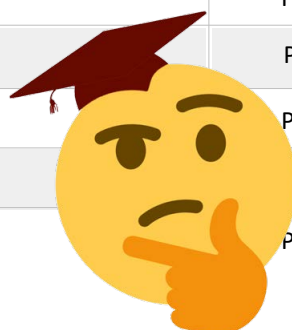


PHYSICS

PAPER 4 2017 — 2023

Chapter 1	PHYSICAL QUANTITIES & UNITS	Page 1
Chapter 2	MEASUREMENT TECHNIQUES	-----
Chapter 3	KINEMATICS	-----
Chapter 4	DYNAMICS	Page 5
Chapter 5	FORCES, DENSITY & PRESSURE	Page 9
Chapter 6	WORK, ENERGY & POWER	-----
Chapter 7	MOTION IN CIRCLE	Page 11
Chapter 8	GRAVITATIONAL FIELDS	Page 32
Chapter 9	DEFORMATION OF SOLIDS	-----
Chapter 10	IDEAL GASES	Page 79
Chapter 11	TEMPERATURE	Page 123
Chapter 12	THERMAL PROPERTIES OF MATERIALS	Page 151
Chapter 13	OSCILLATIONS	Page 189
Chapter 14	WAVES	Page 246
Chapter 15	SUPERPOSITION	-----
Chapter 16	COMMUNICATION	Page 255
Chapter 17	ELECTRIC FIELDS	Page 295
Chapter 18	CAPACITANCE	Page 342
Chapter 19	CURRENT OF ELECTRICITY	Page 370
Chapter 20	D.C. CIRCUITS	Page 376
Chapter 21	ELECTRONICS	Page 380
Chapter 22	MAGNETIC FIELDS	Page 421
Chapter 23	ELECTROMAGNETIC INDUCTION	Page 483
Chapter 24	ALTERNATING CURRENTS	Page 539
Chapter 25	QUANTOM PHYSICS	Page 568
Chapter 26	PARTICLE & NUCLEAR PHYSICS	Page 622
Chapter 27	MEDICAL IMAGING	Page 671
Chapter 28	ASTRONOMY & COSMOLOGY	Page 684
	ANSWERS	Page 692



1 - (9702/41_Summer_2023_Q1) - *Physical Quantities & Units*

(a) (i) Define gravitational field.

.....
..... [1]

(ii) Define electric field.

.....
..... [1]

(iii) State **one** similarity and **one** difference between the gravitational potential due to a point mass and the electric potential due to a point charge.

similarity:

.....

difference:

..... [2]

(b) An isolated uniform conducting sphere has mass M and charge Q .
The gravitational field strength at the surface of the sphere is g .
The electric field strength at the surface of the sphere is E .

(i) Show that

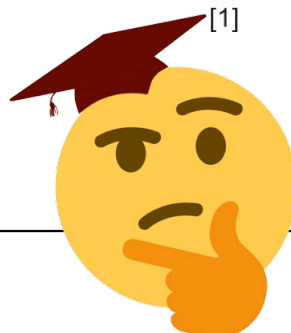
$$\frac{M}{Q} = \alpha \frac{g}{E}$$

where α is a constant.

[3]

(ii) Show that the numerical value of α is $1.35 \times 10^{20} \text{ kg}^2 \text{ C}^{-2}$.

[1]



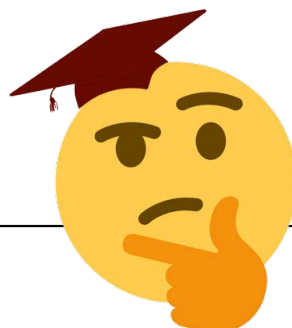
- (c) Assume that the Earth is a uniform conducting sphere of mass $5.98 \times 10^{24} \text{ kg}$.
The surface of the Earth carries a charge of $-4.80 \times 10^5 \text{ C}$ that is evenly distributed.

- (i) Use the information in (b) to determine the electric field strength at the surface of the Earth. Give a unit with your answer.

electric field strength = unit [2]

- (ii) State how the direction of the electric field at the surface of the Earth compares with the direction of the gravitational field.

..... [1]



2 - (9702/42_Summer_2023_Q1) - *Physical Quantities & Units, Dynamics*

(a) State Newton's law of gravitation.

.....
.....
..... [2]

(b) A satellite is in a circular orbit around a planet. The radius of the orbit is R and the period of the orbit is T . The planet is a uniform sphere.

Use Newton's law of gravitation to show that R and T are related by

$$4\pi^2 R^3 = GMT^2$$

where M is the mass of the planet and G is the gravitational constant.

[2]

(c) The Earth may be considered to be a uniform sphere of mass $5.98 \times 10^{24} \text{ kg}$ and radius $6.37 \times 10^6 \text{ m}$.

A geostationary satellite is in orbit around the Earth.

Use the expression in (b) to determine the height of the satellite above the Earth's surface.

height = m [3]



(d) Another satellite is in a circular orbit around the Earth with the same orbital radius and period as the satellite in (c).

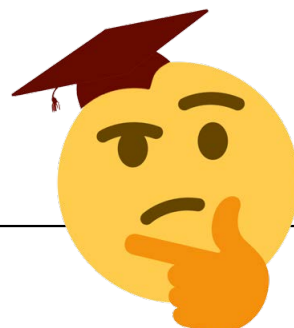
(i) Calculate the angular speed of the satellite in this orbit. Give a unit with your answer.

angular speed = unit [2]

(ii) Despite having the same orbital period, the orbit of this satellite is not geostationary.

Suggest **two** ways in which the orbit of this satellite could be different from the orbit of the satellite in (c).

- 1
.....
- 2
.....
- [2]



1 - (9702/41_Summer_2023_Q2) - Dynamics

A steel sphere of mass 0.29 kg is suspended in equilibrium from a vertical spring. The centre of the sphere is 8.5 cm from the top of the spring, as shown in Fig. 2.1.

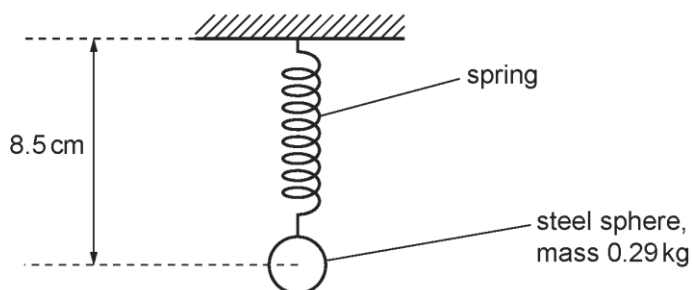


Fig. 2.1

The sphere is now set in motion so that it is moving in a horizontal circle at constant speed, as shown in Fig. 2.2.

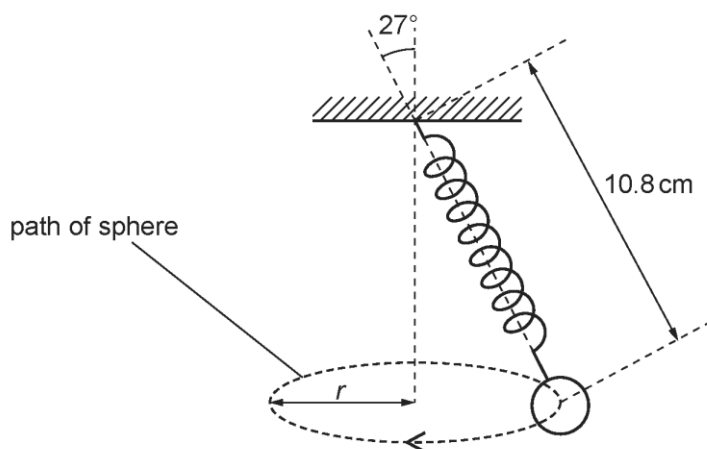


Fig. 2.2

The distance from the centre of the sphere to the top of the spring is now 10.8 cm .

- (a) Explain, with reference to the forces acting on the sphere, why the length of the spring in Fig. 2.2 is greater than in Fig. 2.1.

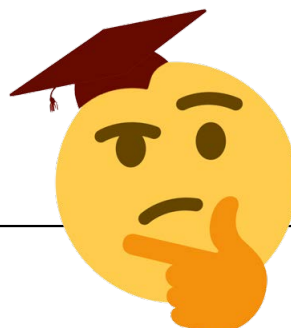
.....

.....

.....

.....

..... [3]



(b) The angle between the linear axis of the spring and the vertical is 27° .

(i) Show that the radius r of the circle is 4.9 cm.

[1]

(ii) Show that the tension in the spring is 3.2 N.

[2]

(iii) The spring obeys Hooke's law.

Calculate the spring constant, in N cm^{-1} , of the spring.

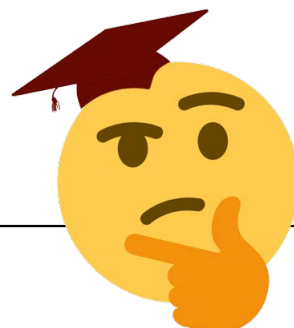
spring constant = N cm^{-1} [2]

(c) (i) Use the information in **(b)** to determine the centripetal acceleration of the sphere.

centripetal acceleration = ms^{-2} [2]

(ii) Calculate the period of the circular motion of the sphere.

period = s [2]



2 - (9702/42_Summer_2023_Q1) - *Physical Quantities & Units, Dynamics*

(a) State Newton's law of gravitation.

.....
.....
..... [2]

(b) A satellite is in a circular orbit around a planet. The radius of the orbit is R and the period of the orbit is T . The planet is a uniform sphere.

Use Newton's law of gravitation to show that R and T are related by

$$4\pi^2 R^3 = GMT^2$$

where M is the mass of the planet and G is the gravitational constant.

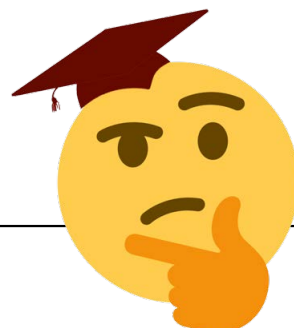
[2]

(c) The Earth may be considered to be a uniform sphere of mass $5.98 \times 10^{24} \text{ kg}$ and radius $6.37 \times 10^6 \text{ m}$.

A geostationary satellite is in orbit around the Earth.

Use the expression in (b) to determine the height of the satellite above the Earth's surface.

height = m [3]



(d) Another satellite is in a circular orbit around the Earth with the same orbital radius and period as the satellite in (c).

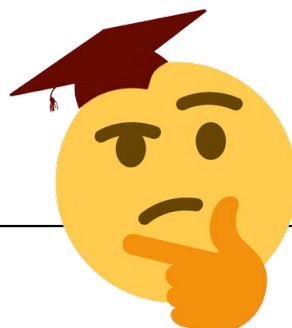
(i) Calculate the angular speed of the satellite in this orbit. Give a unit with your answer.

angular speed = unit [2]

(ii) Despite having the same orbital period, the orbit of this satellite is not geostationary.

Suggest **two** ways in which the orbit of this satellite could be different from the orbit of the satellite in (c).

- 1
-
- 2
-
- [2]



1 - (9702/41_Summer_2023_Q3) - Forces, Density & Pressure, Temperature

- (a) State the reason why two objects that are at the same temperature are described as being in thermal equilibrium.

.....
..... [1]

- (b) Fig. 3.1 shows the variations with temperature of the densities of mercury and of water between 0 °C and 100 °C.

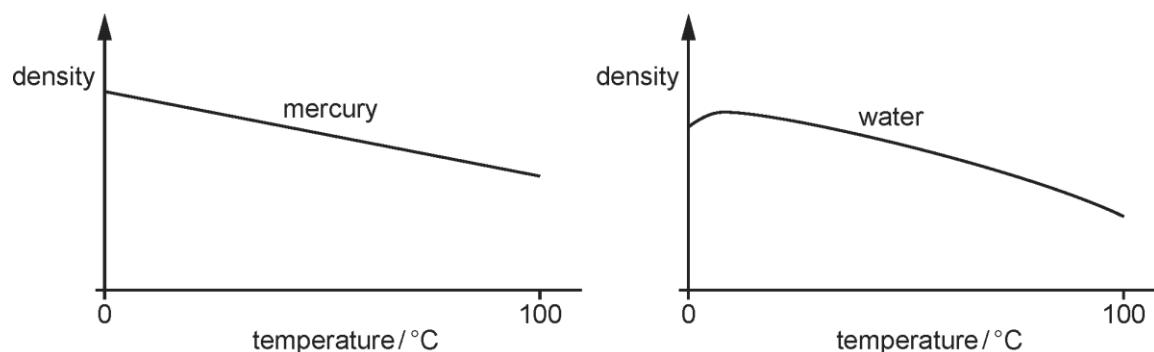


Fig. 3.1

Temperature may be measured using the variation with temperature of the density of a liquid.

Suggest why, for measuring temperature over this temperature range:

- (i) mercury is a suitable liquid

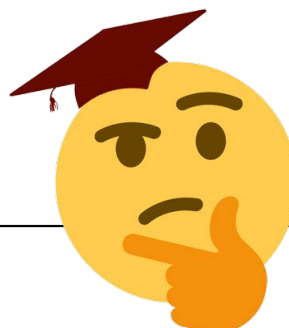
.....
..... [1]

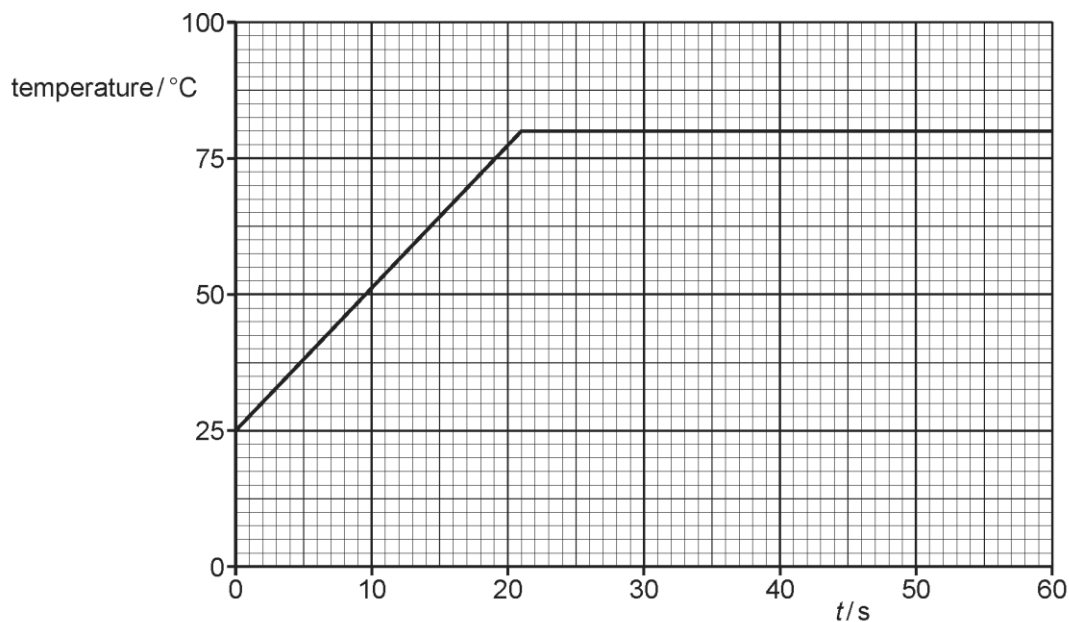
- (ii) water is not a suitable liquid.

.....
.....
..... [2]

- (c) A beaker contains a liquid of mass 120 g. The liquid is supplied with thermal energy at a rate of 810 W. The beaker has a mass of 42 g and a specific heat capacity of $0.84 \text{ J g}^{-1} \text{ K}^{-1}$. The beaker and the liquid are in thermal equilibrium with each other at all times and are insulated from the surroundings.

Fig. 3.2 shows the variation with time t of the temperature of the liquid.



**Fig. 3.2**

- (i) State the boiling temperature, in °C, of the liquid.

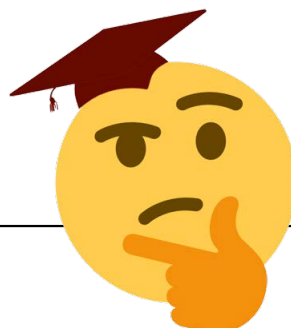
temperature = °C [1]

- (ii) Determine the specific heat capacity, in $\text{J g}^{-1} \text{K}^{-1}$, of the liquid.

specific heat capacity = $\text{J g}^{-1} \text{K}^{-1}$ [4]

- (d) The experiment in (c) is repeated using water instead of the liquid in (c). The mass of liquid used, the power supplied, and the initial temperature are all unchanged.
The specific heat capacity of water is approximately twice that of the liquid in (c).
The boiling temperature of water is 100 °C.

On Fig. 3.2, sketch the variation with time t of the temperature of the water between $t = 0$ and $t = 60$ s. Numerical calculations are not required. [2]



1 - (9702/41_Summer_2017_Q1) - Motion In A Circle, Gravitational Fields

- (a) Explain how a satellite may be in a circular orbit around a planet.

.....
.....
.....[2]

- (b) The Earth and the Moon may be considered to be uniform spheres that are isolated in space. The Earth has radius R and mean density ρ . The Moon, mass m , is in a circular orbit about the Earth with radius nR , as illustrated in Fig. 1.1.

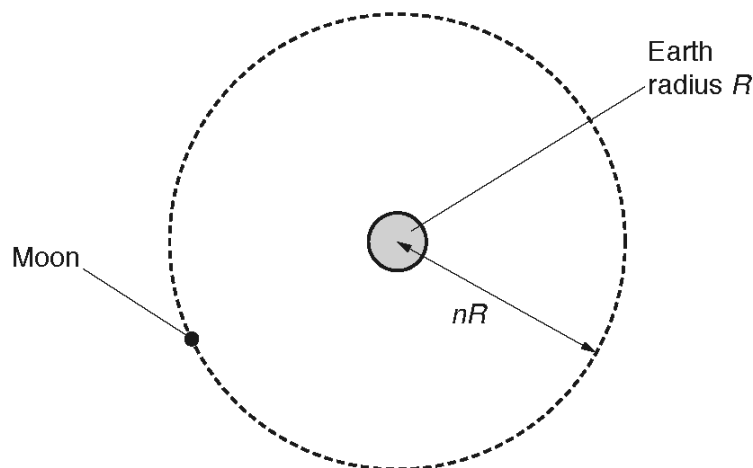


Fig. 1.1

The Moon makes one complete orbit of the Earth in time T .
Show that the mean density ρ of the Earth is given by the expression

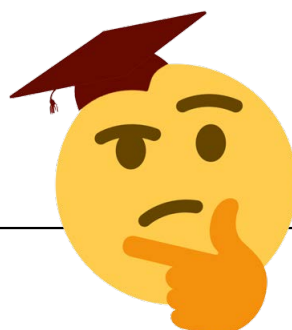
$$\rho = \frac{3\pi n^3}{GT^2}.$$

[4]



- (c) The radius R of the Earth is $6.38 \times 10^3 \text{ km}$ and the distance between the centre of the Earth and the centre of the Moon is $3.84 \times 10^5 \text{ km}$.
The period T of the orbit of the Moon about the Earth is 27.3 days.
Use the expression in (b) to calculate ρ .

$$\rho = \dots\dots\dots \text{ kg m}^{-3} [3]$$



2 - (9702/42_Summer_2017_Q1) - Motion In A Circle, Gravitational Fields

(a) Define *gravitational field strength*.

.....
.....[1]

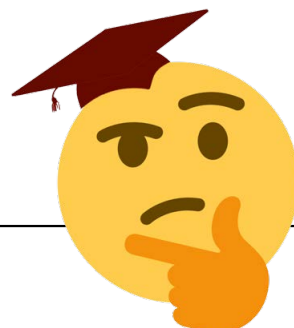
(b) The mass of a spherical comet of radius 3.6km is approximately 1.0×10^{13} kg.

(i) Assuming that the comet has constant density, calculate the gravitational field strength on the surface of the comet.

field strength = N kg^{-1} [2]

(ii) A probe having a weight of 960N on Earth lands on the comet.
Using your answer in (i), determine the weight of the probe on the surface of the comet.

weight = N [2]



- (c) A second comet has a length of approximately 4.5 km and a width of approximately 2.6 km. Its outline is illustrated in Fig. 1.1.

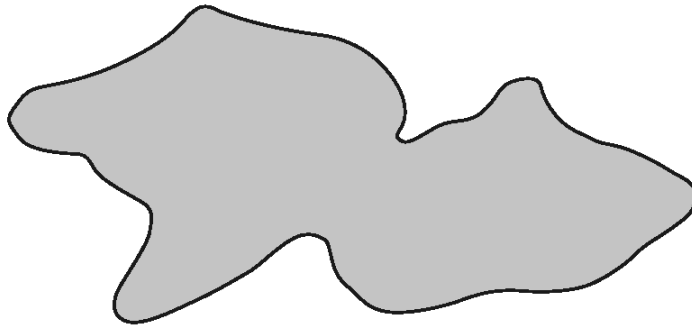


Fig. 1.1

Suggest one similarity and one difference between the gravitational fields at the surface of this comet and at the surface of the comet in (b).

similarity:

.....

difference:

.....

[2]



3 - (9702/42_Winter_2017_Q1) - Motion In A Circle, Gravitational Fields

(a) State Newton's law of gravitation.

.....
.....
.....[2]

(b) The planet Jupiter and one of its moons, Io, may be considered to be uniform spheres that are isolated in space.

Jupiter has radius R and mean density ρ .

Io has mass m and is in a circular orbit about Jupiter with radius nR , as illustrated in Fig. 1.1.

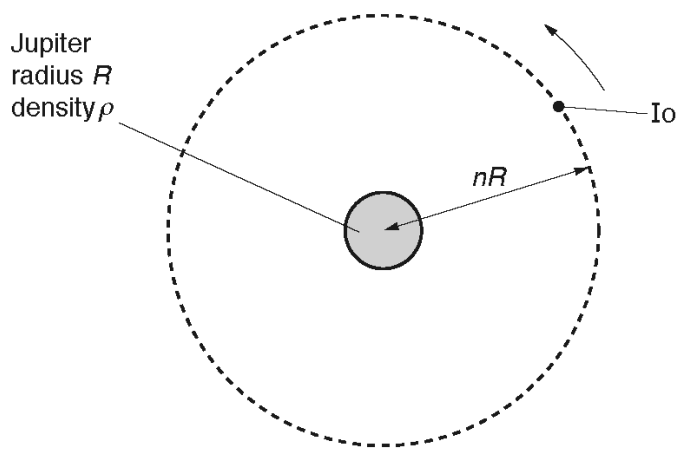


Fig. 1.1

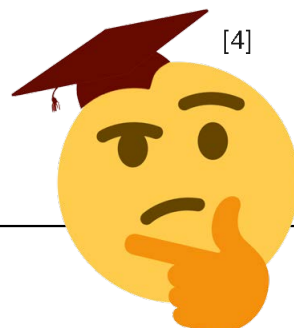
The time for Io to complete one orbit of Jupiter is T .

Show that the time T is related to the mean density ρ of Jupiter by the expression

$$\rho T^2 = \frac{3\pi n^3}{G}$$

where G is the gravitational constant.

[4]



- (c) (i) The radius R of Jupiter is 7.15×10^4 km and the distance between the centres of Jupiter and Io is 4.32×10^5 km.
The period T of the orbit of Io is 42.5 hours.

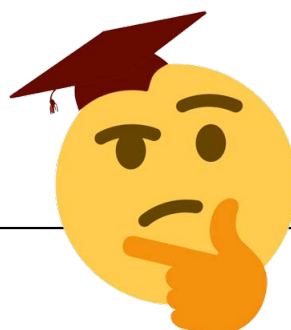
Calculate the mean density ρ of Jupiter.

$$\rho = \dots\dots\dots \text{ kg m}^{-3} [3]$$

- (ii) The Earth has a mean density of $5.5 \times 10^3 \text{ kg m}^{-3}$. It is said to be a planet made of rock.
By reference to your answer in (i), comment on the possible composition of Jupiter.

.....

.....[1]



4 - (9702/41_Summer_2019_Q1) - *Motion In A Circle, Gravitational Fields*

- (a) Two point masses are isolated in space and are separated by a distance x .

State an expression relating the gravitational force F between the two masses to the magnitudes M and m of the masses. State the name of any other symbol used.

.....
.....
..... [1]

- (b) A spacecraft is to be put into a circular orbit about a spherical planet.

The planet may be considered to be isolated in space. The mass of the planet, assumed to be concentrated at its centre, is 7.5×10^{23} kg. The radius of the planet is 3.4×10^6 m.

- (i) The spacecraft is to orbit the planet at a height of 2.4×10^5 m above the surface of the planet. At this altitude, there is no atmosphere.

Show that the speed of the spacecraft in its orbit is $3.7 \times 10^3 \text{ ms}^{-1}$.

[2]



- (ii) One possible path of the spacecraft as it approaches the planet is shown in Fig. 1.1.

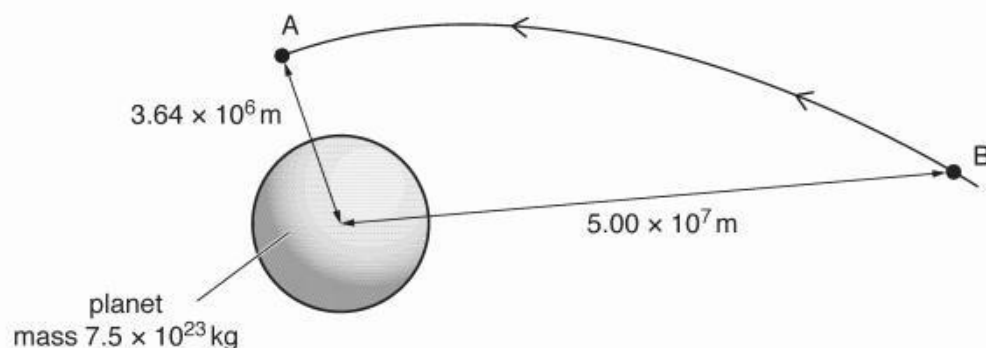


Fig. 1.1 (not to scale)

The spacecraft enters the orbit at point A with speed $3.7 \times 10^3 \text{ m s}^{-1}$.

At point B, a distance of $5.00 \times 10^7 \text{ m}$ from the centre of the planet, the spacecraft has a speed of $4.1 \times 10^3 \text{ m s}^{-1}$. The mass of the spacecraft is 650 kg.

For the spacecraft moving from point B to point A, show that the change in gravitational potential energy of the spacecraft is $8.3 \times 10^9 \text{ J}$.

[3]

- (c) By considering changes in gravitational potential energy and in kinetic energy of the spacecraft, determine whether the total energy of the spacecraft increases or decreases in moving from point B to point A. A numerical answer is not required.

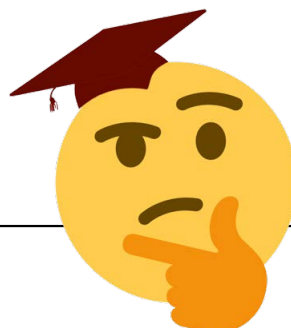
.....

.....

.....

.....

[2]



5 - (9702/41_Winter_2019_Q1) - *Gravitational Fields, Motion In A Circle*

(a) State Newton's law of gravitation.

.....
.....
..... [2]

(b) A geostationary satellite orbits the Earth. The orbit of the satellite is circular and the period of the orbit is 24 hours.

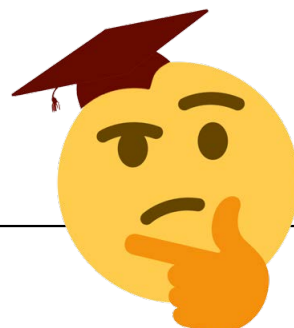
(i) State **two** other features of this orbit.

1.
.....
2.
..... [2]

(ii) The radius of the orbit of the satellite is 4.23×10^4 km.

Determine a value for the mass of the Earth. Explain your working.

mass = kg [4]



6 - (9702/42_Winter_2019_Q1) - Motion In A Circle, Gravitational Fields

- (a) State Newton's law of gravitation.

.....
.....
..... [2]

- (b) The astronomer Johannes Kepler showed that the period T of rotation of a planet about the Sun is related to its mean distance R from the centre of the Sun by the expression

$$\frac{R^3}{T^2} = k$$

where k is a constant.

Use Newton's law to show that, for planets in circular orbits about the Sun of mass M , the constant k is given by

$$k = \frac{GM}{4\pi^2}$$

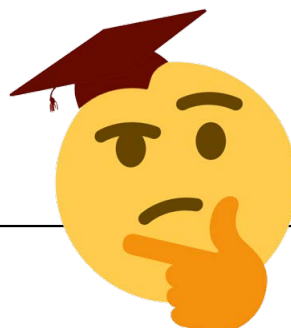
where G is the gravitational constant. Explain your working.

