (1800 + 1200)$ **or** $XZ / 1.2 = 1.8 / (1.8 + 1.2)$	(C1)
	$L = 0.72$ m	(A1)
(b)(ii)	• (intensity) increase	B1
	• (power) increase	B1
	• (length XZ) decrease	B1

41 – (9702/23_Summer_2023_Q5) – *Current Of Electricity*

(a)	correct symbol for the heater **or** for the LDR	M1
	all correct symbols in series (ignore voltmeter) and no extra symbols	A1
	correct symbol for voltmeter and in parallel with the heater	B1
(b)(i)	$R = \rho L / A$	C1
	$= (1.1 \times 10^{-6} \times 2.0) / 3.8 \times 10^{-7}$ $= 5.8\ \Omega$	A1
(b)(ii)	$I = 4.8 / 5.8$ $= 0.83$ A	A1
(c)(i)	A larger (for new wire) **or** $A \propto d^2$ (and d larger for new wire) **or** $R \propto 1 / d^2$ (and d larger for new wire)	M1
	so R is less (than that of first wire)	A1
(c)(ii)	(heater / total resistance decreases so) current (in circuit) increases (so p.d. across LDR increases) **or** heater resistance decreases so it has a smaller share/proportion/fraction of the (total) voltage / e.m.f.	M1
	(so voltmeter) reading is less (than 4.8 V)	A1

42 – (9702/21_Winter_2023_Q6) – *Current Of Electricity*

(a)(i)	(I =) 16 / 320 = 0.050 (A)	A1
(a)(ii)	$R = (25 - 16) / 0.050$ **or** $R = (9 / 16) \times 320$ **or** $R = (25 / 0.050) - 320$	C1
	$R = 180\ (\Omega)$	C1
	$R_{(LDR)} = [(1 / 180) - (1 / 240)]^{-1}$ $= 720\ \Omega$	A1
	or	
	$I = (25 - 16) / 240$ (= 0.0375 A)	(C1)
	$I_{(LDR)} = 0.050 - 0.0375$ (= 0.0125 A)	(C1)
	$R_{(LDR)} = 9.0 / 0.0125$ $= 720\ \Omega$	(A1)

(a)(iii)	$P = V^2 / R$ **or** $P = VI$ **or** $P = I^2R$	C1
	ratio = $(9^2 / 720) / (9^2 / 240)$ **or** ratio = $(9 \times 0.0125) / (9 \times 0.0375)$ **or** ratio = $(0.0125^2 \times 720) / (0.0375^2 \times 240)$ ratio = 0.1125 / 0.3375 = 0.33	A1
(b)	resistance of LDR decreases	B1
	resistance of parallel combination decreases **or** total resistance (of circuit) decreases **or** current in resistor of resistance 320 Ω increases **or** potential difference across parallel combination / LDR / 240 Ω resistor decreases	M1
	voltmeter reading increases	A1

43 - (9702/22_Winter_2023_Q6) - *Current Of Electricity*

(a)	$R = \rho L / A$	C1
	$\rho = 0.92 \times 5.3 \times 10^{-7}$ $= 4.9 \times 10^{-7}\ \Omega\,m$	A1
(b)(i)	(current =) $6.4 / 1600 = 4.0 \times 10^{-3}$ (A)	A1
(b)(ii)	charge = $4.0 \times 10^{-3} \times 3.2 \times 60$ (= 0.768 C)	C1
	number = $0.768 / 1.6 \times 10^{-19}$ $= 4.8 \times 10^{18}$	A1
(b)(iii)	$6.4 / E = 1600 / (1400 + 1600)$ **or** $E = 6.4 + (4.0 \times 10^{-3} \times 1400)$ **or** $E = 4.0 \times 10^{-3} (1600 + 1400)$	C1
	$E = 12$ V	A1
(b)(iv)	$P = I^2R$ **or** $P = VI$ **or** $P = V^2 / R$	C1
	ratio = $(6.4^2 / 1600) / [(4.0 \times 10^{-3})^2 \times 1400]$ = 1.1	A1
(c)(i)	increase	B1
(c)(ii)	increase	B1
(c)(iii)	decrease	B1

44 - (9702/23_Winter_2023_Q7) - *Current Of Electricity*

(a)	current (through a conductor is directly) proportional to potential difference (across the conductor) or vice versa	M1
	(provided that) temperature (of conductor remains) constant	A1
(b)(i)	$R = \rho L / A$	C1
	$\rho = (18 \times 7.2 \times 10^{-8}) / 0.94$ $= 1.4 \times 10^{-6}\ \Omega\,\text{m}$	A1
(b)(ii)	voltmeter reading = 3.1 V	A1
(b)(iii)	current in the battery: increase	B1
	voltmeter reading: decrease	B1
(b)(iv)	cross marked on the resistance wire to right of the arrowhead of S, but not touching the right-hand end of the resistance wire	B1
(c)(i)	$I = Anvq$ $q = 0.93 / [(7.2 \times 10^{-5}) \times (9.0 \times 10^{28}) \times (1.3 \times 10^{-3})]$	C1
	$q = 1.1 \times 10^{-19}$ C	A1
(c)(ii)	charge / q (value) is below 1.6×10^{-19} (C) **or** charge cannot be below 1.6×10^{-19} (C) **or** (the charge carriers / q) should have a charge of 1.6×10^{-19} (C)	B1

1 - (9702/21_Summer_2017_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	volt / ampere
(b)(i)	$R_T = [1/3.0 + 1/6.0]^{-1} + 4.0$ (= 6.0 Ω)
	I = 1.5 / 6.0
	= 0.25 A
(b)(ii)	V_B = 0.5 V I = 0.5 / 3.0 = 0.17 (0.167) A
(b)(iii)	$P = I^2R$ **or** VI **or** V^2/R
	ratio = $(0.167^2 \times 3.0) / (0.25^2 \times 4.0)$ = 0.33
(c)(i)	vary/change/different radius/diameter/<u>cross-sectional</u> area (of wire)
(c)(ii)	$v = I / Ane$ ratio $= \frac{(I_B / A_B)}{(I_C / A_C)}$ **or** $\frac{I_B}{I_C} \times \frac{A_C}{A_B}$
	($R \propto 1/A$ so) ratio $= \frac{I_B}{I_C} \times \frac{R_B}{R_C} = \frac{0.167}{0.25} \times \frac{3.0}{4.0}$ = 0.50
(d)(i)	0.25 A to 0.13 (0.125) A **or** halved
(d)(ii)	no change

2 - (9702/23_Summer_2017_Q6) - *Current Of Electricity, D.c. Circuits*

(a)(i)	straight line <u>through the origin</u>
(a)(ii)	zero current for one direction (–ve V) up to zero or a few tenths of volt (+ve V)
	straight line positive gradient/increasing gradient (+ve V)
(b)(i)	**1.** current = 2.8 A
	2. 4(.0) A for each lamp
	current in circuit = 8(.0) A
(b)(ii)	use of $R = V / I$ with correct values of V from graph for each arrangement
	1. series resistance (= 2.1 + 2.1) = 4.2 or 4.3 Ω **or** (12 / 2.8) = 4.3 Ω
	2. parallel resistance 1.5 Ω (each lamp 3.0 Ω) **or** (12 / 8.0) = 1.5 Ω
(b)(iii)	power = IV **or** V^2/R **or** I^2R
	ratio = $(2.8 \times 6.0) / (4.0 \times 12)$ = 0.35

3 - (9702/22_Summer_2017_Q7) - *D.c. Circuits*

(a)	energy transformed from chemical to electrical / unit charge (driven around a complete circuit)
(b)(i)	the current decreases (as resistance of Y increases)
	lost volts go down (as resistance of Y increases)
	p.d. AB increases (as resistance of Y increases)
(b)(ii)1.	$1.50 = 0.180 \times (6.00 + 0.200 + R_X)$
	$R_X = 2.1(3)\ \Omega$
(b)(ii)2.	p.d. AB = $1.5 - (0.180 \times 0.200)$ **or** $0.18 \times (2.13 + 6.00)$
	= 1.46(4) V
(b)(ii)3.	efficiency = (useful) power output / (total) power input **or** IV / IE
	(= 1.46 / 1.5) = 0.97 [0.98 if full figures used]