[4]

- (c) A satellite is in a circular orbit about Mars.
The radius of the orbit of the satellite is 4.38×10^6 m. The orbital period is 2.44 hours.

Use the expressions in (b) to calculate a value for the mass of Mars.

mass = kg [2]



7 - (9702/41_Summer_2020_Q1) - Motion In A Circle, Gravitational Fields

(a) State what is meant by a *gravitational force*.

.....
..... [1]

(b) A binary star system consists of two stars S_1 and S_2 , each in a circular orbit.

The orbit of each star in the system has a period of rotation T .

Observations of the binary star from Earth are represented in Fig. 1.1.

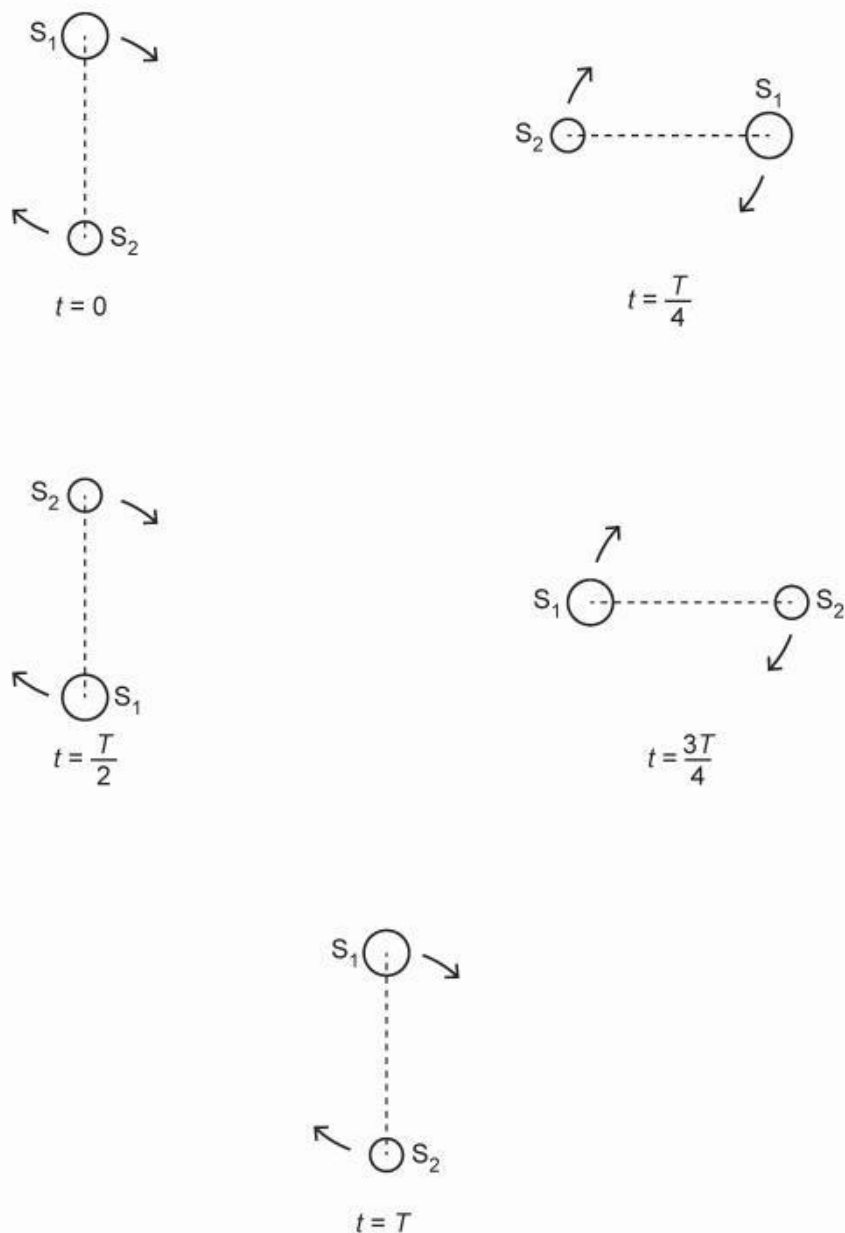


Fig. 1.1 (not to scale)



Observed from Earth, the angular separation of the centres of S_1 and S_2 is 1.2×10^{-5} rad.
The distance of the binary star system from Earth is 1.5×10^{17} m.

Show that the separation d of the centres of S_1 and S_2 is 1.8×10^{12} m.

[1]

- (c) The stars S_1 and S_2 rotate with the same angular velocity ω about a point P, as illustrated in Fig. 1.2.

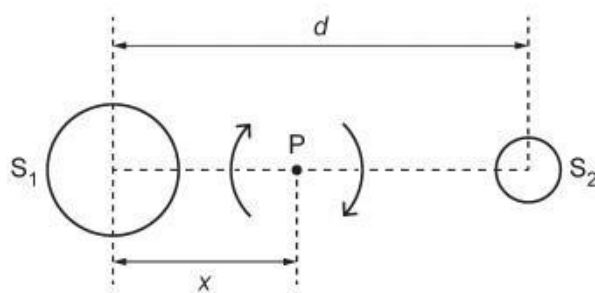
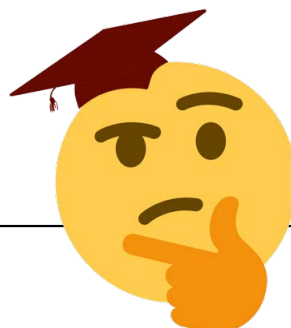


Fig. 1.2 (not to scale)

Point P is at a distance x from the centre of star S_1 .
The period of rotation of the stars is 44.2 years.

- (i) Calculate the angular velocity ω .

$$\omega = \dots\dots\dots \text{rad s}^{-1} \quad [2]$$



- (ii) By considering the forces acting on the two stars, show that the ratio of the masses of the stars is given by

$$\frac{\text{mass of } S_1}{\text{mass of } S_2} = \frac{d-x}{x}.$$

[2]

- (iii) The mass M_1 of star S_1 is given by the expression

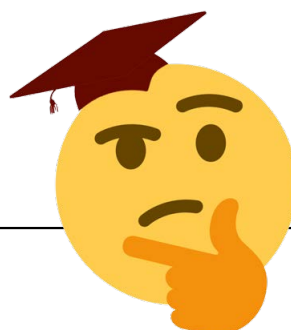
$$GM_1 = d^2(d-x)\omega^2$$

where G is the gravitational constant.

The ratio in (ii) is found to be 1.5.

Use data from (b) and your answer in (c)(i) to determine the mass M_1 .

$$M_1 = \dots\dots\dots \text{ kg [3]}$$



8 - (9702/41_Winter_2021_Q1) - Motion In A Circle

- (a) With reference to velocity and acceleration, describe uniform circular motion.

.....
.....
..... [2]

- (b) Two cars are moving around a horizontal circular track. One car follows path X and the other follows path Y, as shown in Fig. 1.1.

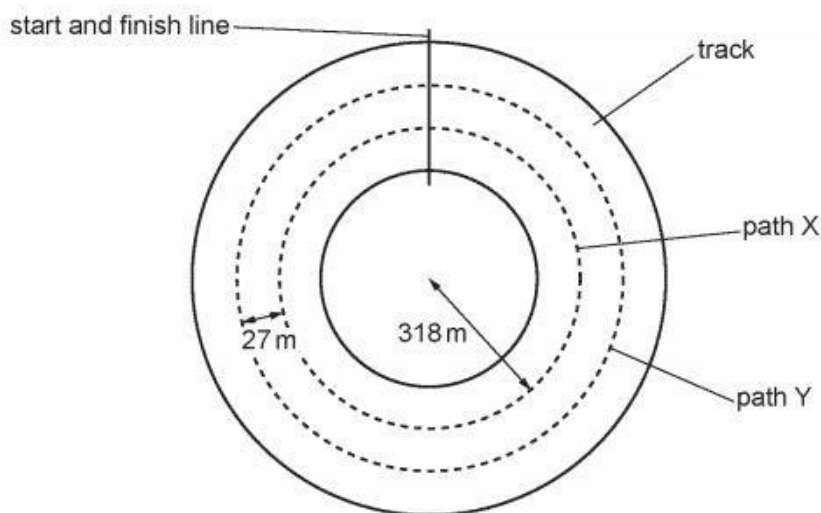


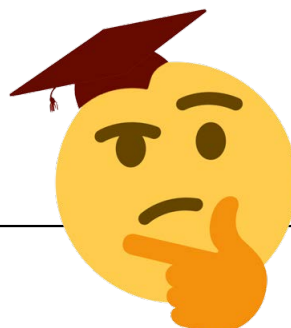
Fig. 1.1 (not to scale)

The radius of path X is 318 m. Path Y is parallel to, and 27 m outside, path X. Both cars have mass 790 kg. The maximum lateral (sideways) friction force F that the cars can experience without sliding is the same for both cars.

- (i) The maximum speed at which the car on path X can move around the track without sliding is 94 ms^{-1} .

Calculate F .

$F = \dots\dots\dots \text{ N}$ [2]



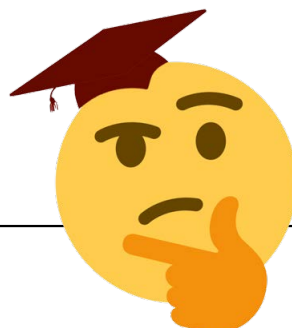
- (ii) Both cars move around the track. Each car has the maximum speed at which it can move without sliding.

Complete Table 1.1, by placing one tick in each row, to indicate how the quantities indicated for the car on path Y compare with the car on path X.

Table 1.1

	Y less than X	Y same as X	Y greater than X
centripetal acceleration			
maximum speed			
time taken for one lap of the track			

[3]



9 - (9702/42_Winter_2021_Q1) - Motion In A Circle

- (a) State what is meant by *centripetal* acceleration.

.....
.....
..... [1]

- (b) An unpowered toy car moves freely along a smooth track that is initially horizontal. The track contains a vertical circular loop around which the car travels, as shown in Fig. 1.1.

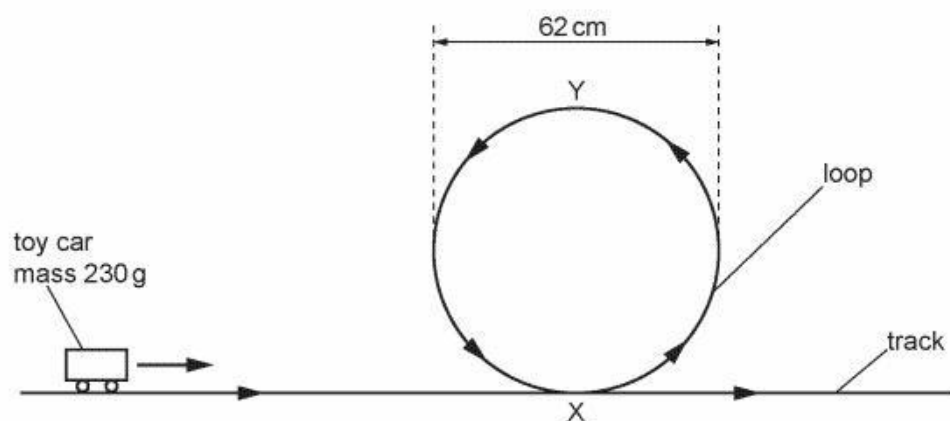


Fig. 1.1

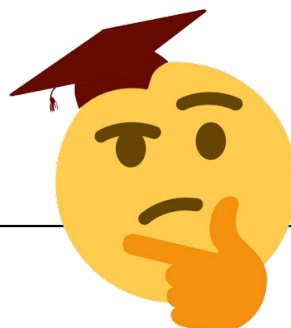
The mass of the car is 230 g and the diameter of the loop is 62 cm. Assume that the resistive forces acting on the car are negligible.

- (i) State what happens to the magnitude of the centripetal acceleration of the car as it moves around the loop from X to Y.

..... [1]

- (ii) Explain, if the car remains in contact with the track, why the centripetal acceleration of the car at point Y must be greater than 9.8 ms^{-2} .

.....
.....
..... [2]



- (c) The initial speed at which the car in (b) moves along the track is 3.8 m s^{-1} .

Determine whether the car is in contact with the track at point Y. Show your working.

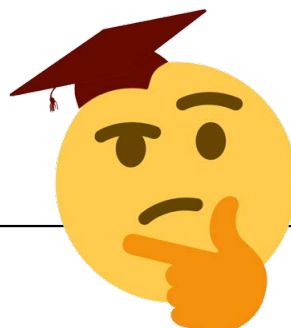
[3]

- (d) Suggest, with a reason but without calculation, whether your conclusion in (c) would be different for a car of mass 460 g moving with the same initial speed.

.....

.....

..... [1]



10 – (9702/41_Winter_2023_Q4) – Oscillations, Motion In A Circle

A heavy metal sphere of mass 0.81 kg is suspended from a string. The sphere is undergoing small oscillations from side to side, as shown in Fig. 4.1.

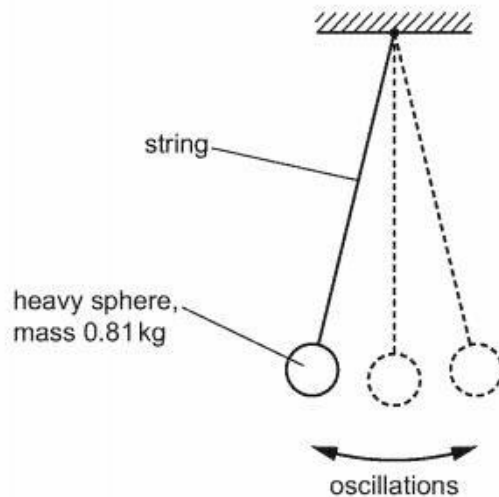


Fig. 4.1

The oscillations of the sphere may be considered to be simple harmonic with amplitude 0.036 m and period 3.0 s.

(a) State what is meant by simple harmonic motion.

.....

.....

..... [2]

(b) Calculate:

(i) the angular frequency of the oscillations

angular frequency = rad s^{-1} [2]



(ii) the total energy of the oscillations.

total energy = J [2]

- (c) The suspended sphere is now lowered into water. The sphere is given a sideways displacement of +0.036 m from its equilibrium position and is then released at time $t = 0$. The water causes the motion of the sphere to be critically damped.

On Fig. 4.2, sketch the variation of the displacement x of the sphere from its equilibrium position with t from $t = 0$ to $t = 6.0$ s.

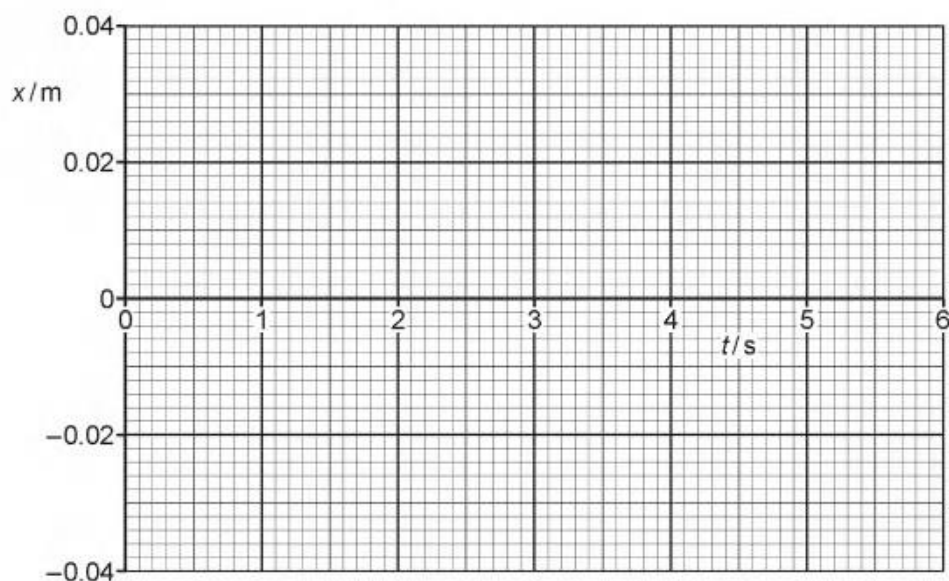
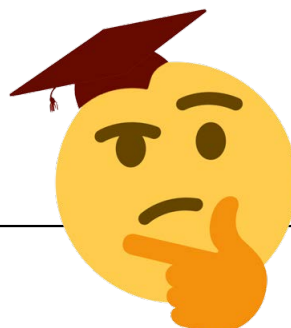


Fig. 4.2

[3]



11 - (9702/42_Winter_2023_Q1) - Motion In A Circle

- (a) Define the radian.

.....
..... [1]

- (b) The minute hand of a clock revolves at constant angular speed around the face of the clock, completing one revolution every hour. A small piece of modelling clay is attached to the hand with its centre of gravity at a distance L from the fixed end of the hand, as shown in Fig. 1.1.

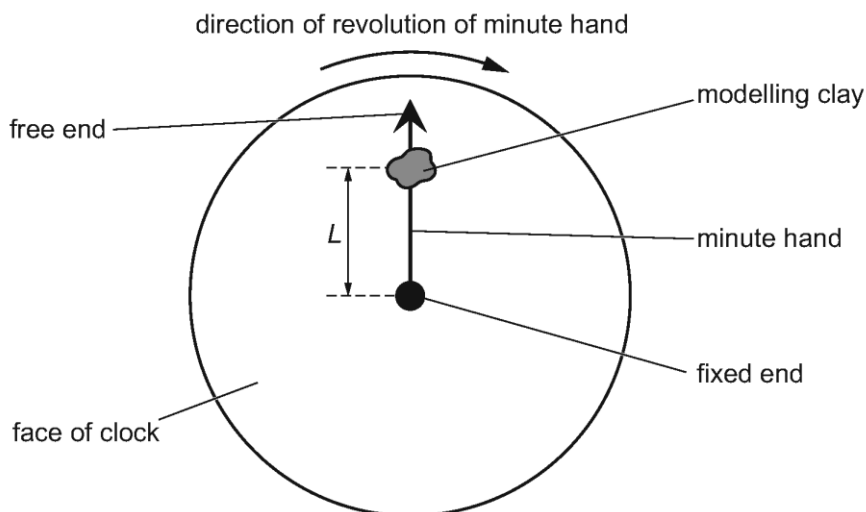


Fig. 1.1

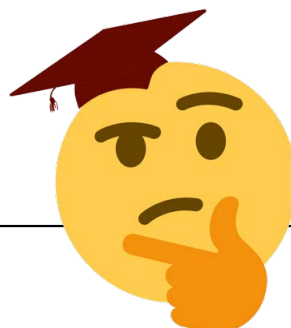
Calculate the angular speed ω of the minute hand.

$$\omega = \dots\dots\dots \text{rad s}^{-1} \quad [2]$$

- (c) During a time interval of 1400 s, the centre of gravity of the piece of modelling clay in Fig. 1.1 moves through a total distance of 0.44 m.

- (i) Calculate the angle through which the minute hand moves in this time interval.

$$\text{angle} = \dots\dots\dots \text{rad} \quad [1]$$



(ii) Determine distance L .

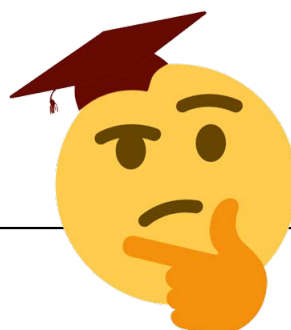
$L = \dots\dots\dots\text{m}$ [2]

(iii) Calculate the magnitude of the centripetal acceleration of the piece of modelling clay.

centripetal acceleration = $\dots\dots\dots\text{ms}^{-2}$ [2]

(d) Use your answer in (c)(iii) to explain why the variation with time of the magnitude of the force exerted by the minute hand on the piece of modelling clay is negligible as the minute hand undergoes one full revolution.

.....
.....
..... [2]



1 - (9702/41_Summer_2017_Q1) - Motion In A Circle, Gravitational Fields

- (a) Explain how a satellite may be in a circular orbit around a planet.

.....
.....
.....[2]

- (b) The Earth and the Moon may be considered to be uniform spheres that are isolated in space. The Earth has radius R and mean density ρ . The Moon, mass m , is in a circular orbit about the Earth with radius nR , as illustrated in Fig. 1.1.

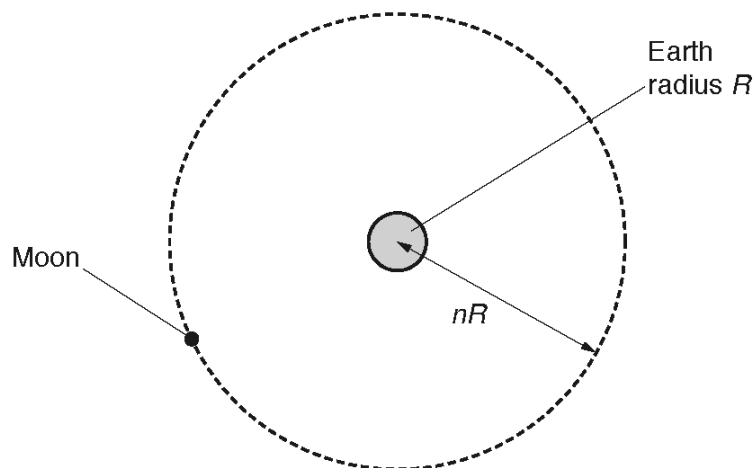
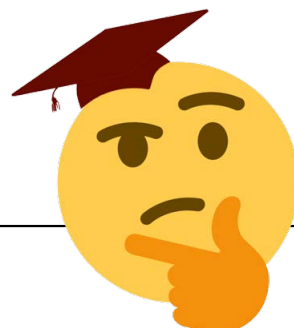


Fig. 1.1

The Moon makes one complete orbit of the Earth in time T .
Show that the mean density ρ of the Earth is given by the expression

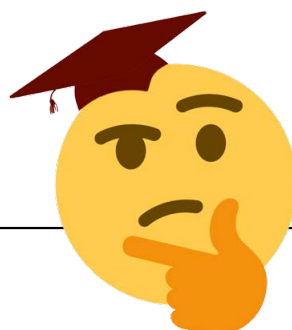
$$\rho = \frac{3\pi n^3}{GT^2}.$$

[4]



- (c) The radius R of the Earth is $6.38 \times 10^3 \text{ km}$ and the distance between the centre of the Earth and the centre of the Moon is $3.84 \times 10^5 \text{ km}$.
The period T of the orbit of the Moon about the Earth is 27.3 days.
Use the expression in (b) to calculate ρ .

$$\rho = \dots\dots\dots \text{ kg m}^{-3} [3]$$



2 - (9702/42_Summer_2017_Q1) - Motion In A Circle, Gravitational Fields

(a) Define *gravitational field strength*.

.....
.....[1]

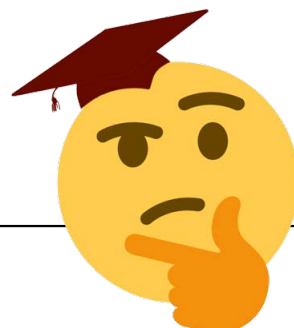
(b) The mass of a spherical comet of radius 3.6 km is approximately 1.0×10^{13} kg.

(i) Assuming that the comet has constant density, calculate the gravitational field strength on the surface of the comet.

field strength = N kg^{-1} [2]

(ii) A probe having a weight of 960 N on Earth lands on the comet.
Using your answer in (i), determine the weight of the probe on the surface of the comet.

weight = N [2]



- (c) A second comet has a length of approximately 4.5 km and a width of approximately 2.6 km. Its outline is illustrated in Fig. 1.1.

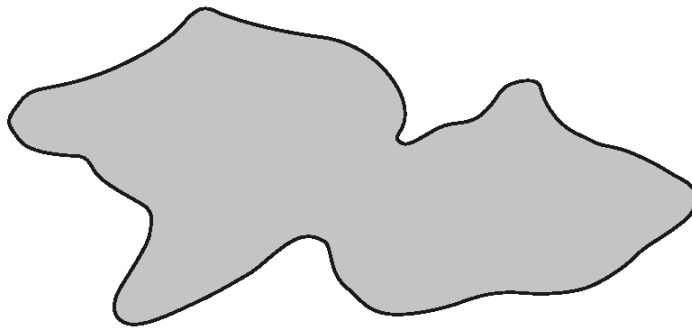


Fig. 1.1

Suggest one similarity and one difference between the gravitational fields at the surface of this comet and at the surface of the comet in (b).

similarity:

.....

difference:

.....

[2]



3 - (9702/42_Winter_2017_Q1) - Motion In A Circle, Gravitational Fields

(a) State Newton's law of gravitation.

.....
.....
.....[2]

(b) The planet Jupiter and one of its moons, Io, may be considered to be uniform spheres that are isolated in space.

Jupiter has radius R and mean density ρ .

Io has mass m and is in a circular orbit about Jupiter with radius nR , as illustrated in Fig. 1.1.

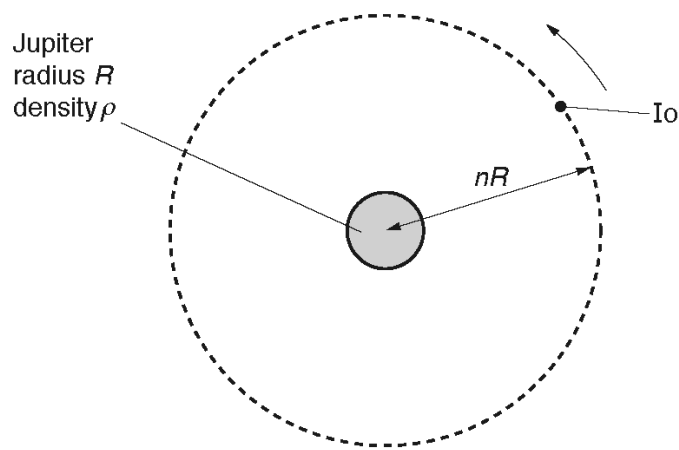


Fig. 1.1

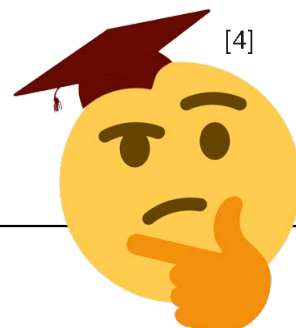
The time for Io to complete one orbit of Jupiter is T .

Show that the time T is related to the mean density ρ of Jupiter by the expression

$$\rho T^2 = \frac{3\pi n^3}{G}$$

where G is the gravitational constant.

[4]



- (c) (i) The radius R of Jupiter is 7.15×10^4 km and the distance between the centres of Jupiter and Io is 4.32×10^5 km.
The period T of the orbit of Io is 42.5 hours.

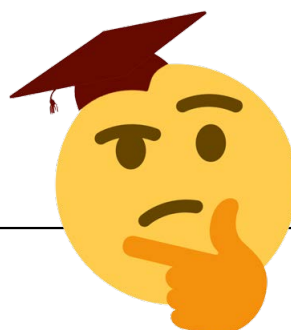
Calculate the mean density ρ of Jupiter.

$$\rho = \dots\dots\dots \text{kg m}^{-3} [3]$$

- (ii) The Earth has a mean density of $5.5 \times 10^3 \text{ kg m}^{-3}$. It is said to be a planet made of rock.
By reference to your answer in (i), comment on the possible composition of Jupiter.

.....

.....[1]



4 - (9702/41_Winter_2017_Q3) - *Gravitational Fields*

- (a) Define *gravitational field strength*.

.....
..... [1]

- (b) Explain why, for changes in vertical position of a point mass near the Earth's surface, the gravitational field strength may be considered to be constant.

.....
.....
.....
..... [2]

- (c) The orbit of the Earth about the Sun is approximately circular with a radius of 1.5×10^8 km. The time period of the orbit is 365 days.

Determine a value for the mass M of the Sun. Explain your working.

$M =$ kg [5]



5 - (9702/41_Summer_2018_Q1) - *Gravitational Fields*

(a) State Newton's law of gravitation.

.....

.....

.....

.....[2]

(b) A distant star is orbited by several planets. Each planet has a circular orbit with a different radius.

(i) Each planet orbits at constant speed.
Explain whether the planets are in equilibrium.

.....

.....

.....[1]

(ii) The radius of the orbit of a planet is R and the orbital period is T .

Data for some of the planets are given in Fig. 1.1.

planet	R/m	T^2/s^2
c	9.6×10^{10}	2.5×10^{11}
e	4.0×10^{11}	1.8×10^{13}
g	2.1×10^{12}	2.6×10^{15}

Fig. 1.1The relationship between R and T is given by the expression

$$R^3 = kT^2.$$



1. Show that the constant k is given by the expression

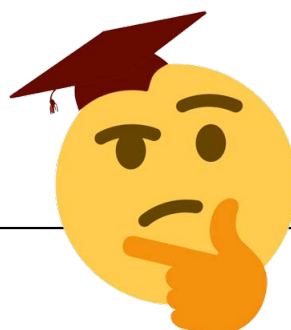
$$k = \frac{GM}{4\pi^2}$$

where G is the gravitational constant and M is the mass of the star.