4 - (9702/21_Winter_2017_Q5) - *Current Of Electricity, D.c. Circuits*

(a)	$I_1 + I_2 = I_3$ [any subject]	**B1**
(b)	$E_1 + E_3 = I_1R_1 + I_3R_3 + I_3R_4$ [any subject]	**B1**
(c)	$E_1 - E_2 = I_1R_1 - I_2R_2$ [any subject]	**B1**

5 - (9702/23_Winter_2017_Q6) - *Current Of Electricity, D.c. Circuits*

(a)(i)	$P = VI$	**C1**
	$I = 30 / 120$ $= 0.25$ A	**A1**
(a)(ii)	$Q = 0.25 \times 3.0 \times 3600$ (= 2700)	**C1**
	number $= (0.25 \times 3.0 \times 3600) / 1.60 \times 10^{-19}$ $= 1.7 \times 10^{22}$	**A1**
(b)	$R = V / I$ **or** $R = P / I^2$ **or** $R = V^2 / P$	**C1**
	$= 120 / 0.25$ **or** $= 30 / 0.25^2$ **or** $= 120^2 / 30$ $= 480\ \Omega$	**A1**

(c)	$R = \rho l / A$	**C1**
	$A = (6.1 \times 10^{-7} \times 580 \times 10^{-3}) / 480$ (= 7.37×10^{-10})	**C1**
	$d = [(4 \times 7.37 \times 10^{-10}) / \pi]^{1/2}$ $= 3.1 \times 10^{-5}$ m	**A1**
(d)	temperature decreases and so resistance decreases	**B1**

6 - (9702/21_Winter_2017_Q7) - *Current Of Electricity, D.c. Circuits*

(a)	(the ohm is) volt / ampere	B1
(b)(i)	$R = \rho L / A$	C1
	ratio = $[\rho L / (\pi d^2 / 4)] / [0.028\rho \times 7.0L / (\pi(14d)^2 / 4)] = 1000$ or ratio = $14^2 / (0.028 \times 7) = 1000$	A1
(b)(ii)	same current (in connecting and filament wires) and the lamp/filament (wire) has greater resistance	B1
(b)(iii)	$P = V^2 / R$ or $P = VI$ or $P = I^2R$	C1
	(for filament wire) $R = 12^2 / 6.0$ or $R = 6.0 / 0.50^2$ or $R = 12 / 0.50$	C1
	(for filament wire) $R = 24\,\Omega$ (for connecting wire) $R = 24 / 1000$ $= 2.4 \times 10^{-2}\,\Omega$	A1
(b)(iv)	resistance of connecting wire increases	B1
	current in circuit/lamp/filament (wire) decreases or potential difference across lamp/filament (wire) decreases	M1
	(so) resistance of lamp/filament (wire) decreases	A1

7 - (9702/21_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	joule / coulomb	B1
(b)(i)	lamps have same p.d./lamps have p.d. of 2.7 V	B1
	current = 0.15 + 0.090 = 0.24 A	A1
(b)(ii)	$R = (4.5 - 2.7) / 0.24$ or $R_P = 18\,(\Omega)$ and $R_Q = 30\,(\Omega)$ $I / R_T = 1/18 + 1/30$ and so $R_T = 11.25$ $4.5 = 0.24 \times (R + 11.25)$	C1
	$R = 7.5\,\Omega$	A1

(b)(iii)	$R = \rho l / A$	C1
	$R_P / R_Q = [(2.7/0.15)/(2.7/0.09)]$ (= 0.60)	C1
	ratio = 0.60×2^2 = 2.4	A1
(b)(iv)	less p.d. across resistor/greater p.d. across P	B1
	greater current through P and so resistance (of P) increases	B1

8 - (9702/22_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a)(i)	sum of current(s) into junction = sum of current(s) out of junction or (algebraic) sum of current(s) at a junction is zero	B1
(a)(ii)	charge	B1
(b)(i)1.	$E = I^2Rt$ or $E = VIt$ or $E = (V^2/R)t$	C1
	$E = 2.5^2 \times 2.0 \times 5.0 \times 60$ or $5.0 \times 2.5 \times 5.0 \times 60$ or $(5.0^2/2.0) \times 5.0 \times 60$ $= 3800$ J	A1
(b)(i)2.	p.d. $= 8.0 - (2.0 \times 2.5)$ $= 3.0$ V	A1
(b)(ii)	$I_X = 3.0/15 = 0.20$ (A)	C1
	$I_Y = 2.5 - 0.20 = 2.3$ (A)	C1
	$R_Y = 3.0/2.3$ $= 1.3\,\Omega$	A1
	or	
	$R_T = 3.0/2.5 = 1.2\,(\Omega)$ or $(8.0/2.5) - 2.0 = 1.2\,(\Omega)$	(C1)
	$1/1.2 = 1/15 + 1/R_Y$	(C1)
	$R_Y = 1.3\,\Omega$	(A1)

(b)(iii)1.	Z has larger radius/diameter/(cross-sectional) area	B1
	Z has (material of) smaller resistivity/greater conductivity	B1
(b)(iii)2.	current/I (in battery) increases	M1
	($P = EI$ so) power/P (produced by battery) increases	A1

9 - (9702/23_Summer_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	$R = \rho L/A$	C1
	$3.0 = \rho/[\pi \times (0.48 \times 10^{-3}/2)^2]$	C1
	$\rho = 5.4 \times 10^{-7}\,\Omega$m	A1
(b)(i)	p.d. $= 5.0 - (2.0 \times 1.6)$ $= 1.8$V	A1
(b)(ii)1.	current in resistor $= 1.8/4.5$ (= 0.40 A)	C1
	current in wire $= 1.6 - 0.40$ (= 1.2 A)	C1
	$R_X = 1.8/1.2$ $= 1.5\,\Omega$	A1
	or	
	$R_T = 1.8/1.6$ or $(5.0/1.6) - 2.0$ (= 1.125 Ω)	(C1)
	$(1/1.125) = (1/4.5) + (1/R_X)$	(C1)
	$R_X = 1.5\,\Omega$	(A1)
(b)(ii)2.	length $= 1.5/3.0$ or $1.5 \times 1.8 \times 10^{-7}/(5.4 \times 10^{-7})$ $= 0.50$m	A1

10 - (9702/21_Winter_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	sum of e.m.f.(s) equal to sum of p.d.(s)	M1
	around a loop/around a closed circuit	A1
(b)(i)	current in variable resistor = (6.0 / 2.4) + (6.0 / 1.2) (= 7.5 A)	C1
	p.d. across variable resistor = 9.0 – 6.0 (= 3.0 V)	C1
	R = 3.0 / 7.5 = 0.40 Ω	A1
	or	
	$\frac{1}{R_T} = \frac{1}{2.4} + \frac{1}{1.2}$ R_T = 0.80 (Ω)	(C1)
	$\frac{3}{9} = \frac{R}{(R + 0.80)}$ or $\frac{3}{R} = \frac{6}{0.8}$	(C1)
	R = 0.40 Ω	(A1)
(b)(ii)	$P = V^2/R$ or $P = I^2R$ or $P = IV$	C1
	P = $6.0^2/24$ or $2.5^2 \times 2.4$ or 6.0×2.5 = 15 W	A1

(b)(iii)	1. $R = \frac{\rho L}{A}$	C1
	ratio = (2.4 / 1.2) × (3 / 1) = 6.0	A1
	2. ($I = nAvq$) I_X / I_Y = 2.5 / 5.0 or 1.2 / 2.4 or 0.5	C1
	ratio = (2.5 / 5.0) × (1 / 3) or (1.2 / 2.4) × (1 / 3) = 0.17	A1