[3]

2. Use data from Fig. 1.1 for the three planets and the expression for k to calculate the mass M of the star.

$M = \dots\dots\dots$ kg [3]



6 - (9702/42_Summer_2018_Q1) - Gravitational Fields

- (a) (i) A gravitational field may be represented by lines of gravitational force.
State what is meant by a *line of gravitational force*.

.....
.....
.....[1]

- (ii) By reference to lines of gravitational force near to the surface of the Earth, explain why the gravitational field strength g close to the Earth's surface is approximately constant.

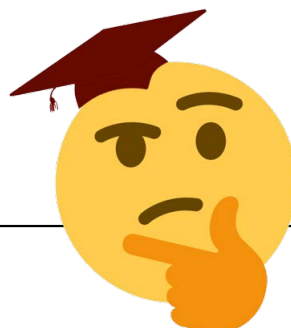
.....
.....
.....
.....
.....
.....[3]

- (b) The Moon may be considered to be a uniform sphere of diameter 3.4×10^3 km and mass 7.4×10^{22} kg. The Moon has no atmosphere.

During a collision of the Moon with a meteorite, a rock is thrown vertically up from the surface of the Moon with a speed of 2.8 km s^{-1} .

Assuming that the Moon is isolated in space, determine whether the rock will travel out into distant space or return to the Moon's surface.

[4]



7 - (9702/41_Winter_2018_Q1) - *Gravitational Fields*

- (a) (i) State what is meant by *gravitational potential* at a point.

.....
.....
.....[2]

- (ii) Suggest why, for small changes in height near the Earth's surface, gravitational potential is approximately constant.

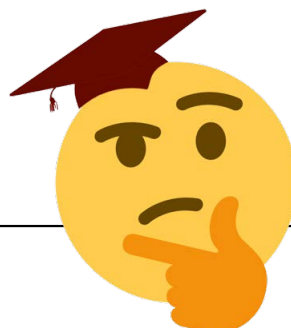
.....
.....
.....
.....[2]

- (b) The Moon may be considered to be a uniform sphere with a diameter of 3.5×10^3 km and a mass of 7.4×10^{22} kg.

A meteor strikes the Moon and, during the collision, a rock is sent off from the surface of the Moon with an initial speed v .

Assuming that the Moon is isolated in space, determine the minimum speed of the rock such that it does not return to the Moon's surface. Explain your working.

minimum speed = ms^{-1} [3]



8 - (9702/42_Winter_2018_Q1) - Gravitational Fields

(a) (i) State what is meant by *gravitational field strength*.

.....
.....
.....[1]

(ii) Explain why, at the surface of a planet, gravitational field strength is numerically equal to the acceleration of free fall.

.....
.....
.....[1]

(b) An isolated uniform spherical planet has radius R .
The acceleration of free fall at the surface of the planet is g .

On Fig. 1.1, sketch a graph to show the variation of the acceleration of free fall with distance x from the centre of the planet for values of x in the range $x = R$ to $x = 4R$.

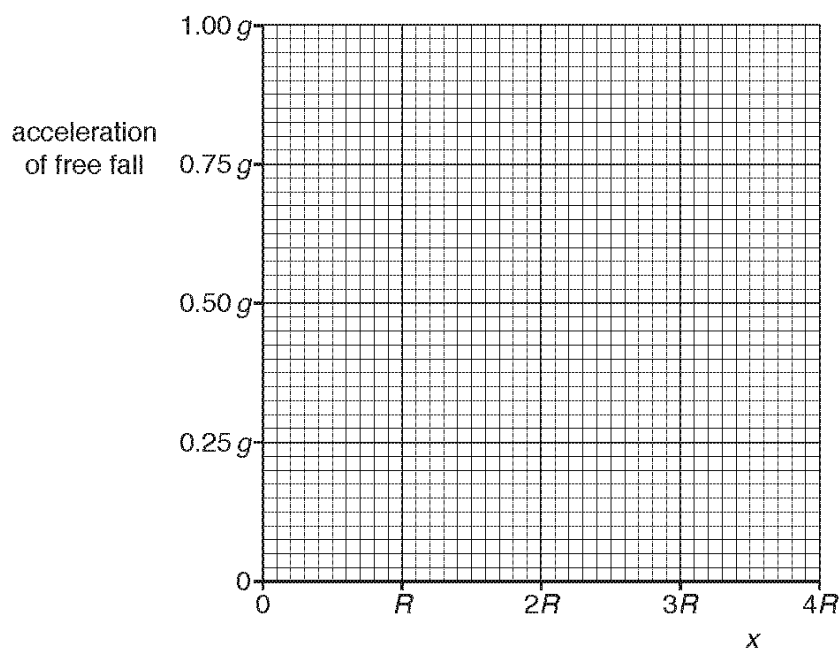


Fig. 1.1

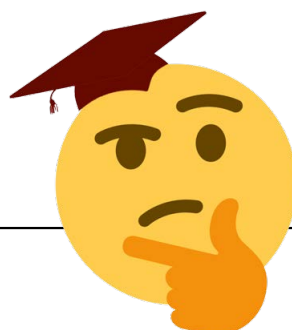
[3]



(c) The planet in (b) has radius R equal to $3.4 \times 10^3 \text{ km}$ and mean density $4.0 \times 10^3 \text{ kg m}^{-3}$.

Calculate the acceleration of free fall at a height R above its surface.

acceleration of free fall = m s^{-2} [3]



9 - (9702/41_Summer_2019_Q1) - *Motion In A Circle, Gravitational Fields*

- (a) Two point masses are isolated in space and are separated by a distance x .

State an expression relating the gravitational force F between the two masses to the magnitudes M and m of the masses. State the name of any other symbol used.

.....
.....
..... [1]

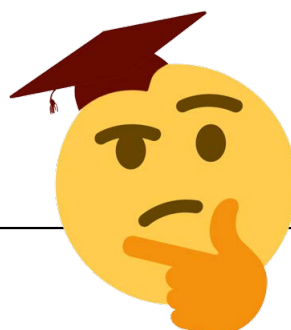
- (b) A spacecraft is to be put into a circular orbit about a spherical planet.

The planet may be considered to be isolated in space. The mass of the planet, assumed to be concentrated at its centre, is 7.5×10^{23} kg. The radius of the planet is 3.4×10^6 m.

- (i) The spacecraft is to orbit the planet at a height of 2.4×10^5 m above the surface of the planet. At this altitude, there is no atmosphere.

Show that the speed of the spacecraft in its orbit is $3.7 \times 10^3 \text{ ms}^{-1}$.

[2]



- (ii) One possible path of the spacecraft as it approaches the planet is shown in Fig. 1.1.

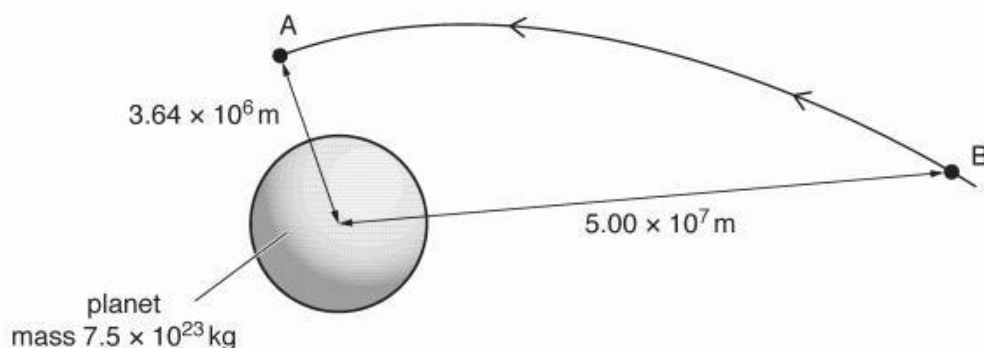


Fig. 1.1 (not to scale)

The spacecraft enters the orbit at point A with speed $3.7 \times 10^3 \text{ m s}^{-1}$.

At point B, a distance of $5.00 \times 10^7 \text{ m}$ from the centre of the planet, the spacecraft has a speed of $4.1 \times 10^3 \text{ m s}^{-1}$. The mass of the spacecraft is 650 kg.

For the spacecraft moving from point B to point A, show that the change in gravitational potential energy of the spacecraft is $8.3 \times 10^9 \text{ J}$.

[3]

- (c) By considering changes in gravitational potential energy and in kinetic energy of the spacecraft, determine whether the total energy of the spacecraft increases or decreases in moving from point B to point A. A numerical answer is not required.

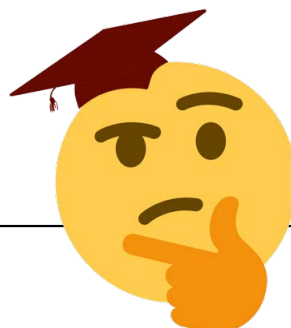
.....

.....

.....

.....

[2]



10 - (9702/42_Summer_2019_Q1) - Gravitational Fields

- (a) Two point masses are separated by a distance x in a vacuum.
State an expression for the force F between the two masses M and m .
State the name of any other symbol used.

.....
.....
.....[1]

- (b) A small sphere S is attached to one end of a rod, as shown in Fig. 1.1.

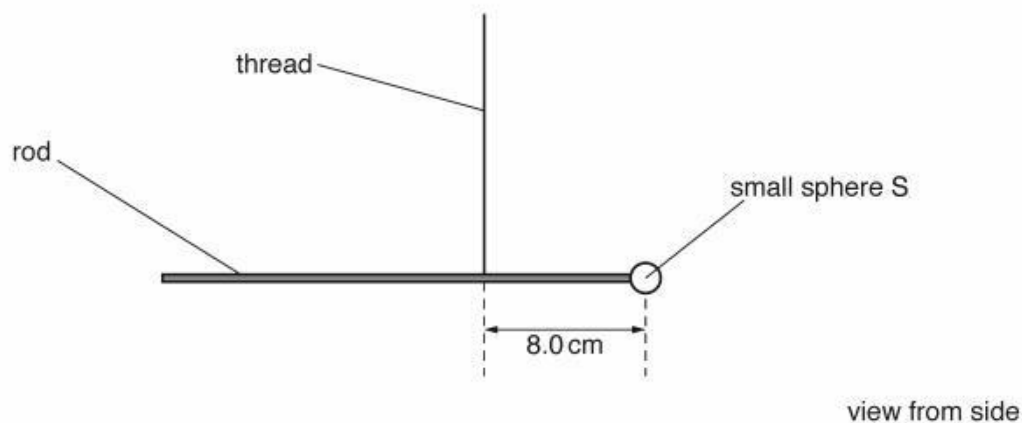


Fig. 1.1 (not to scale)

The rod hangs from a vertical thread and is horizontal.
The distance from the centre of sphere S to the thread is 8.0 cm.

A large sphere L is placed near to sphere S , as shown in Fig. 1.2.

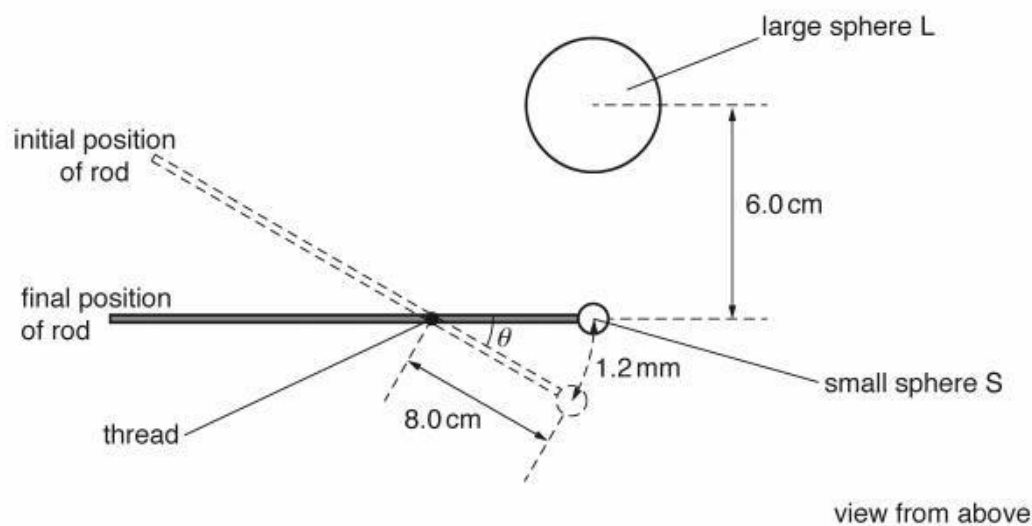


Fig. 1.2 (not to scale)



There is a force of attraction between spheres S and L, causing sphere S to move through a distance of 1.2 mm.

The line joining the centres of S and L is normal to the rod.

- (i) Show that the angle θ through which the rod rotates is 1.5×10^{-2} rad.

[1]

- (ii) The rotation of the rod causes the thread to twist.
The torque T (in Nm) required to twist the thread through an angle β (in rad) is given by

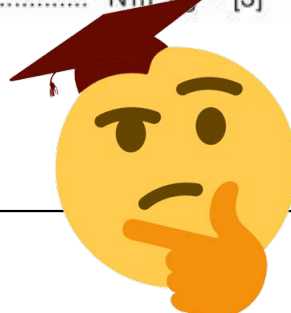
$$T = 9.3 \times 10^{-10} \times \beta.$$

Calculate the torque in the thread when sphere L is positioned as shown in Fig. 1.2.

torque = Nm [1]

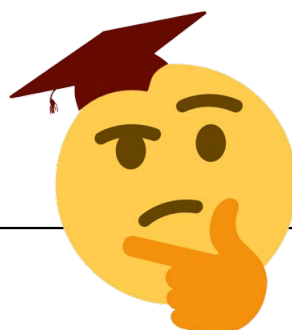
- (c) The distance between the centres of spheres S and L is 6.0 cm.
The mass of sphere S is 7.5 g and the mass of sphere L is 1.3 kg.
- (i) By equating the torque in (b)(ii) to the moment about the thread produced by gravitational attraction between the spheres, calculate a value for the gravitational constant.

gravitational constant = $\text{Nm}^2\text{kg}^{-2}$ [3]



- (ii) Suggest why the total force between the spheres may not be equal to the force calculated using Newton's law of gravitation.

.....
.....[1]



11 – (9702/41_Winter_2019_Q1) – *Gravitational Fields, Motion In A Circle*

(a) State Newton's law of gravitation.

.....

.....

..... [2]

(b) A geostationary satellite orbits the Earth. The orbit of the satellite is circular and the period of the orbit is 24 hours.

(i) State **two** other features of this orbit.

1.

.....

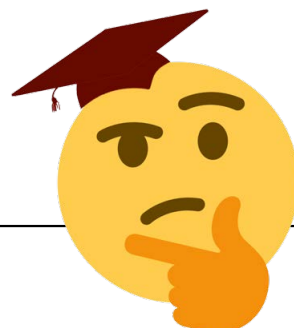
2.

..... [2]

(ii) The radius of the orbit of the satellite is 4.23×10^4 km.

Determine a value for the mass of the Earth. Explain your working.

mass = kg [4]



12 - (9702/42_Winter_2019_Q1) - *Motion In A Circle, Gravitational Fields*

- (a) State Newton's law of gravitation.

.....
.....
..... [2]

- (b) The astronomer Johannes Kepler showed that the period T of rotation of a planet about the Sun is related to its mean distance R from the centre of the Sun by the expression

$$\frac{R^3}{T^2} = k$$

where k is a constant.

Use Newton's law to show that, for planets in circular orbits about the Sun of mass M , the constant k is given by

$$k = \frac{GM}{4\pi^2}$$

where G is the gravitational constant. Explain your working.

[4]

- (c) A satellite is in a circular orbit about Mars.
The radius of the orbit of the satellite is 4.38×10^6 m. The orbital period is 2.44 hours.

Use the expressions in (b) to calculate a value for the mass of Mars.

mass = kg [2]



13 - (9702/41_Summer_2020_Q1) - Motion In A Circle, Gravitational Fields

(a) State what is meant by a *gravitational force*.

.....
..... [1]

(b) A binary star system consists of two stars S_1 and S_2 , each in a circular orbit.

The orbit of each star in the system has a period of rotation T .

Observations of the binary star from Earth are represented in Fig. 1.1.

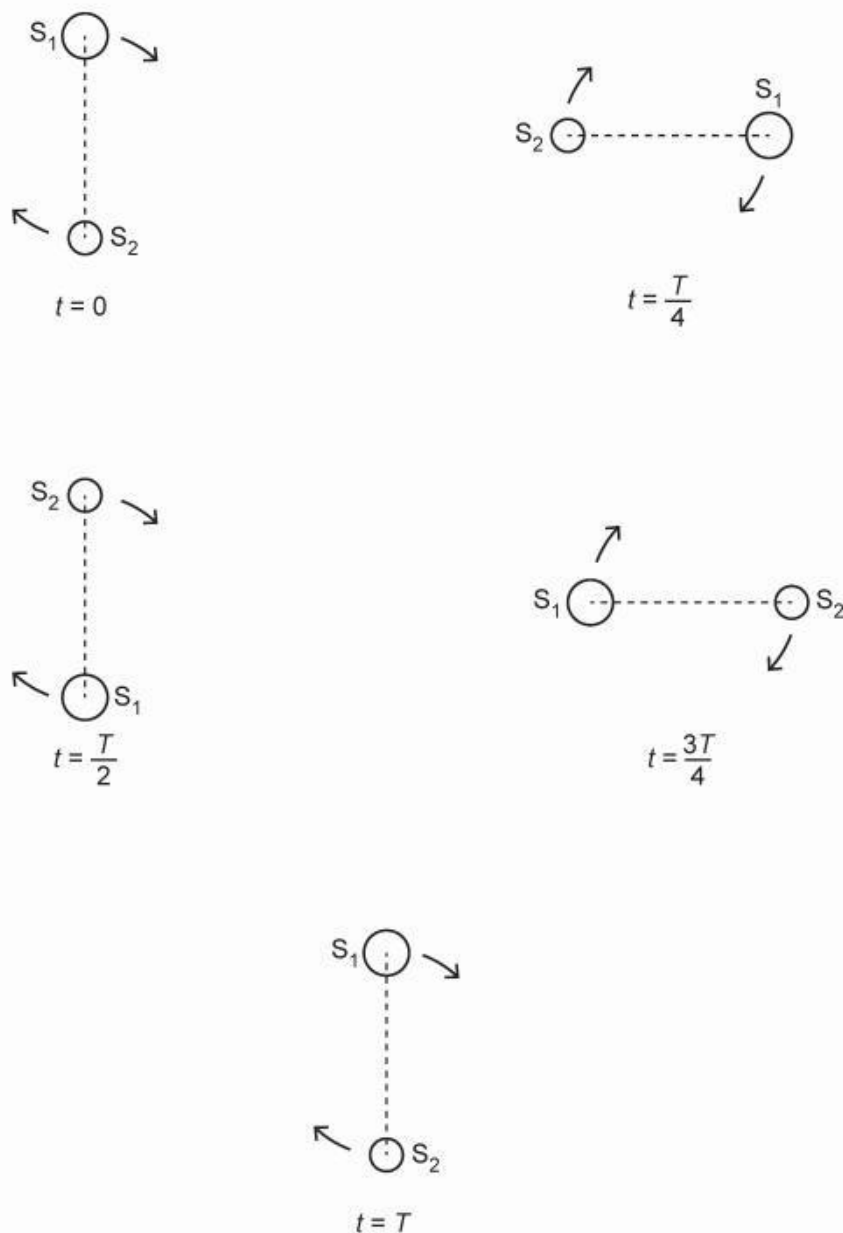


Fig. 1.1 (not to scale)



Observed from Earth, the angular separation of the centres of S_1 and S_2 is 1.2×10^{-5} rad.
The distance of the binary star system from Earth is 1.5×10^{17} m.

Show that the separation d of the centres of S_1 and S_2 is 1.8×10^{12} m.

[1]

- (c) The stars S_1 and S_2 rotate with the same angular velocity ω about a point P, as illustrated in Fig. 1.2.

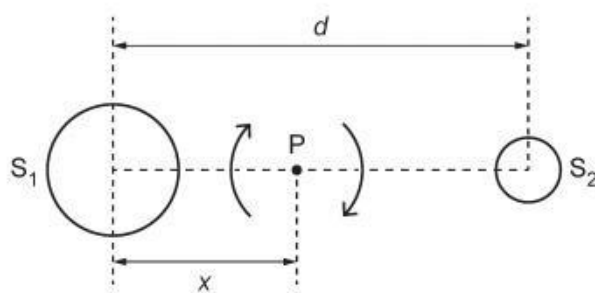
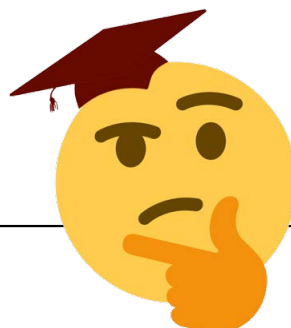


Fig. 1.2 (not to scale)

Point P is at a distance x from the centre of star S_1 .
The period of rotation of the stars is 44.2 years.

- (i) Calculate the angular velocity ω .

$\omega = \dots\dots\dots \text{rad s}^{-1}$ [2]



- (ii) By considering the forces acting on the two stars, show that the ratio of the masses of the stars is given by

$$\frac{\text{mass of } S_1}{\text{mass of } S_2} = \frac{d-x}{x}.$$

[2]

- (iii) The mass M_1 of star S_1 is given by the expression

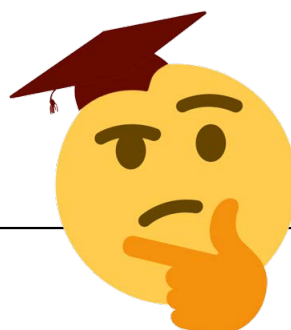
$$GM_1 = d^2(d-x)\omega^2$$

where G is the gravitational constant.

The ratio in (ii) is found to be 1.5.

Use data from (b) and your answer in (c)(i) to determine the mass M_1 .

$$M_1 = \dots\dots\dots \text{ kg [3]}$$



14 - (9702/42_Summer_2020_Q1) - Gravitational Fields

- (a) Define *gravitational potential* at a point.

.....

.....

..... [2]

- (b) An isolated solid sphere of radius r may be assumed to have its mass M concentrated at its centre. The magnitude of the gravitational potential at the surface of the sphere is ϕ .

On Fig. 1.1, show the variation of the gravitational potential with distance d from the centre of the sphere for values of d from $d = r$ to $d = 4r$.

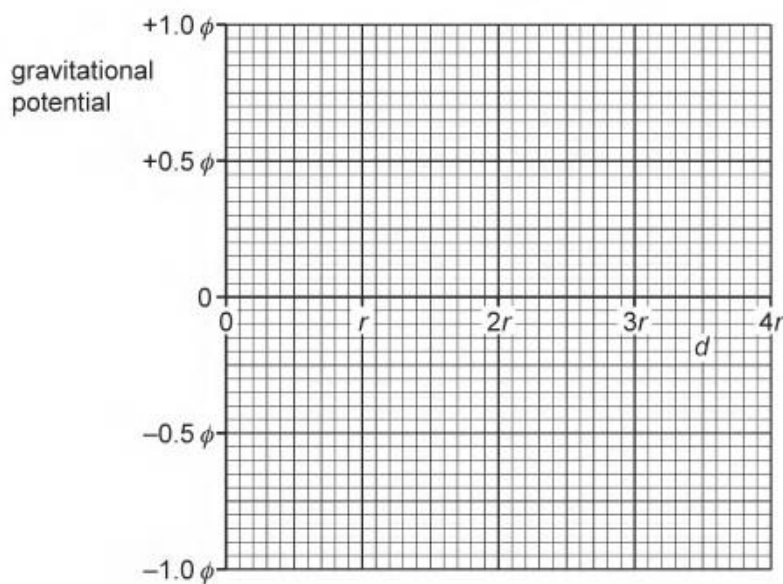
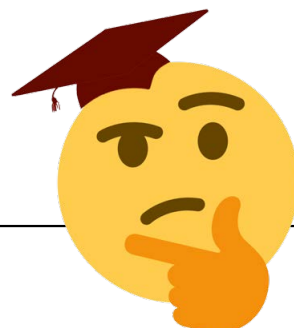


Fig. 1.1

[3]



- (c) The sphere in (b) is a planet with radius r of $6.4 \times 10^6 \text{ m}$ and mass M of $6.0 \times 10^{24} \text{ kg}$. The planet has no atmosphere.

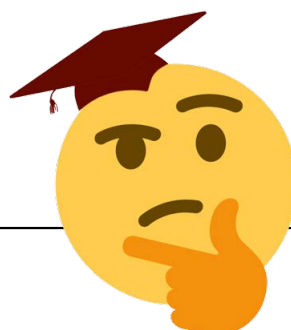
A rock of mass $3.4 \times 10^3 \text{ kg}$ moves directly towards the planet. Its distance from the centre of the planet changes from $4r$ to $3r$.

- (i) Calculate the change in gravitational potential energy of the rock.

change = J [3]

- (ii) Explain whether the rock's speed increases, decreases or stays the same.

.....
..... [2]



15 - (9702/41_Winter_2020_Q1) - Gravitational Fields

- (a) (i) State what is meant by a *field of force*.

.....
.....
..... [2]

- (ii) Define *gravitational field strength*.

.....
..... [1]

- (b) An isolated planet may be assumed to be a uniform sphere of radius $3.39 \times 10^6 \text{ m}$ with its mass of $6.42 \times 10^{23} \text{ kg}$ concentrated at its centre.

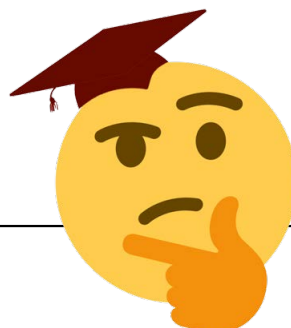
Calculate the gravitational field strength at the surface of the planet.

field strength = N kg^{-1} [3]

- (c) Calculate the height above the surface of the planet in (b) at which the gravitational field strength is 1.0% less than its value at the surface of the planet.

height = m [3]

[Total: 9]



16 - (9702/42_Winter_2020_Q1) - *Gravitational Fields*

- (a) Define *gravitational potential* at a point.

.....
.....
..... [2]

- (b) The Earth may be considered to be a uniform sphere of radius $6.4 \times 10^6 \text{ m}$ with its mass of $6.0 \times 10^{24} \text{ kg}$ concentrated at its centre.

A satellite of mass $2.4 \times 10^3 \text{ kg}$ is launched from the Equator. It is placed in an equatorial orbit at a height of $5.6 \times 10^6 \text{ m}$ above the Earth's surface.

- (i) Calculate the change ΔE_p in gravitational potential energy of the satellite for its movement from the surface of the Earth to its position in the equatorial orbit.

$\Delta E_p = \dots\dots\dots \text{ J}$ [3]

- (ii) Determine the speed of the satellite when in orbit.

speed = $\dots\dots\dots \text{ ms}^{-1}$ [3]

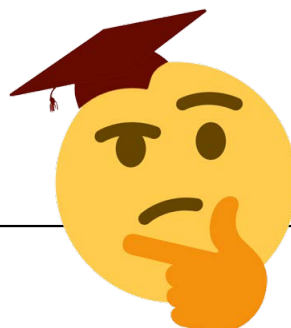


- (c) Before the satellite in (b) is launched, its speed at the Equator due to the Earth's rotation is 470 m s^{-1} .

Suggest why the energy required to launch the satellite depends on whether the satellite, in its orbit, is travelling from west to east or from east to west.

.....
..... [1]

[Total: 9]



17 - (9702/41_Summer_2021_Q1) - Gravitational Fields

The Earth may be assumed to be an isolated uniform sphere with its mass of $6.0 \times 10^{24} \text{ kg}$ concentrated at its centre.

A satellite of mass 1200 kg is in a circular orbit about the Earth in the Earth's gravitational field. The period of the orbit is 94 minutes.

(a) Define *gravitational field strength*.

.....
..... [1]

(b) Calculate the radius of the orbit of the satellite.

radius = m [3]

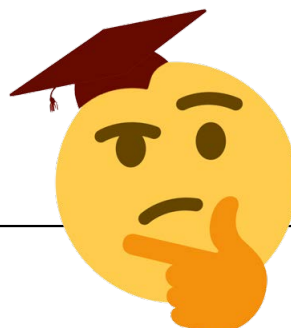
(c) Rockets on the satellite are fired so that the satellite enters a different circular orbit that has a period of 150 minutes. The change in the mass of the satellite may be assumed to be negligible.

(i) Show that the radius of the new orbit is $9.4 \times 10^6 \text{ m}$.