11 - (9702/22_Winter_2018_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	joule / coulomb	B1
(b)(i)	7.0 = (I × 5.2) + (I × 6.0) + 1.4	C1
	I = 0.50 A	A1
(b)(ii)	R = 1.4 / 0.50 = 2.8 Ω	A1
(b)(iii)	$P = EI$ or $P = VI$ or $P = I^2R$ or $P = V^2/R$	C1
	efficiency = [(0.50^2 × 6.0) / (7.0 × 0.50)] (×100) or efficiency = [(0.50 × 3.0) / (7.0 × 0.50)] (×100) or efficiency = [(3.0^2 / 6.0) / (7.0 × 0.50)] (×100)	C1
	efficiency = 43%	A1
(b)(iv)	$R = \rho l / A$	C1
	$\alpha = \rho / R$ = 3.7×10^{-7} / 6.0 = 6.2×10^{-8} m	A1

12 - (9702/23_Winter_2018_Q7) - *Current Of Electricity, D.c. Circuits*

(a)	sum of current(s) in(to) junction = sum of current(s) out of junction **or** (algebraic) sum of current(s) at a junction is zero	**B1**
(b)(i)	**1.** potential difference = 0	**A1**
	2. potential difference = 9.6 V	**A1**
(b)(ii)	for resistance in parallel: $(1 / R_T) = (1 / 400) + (1 / 400)$ $R_T = 200\ (\Omega)$	**C1**
	$V / 9.6 = 200 / 600$	**C1**
	$V = 3.2$ V	**A1**

13 - (9702/22_Summer_2019_Q5) - *Current Of Electricity, D.c. Circuits*

(a)	sum of e.m.f.(s) = sum of p.d.(s)	**M1**
	around a loop/around a closed circuit	**A1**
(b)(i)	**1.** $1 / R = 1 / R_1 + 1 / R_2$ $1 / R = 1 / 90 + 1 / 18$	**C1**
	$R = 15\ \Omega$	**A1**
	2. $I = V / R$	**C1**
	$I = 4.8 / 15$ **or** $I = 4.8 / 90 + 4.8 / 18$ $I = 0.32$ A	**A1**
(b)(ii)	$E = V + Ir$ **or** $E = I(R + r)$	**C1**
	$5.6 = 4.8 + 0.32\ r$ so $r = 2.5\ (\Omega)$ **or** $5.6 = 0.32 \times (15 + r)$ so $r = 2.5\ (\Omega)$	**A1**
(b)(iii)	$P = EI$ **or** $P = VI$ **or** $P = I^2R$ **or** $P = V^2 / R$	**C1**
	ratio $= (0.32^2 \times 2.5) / (5.6 \times 0.32)$ **or** $0.256 / 1.792$	**C1**
	$= 0.14$	**A1**

(c)	$7.2 - 5.6 - 2.5I - 3.5I = 0$	**C1**
	$I = 0.27$ A	**A1**

14 - (9702/21_Summer_2019_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	energy is dissipated in the internal resistance	B1
(b)	$E = V + Ir$	B1
(c)(i)	(graph shows) maximum value of potential difference is 2.8 (V) **or** (graph shows) when current/I (from battery) is zero, V is 2.8 (V) / E	B1
(c)(ii)	r = (–)gradient **or** $r = (E - V) / I$ **or** substituted values from the graph for E, V and I	C1
	$r = 1.4\ \Omega$	A1
(d)(i)	$R = 2.1 / 0.50$ $= 4.2\ \Omega$	A1
(d)(ii)	number $= 0.50 / 1.60 \times 10^{-19}$ $= 3.1 \times 10^{18}$	A1
(d)(iii)	energy $= EIt$ **or** $P = EI$ **and** $P = W / t$	C1
	$(9.2 - 1.6) \times 10^3 = 2.8 \times 0.50 \times t$	C1
	$t = 5.4 \times 10^3$ s	A1

15 - (9702/23_Summer_2019_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	volt / ampere	B1
(b)(i)	**1.** $I = 1.8 + 0.60$ $= 2.4$ A	A1
	2. $(8.0 \times 0.60) = 1.8 \times (2.0 + R_Z)$	C1
	$R_Z = 0.67\ \Omega$	A1
	3. $E - (2.4 \times 1.5) = (0.60 \times 8.0)$ **or** $E - (2.4 \times 1.5) = 1.8 \times (2.0 + 0.67)$ **or** $E = 2.4 \times [1.5 + (8.0 \times 2.67) / (8.0 + 2.67)]$	C1
	$E = 8.4$ V	A1
(b)(ii)	**1.** $R = \rho L / A$ **or** $R \propto 1 / A$	C1
	ratio $= R_Y / R_X = 2.0 / 8.0$ $= 0.25$	A1
	2. $I \propto Av$ **or** $I_X / I_Y = A_X v_X / A_Y v_Y$	C1
	ratio $= (0.60 / 1.8) \times (1 / 0.25)$ $= 1.3$	A1

16 – (9702/21_Winter_2019_Q6) – *Current Of Electricity, D.c. Circuits*

(a)	work done / charge **or** energy (transferred from electrical to other forms) / charge	**B1**
(b)	for $V < 0.25$ V resistance is infinite/very high (as current is zero)	**B1**
	for $V > 0.25$ V resistance decreases (as V increases)	**B1**
(c)(i)	$R = V / I$	**C1**
	$= 0.75 / (15 \times 10^{-3})$	**C1**
	$= 50\ \Omega$	**A1**

(c)(ii)	**1.** $V_Y = 15 \times 10^{-3} \times 60$ (= 0.90 V)	**C1**
	$V_X = 2.0 - 0.90 - 0.75$ (= 0.35 V)	**C1**
	$R_X = 0.35 / (15 \times 10^{-3})$ $= 23\ \Omega$	**A1**
	or	
	total $R = 60 + 50 + R_X$	**(C1)**
	$60 + 50 + R_X = 2.0 / (15 \times 10^{-3})$	**(C1)**
	$R_X = 23\ \Omega$	**(A1)**
	2. $P = VI$ **or** $P = EI$ **or** $P = I^2R$ **or** $P = V^2 / R$	**C1**
	ratio $= \frac{(15 \times 10^{-3})^2 \times 60}{2.0 \times 15 \times 10^{-3}}$ **or** $\frac{0.90 \times 15 \times 10^{-3}}{2.0 \times 15 \times 10^{-3}}$ **or** $\frac{(0.90^2 / 60)}{2.0 \times 15 \times 10^{-3}}$ $= 0.45$	**A1**

17 – (9702/22_Winter_2019_Q6) – *Current Of Electricity, D.c. Circuits*

(a)	<u>sum of</u> current(s) into junction = <u>sum of</u> current(s) out of junction **or** (algebraic) sum of current(s) at a junction is zero	**B1**
(b)(i)	$R = V / I$	**C1**
	$= 0.60 / 7.5 \times 10^{-3}$	**C1**
	$= 80\ \Omega$	**A1**
(b)(ii)	resistance decreases	**B1**
(c)(i)	$E = 0.60 + 0.30$ $= 0.90$ V	**A1**
(c)(ii)	(I =) 9.3 – 7.5	**C1**
	$I = 1.8$ (mA) **or** 1.8×10^{-3} (A) $R = 0.90 / 1.8 \times 10^{-3}$ $= 500\ \Omega$	**A1**
	or	
	total resistance = $0.90 / 9.3 \times 10^{-3} = 96.8\ (\Omega)$ total resistance of diode and X = $0.90 / 7.5 \times 10^{-3} = 120\ (\Omega)$ $1 / 96.8 = 1 / R + 1 / 120$	**(C1)**
	$R = 500\ \Omega$	**(A1)**