[2]

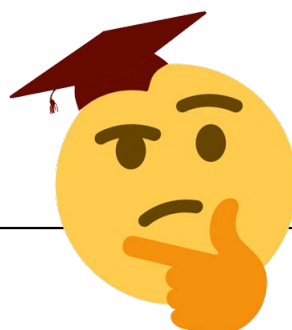
(ii) State, with a reason, whether the gravitational potential energy of the satellite increases or decreases.

.....
..... [1]



- (iii) Determine the magnitude of the change in the gravitational potential energy of the satellite.

change in potential energy = J [3]



18 - (9702/42_Summer_2021_Q1) - Gravitational Fields

(a) Define *gravitational field strength*.

.....
..... [1]

(b) An isolated planet is a uniform sphere of radius 3.39×10^6 m. Its mass of 6.42×10^{23} kg may be considered to be a point mass concentrated at its centre. The planet rotates about its axis with a period of 24.6 hours.

For an object resting on the surface of the planet at the equator, calculate, to three significant figures:

(i) the gravitational field strength

field strength = N kg^{-1} [2]

(ii) the centripetal acceleration

acceleration = ms^{-2} [2]

(iii) the force per unit mass exerted on the object by the surface of the planet.

force per unit mass = N kg^{-1} [1]



19 - (9702/41_Winter_2021_Q2) - Gravitational Fields

(a) Define *gravitational potential*.

.....
.....
..... [2]

(b) The Earth E and the Moon M can both be considered as isolated point masses at their centres. The mass of the Earth is $5.98 \times 10^{24} \text{ kg}$ and the mass of the Moon is $7.35 \times 10^{22} \text{ kg}$. The Earth and the Moon are separated by a distance of $3.84 \times 10^8 \text{ m}$, as shown in Fig. 2.1.

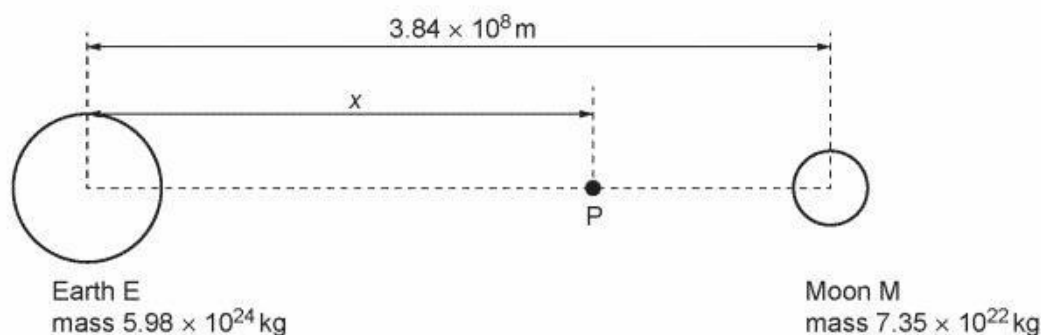


Fig. 2.1 (not to scale)

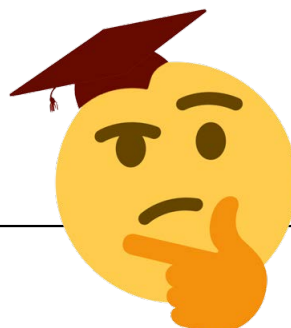
P is a point, on the line joining the centres of E and M, where the resultant gravitational field strength is zero. Point P is at a distance x from the centre of the Earth.

(i) Explain how it is possible for the gravitational field strength to be zero despite the presence of two large masses nearby.

.....
.....
..... [2]

(ii) Show that x is approximately $3.5 \times 10^8 \text{ m}$.

[2]



(iii) Calculate the gravitational potential ϕ at point P.

$$\phi = \dots\dots\dots \text{J kg}^{-1} \text{ [3]}$$



20 – (9702/42_Winter_2021_Q2) – Gravitational Fields

- (a) State the relationship between gravitational potential and gravitational field strength.

.....

 [2]

- (b) A moon of mass M and radius R orbits a planet of mass $3M$ and radius $2R$. At a particular time, the distance between their centres is D , as shown in Fig. 2.1.

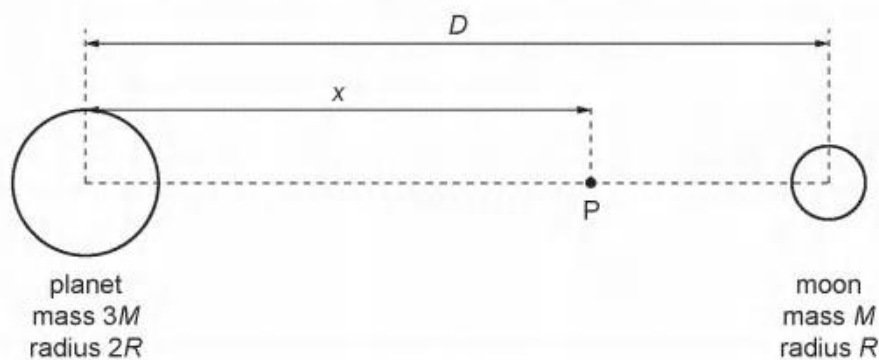


Fig. 2.1

Point P is a point along the line between the centres of the planet and the moon, at a variable distance x from the centre of the planet.

The variation with x of the gravitational potential ϕ at point P , for points between the planet and the moon, is shown in Fig. 2.2.

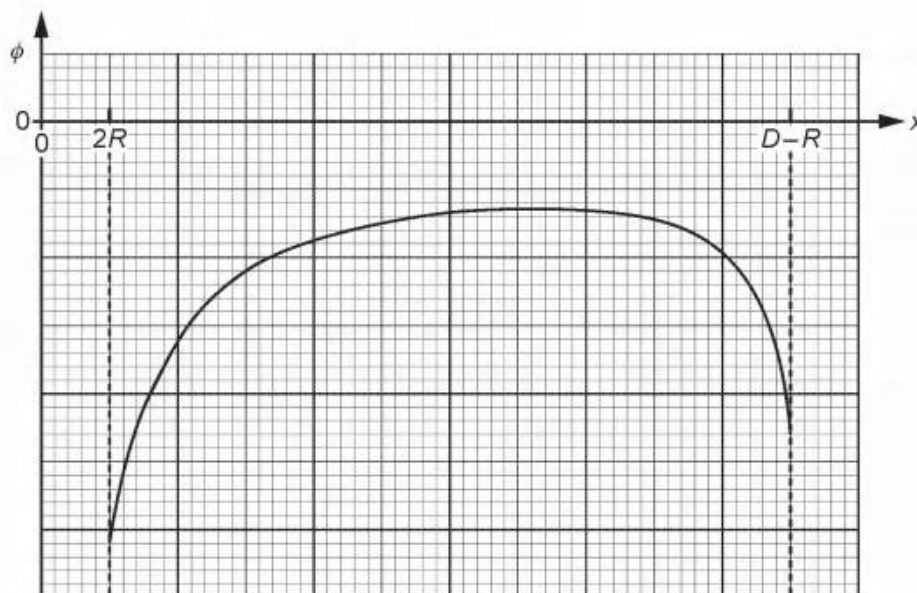


Fig. 2.2



- (i) Explain why ϕ is negative throughout the entire range $x = 2R$ to $x = D - R$.

.....

 [3]

- (ii) One of the features of Fig. 2.2 is that ϕ is negative throughout.

Describe **two** other features of Fig. 2.2.

1.

 2.
 [2]

- (iii) On Fig. 2.3, sketch the variation with x of the gravitational field strength g at point P between $x = 2R$ and $x = D - R$.

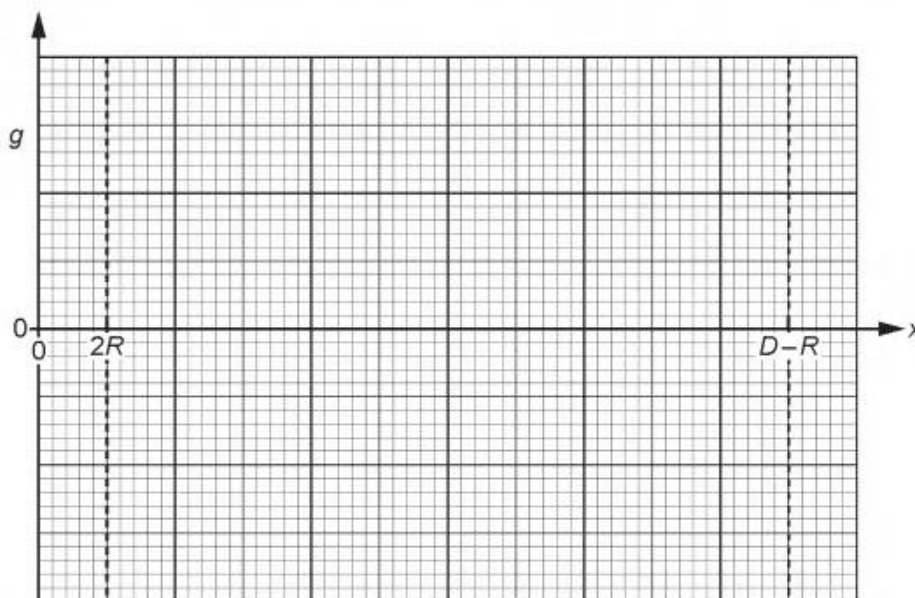
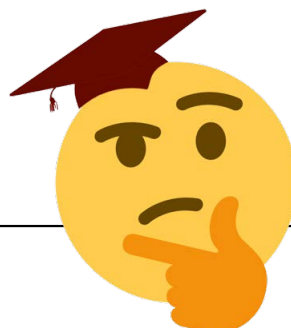


Fig. 2.3

[3]



21 - (9702/41_Summer_2022_Q1) - Gravitational Fields

- (a) (i) State Newton's law of gravitation.

.....
.....
..... [2]

- (ii) Use Newton's law of gravitation to show that the gravitational field strength g at a distance r away from a point mass M is given by

$$g = \frac{GM}{r^2}.$$

[2]

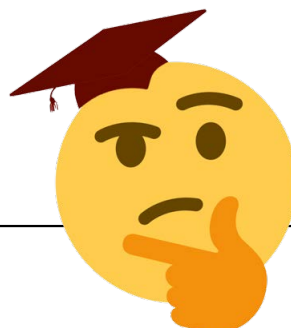
- (b) The Earth has a mass of 5.98×10^{24} kg and a radius of 6.37×10^6 m.
The Moon has a mass of 7.35×10^{22} kg and a radius of 1.74×10^6 m.
The Earth and the Moon can both be considered as point masses at their centres. Their centres are a distance of 3.84×10^8 m apart.

- (i) Show that the gravitational field strength at the surface of the Moon due to the mass of the Moon is 1.62 N kg^{-1} .

[1]

- (ii) Explain why there is a point X on the line between the centres of the Earth and the Moon where the resultant gravitational field strength due to the Earth and the Moon is zero.

.....
.....
..... [2]



(iii) Calculate the distance x of point X from the centre of the Moon.

$x = \dots\dots\dots$ m [3]

[Total: 10]



22 - (9702/42_Summer_2022_Q1) - Gravitational Fields

- (a) (i) Define gravitational potential at a point.

.....
.....
..... [2]

- (ii) Starting from the equation for the gravitational potential due to a point mass, show that the gravitational potential energy E_p of a point mass m at a distance r from another point mass M is given by

$$E_p = -\frac{GMm}{r}$$

where G is the gravitational constant.

[1]

- (b) Fig. 1.1 shows the path of a comet of mass $2.20 \times 10^{14} \text{ kg}$ as it passes around a star of mass $1.99 \times 10^{30} \text{ kg}$.

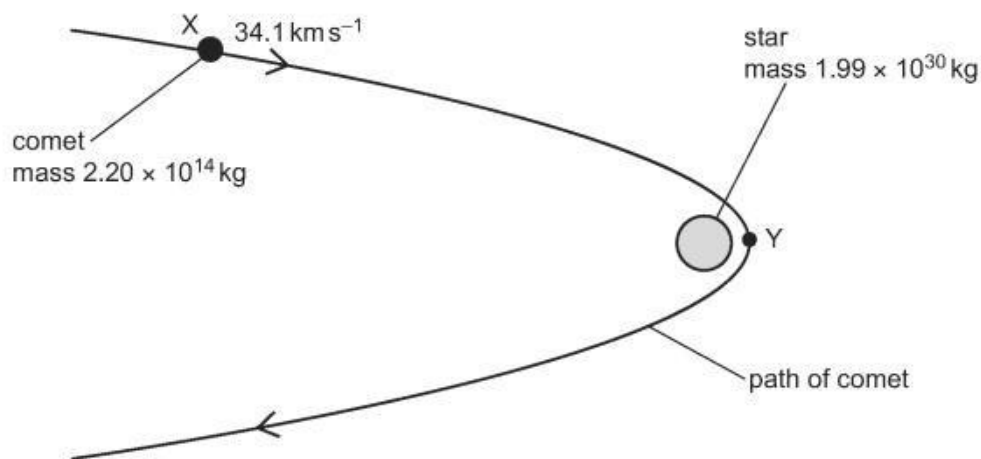
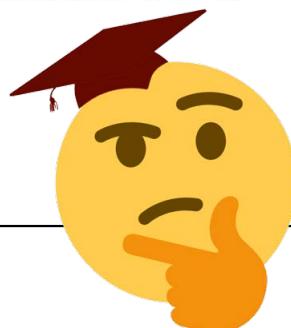


Fig. 1.1 (not to scale)

At point X, the comet is $8.44 \times 10^{11} \text{ m}$ from the centre of the star and is moving at a speed of 34.1 km s^{-1} .

At point Y, the comet passes its point of closest approach to the star. At this point, the comet is a distance of $6.38 \times 10^{10} \text{ m}$ from the centre of the star.



Both the comet and the star can be considered as point masses at their centres.

- (i) Calculate the magnitude of the change in the gravitational potential energy ΔE_p of the comet as it moves from position X to position Y.

$$\Delta E_p = \dots\dots\dots \text{ J [2]}$$

- (ii) State, with a reason, whether the change in gravitational potential energy in **(b)(i)** is an increase or a decrease.

.....
..... [1]

- (iii) Use your answer in **(b)(i)** to determine the speed, in km s^{-1} , of the comet at point Y.

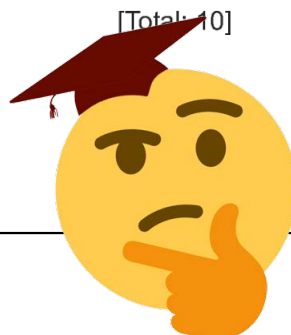
$$\text{speed} = \dots\dots\dots \text{ km s}^{-1} [3]$$

- (c) A second comet passes point X with the same speed as the comet in **(b)** and travelling in the same direction. This comet is gradually losing mass. The mass of this comet when it passes point X is the same as the mass of the comet in **(b)**.

Suggest, with a reason, how the path of the second comet compares with the path shown in Fig. 1.1.

.....
..... [1]

[Total: 10]



23 - (9702/41_Winter_2022_Q1) - Gravitational Fields

- (a) State the equation for the gravitational force F between two point masses m_1 and m_2 that are separated by a distance r . State the meaning of any other symbols you use.

[2]

- (b) A satellite is in a circular orbit of radius R around a planet of mass M .

Show that the period T of the orbit is given by

$$T^2 = kR^3$$

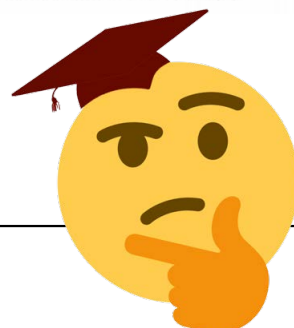
where k is a constant that depends on the value of M . Explain your reasoning.

[3]

- (c) A satellite is in a circular orbit around the Earth with a period of 24 hours. The mass of the Earth is 6.0×10^{24} kg.

- (i) Calculate the radius of the orbit.

radius = m [2]



(ii) State the **two** other conditions that must be met for the orbit to be geostationary.

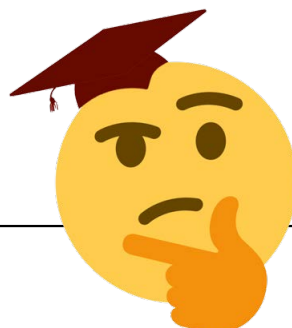
1

.....

2

.....

[2]



24 - (9702/42_Winter_2022_Q1) - Gravitational Fields

(a) Define gravitational field.

.....
..... [1]

(b) A spherical planet can be considered as a point mass at its centre.

(i) On Fig. 1.1, draw gravitational field lines outside the planet to represent the gravitational field due to the planet.

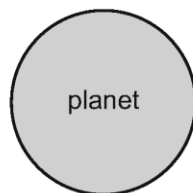


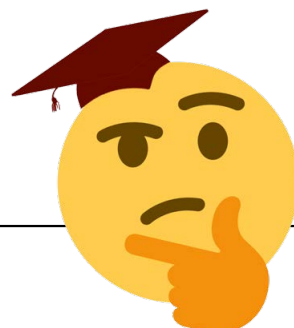
Fig. 1.1

[2]

(ii) A satellite is in a circular orbit around the planet.

Explain, with reference to your answer in (b)(i), why the path of the satellite is circular.

.....
.....
..... [2]



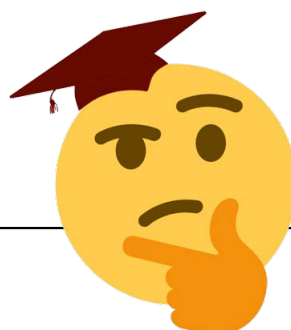
- (c) An object rests on the surface of the Earth at the Equator.
The radius of the Earth is 6.4×10^6 m.

- (i) Determine the centripetal acceleration of the object.

centripetal acceleration = ms^{-2} [3]

- (ii) Describe how the two forces acting on the object give rise to this centripetal acceleration.
You may draw a diagram if you wish.

.....
.....
..... [2]



25 – (9702/41_Winter_2023_Q1) – *Gravitational Fields*

- (a) (i) State what is indicated by the direction of the gravitational field line at a point in a gravitational field.

.....
..... [1]

- (ii) Explain, with reference to gravitational field lines, why the gravitational field near the surface of the Earth is approximately constant for small changes in height.

.....
.....
..... [2]

- (b) A large isolated uniform sphere has mass M and radius R .

Point P lies on a straight line passing through the centre of the sphere, at a variable displacement x from the centre, as shown in Fig. 1.1.

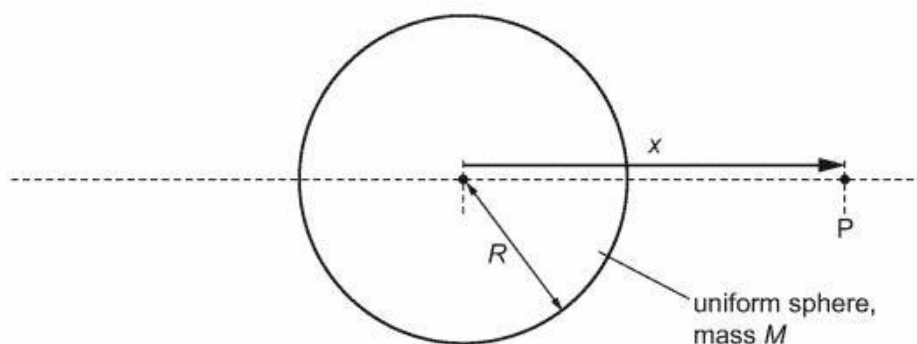


Fig. 1.1

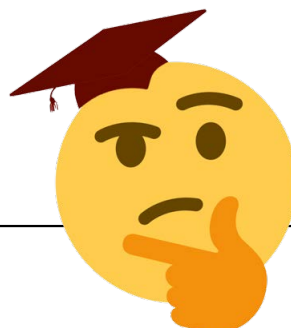


Fig. 1.2 shows the variation with x of the gravitational field g at point P due to the sphere for the values of x for which P is inside the sphere.

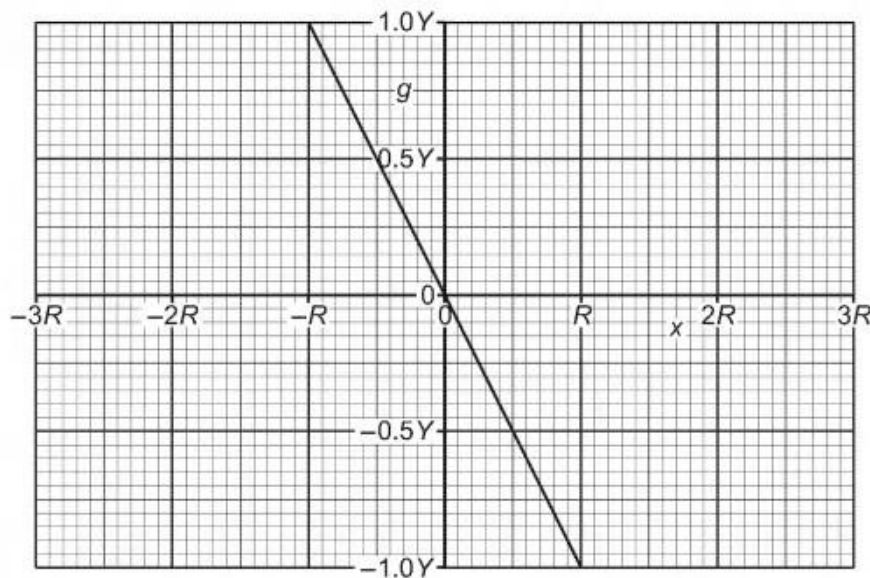


Fig. 1.2

The magnitude of the gravitational field at the surface of the sphere is Y .

- (i) Determine an expression for Y in terms of M and R . Identify any other symbols that you use.

[2]

- (ii) Explain why, at the surface of the sphere, g always has the opposite sign to x .

.....

.....

..... [2]

- (iii) Complete Fig. 1.2 to show the variation of g with x for values of x , up to $\pm 3R$, for which point P is outside the sphere. [3]



26 – (9702/42_Winter_2023_Q2) – Gravitational Fields

- (a) (i) Define gravitational potential at a point.

.....
.....
..... [2]

- (ii) The Moon may be considered to be an isolated uniform sphere of mass $7.3 \times 10^{22} \text{ kg}$ and radius $1.7 \times 10^6 \text{ m}$.

Calculate the gravitational potential at the surface of the Moon. Give a unit with your answer.

gravitational potential = unit [2]

- (b) An isolated uniform spherical planet has gravitational potential ϕ at its surface.

A particle of mass m is projected vertically upwards from the surface. The particle is given just enough kinetic energy to travel to an infinite distance away from the planet, escaping from the gravitational pull of the planet, without any additional work being done on it.

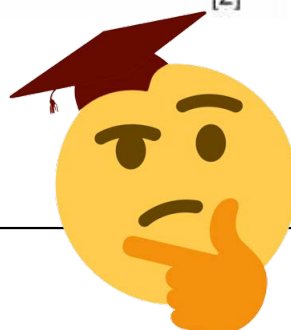
- (i) Determine an expression, in terms of m and ϕ , for the gravitational potential energy E_p of the particle at the surface of the planet.

$E_p = \dots\dots\dots$ [1]

- (ii) Show that the speed v at which the particle is projected upwards from the surface of the planet is given by

$$v = \sqrt{-2\phi}.$$

[2]



- (c) A particle is moving upwards at the surface of the Moon.

Use your answer in (a)(ii) and the expression in (b)(ii) to determine the minimum speed of this particle that will result in it escaping from the gravitational pull of the Moon.

speed = ms^{-1} [1]

- (d) Hydrogen may be assumed to be an ideal gas.
The mass of a hydrogen molecule is $3.34 \times 10^{-27} \text{ kg}$.

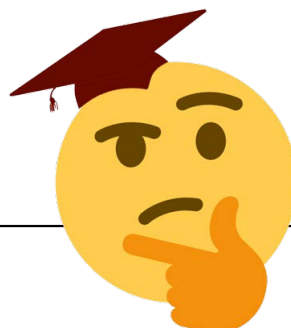
Calculate the root-mean-square (r.m.s.) speed of a hydrogen molecule in hydrogen gas that is at a temperature of 400K.

r.m.s. speed = ms^{-1} [3]

- (e) The surface of the Moon reaches temperatures of approximately 400K when in direct sunlight.

Use your answers in (c) and (d) to suggest a reason why the Moon does not have an atmosphere consisting of hydrogen.

.....
..... [1]



1 - (9702/42_Summer_2017_Q2) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

- (a) The pressure p and volume V of an ideal gas are related to the density ρ of the gas by the expression

$$p = \frac{1}{3}\rho\langle c^2 \rangle.$$

- (i) State what is meant by the symbol $\langle c^2 \rangle$.

.....
.....[1]

- (ii) Use the expression to show that the mean kinetic energy E_K of a gas molecule is given by

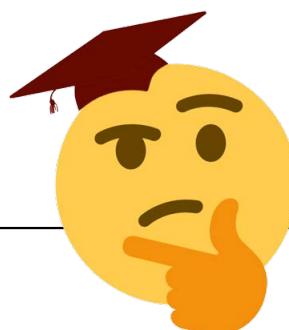
$$E_K = \frac{3}{2} kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

[3]

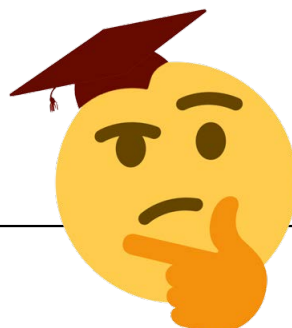
- (b) (i) An ideal gas containing 1.0 mol of molecules is heated at constant volume.
Use the expression in (a)(ii) to show that the thermal energy required to raise the temperature of the gas by 1.0 K has a value of $\frac{3}{2}R$, where R is the molar gas constant.

[3]



- (ii) Nitrogen may be assumed to be an ideal gas. The molar mass of nitrogen gas is 28 g mol^{-1} . Use the answer in **(b)(i)** to calculate a value for the specific heat capacity, in $\text{J kg}^{-1} \text{K}^{-1}$, at constant volume for nitrogen.

specific heat capacity = $\text{J kg}^{-1} \text{K}^{-1}$ [2]



2 - (9702/41_Summer_2017_Q4) - *Ideal Gases*

(a) Describe the motion of molecules in a gas, according to the kinetic theory of gases.

.....
.....
.....[2]

(b) Describe what is observed when viewing Brownian motion that provides evidence for your answer in (a).

.....
.....
.....[2]

(c) At a pressure of $1.05 \times 10^5 \text{ Pa}$ and a temperature of 27°C , 1.00 mol of helium gas has a volume of 0.0240 m^3 .

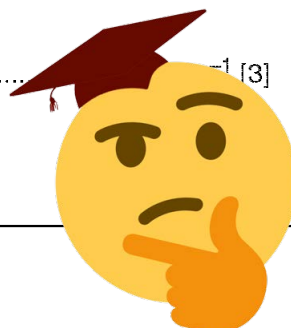
The mass of 1.00 mol of helium gas, assumed to be an ideal gas, is 4.00 g .

(i) Calculate the root-mean-square (r.m.s.) speed of an atom of helium gas for a temperature of 27°C .

r.m.s. speed = ms^{-1} [3]

(ii) Using your answer in (i), calculate the r.m.s. speed of the atoms at 177°C .

r.m.s. speed = ms^{-1} [3]



3 - (9702/42_Summer_2018_Q2) - *Ideal Gases, Thermal Properties Of Materials*

- (a) Use one of the assumptions of the kinetic theory of gases to explain why the potential energy of the molecules of an ideal gas is zero.

.....
[1]

- (b) The average translational kinetic energy E_K of a molecule of an ideal gas is given by the expression

$$E_K = \frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$$

where m is the mass of a molecule and k is the Boltzmann constant.

State the meaning of the symbol

- (i) $\langle c^2 \rangle$,

.....[1]

- (ii) T .

.....[1]

- (c) A cylinder of constant volume $4.7 \times 10^4 \text{ cm}^3$ contains an ideal gas at pressure $2.6 \times 10^5 \text{ Pa}$ and temperature 173°C .

The gas is heated. The thermal energy transferred to the gas is 2900 J . The final temperature and pressure of the gas are T and p , as illustrated in Fig. 2.1.

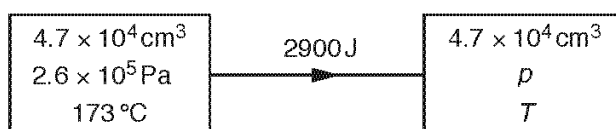
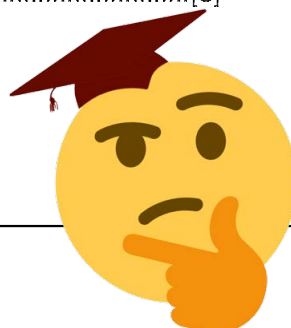


Fig. 2.1

- (i) Calculate

1. the number N of molecules in the cylinder,

$N =$ [3]

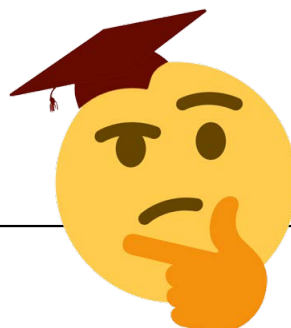


2. the increase in average kinetic energy of a molecule during the heating process.

increase = J [1]

- (ii) Use your answer in (i) **part 2** to determine the final temperature T , in kelvin, of the gas in the cylinder.

$T =$ K [3]



4 - (9702/41_Summer_2018_Q3) - *Ideal Gases*

(a) (i) State what is meant by the *internal energy* of a system.

.....

.....

.....

.....[2]

(ii) Explain why, for an ideal gas, the change in internal energy is directly proportional to the change in thermodynamic temperature of the gas.

.....

.....

.....

.....

.....[3]

(b) A cylinder of volume $1.8 \times 10^4 \text{ cm}^3$ contains helium gas at pressure $6.4 \times 10^6 \text{ Pa}$ and temperature 25°C .

Helium gas may be considered to be an ideal gas consisting of single atoms.

Calculate the number of helium atoms in the cylinder.

number =[3]



5 - (9702/41_Winter_2018_Q2) - *Ideal Gases, Thermal Properties Of Materials*

(a) State what is meant by the *internal energy* of a system.

.....

.....

.....

.....[2]

(b) An ideal gas undergoes a cycle of changes as shown in Fig. 2.1.

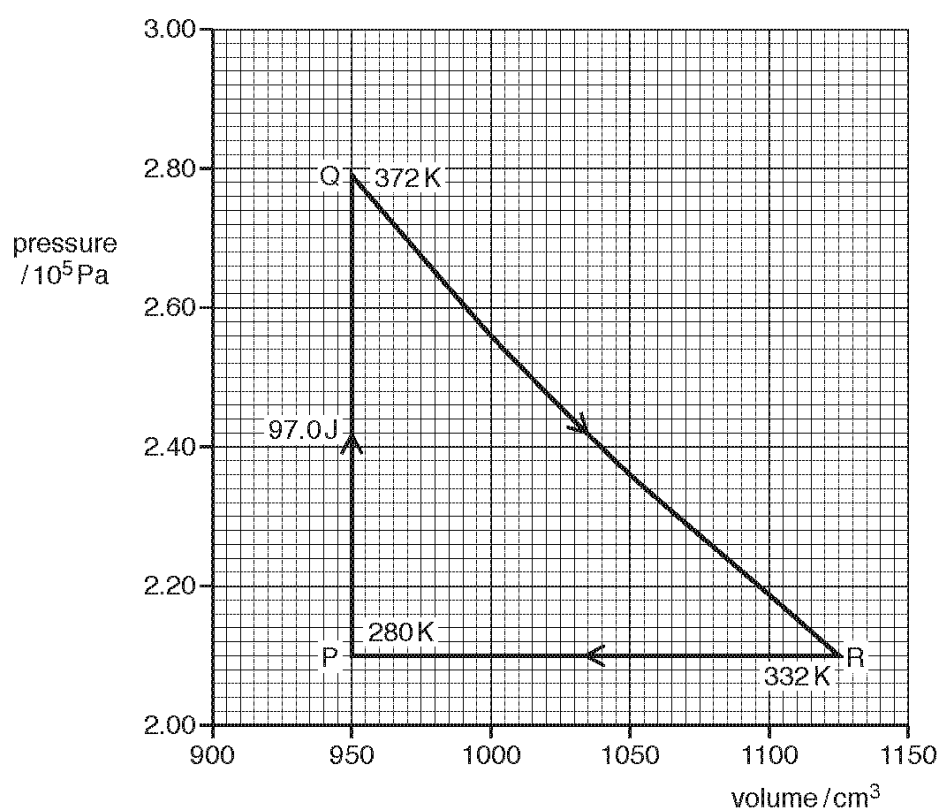
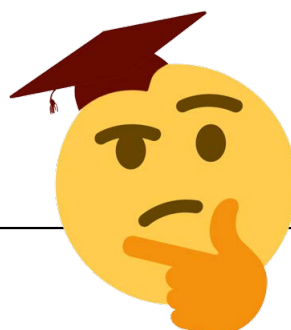


Fig. 2.1

At point P, the gas has volume 950 cm^3 , pressure $2.10 \times 10^5\text{ Pa}$ and temperature 280 K .

The gas is heated at constant volume and 97.0 J of thermal energy is transferred to the gas. Its pressure and temperature change so that the gas is at point Q on Fig. 2.1.

The gas then undergoes the change from point Q to point R and then from point R back to point P, as shown on Fig. 2.1.



Some energy changes that take place during the cycle PQRP are shown in Fig. 2.2.

	change $P \rightarrow Q$	change $Q \rightarrow R$	change $R \rightarrow P$
thermal energy transferred to gas / J	+97.0	0	.....
work done on gas / J	.....	–42.5	+37.0
increase in internal energy of gas / J	.....	.....	.....

Fig. 2.2

- (i) State the total change in internal energy of the gas during the complete cycle PQRP. Explain your answer.

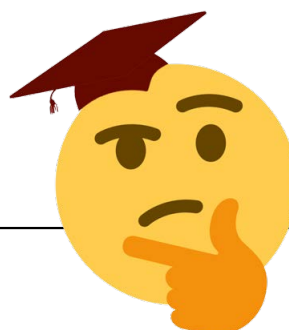
.....

[2]

- (ii) On Fig. 2.2, complete the energy changes for the gas during

1. the change $P \rightarrow Q$,
2. the change $Q \rightarrow R$,
3. the change $R \rightarrow P$.

[5]



6 - (9702/42_Winter_2018_Q2) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

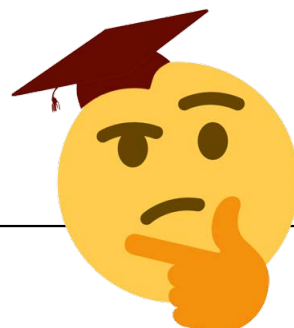
(a) State what is meant by an *ideal gas*.

.....
.....
.....[2]

(b) An ideal gas comprised of single atoms is contained in a cylinder and has a volume of $1.84 \times 10^{-2} \text{ m}^3$ at a pressure of $2.12 \times 10^7 \text{ Pa}$.
The mass of gas in the cylinder is 3.20 kg.

(i) Determine, to three significant figures, the root-mean-square (r.m.s.) speed of the atoms of the gas.

r.m.s. speed = ms^{-1} [3]



(ii) The temperature of the gas in the cylinder is 22°C .

Determine, to three significant figures,

1. the amount, in mol, of the gas,

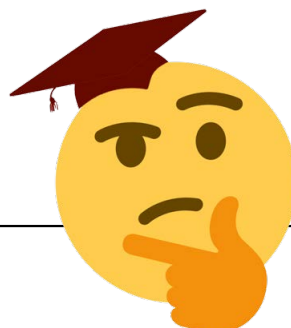
amount = mol [2]

2. the mass of one atom of the gas.

mass = kg [2]

(c) Use your answer in (b)(ii) **part 2** to determine the nucleon number A of an atom of the gas.

A = [1]



7 - (9702/41_Summer_2019_Q2) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

A fixed mass of an ideal gas has volume 210 cm^3 at pressure $3.0 \times 10^5\text{ Pa}$ and temperature 270 K .

The volume of the gas is reduced at constant pressure to 140 cm^3 , as shown in Fig. 2.1.



Fig. 2.1

The final temperature of the gas is T .

(a) Determine:

(i) the amount of gas

amount = mol [3]

(ii) the final temperature T of the gas

$T = \dots\dots\dots\text{K}$ [2]

(iii) the external work done on the gas.

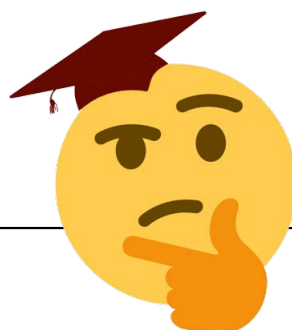
work done = J [2]



(b) For this change in volume and temperature of the gas, the thermal energy transferred is 53 J.

Determine ΔU , the change in internal energy of the gas.

$\Delta U = \dots\dots\dots$ J [3]



8 - (9702/42_Summer_2019_Q2) - *Ideal Gases, Thermal Properties Of Materials*

(a) The first law of thermodynamics may be expressed in the form

$$\Delta U = q + w.$$

(i) State, for a system, what is meant by:

1. $+q$

.....
.....

2. $+w$.

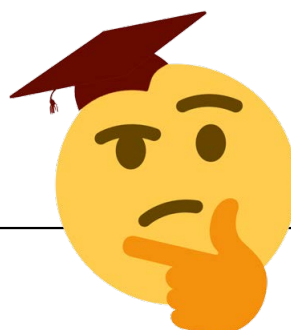
.....
.....

[2]

(ii) State what is represented by a negative value of ΔU .

.....
.....

[1]



(b) An ideal gas, sealed in a container, undergoes the cycle of changes shown in Fig. 2.1.

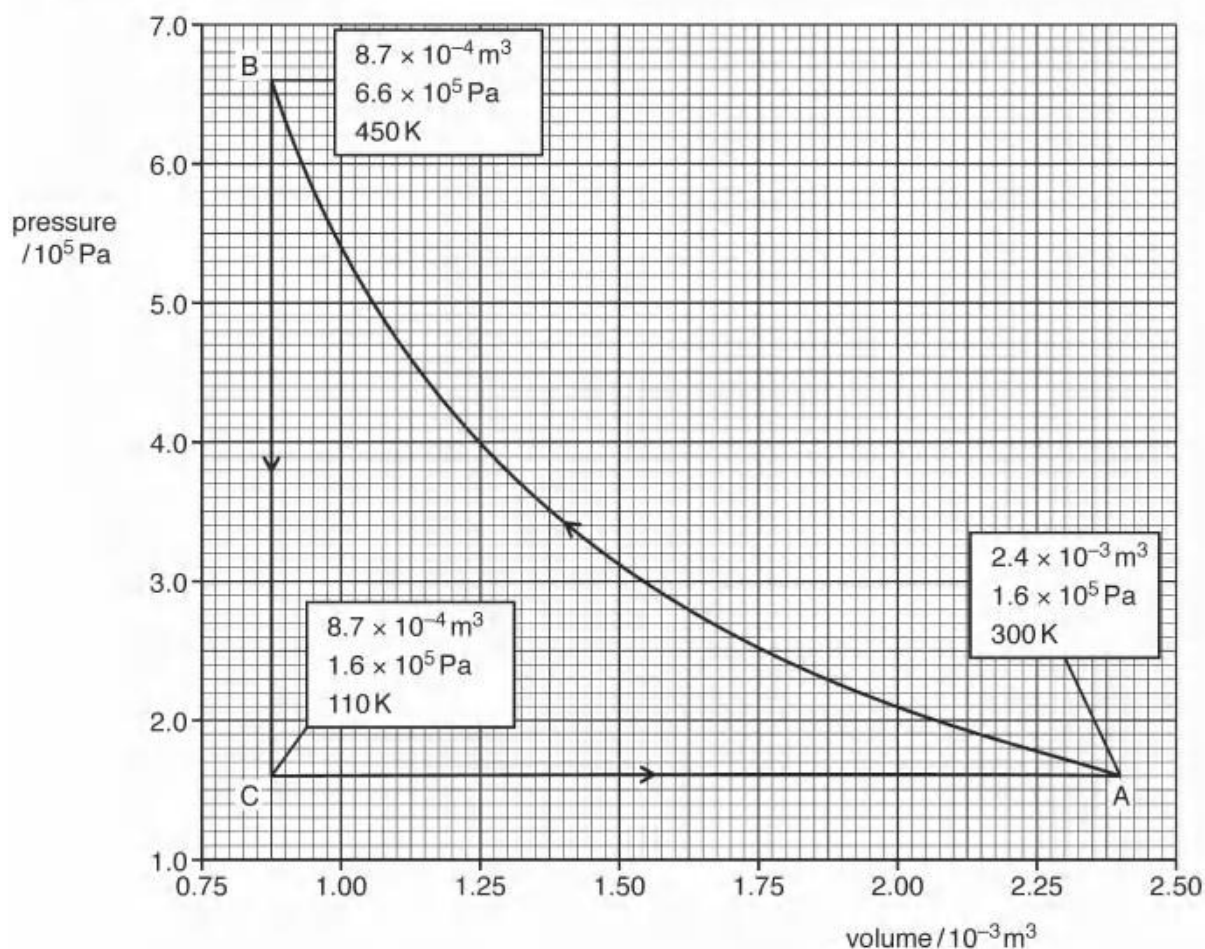


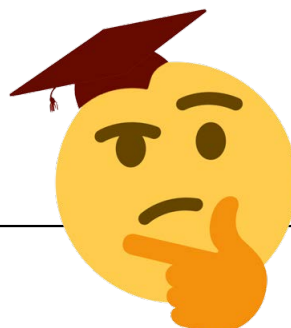
Fig. 2.1

At point A, the gas has volume $2.4 \times 10^{-3} \text{ m}^3$, pressure $1.6 \times 10^5 \text{ Pa}$ and temperature 300 K .

The gas is compressed suddenly so that no thermal energy enters or leaves the gas during the compression. The amount of work done is 480 J so that, at point B, the gas has volume $8.7 \times 10^{-4} \text{ m}^3$, pressure $6.6 \times 10^5 \text{ Pa}$ and temperature 450 K .

The gas is now cooled at constant volume so that, between points B and C, 1100 J of thermal energy is transferred. At point C, the gas has pressure $1.6 \times 10^5 \text{ Pa}$ and temperature 110 K .

Finally, the gas is returned to point A.



- (i) State and explain the total change in internal energy of the gas for one complete cycle ABCA.

.....

 [2]

- (ii) Calculate the external work done on the gas during the expansion from point C to point A.

work done = J [2]

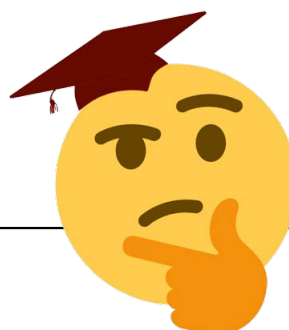
- (iii) Complete Fig. 2.2 for the changes from:

1. point A to point B
2. point B to point C
3. point C to point A.

change	+q/J	+w/J	$\Delta U/J$
A → B			
B → C			
C → A			

Fig. 2.2

[4]



9 - (9702/41_Winter_2019_Q2) - *Ideal Gases*

- (a) The kinetic theory of gases is based on a number of assumptions about the molecules of a gas.

State the assumption that is related to the volume of the molecules of the gas.

.....
.....
..... [2]

- (b) An ideal gas occupies a volume of $2.40 \times 10^{-2} \text{ m}^3$ at a pressure of $4.60 \times 10^5 \text{ Pa}$ and a temperature of 23°C .

- (i) Calculate the number of molecules in the gas.

number = [3]

- (ii) Each molecule has a diameter of approximately $3 \times 10^{-10} \text{ m}$.

Estimate the total volume of the gas molecules.

volume = m^3 [3]

- (c) By reference to your answer in (b)(ii), suggest why the assumption in (a) is justified.

.....
..... [1]



10 – (9702/42_Winter_2019_Q2) – *Ideal Gases, Thermal Properties Of Materials*

- (a) Smoke particles are suspended in still air. Brownian motion of the smoke particles is seen through a microscope.

Describe:

- (i) what is seen through the microscope

..... [1]

- (ii) how Brownian motion provides evidence for the nature of the movement of gas molecules.

..... [2]

- (b) A fixed mass of an ideal gas has volume $2.40 \times 10^3 \text{ cm}^3$ at pressure $3.51 \times 10^5 \text{ Pa}$ and temperature 290 K. The gas is heated at constant volume until the temperature is 310 K at pressure $3.75 \times 10^5 \text{ Pa}$, as illustrated in Fig. 2.1.

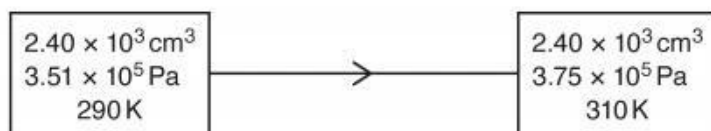


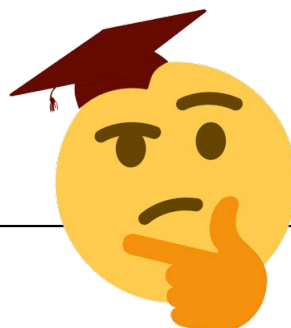
Fig. 2.1

The quantity of thermal energy required to raise the temperature of 1.00 mol of the gas by 1.00 K at constant volume is 12.5 J.

Calculate, to three significant figures:

- (i) the amount, in mol, of the gas

amount = mol [3]



- (ii) the thermal energy transfer during the change.

energy transfer = J [2]

- (c) For the change in the gas in (b), state:

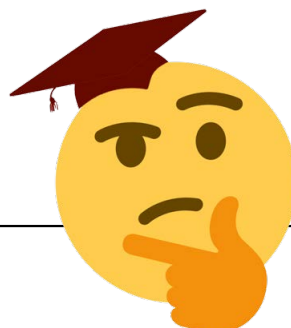
- (i) the quantity of external work done on the gas

work done = J [1]

- (ii) the change in internal energy, with the direction of this change.

change = J

direction [2]



11 - (9702/41_Summer_2020_Q2) - *Ideal Gases, Thermal Properties Of Materials*

(a) State what is meant by the *internal energy* of a system.

.....

.....

.....

..... [2]

(b) By reference to intermolecular forces, explain why the change in internal energy of an ideal gas is equal to the change in total kinetic energy of its molecules.

.....

.....

..... [2]

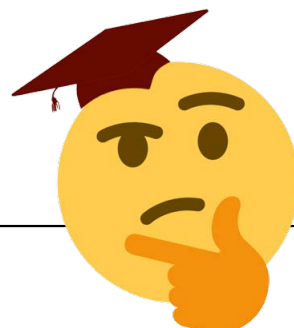
(c) State and explain the change, if any, in the internal energy of a solid metal ball as it falls under gravity in a vacuum.

.....

.....

.....

..... [3]



12 - (9702/42_Summer_2020_Q2) - *Ideal Gases*

- (a) A square box of volume V contains N molecules of an ideal gas. Each molecule has mass m .

Using the kinetic theory of ideal gases, it can be shown that, if all the molecules are moving with speed v at right angles to one face of the box, the pressure p exerted on the face of the box is given by the expression

$$pV = Nm\overline{v^2} \quad (\text{equation 1})$$

This expression leads to the formula

$$p = \frac{1}{3}\rho\langle c^2 \rangle \quad (\text{equation 2})$$

for the pressure p of an ideal gas, where ρ is the density of the gas and $\langle c^2 \rangle$ is the mean-square speed of the molecules.

Explain how each of the following terms in equation 2 is derived from equation 1:

ρ :

.....

$\frac{1}{3}$:

.....

$\langle c^2 \rangle$:

.....

[4]

- (b) An ideal gas has volume, pressure and temperature as shown in Fig. 2.1.

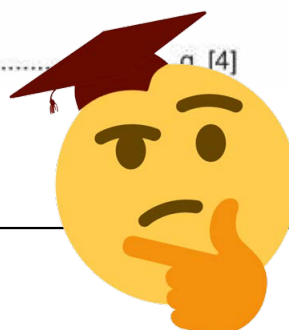
volume $6.0 \times 10^{-3} \text{ m}^3$ pressure $3.0 \times 10^5 \text{ Pa}$ temperature 17°C

Fig. 2.1

The mass of the gas is 20.7 g.

Calculate the mass of one molecule of the gas.

mass = g [4]



13 - (9702/41_Winter_2020_Q2) - Ideal Gases, Temperature

(a) The first law of thermodynamics may be expressed as

$$\Delta U = (+q) + (+w)$$

where ΔU is the increase in internal energy of the system.

State the meaning of:

$+q$

.....

$+w$

.....

[2]

(b) The variation with pressure p of the volume V of a fixed mass of an ideal gas is shown in Fig. 2.1.

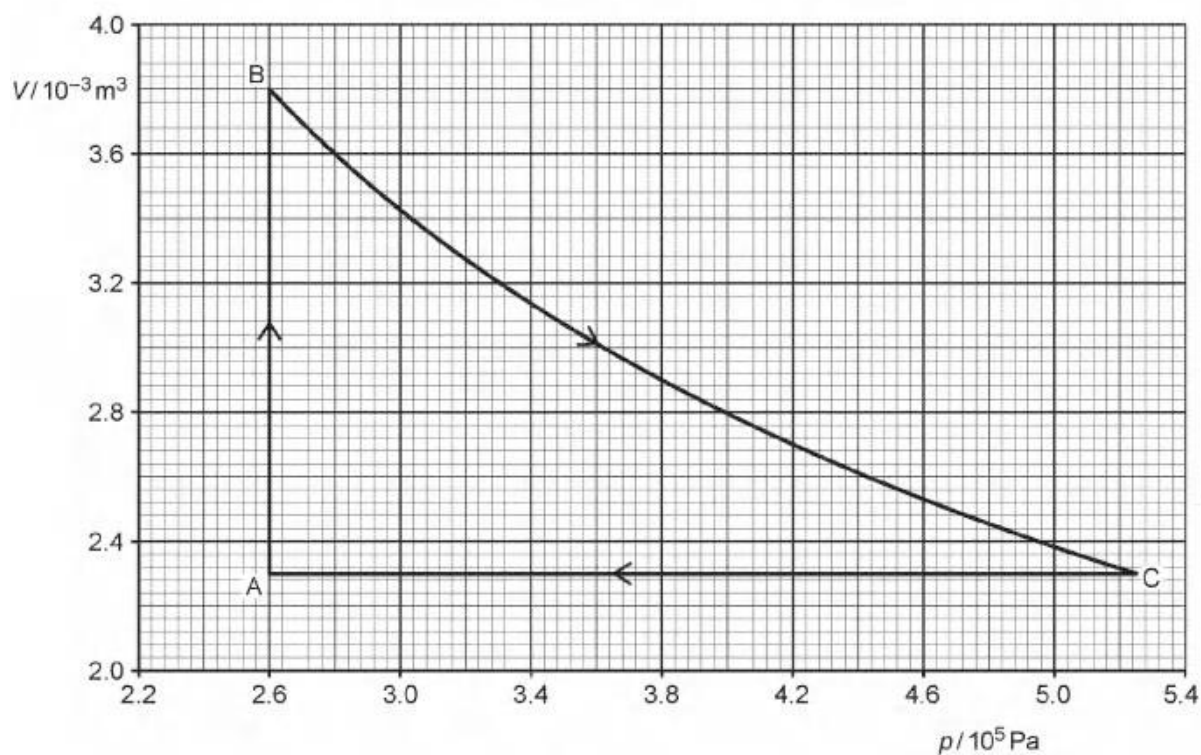
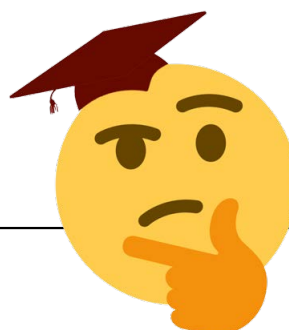


Fig. 2.1

The gas undergoes a cycle of changes A to B to C to A.

During the change A to B, the volume of the gas increases from $2.3 \times 10^{-3} \text{ m}^3$ to $3.8 \times 10^{-3} \text{ m}^3$.



- (i) Show that the magnitude of the work done during the change A to B is 390 J.

[1]

- (ii) State and explain the total change, if any, in the internal energy of the gas during one complete cycle.

.....

 [2]

- (c) During the change A to B, 1370 J of thermal energy is transferred to the gas.

During the change B to C, no thermal energy enters or leaves the gas. The work done on the gas during this change is 550 J.

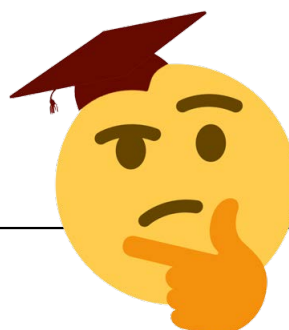
Use these data and the information in (b) to complete Table 2.1.

Table 2.1

change	q/J	w/J	$\Delta U/\text{J}$
A to B			
B to C			
C to A			

[4]

[Total: 9]



14 - (9702/42_Winter_2020_Q2) - *Ideal Gases, Temperature*

- (a) State what is meant by the *internal energy* of a system.

.....
.....
..... [2]

- (b) The atoms of an ideal gas occupy a container of volume $2.30 \times 10^{-3} \text{ m}^3$ at pressure $2.60 \times 10^5 \text{ Pa}$ and temperature 180 K , as illustrated in Fig. 2.1.

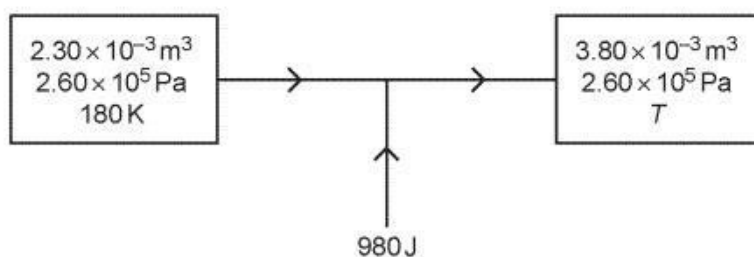


Fig. 2.1

The gas is heated at constant pressure so that its volume becomes $3.80 \times 10^{-3} \text{ m}^3$ at a temperature T .

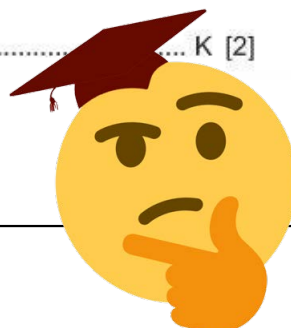
For the fixed mass of gas, calculate:

- (i) the amount of substance, in mol

amount = mol [2]

- (ii) the temperature T , in K.

$T = \dots\dots\dots \text{ K}$ [2]



(c) During the change in (b), the thermal energy supplied to the gas is 980 J.

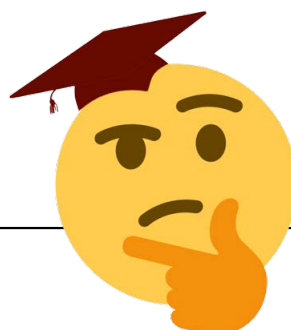
(i) Determine the work done on the gas during this change. Explain your working.

work done = J [3]

(ii) Determine the change ΔU in internal energy of the gas.

$\Delta U =$ J [1]

[Total: 10]



15 - (9702/41_Summer_2021_Q2) - *Ideal Gases*

An ideal gas is contained in a cylinder by means of a movable frictionless piston, as illustrated in Fig. 2.1.

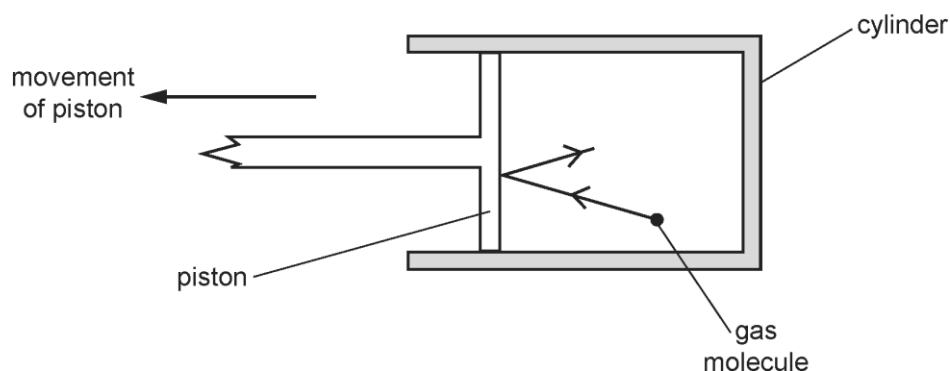


Fig. 2.1

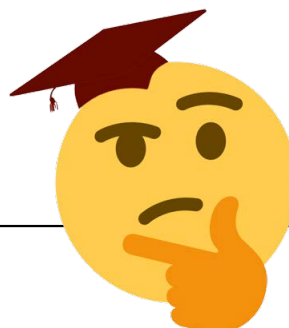
Initially, the gas has a volume of $1.8 \times 10^{-3} \text{ m}^3$ at a pressure of $3.3 \times 10^5 \text{ Pa}$ and a temperature of 310 K .

- (a) Show that the number of gas molecules in the cylinder is 1.4×10^{23} .

[2]

- (b) Use kinetic theory to explain why, when the piston is moved so that the gas expands, this causes a decrease in the temperature of the gas.