(c)(iii)	$P = VI$ **or** I^2R **or** V^2/R	C1
	$= 0.60 \times 7.5 \times 10^{-3}$ **or** $(7.5 \times 10^{-3})^2 \times 80$ **or** $0.60^2/80$ $= 4.5 \times 10^{-3}$ W	A1
(c)(iv)	current = 2.5 mA	A1

18 – (9702/23_Winter_2019_Q6) – *Current Of Electricity, D.c. Circuits*

(a)(i)	$R = V/I$	C1
	resistance = (12 / 0.20) / 2 **or** 6 / 0.20 = 30 Ω	A1
(a)(ii)	I = 0.50 – 0.20 (= 0.30 A)	C1
	R + 28 = 12 / 0.30 (= 40 Ω) R = 12 Ω	A1

(b)	p.d. across lamp = 0.20 × 30 (= 6.0 V)	C1
	p.d. across R = 0.30 × 12 (= 3.6 V)	C1
	V_{XY} = 6.0 – 3.6 = 2.4 V	A1
	or	
	p.d. across lamp = 0.20 × 30 (= 6.0 V)	(C1)
	p.d. across 28 Ω resistor = 0.30 × 28 (= 8.4 V)	(C1)
	V_{XY} = 8.4 – 6.0 = 2.4 V	(A1)
(c)	$P = VI$ **or** $P = EI$ **or** $P = I^2R$ **or** $P = V^2/R$	C1
	ratio = (6.0 × 0.20) × 2 / (12 × 0.50) **or** 0.20 / 0.50 = 0.40	A1
(d)	no change to V across lamps, so power in lamps unchanged **or** current in battery/total current increases (and e.m.f. the same) so power produced by battery increases	B1
	both the above statements and so the ratio decreases	B1

19 – (9702/21_Summer_2020_Q5) – *Current Of Electricity, D.c. Circuits*

(a)(i)	$R = \rho L / A$	C1
	$A = (2.6 \times 10^{-8} \times 59) / 3.4 = 4.5 \times 10^{-7}\ m^2$	A1
(a)(ii)	$I = 1.8 / 3.4$ $= 0.53\ A$	A1
(a)(iii)	$I = Anvq$ $v = 0.53 / (4.5 \times 10^{-7} \times 6.1 \times 10^{28} \times 1.60 \times 10^{-19})$	C1
	$= 1.2 \times 10^{-4}\ m\ s^{-1}$	A1
(b)(i)	(cross-sectional) area/A is less	M1
	(I, n, e the same so) average drift speed is greater	A1
(b)(ii)	(area is less so) more resistance/R	M1
	(I is the same, so) more power/P	A1
	or	
	($P = I^2\rho L / A$ so) $P \propto 1 / A$	(M1)
	(A is less so) more P	(A1)
(c)(i)	180 Ω and 90 Ω resistors shown connected in parallel	B1
(c)(ii)	resistors connected in parallel labelled as 180 Ω and 90 Ω **and** the other resistor labelled as 30 Ω	M1
	V_{OUT} or 8.0 V labelled across the two resistors in parallel	A1

20 – (9702/23_Summer_2020_Q5) – *D.c. Circuits*

(a)	joule per coulomb	B1
(b)(i)	$1 / R = 1 / R_1 + 1 / R_2$ $= 1 / 300 + 1 / 200$ $R = 75\ \Omega$	A1
(b)(ii)	$R = 75 + 55$ $= 130\ \Omega$	A1
(c)(i)	**1.** $P = I^2R$ **or** $P = VI$ **and** $V = IR$	C1
	$I = (0.20 / 55)^{0.5}$ $= 0.060\ A$	A1
	2. $I = 0.060 / 4$ $= 0.015\ A$	A1
(c)(ii)	potential difference $= 130 \times 0.060$ $= 7.8\ V$	A1
	or	
	potential difference $= (300 \times 0.015) + (55 \times 0.060)$ $= 7.8\ V$ (*other valid methods are also possible*)	(A1)

21 - (9702/22_Summer_2020_Q6) - *D.c. Circuits*

(a)(i)	energy is dissipated in the internal resistance/r	B1
(a)(ii)	**1.** $I = Q / t$	C1
	$= 750 / 1500$ $= 0.50$ A	A1
	2. $V = W / Q$ **or** $V = W / It$	C1
	$= 5700 / 750$ **or** $5700 / (0.50 \times 1500)$ $= 7.6$ V	A1
	or	
	$V = P / I$ **and** $P = W / t$	(C1)
	$V = 3.8 / 0.50$ $= 7.6$ V	(A1)
	3. $r = (7.8 - 7.6) / 0.50$	C1
	$= 0.40\ \Omega$	A1
(b)(i)	$90\ \Omega$ and $45\ \Omega$ resistors shown connected in parallel	B1
(b)(ii)	the resistors connected in parallel labelled as $90\ \Omega$ and $45\ \Omega$ with the other resistor labelled as $20\ \Omega$	M1
	V_{OUT} or 3.6 V labelled across the $20\ \Omega$ resistor	A1

22 - (9702/22_Winter_2020_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	$I = I_1 + I_2 + I_3$	B1
	$(V / R) = (V / R_1) + (V / R_2) + (V / R_3)$ **or** $(I / V) = (I_1 / V) + (I_2 / V) + (I_3 / V)$ **and** $1 / R = 1 / R_1 + 1 / R_2 + 1 / R_3$	B1
(b)(i)	current = 0.49 + 0.45 = 0.94 A	A1
(b)(ii)	$8.0 = (0.94 \times r) + (0.45 \times 16)$	C1
	$r = 0.85\ \Omega$	A1
(c)	$I = Anvq$ $v = (0.45 / 0.49) \times 2.1 \times 10^{-4}$	C1
	$= 1.9 \times 10^{-4}$ m s^{-1}	A1
(d)	total/combined resistance decreases	B1
	(current in battery increases so terminal) potential difference decreases	B1

23 - (9702/23_Winter_2020_Q6) - *Current Of Electricity, D.c. Circuits*

(a)	$\frac{\text{work (done) / energy (transferred from electrical to other forms)}}{\text{charge}}$	B1
(b)	$R = \rho L / A$	B1
	$V = LA$ **and** (so) $R = \rho V / A^2$ (with ρ and V constant)	B1
(c)	$E = IR + Ir$ **or** $E = I(R + r)$ **or** $E - Ir = IR$ **and** $R = (E / I) - r$	A1
(d)(i)	$P = I^2R$ **or** $P = IV$ **or** $P = V^2 / R$	C1
	$R = 5.4\ (\Omega)$ **or** $V = 10.8\ (V)$	C1
	$P = 2.0^2 \times 5.4$ $= 22\ W$	A1
(d)(ii)	**1.** $r = 0.60\ \Omega$	A1
	2. E = gradient	C1
	= e.g. 5.4 / 0.45 = 12 V	A1

24 - (9702/21_Winter_2020_Q7) - *Current Of Electricity, D.c. Circuits*

(a)	volt / ampere	B1
(b)	$R = \rho L / A$	C1
	$A = 460 \times 10^{-9} \times 2.5 / 3.2$	C1
	$= 3.6 \times 10^{-7}\ m^2$	A1
(c)(i)	energy is dissipated in the internal resistance/r	B1
(c)(ii)	$E = IR + Ir$ **or** $E = I(R + r)$	B1
(c)(iii)	$P = I^2R$ **or** $P = I^2r$	C1
	$I = E / 2r$ (so) $P = E^2 / 4r$	A1