.....
.....
.....
..... [3]



- (c) The gas expands so that its volume increases to $2.4 \times 10^{-3} \text{ m}^3$ at a pressure of $2.3 \times 10^5 \text{ Pa}$ and a temperature of 288 K , as shown in Fig. 2.2.

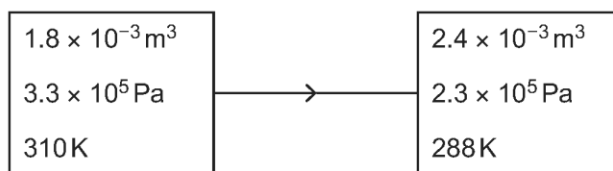


Fig. 2.2

- (i) The average translational kinetic energy E_k of a molecule of an ideal gas is given by

$$E_k = \frac{3}{2} kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

Calculate the increase in internal energy ΔU of the gas during the expansion.

$$\Delta U = \dots\dots\dots \text{ J [3]}$$

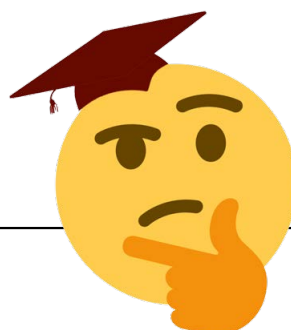
- (ii) The work done by the gas during the expansion is 76 J .

Use your answer in (i) to explain whether thermal energy is transferred to or from the gas during the expansion.

.....

.....

..... [2]



16 - (9702/42_Summer_2021_Q2) - *Ideal Gases, Temperature*

An ideal gas has a volume of $3.1 \times 10^{-3} \text{ m}^3$ at a pressure of $8.5 \times 10^5 \text{ Pa}$ and a temperature of 290 K , as shown in Fig. 2.1.

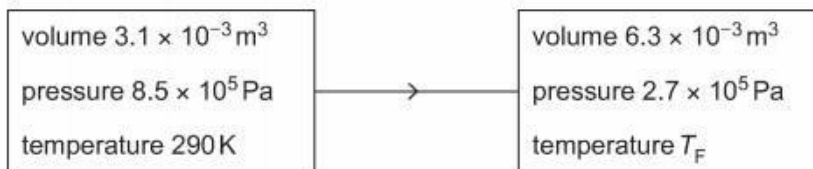


Fig. 2.1

The gas suddenly expands to a volume of $6.3 \times 10^{-3} \text{ m}^3$. During the expansion, no thermal energy is transferred. The final pressure of the gas is $2.7 \times 10^5 \text{ Pa}$ at temperature T_F , as shown in Fig. 2.1.

(a) Show that the number of gas molecules is 6.6×10^{23} .

[3]

(b) (i) Show that the final temperature T_F of the gas is 190 K .

[1]



- (ii) The average translational kinetic energy E_K of a molecule of an ideal gas is given by

$$E_K = \frac{3}{2} kT$$

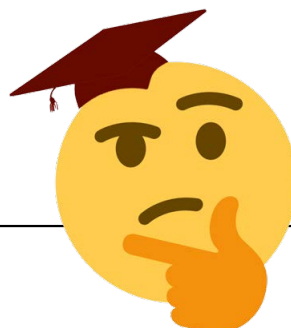
where T is the thermodynamic temperature and k is the Boltzmann constant.

Calculate the increase in internal energy ΔU of the gas.

$$\Delta U = \dots\dots\dots \text{ J [3]}$$

- (c) Use the first law of thermodynamics to explain why the external work w done on the gas during the expansion is equal to the increase in internal energy in (b)(ii).

.....
.....
..... [2]



17 - (9702/42_Winter_2021_Q3) - *Ideal Gases*

- (a) One of the assumptions of the kinetic theory of gases is that all collisions involving molecules of the gas are elastic.

(i) State what is meant by an *elastic* collision.

.....
 [1]

(ii) State **two** other assumptions of the kinetic theory of gases.

1.

 2.
 [2]

- (b) A molecule of an ideal gas has mass m and is contained in a cubic box of side length L . The molecule is moving with velocity u towards the face of the box that is shaded in Fig. 3.1.

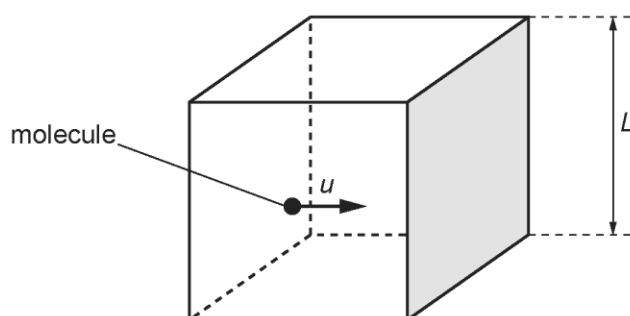


Fig. 3.1

The molecule collides elastically with the shaded face and the face opposite to it alternately.

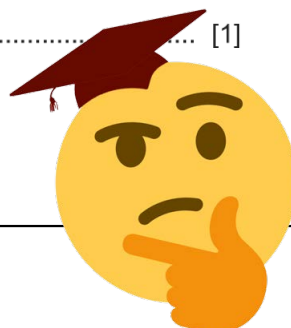
Deduce expressions, in terms of m , u and L , for:

- (i) the magnitude of the change in momentum of the molecule on colliding with a face

change in momentum = [1]

- (ii) the time between consecutive collisions of the molecule with the shaded face

time = [1]



- (iii) the average force exerted by the molecule on the shaded face

force = [1]

- (iv) the pressure on the shaded face if the force in (iii) is exerted over the whole area of the face.

pressure = [1]

- (c) When the model described in (b) is extended to three dimensions, and to a gas containing N molecules, each of mass m , travelling with mean-square speed $\langle c^2 \rangle$, it can be shown that

$$pV = \frac{1}{3}Nm\langle c^2 \rangle$$

where p is the pressure exerted by the gas and V is the volume of the gas.

Use this expression, together with the equation of state of an ideal gas, to show that the average translational kinetic energy E_K of a molecule of an ideal gas is given by

$$E_K = \frac{3}{2}kT$$

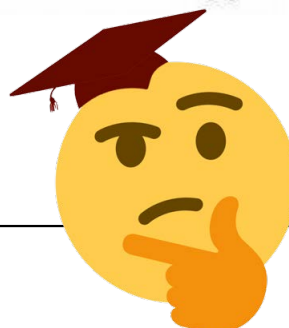
where T is the thermodynamic temperature of the gas and k is the Boltzmann constant.

[2]

- (d) The mass of a hydrogen molecule is 3.34×10^{-27} kg.

Use the expression for E_K in (c) to determine the root-mean-square (r.m.s.) speed of a molecule of hydrogen gas at 25°C .

r.m.s. speed = ms^{-1} [2]



18 - (9702/41_Summer_2022_Q3) - Ideal Gases

A fixed mass of an ideal gas is initially at a temperature of 17°C .
The gas has a volume of 0.24 m^3 and a pressure of $1.2 \times 10^5\text{ Pa}$.

(a) (i) State what is meant by an ideal gas.

.....
.....
..... [2]

(ii) Calculate the amount n of gas.

$n = \dots\dots\dots \text{ mol}$ [2]

(b) The gas undergoes three successive changes, as shown in Fig. 3.1.

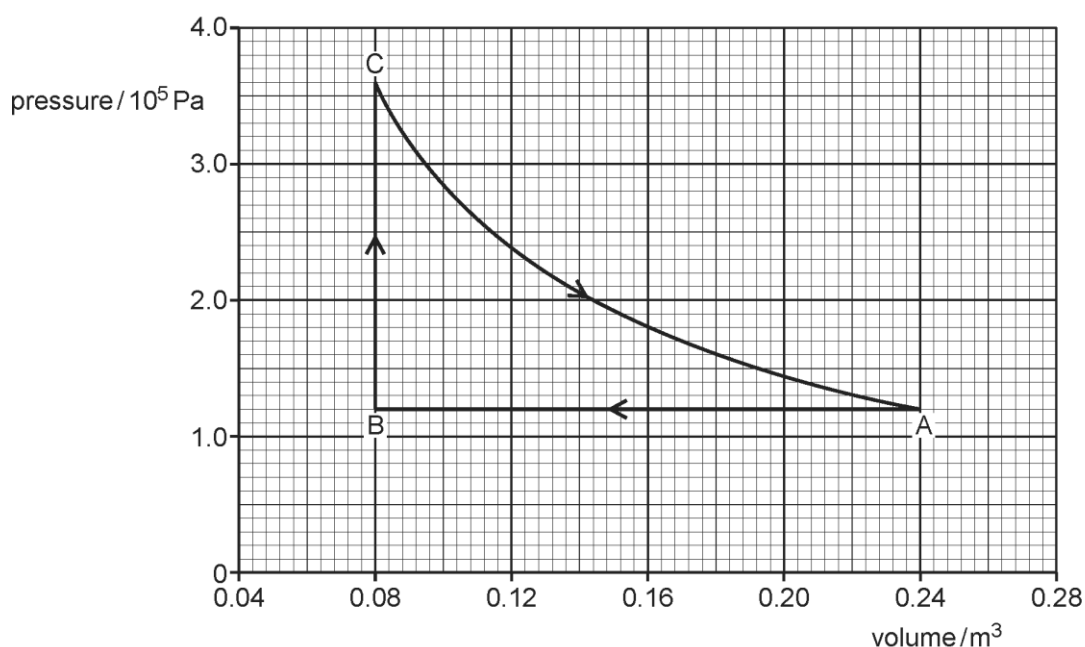
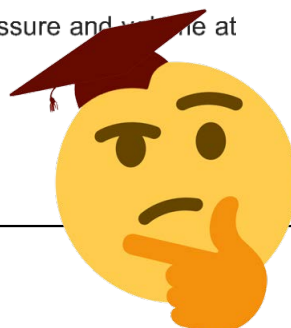


Fig. 3.1

The initial state is represented by point A. The gas is cooled at constant pressure to point B by the removal of 48.0 kJ of thermal energy.

The gas is then heated at constant volume to point C.

Finally, the gas expands at constant temperature back to its original pressure and volume at point A. During this expansion, the gas does 31.6 kJ of work.



- (i) Show that the magnitude of the work done during the change AB is 19.2 kJ.

[2]

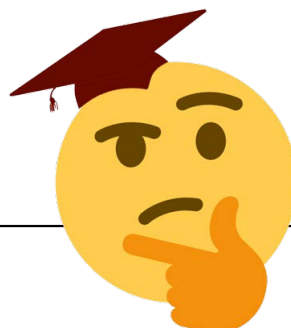
- (ii) Complete Table 3.1 to show the work done on the gas, the thermal energy supplied to the gas and the increase in internal energy of the gas, for each of the changes AB, BC and CA.

Table 3.1

change	work done on gas / kJ	thermal energy supplied to gas / kJ	increase in internal energy of gas / kJ
AB		–48.0	
BC			
CA	–31.6		

[5]

[Total: 11]



19 - (9702/42_Winter_2022_Q3) - *Ideal Gases*

- (a) The equation of state for an ideal gas can be written as

$$pV = NkT.$$

State the meaning of each of the symbols in this equation.

p :

V :

N :

k :

T : [3]

- (b) Use the equation in (a) to show that the average translational kinetic energy E_k of a molecule of an ideal gas is given by

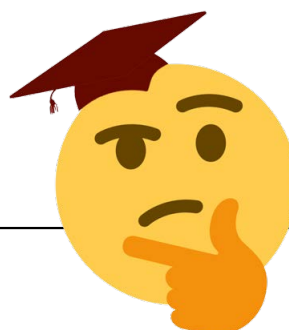
$$E_k = \frac{3}{2}kT.$$

[2]

- (c) The mass of an oxygen molecule is 5.31×10^{-26} kg. Assume that oxygen behaves as an ideal gas.

- (i) Use the equation in (b) to determine the root-mean-square (r.m.s.) speed u of an oxygen molecule at 23°C .

$u = \dots\dots\dots \text{ms}^{-1}$ [3]



- (ii) A fixed mass of oxygen gas at initial pressure P is sealed in a cylindrical container by a movable piston at one end, as shown in Fig. 3.1.

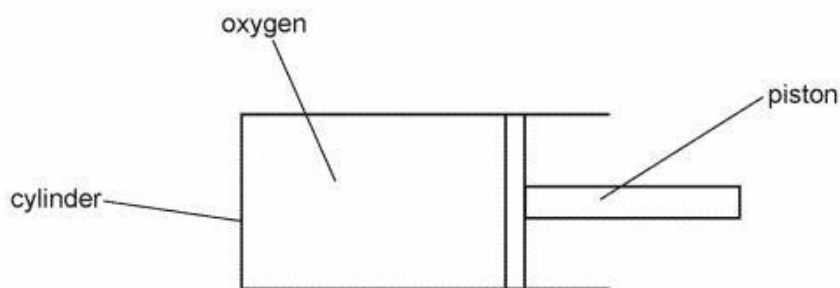


Fig. 3.1

The temperature of the gas is 23°C .

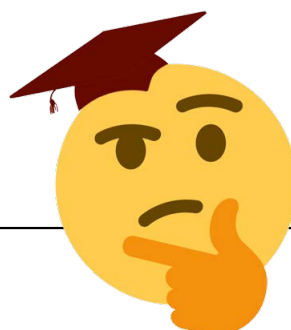
The piston is slowly moved into the cylinder so that the oxygen gas is compressed. At all times, the gas and the container remain in thermal equilibrium with the surroundings.

On Fig. 3.2, sketch the variation with pressure of the r.m.s. speed of the oxygen molecules as the pressure increases.



Fig. 3.2

[2]



20 - (9702/41_Summer_2023_Q4) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

(a) State **two** of the basic assumptions of the kinetic theory of gases.

- 1
-
- 2
-
- [2]

(b) An ideal gas has amount of substance n .

The gas is initially in state X, with pressure $2p$ and volume V .

The gas is cooled at constant volume to state Y, with pressure p .

The gas is then heated at constant pressure to state Z, with volume $2V$.

Finally, the gas returns at constant temperature to state X.

- (i) Determine an expression for the temperature T of the gas in state X, in terms of n , p and V .
Identify any other symbols that you use.

[2]

- (ii) On Fig. 4.1, sketch the variation with volume of pressure for the gas as the gas undergoes the three changes. The state X is labelled. Label states Y and Z.

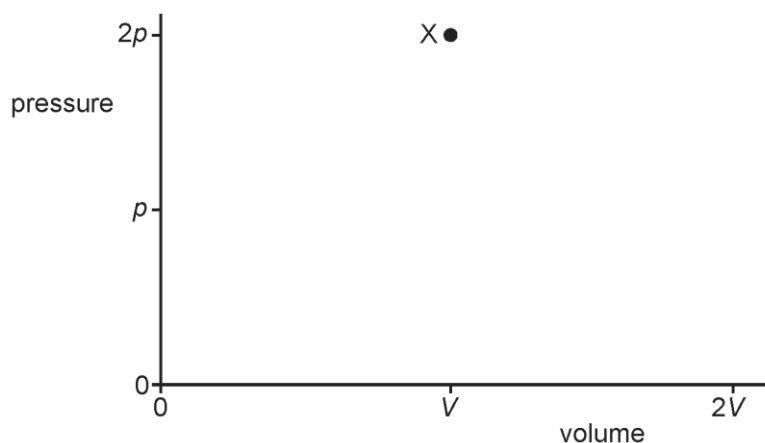
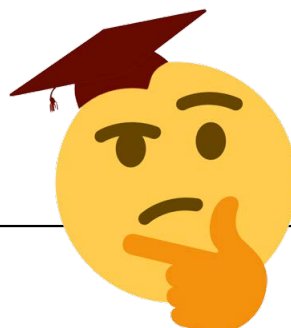


Fig. 4.1

[3]



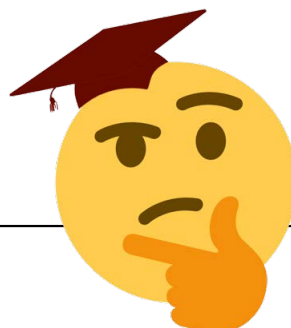
- (iii) During the change of state from Y to Z, the increase in internal energy of the gas is U .
During the change of state from Z to X, the work done on the gas is W .

Complete Table 4.1 to indicate, for each of the three changes of state, the increase in internal energy of the gas, the thermal energy transferred to the gas and the work done on the gas, in terms of p , V , U and W .

Table 4.1

change	increase in internal energy of gas	thermal energy transferred to gas	work done on gas
X to Y			
Y to Z	$+U$		
Z to X			$+W$

[5]



21 - (9702/42_Summer_2023_Q2) - *Ideal Gases*

- (a) (i) State what is meant by an ideal gas.

.....
.....
..... [2]

- (ii) State the temperature, in degrees Celsius, of absolute zero.

temperature = °C [1]

- (b) A sealed vessel contains a mass of 0.0424 kg of an ideal gas at 227 °C.
The pressure of the gas is 1.37×10^5 Pa and the volume of the gas is 0.640 m³.

Calculate:

- (i) the number of molecules of the gas in the vessel

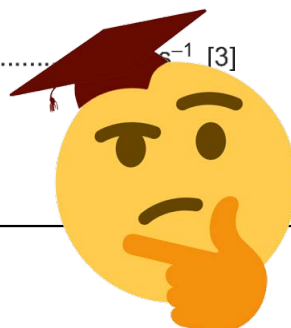
number of molecules = [3]

- (ii) the mass of one molecule of the gas

mass = kg [1]

- (iii) the root-mean-square (r.m.s.) speed v of the molecules of the gas.

$v = \dots\dots\dots \text{m s}^{-1}$ [3]



(c) The gas in (b) is now cooled gradually to absolute zero.

On Fig. 2.1, sketch the variation with thermodynamic temperature T of the r.m.s. speed of the molecules of the gas.

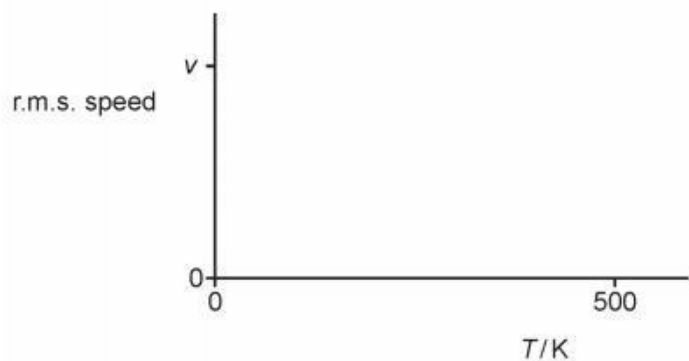
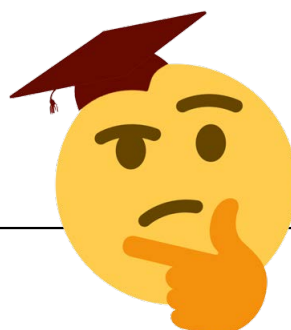


Fig. 2.1

[2]



22 - (9702/42_Summer_2023_Q3) - *Ideal Gases, Temperature*

(a) State the first law of thermodynamics. Identify the meaning of any symbols that you use.

.....

.....

..... [2]

(b) The state of an ideal gas is continuously changed according to the cycle ABCDA shown in Fig. 3.1.

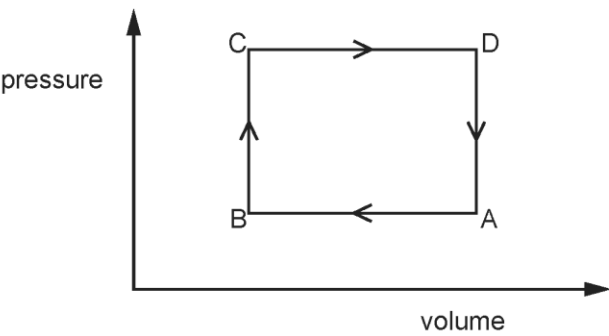


Fig. 3.1

(i) Complete Table 3.1 for the changes A to B and B to C by placing two ticks (✓) in each row.

Table 3.1

change	change in internal energy			work done on gas		
	decrease	no change	increase	negative	zero	positive
A to B						
B to C						

[4]

(ii) Use the first law of thermodynamics to describe and explain the energy transfers associated with one complete cycle ABCDA.

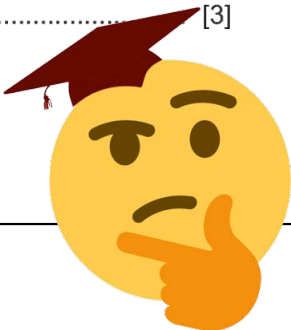
.....

.....

.....

.....

..... [3]



23 – (9702/41_Winter_2023_Q2) – *Ideal Gases*

(a) Define specific heat capacity.

.....
.....
..... [2]

(b) An ideal gas of mass 0.35 kg is heated at a constant pressure of $2.0 \times 10^5 \text{ Pa}$ so that its internal energy increases by 7600 J. During this process, the volume of the gas increases from 0.038 m^3 to 0.063 m^3 and the temperature increases by 56°C .

(i) Show that the magnitude of the work done on the gas is 5000 J.

[1]

(ii) Explain whether the work done on the gas is positive or negative.

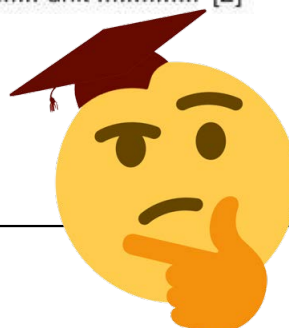
.....
.....
..... [2]

(iii) Determine the magnitude of the thermal energy q transferred to the gas.

$q = \dots\dots\dots \text{ J}$ [2]

(iv) Calculate the specific heat capacity of the gas for this process. Give a unit with your answer.

specific heat capacity = $\dots\dots\dots$ unit $\dots\dots\dots$ [2]



- (c) The gas in (b) is now heated at constant volume rather than at constant pressure. The increase in internal energy of the gas is the same as in (b).

Use the first law of thermodynamics to explain whether the specific heat capacity of the gas for this process is less than, the same as, or greater than the answer in (b)(iv).

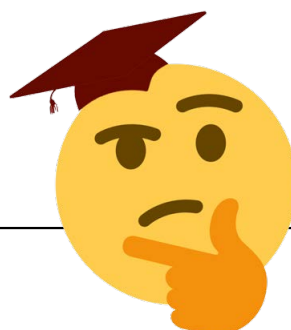
.....

.....

.....

.....

..... [3]



24 – (9702/41_Winter_2023_Q3) – *Ideal Gases, Astronomy & Cosmology*

- (a) The product pV for an ideal gas is given by

$$pV = \frac{1}{3} Nm \langle c^2 \rangle$$

where p is the pressure of the gas and V is the volume of the gas.

- (i) State the meaning of the symbols N , m and $\langle c^2 \rangle$ in this equation.

N :

m :

$\langle c^2 \rangle$: [3]

- (ii) Use the equation of state for an ideal gas to show that the average translational kinetic energy E_k of a molecule of the gas at thermodynamic temperature T is given by

$$E_k = \frac{3}{2} kT.$$

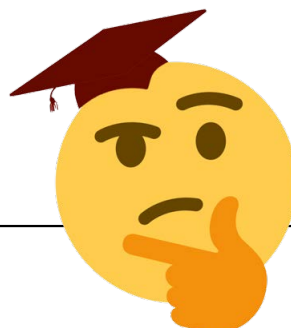
[2]

- (b) The surface of a star consists mainly of a gas that may be assumed to be ideal. The molecules of the gas have a root-mean-square (r.m.s.) speed of 9300 m s^{-1} .

The mass of a molecule of the gas is $3.34 \times 10^{-27} \text{ kg}$.

Determine, to three significant figures, the temperature of the surface of the star.

temperature = K [2]



- (c) The radiant flux intensity of the radiation from the star in (b) is $2.52 \times 10^{-8} \text{ W m}^{-2}$ when observed at a distance of $4.16 \times 10^{16} \text{ m}$ from the star.

(i) Calculate the luminosity of the star. Give a unit with your answer.

luminosity = unit [2]

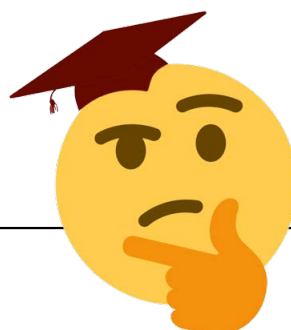
(ii) Determine the radius of the star.

radius = m [2]

- (d) The gas at the surface of a star has a very high pressure.

Use the basic assumptions of the kinetic theory to suggest why, in practice, a gas at the surface of a star is unlikely to behave as an ideal gas.

.....
.....
.....
..... [2]



25 – (9702/42_Winter_2023_Q3) – *Ideal Gases*

(a) State what is meant by the internal energy of a system.

.....
.....
..... [2]

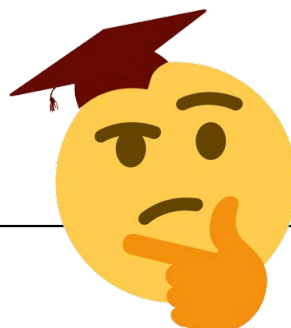
(b) Use the first law of thermodynamics to explain what happens to the internal energy:

(i) of a spring when it is stretched at constant temperature within its elastic limit

.....
.....
.....
.....
..... [3]

(ii) of a sample of water when it evaporates from a rain puddle on a hot day.

.....
.....
.....
.....
..... [3]



1 - (9702/42_Summer_2017_Q2) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

- (a) The pressure p and volume V of an ideal gas are related to the density ρ of the gas by the expression

$$p = \frac{1}{3}\rho\langle c^2 \rangle.$$

- (i) State what is meant by the symbol $\langle c^2 \rangle$.

.....
[1]

- (ii) Use the expression to show that the mean kinetic energy E_K of a gas molecule is given by

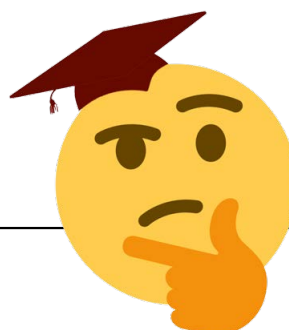
$$E_K = \frac{3}{2} kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

[3]

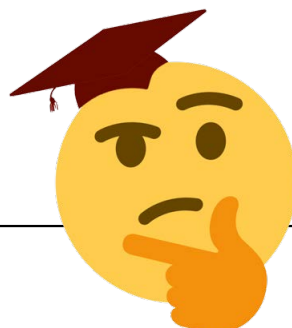
- (b) (i) An ideal gas containing 1.0 mol of molecules is heated at constant volume.
 Use the expression in (a)(ii) to show that the thermal energy required to raise the temperature of the gas by 1.0 K has a value of $\frac{3}{2}R$, where R is the molar gas constant.

[3]



- (ii) Nitrogen may be assumed to be an ideal gas. The molar mass of nitrogen gas is 28 g mol^{-1} . Use the answer in **(b)(i)** to calculate a value for the specific heat capacity, in $\text{J kg}^{-1} \text{K}^{-1}$, at constant volume for nitrogen.

specific heat capacity = $\text{J kg}^{-1} \text{K}^{-1}$ [2]



2 - (9702/41_Winter_2017_Q1) - *Temperature, Thermal Properties Of Materials*

(a) State

(i) what may be deduced from the difference in the temperatures of two objects,

.....
..... [1]

(ii) the basic principle by which temperature is measured.

.....
..... [1]

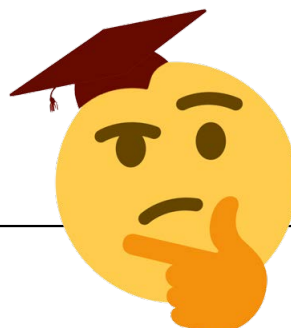
(b) By reference to your answer in (a)(ii), explain why two thermometers may not give the same temperature reading for an object.

.....
.....
..... [2]

(c) A block of aluminium of mass 670g is heated at a constant rate of 95W for 6.0 minutes.
The specific heat capacity of aluminium is $910 \text{ J kg}^{-1} \text{ K}^{-1}$.
The initial temperature of the block is 24°C .

(i) Assuming that no thermal energy is lost to the surroundings, show that the final temperature of the block is 80°C .

[3]



- (ii) In practice, there are energy losses to the surroundings.
The actual variation with time t of the temperature θ of the block is shown in Fig. 1.1.

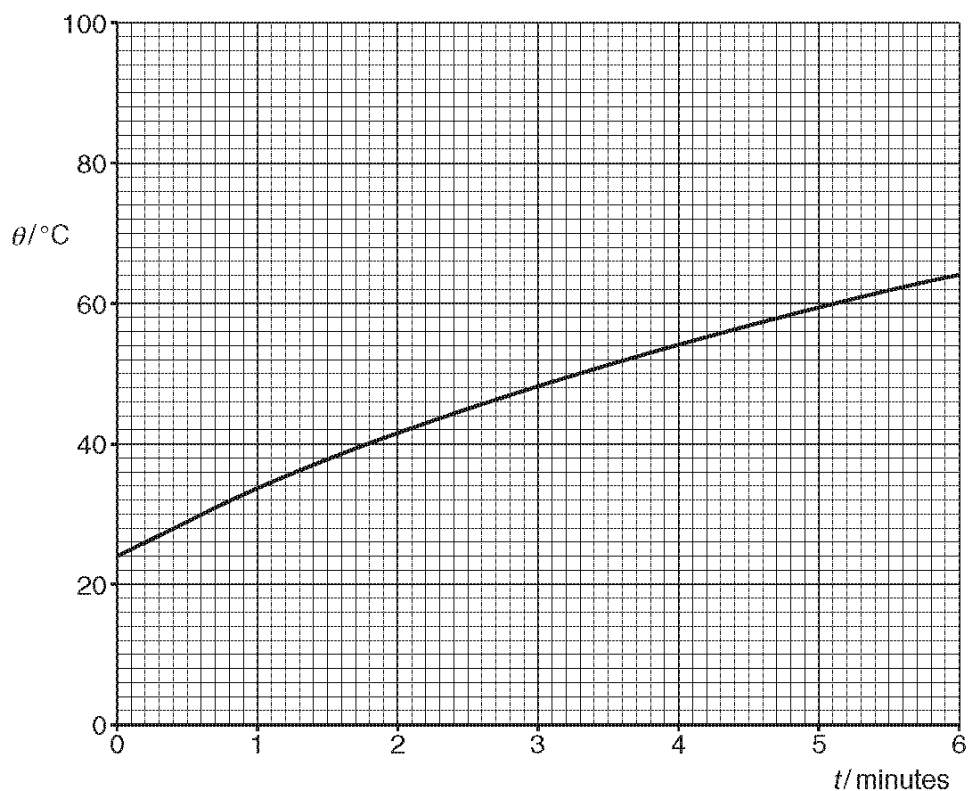
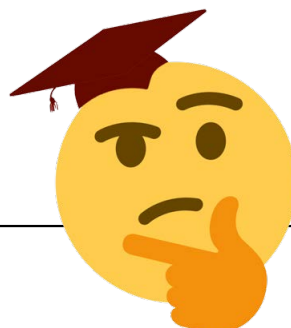


Fig. 1.1

1. Use the information in (i) to draw, on Fig. 1.1, a line to represent the temperature of the block, assuming no energy losses to the surroundings. [1]
2. Using Fig. 1.1, calculate the total energy loss to the surroundings during the heating process.

energy loss = J [2]



3 - (9702/42_Summer_2018_Q3) - *Temperature, Thermal Properties Of Materials*

- (a) During melting, a solid becomes liquid with little or no change in volume.

Use kinetic theory to explain why, during the melting process, thermal energy is required although there is no change in temperature.

.....

.....

.....

.....

.....[3]

- (b) An aluminium can of mass 160 g contains a mass of 330 g of warm water at a temperature of 38 °C, as illustrated in Fig. 3.1.

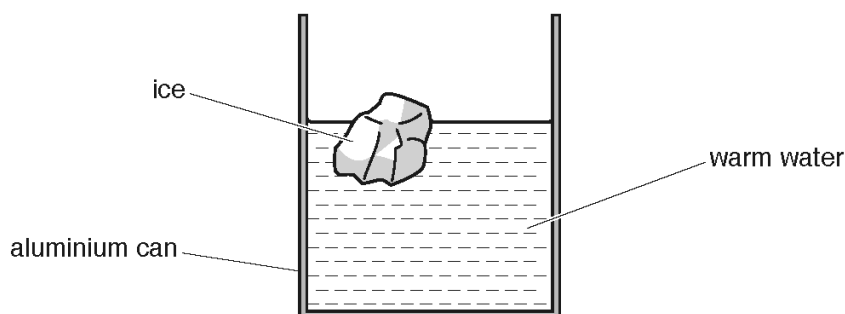


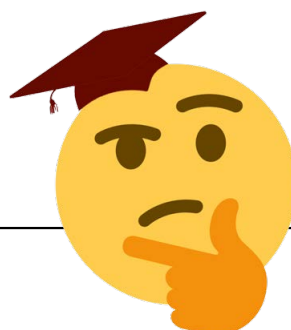
Fig. 3.1

A mass of 48 g of ice at -18°C is taken from a freezer and put in to the water. The ice melts and the final temperature of the can and its contents is 23°C .

Data for the specific heat capacity c of aluminium, ice and water are given in Fig. 3.2.

	$c/\text{Jg}^{-1}\text{K}^{-1}$
aluminium	0.910
ice	2.10
water	4.18

Fig. 3.2



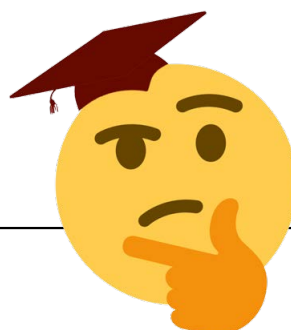
Assuming no exchange of thermal energy with the surroundings,

- (i) show that the loss in thermal energy of the can and the warm water is $2.3 \times 10^4 \text{ J}$,

[2]

- (ii) use the information in (i) to calculate a value L for the specific latent heat of fusion of ice.

$$L = \dots\dots\dots \text{ J g}^{-1} \text{ [2]}$$



4 - (9702/42_Winter_2018_Q2) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

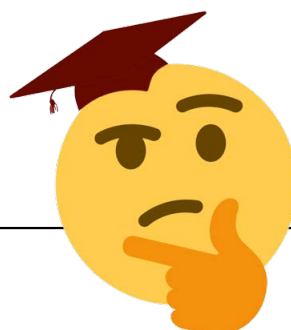
(a) State what is meant by an *ideal gas*.

.....
.....
.....[2]

(b) An ideal gas comprised of single atoms is contained in a cylinder and has a volume of $1.84 \times 10^{-2} \text{ m}^3$ at a pressure of $2.12 \times 10^7 \text{ Pa}$.
The mass of gas in the cylinder is 3.20 kg.

(i) Determine, to three significant figures, the root-mean-square (r.m.s.) speed of the atoms of the gas.

r.m.s. speed = ms^{-1} [3]



(ii) The temperature of the gas in the cylinder is 22°C .

Determine, to three significant figures,

1. the amount, in mol, of the gas,

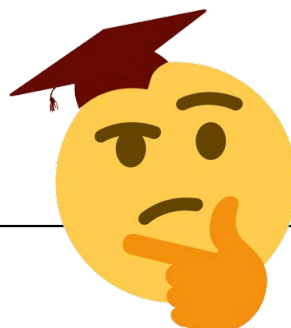
amount = mol [2]

2. the mass of one atom of the gas.

mass = kg [2]

(c) Use your answer in (b)(ii) **part 2** to determine the nucleon number A of an atom of the gas.

A = [1]



5 - (9702/41_Summer_2019_Q2) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

A fixed mass of an ideal gas has volume 210 cm^3 at pressure $3.0 \times 10^5\text{ Pa}$ and temperature 270 K .

The volume of the gas is reduced at constant pressure to 140 cm^3 , as shown in Fig. 2.1.



Fig. 2.1

The final temperature of the gas is T .

(a) Determine:

(i) the amount of gas

amount = mol [3]

(ii) the final temperature T of the gas

$T =$ K [2]

(iii) the external work done on the gas.

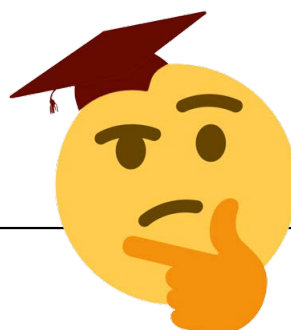
work done =



(b) For this change in volume and temperature of the gas, the thermal energy transferred is 53 J.

Determine ΔU , the change in internal energy of the gas.

$\Delta U = \dots\dots\dots$ J [3]



6 - (9702/41_Winter_2019_Q3) - Temperature, Thermal Properties Of Materials

(a) State what is meant by *specific latent heat*.

.....

.....

..... [2]

(b) A student determines the specific latent heat of vaporisation of a liquid using the apparatus illustrated in Fig. 3.1.

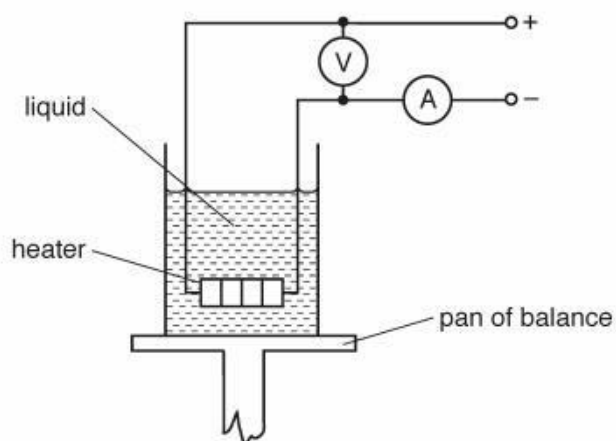
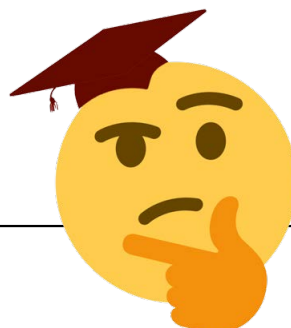


Fig. 3.1

The heater is switched on. When the liquid is boiling at a constant rate, the balance reading is noted at 2.0 minute intervals.

After 10 minutes, the current in the heater is reduced and the balance readings are taken for a further 12 minutes.



The readings of the ammeter and of the voltmeter are given in Fig. 3.2.

	ammeter reading /A	voltmeter reading /V
from time 0 to time 10 minutes	1.2	230
after time 10 minutes	1.0	190

Fig. 3.2

The variation with time of the balance reading is shown in Fig. 3.3.

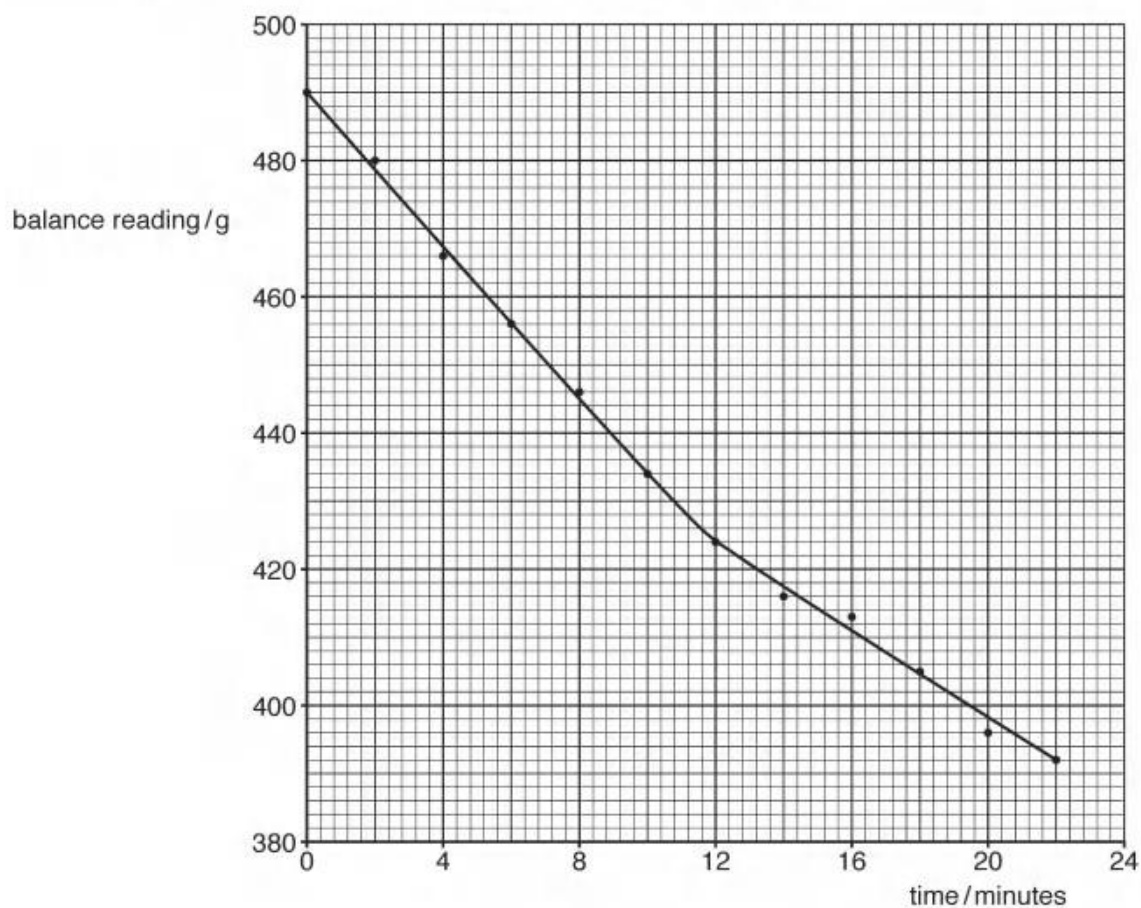
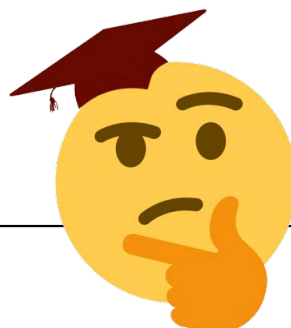


Fig. 3.3



- (i) From time 0 to time 10.0 minutes, the mass of liquid evaporated is 56 g.

Use Fig. 3.3 to determine the mass of liquid evaporated from time 12.0 minutes to time 22.0 minutes.

mass = g [1]

- (ii) Explain why, although the power of the heater is changed, the rate of loss of thermal energy to the surroundings may be assumed to be constant.

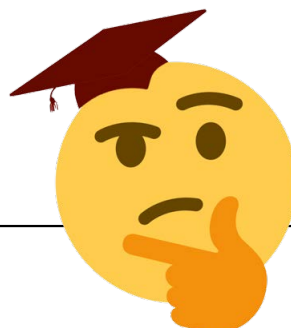
.....
..... [1]

- (iii) Determine a value for the specific latent heat of vaporisation L of the liquid.

$L = \dots\dots\dots \text{Jg}^{-1}$ [4]

- (iv) Calculate the rate at which thermal energy is transferred to the surroundings.

rate = W [2]



7 - (9702/41_Winter_2020_Q2) - *Ideal Gases, Temperature*

- (a) The first law of thermodynamics may be expressed as

$$\Delta U = (+q) + (+w)$$

where ΔU is the increase in internal energy of the system.

State the meaning of:

$+q$

.....

$+w$

.....

[2]

- (b) The variation with pressure p of the volume V of a fixed mass of an ideal gas is shown in Fig. 2.1.

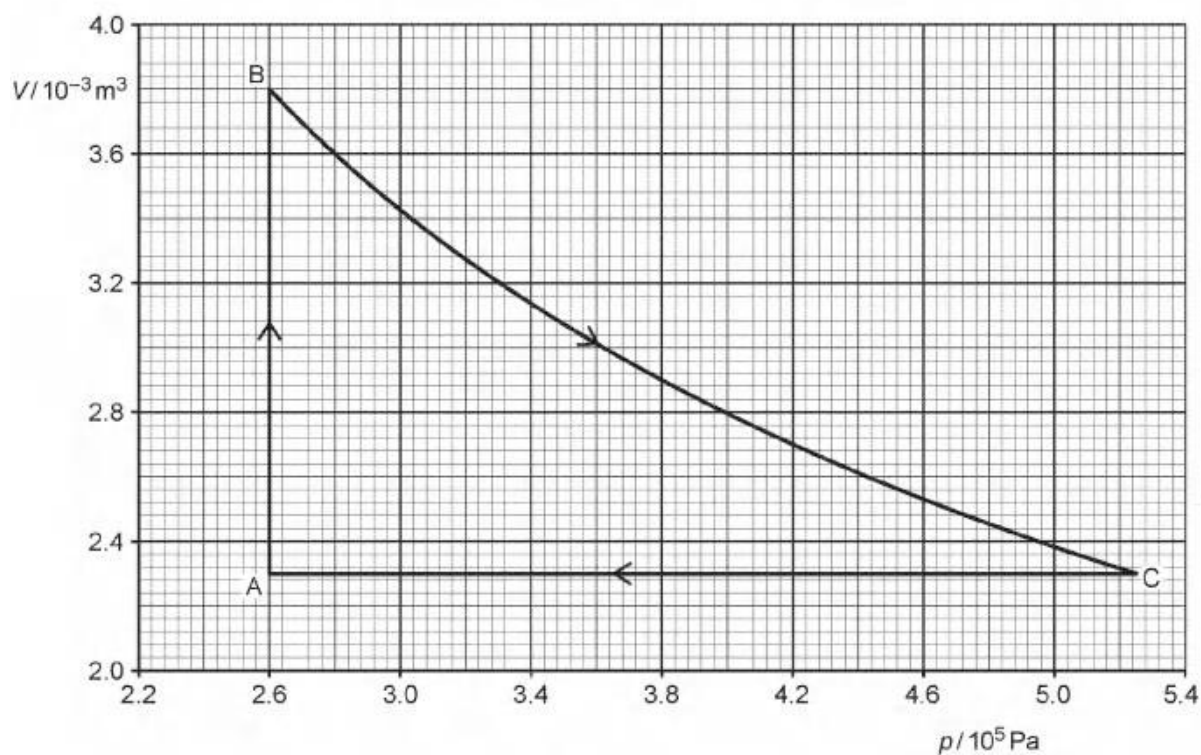
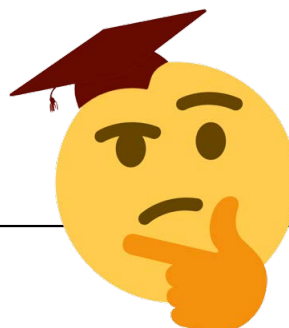


Fig. 2.1

The gas undergoes a cycle of changes A to B to C to A.

During the change A to B, the volume of the gas increases from $2.3 \times 10^{-3} \text{ m}^3$ to $3.8 \times 10^{-3} \text{ m}^3$.



- (i) Show that the magnitude of the work done during the change A to B is 390 J.

[1]

- (ii) State and explain the total change, if any, in the internal energy of the gas during one complete cycle.

.....
.....
..... [2]

- (c) During the change A to B, 1370 J of thermal energy is transferred to the gas.

During the change B to C, no thermal energy enters or leaves the gas. The work done on the gas during this change is 550 J.

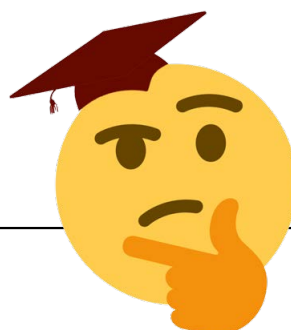
Use these data and the information in (b) to complete Table 2.1.

Table 2.1

change	q/J	w/J	$\Delta U/\text{J}$
A to B			
B to C			
C to A			

[4]

[Total: 9]



8 - (9702/42_Winter_2020_Q2) - *Ideal Gases, Temperature*

- (a) State what is meant by the *internal energy* of a system.

.....
.....
..... [2]

- (b) The atoms of an ideal gas occupy a container of volume $2.30 \times 10^{-3} \text{ m}^3$ at pressure $2.60 \times 10^5 \text{ Pa}$ and temperature 180 K , as illustrated in Fig. 2.1.

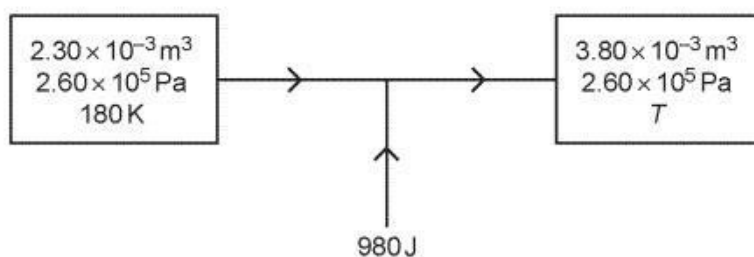


Fig. 2.1

The gas is heated at constant pressure so that its volume becomes $3.80 \times 10^{-3} \text{ m}^3$ at a temperature T .

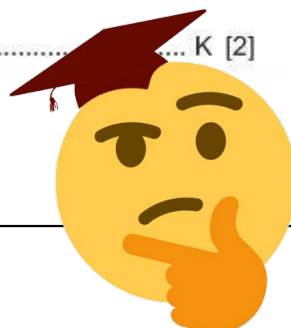
For the fixed mass of gas, calculate:

- (i) the amount of substance, in mol

amount = mol [2]

- (ii) the temperature T , in K.

$T = \dots\dots\dots \text{ K}$ [2]



(c) During the change in (b), the thermal energy supplied to the gas is 980 J.

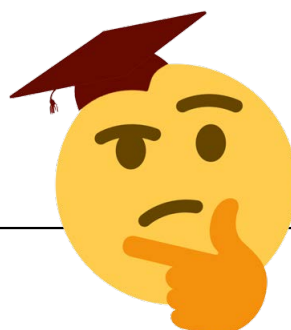
(i) Determine the work done on the gas during this change. Explain your working.

work done = J [3]

(ii) Determine the change ΔU in internal energy of the gas.

$\Delta U =$ J [1]

[Total: 10]



9 - (9702/42_Summer_2021_Q2) - *Ideal Gases, Temperature*

An ideal gas has a volume of $3.1 \times 10^{-3} \text{ m}^3$ at a pressure of $8.5 \times 10^5 \text{ Pa}$ and a temperature of 290 K , as shown in Fig. 2.1.

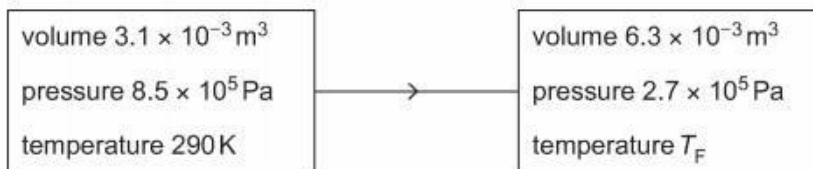


Fig. 2.1

The gas suddenly expands to a volume of $6.3 \times 10^{-3} \text{ m}^3$. During the expansion, no thermal energy is transferred. The final pressure of the gas is $2.7 \times 10^5 \text{ Pa}$ at temperature T_F , as shown in Fig. 2.1.

(a) Show that the number of gas molecules is 6.6×10^{23} .

[3]

(b) (i) Show that the final temperature T_F of the gas is 190 K .

[1]



- (ii) The average translational kinetic energy E_K of a molecule of an ideal gas is given by

$$E_K = \frac{3}{2} kT$$

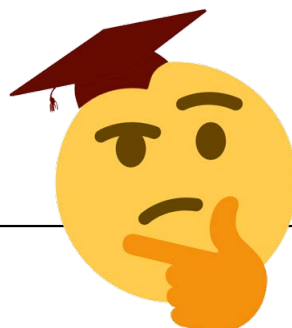
where T is the thermodynamic temperature and k is the Boltzmann constant.

Calculate the increase in internal energy ΔU of the gas.

$$\Delta U = \dots\dots\dots \text{ J [3]}$$

- (c) Use the first law of thermodynamics to explain why the external work w done on the gas during the expansion is equal to the increase in internal energy in (b)(ii).

.....
.....
..... [2]



10 - (9702/42_Summer_2022_Q3) - Temperature

- (a) Define specific latent heat of vaporisation.

.....
.....
..... [2]

- (b) The specific latent heat of vaporisation of water at atmospheric pressure of $1.0 \times 10^5 \text{ Pa}$ is $2.3 \times 10^6 \text{ J kg}^{-1}$. A mass of 0.37 kg of liquid water at 100°C is provided with the thermal energy needed to vaporise all of the water at atmospheric pressure.

- (i) Calculate the thermal energy q supplied to the water.

$q = \dots\dots\dots \text{ J}$ [1]

- (ii) The mass of 1.0 mol of water is 18 g . Assume that water vapour can be considered to behave as an ideal gas.

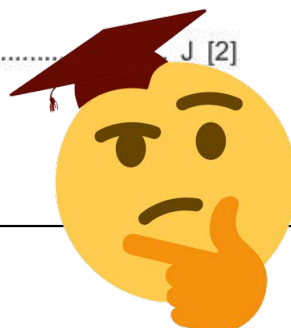
Show that the volume of water vapour produced is 0.64 m^3 .

[3]

- (iii) Assume that the initial volume of the liquid water is negligible compared with the volume of water vapour produced.

Determine the magnitude of the work done by the water in expanding against the atmosphere when it vaporises.

work done = $\dots\dots\dots \text{ J}$ [2]



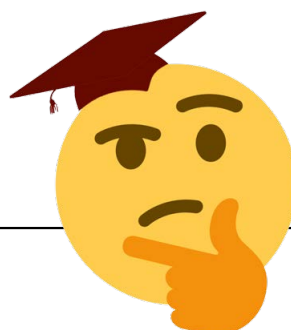
- (iv) Use your answers in (b)(i) and (b)(iii) to determine the increase in internal energy of the water when it vaporises at 100 °C. Explain your reasoning.

increase in internal energy = J [2]

- (c) Use the first law of thermodynamics to suggest, with a reason, how the specific latent heat of vaporisation of water at a pressure greater than atmospheric pressure compares with its value at atmospheric pressure.

.....
.....
..... [2]

[Total: 12]



11 - (9702/43_Winter_2022_Q2) - Temperature

Fig. 2.1 shows a laboratory thermometer that is calibrated to measure temperature in degrees Celsius.

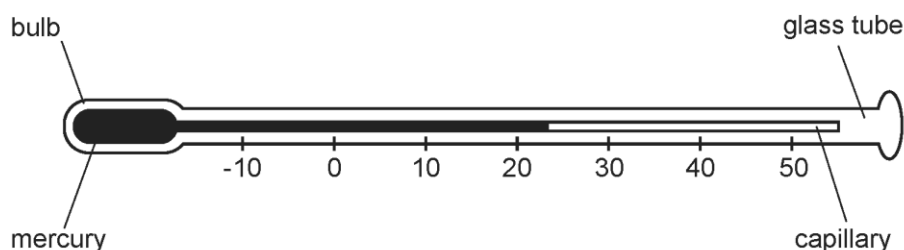


Fig. 2.1

The thermometer makes use of the fact that the density of mercury varies with temperature.

- (a) State **two** other physical properties of materials, apart from the density of a liquid, that can be used for measuring temperature.

1

2 [2]

- (b) The thermometer is initially at 23.0°C , as shown in Fig. 2.1. It is used to measure the temperature of an insulated beaker of water that is at 37.4°C . The bulb of the thermometer is inserted into the water, and the water is stirred until the reading on the thermometer becomes steady.

The mass of water in the beaker is 18.7 g.

The mass of mercury in the thermometer is 6.94 g.

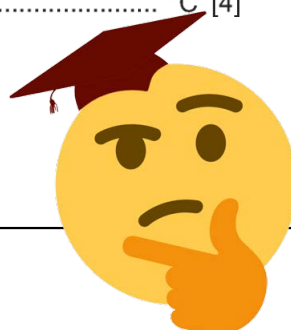
The specific heat capacity of water is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$.

The specific heat capacity of mercury is $0.140 \text{ J g}^{-1} \text{ K}^{-1}$.

The glass of the thermometer and the beaker containing the water can be considered to have negligible heat capacity.

- (i) Calculate, to three significant figures, the final steady temperature indicated by the thermometer in the water.

temperature = $^{\circ}\text{C}$ [4]



- (ii) Suggest **one** change that could be made to the design of the thermometer that would enable it to give a more accurate measurement of temperature.

.....
..... [1]

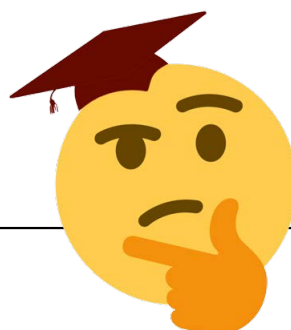
- (c) (i) Explain why the thermometer in Fig. 2.1 does **not** provide a direct measurement of thermodynamic temperature.

.....
.....
..... [2]

- (ii) Thermodynamic temperature T may be determined by the behaviour of a type of substance for which T is proportional to the product of pressure and volume.

State the name of this type of substance.

..... [1]



12 - (9702/41_Summer_2023_Q3) - Forces, Density & Pressure, Temperature

- (a) State the reason why two objects that are at the same temperature are described as being in thermal equilibrium.

.....
 [1]

- (b) Fig. 3.1 shows the variations with temperature of the densities of mercury and of water between 0 °C and 100 °C.