25 - (9702/21_Summer_2021_Q5) - *Current Of Electricity, D.c. Circuits*

(a)	sum of e.m.f.(s) = sum of p.d.(s) **or** (algebraic) sum of e.m.f.(s) and p.d.(s) is zero	M1
	around a loop/around a closed circuit	A1
(b)(i)	$I = 1.8 / 0.90$ $= 2.0$ A	A1
(b)(ii)	$Q = It$	C1
	number = $(2.0 \times 45) / 1.60 \times 10^{-19}$ $= 5.6 \times 10^{20}$	A1
(b)(iii)	$4.0 = 1.8 + [2.0 \times (0.35 + R)]$ **or** $4.0 = 2.0 \times (0.90 + 0.35 + R)$	C1
	$R = 0.75\ \Omega$	A1
(c)(i)	$1.2 / 1.8 = 0.30 / L$	C1
	$L = 0.45$ m	A1
(c)(ii)	p.d. across XY decreases/p.d. across XP decreases	B1
	(so) P is moved towards Y/away from X/to the right	B1

26 - (9702/22_Summer_2021_Q5) - *Current Of Electricity, D.c. Circuits*

(a)	volt / ampere	B1
(b)	$R = \rho L / A$	B1
	$(A = V / L)$ (so) $R = \rho L^2 / V$ (with ρ and V constant so $R \propto L^2$)	B1
(c)(i)	$E = 2.4$ V	A1
(c)(ii)	$P = VI$ **or** I^2R **or** V^2 / R	C1
	$= 1.3 \times 5.0$ **or** $5.0^2 \times 0.26$ **or** $1.3^2 / 0.26$	C1
	$= 6.5$ W	A1
(c)(iii)	(–) internal resistance **or** (–) r	B1

27 - (9702/23_Summer_2021_Q5) - *D.c. Circuits*

(a)	energy per unit charge	B1
	energy transferred by source driving charge around the complete circuit **or** energy transferred from other forms to electrical energy	B1
(b)	there is a p.d. across the internal resistance/r	B1
	change in current/I results in a change in p.d. across the internal resistance	B1
	$V = E$ – p.d. across internal resistance **or** change in p.d. across r causes a change in V (as e.m.f. is constant)	B1
(c)(i)	$E = 7.4$ V	A1
(c)(ii)	maximum current = 0.92 A	A1
(c)(iii)	$r = E / I_{MAX}$ **or** (–)gradient	C1
	e.g. $r = 7.4 / 0.92$ $= 8.0\,\Omega$	A1
(d)	straight line with negative gradient that is smaller in magnitude than the original line	B1
	line which would have intercept on V-axis below the original line	B1

28 - (9702/22_Winter_2021_Q6) - *D.c. Circuits*

(a)	$Q = It$	C1
	$= 0.80 \times 7.5 \times 60$ $= 360$ C	A1
(b)	$P = EI$ **or** $P = VI$ **or** $P = I^2R$ **or** $P = V^2 / R$	C1
	$0.80^2 \times 0.40$ (= 0.256 W) **or** 0.48×0.80 (= 0.384 W)	C1
	efficiency = $(0.256 / 0.384) \times 100$ = 67%	A1
(c)(i)	$n = 3.2 \times 10^{22} / (1.3 \times 10^{-7} \times 3.0)$ $= 8.2 \times 10^{28}$ m^{-3}	A1
(c)(ii)	$I = Anvq$ $v = 0.80 / (1.3 \times 10^{-7} \times 8.2 \times 10^{28} \times 1.60 \times 10^{-19})$	C1
	$= 4.7 \times 10^{-4}$ m s^{-1}	A1
(d)	(wire Y has) larger resistance / resistance increases	M1
	(wire Y has) smaller current / current decreases	M1
	(average drift) speed is less (in wire Y)	A1

29 - (9702/21_Summer_2022_Q6) - *D.c. Circuits*

(a)	sum of current(s) into junction = sum of current(s) out of junction **or** (algebraic) sum of current(s) at a junction is zero	**B1**
(b)(i)	same potential difference (across X and Y as in parallel)	**B1**
	power = V^2 / R (and $R_X > R_Y$) **or** power = VI **and** $I_X < I_Y$	**M1**
	(so) Y (dissipates more power)	**A1**
(b)(ii)	$R = \rho L / A$ (and $R_X > R_Y$)	**M1**
	(so) Y (has the larger (cross-sectional) area)	**A1**
(c)(i)	current = 5.4 / 1800 = 3.0×10^{-3} A	**A1**
(c)(ii)	5.4 / 9.0 = 1800 / (1800 + R_L) **or** R_L = (9.0 – 5.4) / 3.0×10^{-3}	**C1**
	R_L = 1200 Ω	**A1**
(c)(iii)	resistance of LDR / R_L decreases	**B1**
	current (in the circuit) increases (so) voltmeter reading increases	**B1**

1 – (9702/23_Summer_2017_Q3) – *Electric Fields, Particle & Nuclear Physics*

(a)	force per unit (positive) charge
(b)(i)	$a = (v^2 - u^2) / 2s$
	$= [(18 \times 10^6)^2 - (2.5 \times 10^3)^2] / (2 \times 12 \times 10^{-3})$
	$= 1.3\ (1.35) \times 10^{16}\ \text{m s}^{-2}$
(b)(ii)	KE = $\frac{1}{2} mv^2$ **or** $\frac{1}{2} m(v^2 - u^2)$
	change in KE $= 0.5 \times 9.11 \times 10^{-31} \times [(18 \times 10^6)^2 - (2.5 \times 10^3)^2]$
	$= 1.5\ (1.48) \times 10^{-16}$ J
(b)(iii)	$E = F / e = ma / e$ **or** $eV = \Delta\text{KE}$ so $E = \Delta\text{KE} / (e \times d)$
	$E = (9.11 \times 10^{-31} \times 1.35 \times 10^{16}) / 1.60 \times 10^{-19}$ **or** $E = (1.48 \times 10^{-16}) / (12 \times 10^{-3} \times 1.60 \times 10^{-19})$
	$= 7.7\ (7.69) \times 10^4\ \text{V m}^{-1}$
(c)	charge on α opposite to electron/charge on α is positive
	ΔKE is negative/KE reduced
	charge of α greater/twice that of electron causes larger/twice ΔKE (in magnitude)

2 – (9702/21_Summer_2017_Q7) – *Particle & Nuclear Physics*

(a)(i)	(proton is uud so) $(2/3)e + (2/3)e - (1/3)e = e$
(a)(ii)	(neutron is udd so) $(2/3)e - (1/3)e - (1/3)e = 0$
(b)(i)	<table><tr><td></td><td>β^-</td><td>β^+</td></tr><tr><td>nucleon number</td><td>90</td><td>64</td></tr><tr><td>proton number</td><td>39</td><td>28</td></tr></table> *all correct*
(b)(ii)	weak (nuclear force/interaction)
(b)(iii)	β^- decay: electron and (electron) antineutrino β^+ decay: positron and (electron) neutrino *all correct*

3 – (9702/23_Summer_2017_Q7) – *Particle & Nuclear Physics*

(a)	electron **and** quark both underlined/clearly indicated and no others
(b)(i)	<table><tr><td></td><td>value</td></tr><tr><td>A</td><td>60</td></tr><tr><td>B</td><td>28</td></tr></table> *both correct*
(b)(ii)	(electron) antineutrino

4 – (9702/22_Summer_2017_Q8) – *Particle & Nuclear Physics*

(a)	β^- emission: neutron changes to proton (+ beta$^-$/electron) **and** β^+ emission: proton changes to neutron (+ beta$^+$/positron)
	β^- emission: (electron) antineutrino also emitted **and** β^+ emission: (electron) neutrino also emitted
(b)	proton: up up down (and zero strange) neutron: up down down (and zero strange)

5 – (9702/22_Winter_2017_Q7) – *Particle & Nuclear Physics*

(a)	lepton(s)	**B1**
(b)	protons: 7 **and** neutrons: 6	**A1**
(c)	$E = ½mv^2$	**C1**
	$= 0.80 \times 10^6 \times 1.60 \times 10^{-19}$	**C1**
	$= 1.28 \times 10^{-13}$ (J) $v^2 = 2 \times 1.28 \times 10^{-13} / 2.2 \times 10^{-26}$ $v = 3.4 \times 10^6\,\text{m s}^{-1}$	**A1**
(d)	an (electron) neutrino/$\nu_{(e)}$ is also produced (and this has energy)	**B1**

6 – (9702/23_Winter_2017_Q7) – *Particle & Nuclear Physics*

(a)	nucleons = 23	**B1**
	neutrons = 11	**B1**
(b)	similarity: same (rest) mass **or** equal (magnitude of) charge	**B1**
	difference: opposite (sign of) charge **or** one is matter and one is antimatter **or** one is an electron and one is an antielectron	**B1**

7 – (9702/21_Winter_2017_Q8) – *Particle & Nuclear Physics*

(a)	(quark structure is) up, down, down/udd	**B1**
	up/u has charge $+⅔(e)$, down/d has charge $-⅓(e)$	**C1**
	$+⅔e - ⅓e - ⅓e = 0$	**A1**
(b)	charge: p $+1.6(0) \times 10^{-19}$ (C) **or** $+e$ β^- $-1.6(0) \times 10^{-19}$ (C) **or** $-e$ $\bar{\nu}$ zero/0	**B1**
	mass: p 1.67×10^{-27} (kg)/1.7×10^{-27} (kg) β^- $9.1(1) \times 10^{-31}$ (kg) $\bar{\nu}$ very small/zero/0	**B1**

8 - (9702/22_Summer_2018_Q7) - *Particle & Nuclear Physics*

(a)	circle(s) drawn only around β^- and $\bar{\nu}$ symbols	B1
(b)	(electron) antineutrino	B1
(c)	kinetic (energy)	B1
(d)	Y has one more proton (and one less neutron)/X has one less proton (and one more neutron) **or** Y has more protons (and fewer neutrons)/X has fewer protons (and more neutrons) **or** a neutron changes to a proton **or** the number of protons increases	M1
	(so) not isotopes	A1
(e)	up down down changes to up up down **or** udd → uud **or** down changes to up **or** d → u	B1

9 - (9702/23_Summer_2018_Q7) - *Particle & Nuclear Physics*

(a)(i)	Q plotted at (82, 210)	A1
(a)(ii)	R plotted at (83, 210)	A1
(b)	lepton(s)	B1
(c)	up down down changes to up up down **or** udd → uud **or** down changes to up **or** d → u	B1

10 - (9702/21_Winter_2018_Q5) - *Electric Fields, Particle & Nuclear Physics, Kinematics*

(a)	region (of space) where a force acts on a (stationary) charge	B1
(b)	$E = F/Q$	B1
	$F = ma$ **and** (so) $a = \frac{Eq}{m}$	A1
(c)(i)	protons = 96	A1
	neutrons = 148	A1
(c)(ii)	mass-energy is conserved/mass change is 'seen' as energy	B1
	energy released as gamma (radiation)/KE of α/KE of Pu	B1
(c)(iii)	ratio $= \frac{2}{4} \times \frac{240}{94}$ **or** ratio $= \frac{2 \times 1.60 \times 10^{-19}}{4 \times 1.66 \times 10^{-27}} \times \frac{240 \times 1.66 \times 10^{-27}}{94 \times 1.60 \times 10^{-19}}$	C1
	ratio = 1.3	A1

11 - (9702/23_Winter_2018_Q5) - *Electric Fields, Particle & Nuclear Physics*

(a)	$E = F/Q$	M1
	$F = ma$ **and** (so) $q/m = a/E$	A1
(b)	$m = (4 \times 1.60 \times 10^{-19} \times 3.5 \times 10^4)/1.5 \times 10^{12}$ (= 1.49×10^{-26} kg)	B1
	$= 1.49 \times 10^{-26}/1.66 \times 10^{-27} = 9.0$ (u)	A1
(c)	protons: 4 **and** neutrons: 5	A1
(d)(i)	nuclei have the same charge and so same (magnitudes of) force	B1
(d)(ii)	nuclei have different masses and same force and so different (magnitudes of) acceleration	B1

12 – (9702/22_Winter_2018_Q8) – *Particle & Nuclear Physics*

(a)	antineutrino **and** positron both underlined (and no other particles)	B1
(b)(i)	nucleon number = 27	A1
	proton number = 13	A1
(b)(ii)	weak (nuclear force/interaction)	B1
(b)(iii)	an (electron) antineutrino / $\bar{\nu}_{(e)}$ is produced (and this has energy)	B1
	X has kinetic energy	B1

13 – (9702/22_Summer_2019_Q6) – *Electric Fields, Particle & Nuclear Physics*

(a)	path/direction in which a (free) positive charge will move	B1
(b)	(lines) closer together in Y/further apart in X	B1
(c)(i)	$a = Eq / m$ **or** $F = Eq$ **and** $F = ma$	C1
	ratio = (1e / 0.15 u) × (4 u / 2e) **or** 1 / 0.15 × 4 / 2	C1
	ratio = 13	A1
(c)(ii)	down quark charge is –(1 / 3)e	C1
	– (1 / 3)e + q = –1e so q = –(2 / 3)e	A1
	(–(2 / 3)e is) anti-up / $\bar{u}$ (quark) (*allow charm or top antiquark*)	B1

14 – (9702/21_Summer_2019_Q7) – *Particle & Nuclear Physics*

(a)	nucleus is charged	B1
	the mass is concentrated in (very small) nucleus **or** the majority of the mass is in (very small) nucleus	B1
(b)(i)	–(1 / 3)e	B1
(b)(ii)	2q – (1 / 3)e = e so q = (2 / 3)e	M1
	up / u (quarks) (*allow charm or top quarks*)	A1

15 – (9702/23_Summer_2019_Q7) – *Particle & Nuclear Physics*

(a)	beta/β	B1
(b)	alpha/α	B1
(c)	gamma/γ	B1
(d)	beta/β	B1

16 – (9702/21_Winter_2019_Q7) – *Particle & Nuclear Physics*

(a)(i)	proton number = 17 **and** nucleon number = 35	**A1**
(a)(ii)	(electron) neutrino	**B1**
(b)	d/down (quark charge) is $-\frac{1}{3}(e)$ **or** two d/down (quark charges) is $-\frac{2}{3}(e)$ **or** s/strange (quark charge) is $-\frac{1}{3}(e)$	**C1**
	charge = $-\frac{1}{3}(e) - \frac{1}{3}(e) - \frac{1}{3}(e)$ $= -1(e)$	**A1**

17 – (9702/22_Winter_2019_Q7) – *Particle & Nuclear Physics*

(a)	number of protons = 92	**A1**
	number of neutrons = 142	**A1**
(b)	5.6 MeV = $5.6 \times 1.60 \times 10^{-19} \times 10^{6}$ (= 8.96×10^{-13} J)	**C1**
	number = $0.15 / (5.6 \times 1.60 \times 10^{-13})$ $= 1.7 \times 10^{11}$	**A1**
	or	
	0.15 W = $0.15 / (1.60 \times 10^{-19} \times 10^{6})$ (= 9.38×10^{11} MeV s^{-1})	**(C1)**
	number = $9.38 \times 10^{11} / 5.6$ $= 1.7 \times 10^{11}$	**(A1)**

18 – (9702/23_Winter_2019_Q7) – *Particle & Nuclear Physics*

(a)	number of protons = 95	**A1**
	number of neutrons = 146	**A1**
(b)	Np/neptunium (nucleus) has kinetic energy **or** gamma/γ-radiation produced	**B1**
(c)(i)	$I = NQ / t$	**C1**
	$I = (6.9 \times 10^{11} \times 2 \times 1.60 \times 10^{-19}) / 30$ $= 7.4 \times 10^{-9}$ A	**A1**
(c)(ii)	$P = (6.9 \times 10^{11} \times 5.5 \times 10^{6} \times 1.60 \times 10^{-19}) / 30$	**C1**
	= 0.020 W	**A1**

19 – (9702/21_Summer_2020_Q6) – *Electric Fields, Particle & Nuclear Physics*

(a)(i)	$E = \Delta V / \Delta d$	C1
	$E = (180 + 120) / (2.0 \times 10^{-2})$ $= 1.5 \times 10^4$ N C^{-1}	A1
(a)(ii)	vertically downwards	B1
(b)(i)	number of protons = 92	A1
	number of neutrons = 146	A1
	number of electrons = 90	A1
(b)(ii)	$F = EQ$	C1
	$= 1.5 \times 10^4 \times 2 \times 1.60 \times 10^{-19}$ $= 4.8 \times 10^{-15}$ N	A1
(b)(iii)	number of α-particles = 2	A1
	number of β^- particles = 2	A1

20 – (9702/22_Summer_2020_Q7) – *Particle & Nuclear Physics*

(a)(i)	P = 0 **and** Q = 39	A1
	R = (+)1 **and** S = 20	A1
(a)(ii)	weak (nuclear force/interaction)	B1
(b)	charge of quark(s) = (+) $2e / 3$	B1
	up/u (quarks)	B1

21 – (9702/23_Summer_2020_Q7) – *Electric Fields, Particle & Nuclear Physics*

(a)(i)	$E = V / d$ **or** $E = F / Q$	C1
	$F = (450 \times 1.60 \times 10^{-19}) / 6.0 \times 10^{-3}$	C1
	$= 1.2 \times 10^{-14}$ N	A1
	direction: vertically downwards	B1

(a)(ii)	work done = Fs **or** Fd **or** EQd	C1
	$= (-)1.2 \times 10^{-14} \times 6.0 \times 10^{-3}$ $= (-)7.2 \times 10^{-17}$ J	A1
	or	
	work done = VQ	(C1)
	$= (-)450 \times 1.60 \times 10^{-19}$ $= (-)7.2 \times 10^{-17}$ J	(A1)
(b)	$E = ½mv^2$	C1
	$3.4 \times 10^{-16} = ½ \times 9.11 \times 10^{-31} \times v^2$ $v = 2.7 \times 10^7$ m s^{-1}	A1
(c)(i)	^1_1p	A1
	$^0_{-1}V_{(e)}$	A1
(c)(ii)	**1.** hadrons	B1
	2. leptons	B1

22 – (9702/22_Winter_2020_Q7) – *Electric Fields, Particle & Nuclear Physics*

(a)	similarity: same/equal mass **or** same/equal (magnitude of) charge **or** both fundamental (particles)	B1
	difference: opposite (sign of) charge **or** one is matter and the other is antimatter	B1
(b)(i)	arrow points to the right	B1
(b)(ii)	(electric) field strength increases **or** (electric) force increases	B1
	acceleration increases	B1
(b)(iii)	force (on α-particle) has twice the magnitude (of force on electron)	B1
	force (on α-particle) is in opposite direction (to force on electron)	B1

23 – (9702/23_Winter_2020_Q7) – *Electric Fields, Particle & Nuclear Physics*

(a)(i)	electric field strength = V / d	B1
(a)(ii)	force = Vq / d	B1
(a)(iii)	kinetic energy = Vq	B1
(b)(i)	no change	B1
(b)(ii)	no change	B1
(c)(i)	nucleon number = 14 **and** proton number = 7	A1
(c)(ii)	(electron) antineutrino	B1

24 – (9702/21_Winter_2020_Q8) – *Particle & Nuclear Physics*

(a)	similarity: same/equal mass **or** same/equal (magnitude of) charge **or** both fundamental (particles)	B1
	difference: opposite (sign of) charge **or** one is matter and the other is antimatter	B1
(b)(i)	number of protons = 13 **and** number of neutrons = 12	A1
(b)(ii)	(charge =) $13 \times 1.60 \times 10^{-19}$ (C) = 2.1×10^{-18} (C)	A1
(c)	force = $11 \times 10^3 \times 2.1 \times 10^{-18}$	C1
	work done = $11 \times 10^3 \times 2.1 \times 10^{-18} \times 0.04$	C1
	= 9.2×10^{-16} J	A1

25 – (9702/21_Summer_2021_Q6) – *Particle & Nuclear Physics*

(a)(i)	(electron) neutrino	B1
(a)(ii)	weak (nuclear force/interaction)	B1
(a)(iii)	β^+ (particle)	B1
(a)(iv)	(quark structure is) up up down **or** uud	B1
	$(2/3)e + (2/3)e - (1/3)e = (+)e$	B1
(a)(v)	up up down changes to up down down **or** uud → udd **or** up changes to down **or** u → d	B1
(b)(i)	$F = Eq$	C1
	ratio = 6 / 8 = 0.75	A1
(b)(ii)	ratio = 0.75 × (16 / 12) = 1.0	A1
(b)(iii)	horizontal straight line at a non-zero value of *a*	B1

26 – (9702/22_Summer_2021_Q6) – *Particle & Nuclear Physics*

(a)	the nucleus is charged	B1
	the majority of the mass (of atom) is in the nucleus	B1
(b)	made up of quarks (so) not a fundamental particle	B1
(c)	$(Q =)\ 6.9 \times 10^{-9} \times 60$	C1
	number $= (6.9 \times 10^{-9} \times 60) / (2 \times 1.60 \times 10^{-19})$	C1
	$= 1.3 \times 10^{12}$	A1
(d)	(magnitude of electric) force is constant	B1
	(so magnitude of) acceleration is constant	B1
(e)	(nuclei have) same charge/same number of protons	B1
	(so) same (magnitude of) force	B1

27 – (9702/23_Summer_2021_Q6) – *Particle & Nuclear Physics*

(a)(i)	up up down	B1
(a)(ii)	up down down	B1
(a)(iii)	(alpha-particle is) 2 protons and 2 neutrons	C1
	6 up, 6 down	A1
(b)(i)	most of an <u>atom</u> is empty space **or** the nucleus (volume) is (very) small <u>compared with the atom</u>	B1
(b)(ii)	the nucleus is charged	B1
	the majority of the mass of atom is in the nucleus	B1
(c)	$F = Eq$ **and** $a = F / m$	C1
	$a = Eq / m$ ratio = $(e / m) / (2e / 4m)$ = 2	A1

28 - (9702/21_Winter_2021_Q6) - *Particle & Nuclear Physics*

(a)	α-particle mass given as 4u	B1
	α-particle charge given as (+)2*e*	B1
	both β-particles mass given as 0.0005 u	B1
	β^+ charge given as (+)*e* and β^- charge given as –*e* (Completed table: mass / u: α 4, β^+ 0.0005, β^- 0.0005 charge / *e*: α (+)2, β^+ (+)1, β^- –1)	B1
(b)(i)	neutron decays into proton and an electron / β^- particle	B1
(b)(ii)	down to up	B1
(b)(iii)	(electron) antineutrino(s) emitted	B1
	energy (released in decay)/momentum shared between antineutrino and β^- particle	B1

29 - (9702/22_Winter_2021_Q7) - *Particle & Nuclear Physics*

(a)	(total) momentum before (decay) is zero **or** P has zero momentum	B1
	(total momentum after decay must be zero so) α-particle and Q have momenta in opposite directions (and therefore velocities are in opposite directions)	B1
(b)	$p = 239\ (u) \times v$ **or** $4\ (u) \times 1.6 \times 10^7$	C1
	$239\ (u) \times v = 4\ (u) \times 1.6 \times 10^7$ $v = 2.7 \times 10^5\ m\ s^{-1}$	A1
(c)	$E_{(K)} = ½mv^2$	C1
	$= ½ \times 4 \times 1.66 \times 10^{-27} \times (1.6 \times 10^7)^2$	C1
	$= 8.5 \times 10^{-13}$ (J) $= 8.5 \times 10^{-13} / 1.60 \times 10^{-13}$ (MeV) = 5.3 MeV	A1
(d)(i)	**1.** R plotted at (95,147)	B1
	2. S plotted at (96,146)	B1
(d)(ii)	(electron) antineutrino	B1

30 - (9702/21_Summer_2022_Q7) - *Particle & Nuclear Physics*

(a)(i)	change in *A* = 0	A1
	change in *Z* = (+)1	A1
(a)(ii)	(electron) antineutrino	B1
(b)(i)	up / u (charge) = $(+)\frac{2}{3}e$ **or** antidown / $\bar{d}$ = $(+)\frac{1}{3}e$ **or** $(q) = \frac{2}{3}e + \frac{1}{3}e$	M1
	$q = (+)1e$	A1
(b)(ii)	hadron(s)	B1
	meson(s)	B1

31 – (9702/22_Summer_2022_Q7) – *Particle & Nuclear Physics*

(a)(i)	P = 0 **and** Q = 137	A1
	R = –1 **and** S = 56	A1
(a)(ii)	lepton(s)	B1
(b)(i)	(charge of ddd / Y =) $-\frac{1}{3}(e)\ -\frac{1}{3}(e)\ -\frac{1}{3}(e) = -1(e)$	B1
	(charge of $\bar{u}$d / Z =) $-\frac{1}{3}(e)\ -\frac{2}{3}(e) = -1(e)$	B1
(b)(ii)	meson: Z / $\bar{u}$ d because consists of a quark and an antiquark	B1
	baryon: Y / ddd because consists of three quarks	B1

32 – (9702/23_Summer_2022_Q7) – *Particle & Nuclear Physics*

(a)(i)	$^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{0}_{(-)1}\beta^{(+)} + {}^{(0)}_{(0)}\nu_{(e)}$ ν **or** neutrino (B1) $^{0}_{(-)1}\beta^{(+)}$ (B1) $^{18}_{8}O$ (B1)	B3
(a)(ii)	up quark to down quark	B1
(b)(i)	must be three (anti)quarks as largest (negative) quark charge is (–)2/3 (*e*) **or** mesons can only have a charge of 0 or ±1(*e*)	M1
	(so hadron is) a baryon	A1
(b)(ii)	any combination of three from: antiup (quark) / up antiquark and/or anticharm (quark) / charm antiquark and/or antitop (quark) / top antiquark	B1

33 – (9702/21_Winter_2022_Q6) – *Particle & Nuclear Physics*

(a)	particle with no internal structure / particle which cannot be broken down into anything smaller	A1
(b)	charges: $u = (+)\frac{2}{3}(e)$ **or** $d = -\frac{1}{3}(e)$ **or** $s = -\frac{1}{3}(e)$	C1
	$(+)\frac{2}{3}(e) - \frac{1}{3}(e) - \frac{1}{3}(e) = 0(e)$	A1
(c)(i)	• same/equal mass • same/equal (magnitude of) charge • both fundamental (particles) • opposite (sign of) charge • one is matter and the other is antimatter *Any two points, 1 mark each.*	B2
(c)(ii)	neutron/baryon consists of three quarks	B1
	pion/meson consists of one quark and one antiquark	B1

34 – (9702/23_Winter_2022_Q6) – *Particle & Nuclear Physics*

(a)	$^{14}_{7}X$	B1
	$^{0}_{-1}e^{-}$	B1
(b)(i)	$d \rightarrow u + e^{-} + \bar{\nu}$ **or** $udd \rightarrow uud + e^{-} + \bar{\nu}$	B1
(b)(ii)	$-1/3\,(e) = +2/3\,(e) - 1(e)\ (+0)$ **or** $2/3\,(e) - 1/3\,(e) - 1/3\,(e) = 2/3\,(e) + 2/3\,(e) - 1/3\,(e) - 1\,(e)\ \ (+0)$	B1
(c)(i)	electrons / β-particles (emitted from the nucleus) have a (continuous) range of / different (kinetic) energies	B1
(c)(ii)	the (emitted) neutrinos take varying amounts of the (same total) energy (released in the decay)	B1

35 – (9702/22_Winter_2022_Q7) – *Particle & Nuclear Physics*

(a)	92 protons and 146 neutrons (in nucleus)	B1
	92 (orbital) electrons	B1
(b)	charge = 2*e* $(= 2 \times 1.60 \times 10^{-19}$ C)	C1
	mass = 4u $(= 4 \times 1.66 \times 10^{-27}$ kg)	C1
	ratio $= (2 \times 1.60 \times 10^{-19}) / (4 \times 1.66 \times 10^{-27})$ $= 4.8 \times 10^{7}$ C kg^{-1}	A1
(c)(i)	up down down / udd	B1
(c)(ii)	up up up / uuu	B1

36 – (9702/21_Summer_2023_Q8) – *Particle & Nuclear Physics*

(a)(i)	Y and Z have equal numbers of protons and (so) they have the same charge	B1
(a)(ii)	Y has (two) fewer protons (than X)	M1
	(so) Y has less charge (than X)	A1
(b)	(total) momentum before decay is zero **or** X has zero / no momentum	B1
	(total momentum after decay must be zero so) Y must have equal (and opposite) momentum to α-particle (so cannot be stationary / must have speed/velocity)	B1

37 – (9702/22_Summer_2023_Q8) – *Particle & Nuclear Physics*

(a)(i)	number of protons: equal/same	B1
	number of neutrons: unequal/different	B1
(a)(ii)	down (quark) changes to up (quark) **or** up down down (quarks) change to up up down (quarks)	B1
(a)(iii)	(electron) antineutrino	B1
(b)	charm (quark charge) is (+)2/3(*e*) **or** 2 charm (quark charges) is (+)4/3(*e*) **or** bottom (quark charge) is –1/3(*e*)	C1
	charge = +2/3(*e*) + 2/3(*e*) –1/3(*e*) = (+)1(*e*)	A1

38 - (9702/23_Summer_2023_Q7) - *Particle & Nuclear Physics*

(a)	down charge = –1/3(e) **and** charm charge = (+)2/3(e)	B1
	all antiquarks have opposite sign and same (non-zero) magnitude of charge as the corresponding quarks	B1
(b)(i)	udd **or** cdd	B1
(b)(ii)	$u\bar{d}$ **or** $c\bar{d}$	B1
(c)(i)	lepton(s)	B1
(c)(ii)	positron / neutrino / antineutrino	B1

39 - (9702/21_Winter_2023_Q7) - *Particle & Nuclear Physics*

(a)	a (very) small proportion of (alpha) particles are deflected (back) through large angles / angles greater than 90°	B1
	a large proportion of (alpha) particles pass straight through / deflected by small angles	B1
(b)	electromagnetic wave / electromagnetic radiation	A1
(c)	neutrino classified as a lepton only <u>and</u> positron classified as a lepton only	B1
	neutron classified as a baryon and a hadron and not as a lepton	B1
(d)(i)	1.32 u	A1
(d)(ii)	working states or implies 3 quarks and each quark has a charge of (+) ⅔(e)	B1
	any combination of 3 quarks comprised of one or more of up / charm / top	B1

40 - (9702/22_Winter_2023_Q7) - *Particle & Nuclear Physics*

(a)	only baryon **and** nucleon underlined	B1
(b)	number of α-particles = 6	B1
	number of β^- particles = 4	B1
(c)	charm antiquark (charge) = –⅔(e) **or** –⅔(e) + q = –1(e)	B1
	(other quark q = –⅓(e) so) down / strange / bottom	B1

41 - (9702/23_Winter_2023_Q8) - *Particle & Nuclear Physics*

(a)(i)	23: nucleon number **or** number of neutrons and protons	B1
	12: proton number **or** number of protons	B1
(a)(ii)	both numbers correct for X: $^{23}_{11}X$	B1
	both numbers correct for beta-plus: $^{0}_{1}\beta^{+}$	B1
(a)(iii)	lepton(s)	A1
(b)	(the emitted particles) have a single (kinetic) energy **or** beta particles / decay have a (continuous) range of (kinetic) energies	B1