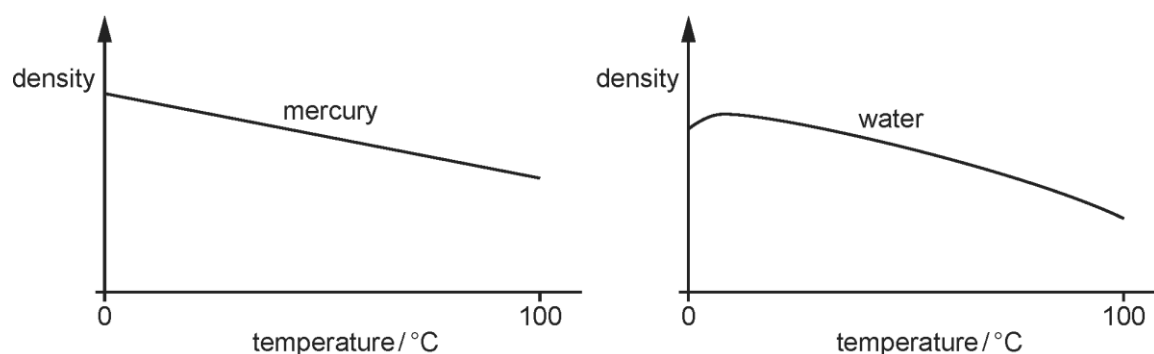


Fig. 3.1

Temperature may be measured using the variation with temperature of the density of a liquid.

Suggest why, for measuring temperature over this temperature range:

- (i) mercury is a suitable liquid

.....
 [1]

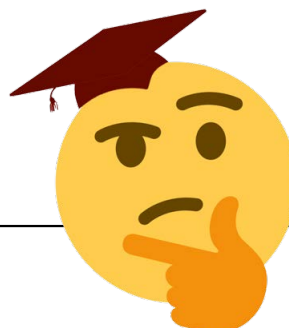
- (ii) water is not a suitable liquid.

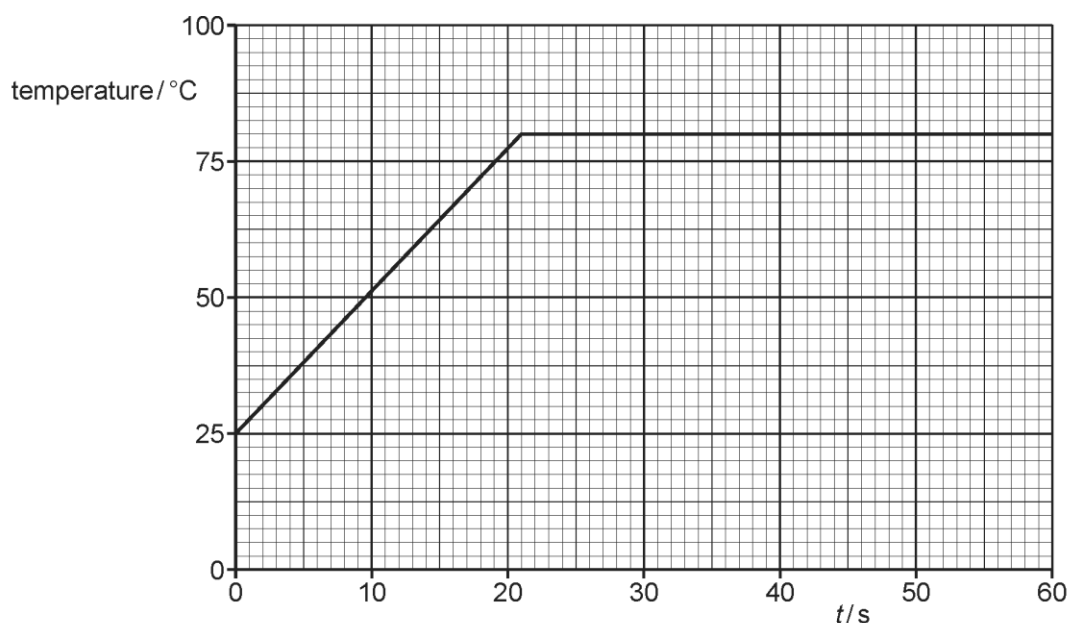
.....

 [2]

- (c) A beaker contains a liquid of mass 120 g. The liquid is supplied with thermal energy at a rate of 810 W. The beaker has a mass of 42 g and a specific heat capacity of $0.84 \text{ J g}^{-1} \text{ K}^{-1}$. The beaker and the liquid are in thermal equilibrium with each other at all times and are insulated from the surroundings.

Fig. 3.2 shows the variation with time t of the temperature of the liquid.



**Fig. 3.2**

- (i) State the boiling temperature, in °C, of the liquid.

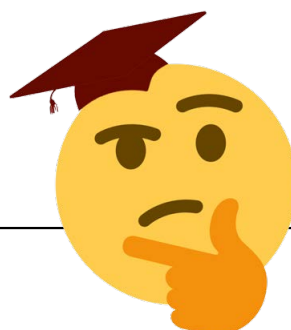
temperature = °C [1]

- (ii) Determine the specific heat capacity, in $\text{J g}^{-1} \text{K}^{-1}$, of the liquid.

specific heat capacity = $\text{J g}^{-1} \text{K}^{-1}$ [4]

- (d) The experiment in (c) is repeated using water instead of the liquid in (c). The mass of liquid used, the power supplied, and the initial temperature are all unchanged.
The specific heat capacity of water is approximately twice that of the liquid in (c).
The boiling temperature of water is 100 °C.

On Fig. 3.2, sketch the variation with time t of the temperature of the water between $t = 0$ and $t = 60$ s. Numerical calculations are not required. [2]



13 - (9702/41_Summer_2023_Q4) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

(a) State **two** of the basic assumptions of the kinetic theory of gases.

1

.....

2

.....

[2]

(b) An ideal gas has amount of substance n .

The gas is initially in state X, with pressure $2p$ and volume V .

The gas is cooled at constant volume to state Y, with pressure p .

The gas is then heated at constant pressure to state Z, with volume $2V$.

Finally, the gas returns at constant temperature to state X.

(i) Determine an expression for the temperature T of the gas in state X, in terms of n , p and V .

Identify any other symbols that you use.

[2]

(ii) On Fig. 4.1, sketch the variation with volume of pressure for the gas as the gas undergoes the three changes. The state X is labelled. Label states Y and Z.

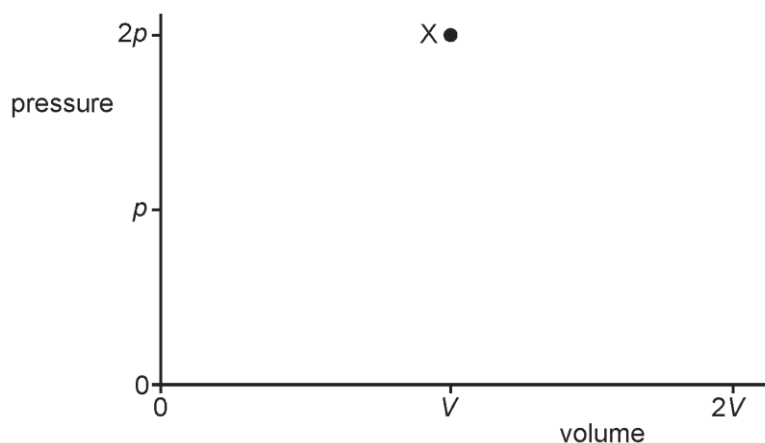
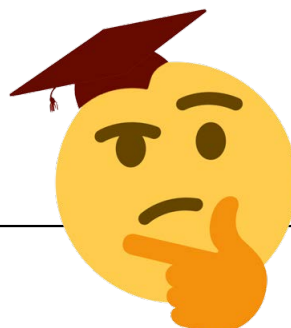


Fig. 4.1

[3]



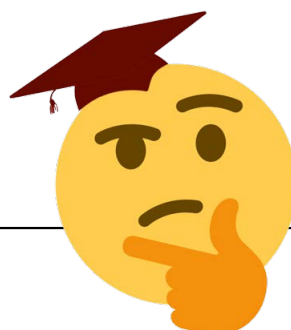
- (iii) During the change of state from Y to Z, the increase in internal energy of the gas is U .
During the change of state from Z to X, the work done on the gas is W .

Complete Table 4.1 to indicate, for each of the three changes of state, the increase in internal energy of the gas, the thermal energy transferred to the gas and the work done on the gas, in terms of p , V , U and W .

Table 4.1

change	increase in internal energy of gas	thermal energy transferred to gas	work done on gas
X to Y			
Y to Z	$+U$		
Z to X			$+W$

[5]



14 - (9702/42_Summer_2023_Q3) - *Ideal Gases, Temperature*

(a) State the first law of thermodynamics. Identify the meaning of any symbols that you use.

.....

.....

..... [2]

(b) The state of an ideal gas is continuously changed according to the cycle ABCDA shown in Fig. 3.1.

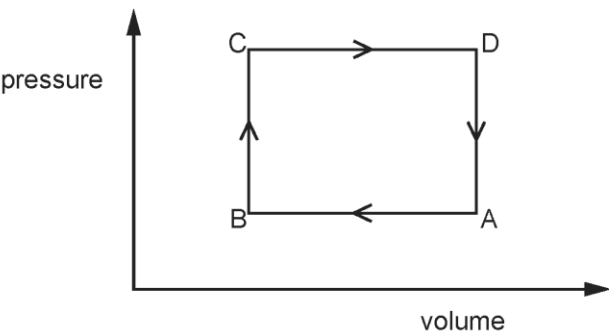


Fig. 3.1

(i) Complete Table 3.1 for the changes A to B and B to C by placing two ticks (✓) in each row.

Table 3.1

change	change in internal energy			work done on gas		
	decrease	no change	increase	negative	zero	positive
A to B						
B to C						

[4]

(ii) Use the first law of thermodynamics to describe and explain the energy transfers associated with one complete cycle ABCDA.

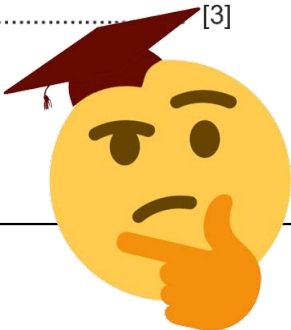
.....

.....

.....

.....

..... [3]



1 - (9702/42_Summer_2017_Q2) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

- (a) The pressure p and volume V of an ideal gas are related to the density ρ of the gas by the expression

$$p = \frac{1}{3}\rho\langle c^2 \rangle.$$

- (i) State what is meant by the symbol $\langle c^2 \rangle$.

.....
[1]

- (ii) Use the expression to show that the mean kinetic energy E_K of a gas molecule is given by

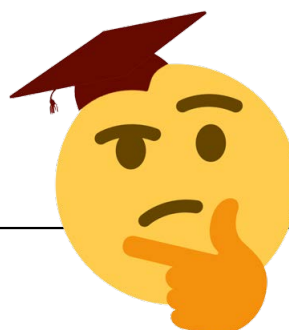
$$E_K = \frac{3}{2} kT$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

[3]

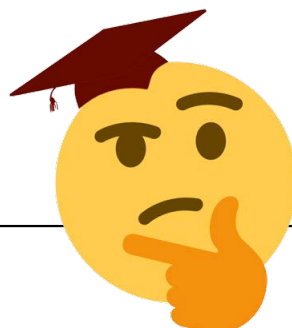
- (b) (i) An ideal gas containing 1.0 mol of molecules is heated at constant volume.
 Use the expression in (a)(ii) to show that the thermal energy required to raise the temperature of the gas by 1.0 K has a value of $\frac{3}{2}R$, where R is the molar gas constant.

[3]



- (ii) Nitrogen may be assumed to be an ideal gas. The molar mass of nitrogen gas is 28 g mol^{-1} . Use the answer in **(b)(i)** to calculate a value for the specific heat capacity, in $\text{J kg}^{-1} \text{K}^{-1}$, at constant volume for nitrogen.

specific heat capacity = $\text{J kg}^{-1} \text{K}^{-1}$ [2]



2 - (9702/41_Winter_2017_Q1) - *Temperature, Thermal Properties Of Materials*

(a) State

(i) what may be deduced from the difference in the temperatures of two objects,

.....
..... [1]

(ii) the basic principle by which temperature is measured.

.....
..... [1]

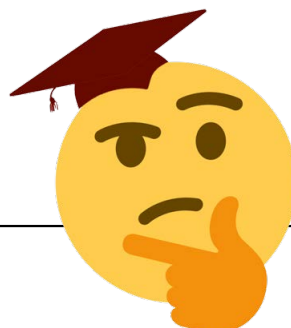
(b) By reference to your answer in (a)(ii), explain why two thermometers may not give the same temperature reading for an object.

.....
.....
..... [2]

(c) A block of aluminium of mass 670g is heated at a constant rate of 95W for 6.0 minutes.
The specific heat capacity of aluminium is $910 \text{ J kg}^{-1} \text{ K}^{-1}$.
The initial temperature of the block is 24°C .

(i) Assuming that no thermal energy is lost to the surroundings, show that the final temperature of the block is 80°C .

[3]



- (ii) In practice, there are energy losses to the surroundings.
The actual variation with time t of the temperature θ of the block is shown in Fig. 1.1.

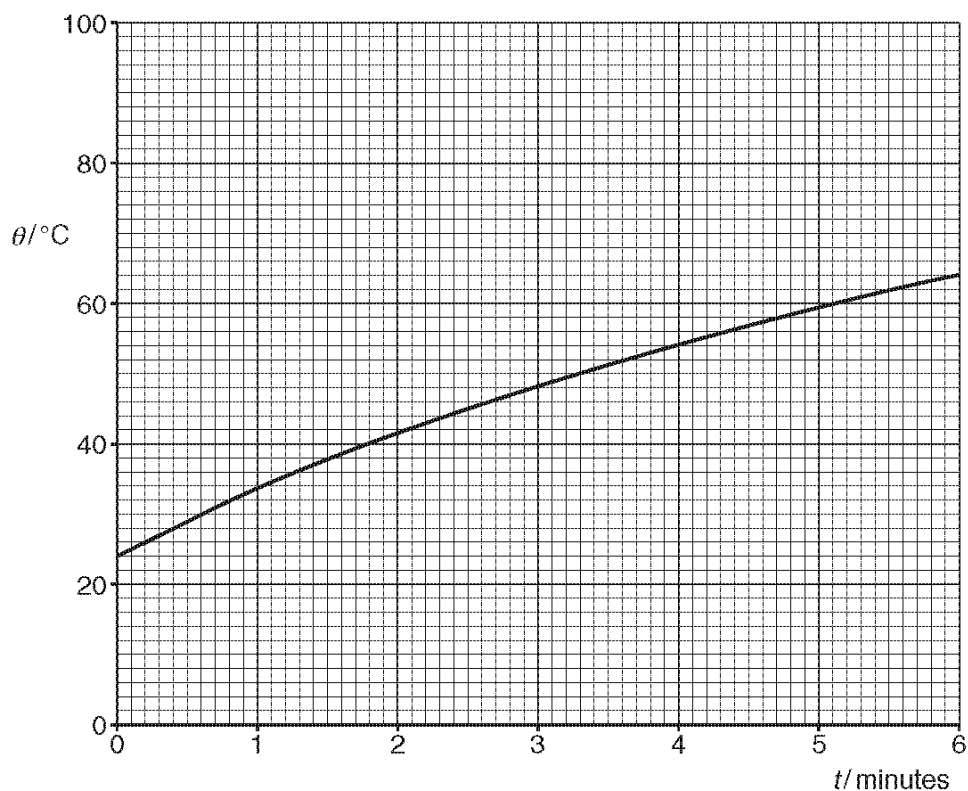
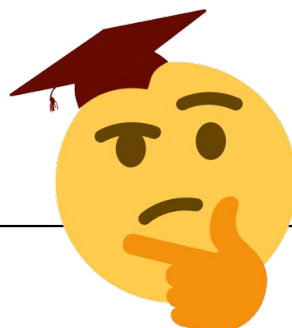


Fig. 1.1

1. Use the information in (i) to draw, on Fig. 1.1, a line to represent the temperature of the block, assuming no energy losses to the surroundings. [1]
2. Using Fig. 1.1, calculate the total energy loss to the surroundings during the heating process.

energy loss = J [2]



3 - (9702/42_Winter_2017_Q2) - Thermal Properties Of Materials

(a) State what is meant by *specific latent heat*.

.....

.....

.....[2]

(b) A beaker of boiling water is placed on the pan of a balance, as illustrated in Fig. 2.1.

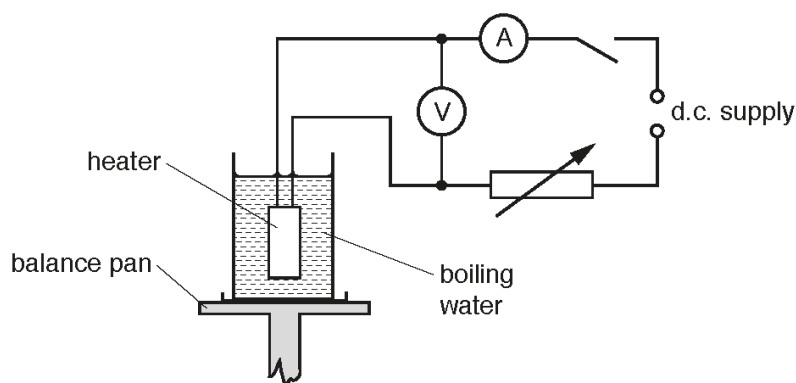


Fig. 2.1

The water is maintained at its boiling point by means of a heater.
 The change M in the balance reading in 300 s is determined for two different input powers to the heater.
 The results are shown in Fig. 2.2.

voltmeter reading / V	ammeter reading / A	M/g
11.5	5.2	5.0
14.2	6.4	9.1

Fig. 2.2

(i) Energy is supplied continuously by the heater.
 State where, in this experiment,

1. external work is done,

.....

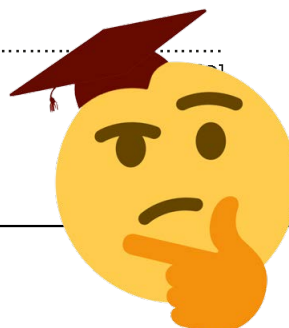
.....

2. internal energy increases. Explain your answer.

.....

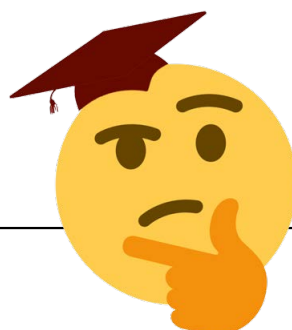
.....

.....



(ii) Use data in Fig. 2.2 to determine the specific latent heat of vaporisation of water.

specific latent heat = J g^{-1} [3]



4 - (9702/42_Summer_2018_Q2) - *Ideal Gases, Thermal Properties Of Materials*

- (a) Use one of the assumptions of the kinetic theory of gases to explain why the potential energy of the molecules of an ideal gas is zero.

.....
[1]

- (b) The average translational kinetic energy E_K of a molecule of an ideal gas is given by the expression

$$E_K = \frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$$

where m is the mass of a molecule and k is the Boltzmann constant.

State the meaning of the symbol

- (i) $\langle c^2 \rangle$,

.....[1]

- (ii) T .

.....[1]

- (c) A cylinder of constant volume $4.7 \times 10^4 \text{ cm}^3$ contains an ideal gas at pressure $2.6 \times 10^5 \text{ Pa}$ and temperature 173°C .

The gas is heated. The thermal energy transferred to the gas is 2900 J . The final temperature and pressure of the gas are T and p , as illustrated in Fig. 2.1.

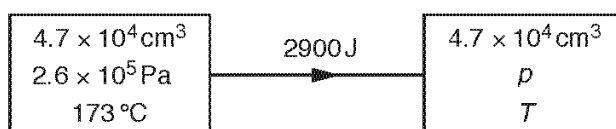
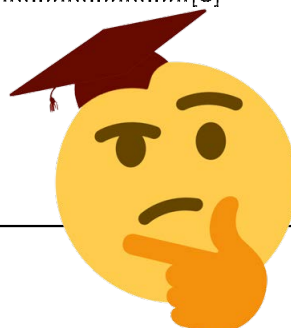


Fig. 2.1

- (i) Calculate

1. the number N of molecules in the cylinder,

$N =$ [3]

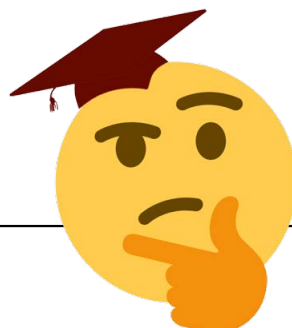


2. the increase in average kinetic energy of a molecule during the heating process.

increase = J [1]

- (ii) Use your answer in (i) **part 2** to determine the final temperature T , in kelvin, of the gas in the cylinder.

$T =$ K [3]



5 - (9702/42_Summer_2018_Q3) - *Temperature, Thermal Properties Of Materials*

- (a) During melting, a solid becomes liquid with little or no change in volume.

Use kinetic theory to explain why, during the melting process, thermal energy is required although there is no change in temperature.

.....

.....

.....

.....

.....[3]

- (b) An aluminium can of mass 160 g contains a mass of 330 g of warm water at a temperature of 38 °C, as illustrated in Fig. 3.1.

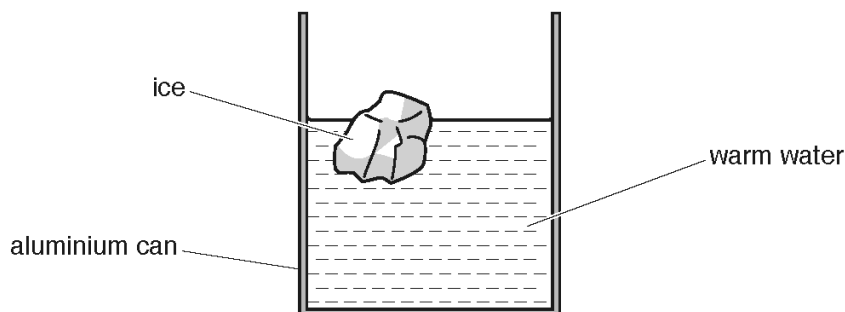


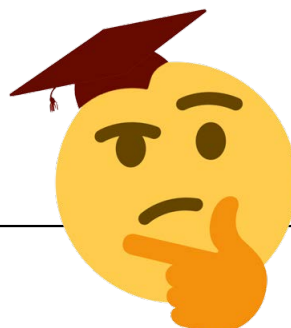
Fig. 3.1

A mass of 48 g of ice at -18°C is taken from a freezer and put in to the water. The ice melts and the final temperature of the can and its contents is 23°C .

Data for the specific heat capacity c of aluminium, ice and water are given in Fig. 3.2.

	$c/\text{Jg}^{-1}\text{K}^{-1}$
aluminium	0.910
ice	2.10
water	4.18

Fig. 3.2



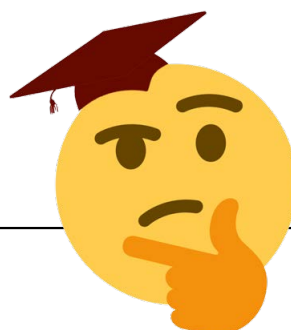
Assuming no exchange of thermal energy with the surroundings,

- (i) show that the loss in thermal energy of the can and the warm water is $2.3 \times 10^4 \text{ J}$,

[2]

- (ii) use the information in (i) to calculate a value L for the specific latent heat of fusion of ice.

$$L = \dots\dots\dots \text{ J g}^{-1} \text{ [2]}$$



6 - (9702/41_Winter_2018_Q2) - *Ideal Gases, Thermal Properties Of Materials*

(a) State what is meant by the *internal energy* of a system.

.....

.....

.....

.....[2]

(b) An ideal gas undergoes a cycle of changes as shown in Fig. 2.1.

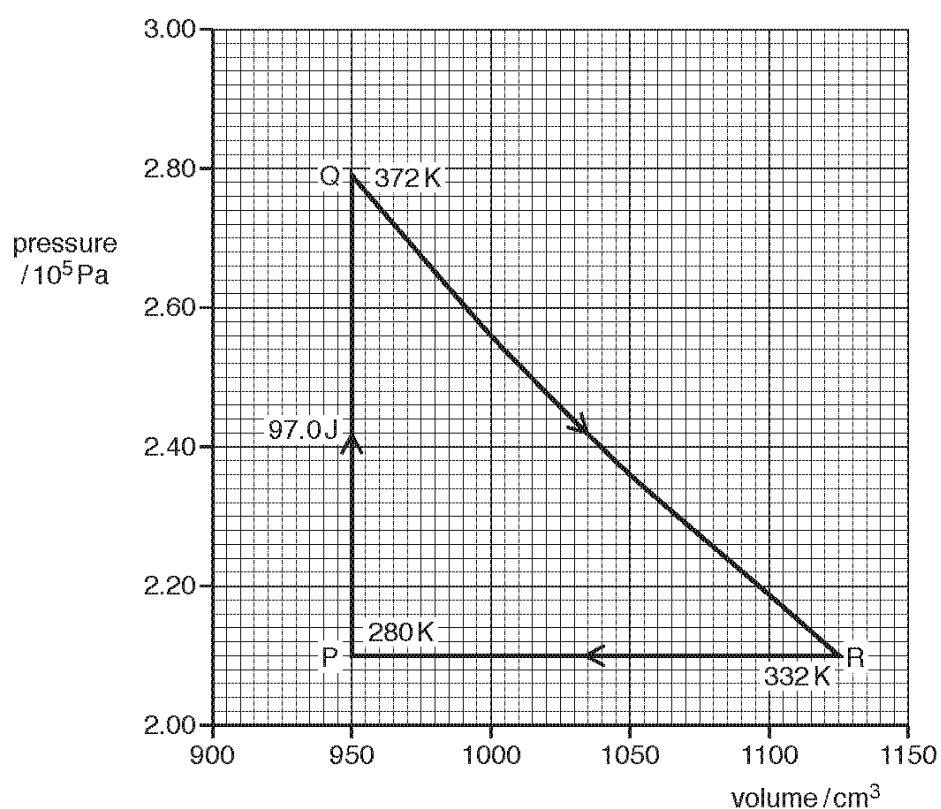
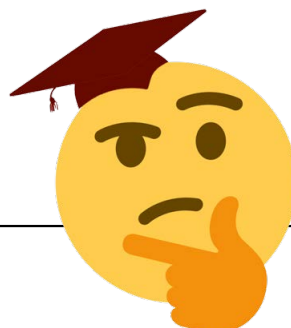


Fig. 2.1

At point P, the gas has volume 950 cm^3 , pressure $2.10 \times 10^5\text{ Pa}$ and temperature 280 K .

The gas is heated at constant volume and 97.0 J of thermal energy is transferred to the gas. Its pressure and temperature change so that the gas is at point Q on Fig. 2.1.

The gas then undergoes the change from point Q to point R and then from point R back to point P, as shown on Fig. 2.1.



Some energy changes that take place during the cycle PQRP are shown in Fig. 2.2.

	change $P \rightarrow Q$	change $Q \rightarrow R$	change $R \rightarrow P$
thermal energy transferred to gas / J	+97.0	0	.....
work done on gas / J	.....	–42.5	+37.0
increase in internal energy of gas / J	.....	.....	.....

Fig. 2.2

- (i) State the total change in internal energy of the gas during the complete cycle PQRP. Explain your answer.

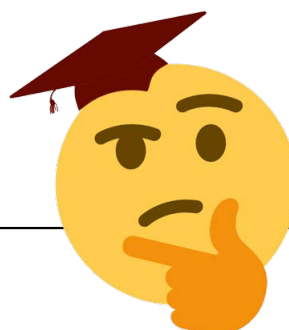
.....

[2]

- (ii) On Fig. 2.2, complete the energy changes for the gas during

1. the change $P \rightarrow Q$,
2. the change $Q \rightarrow R$,
3. the change $R \rightarrow P$.

[5]



7 - (9702/42_Winter_2018_Q2) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

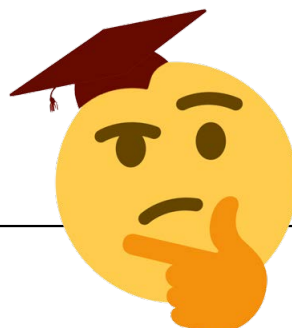
(a) State what is meant by an *ideal gas*.

.....
.....
.....[2]

(b) An ideal gas comprised of single atoms is contained in a cylinder and has a volume of $1.84 \times 10^{-2} \text{ m}^3$ at a pressure of $2.12 \times 10^7 \text{ Pa}$.
The mass of gas in the cylinder is 3.20 kg.

(i) Determine, to three significant figures, the root-mean-square (r.m.s.) speed of the atoms of the gas.

r.m.s. speed = ms^{-1} [3]



(ii) The temperature of the gas in the cylinder is 22°C .

Determine, to three significant figures,

1. the amount, in mol, of the gas,

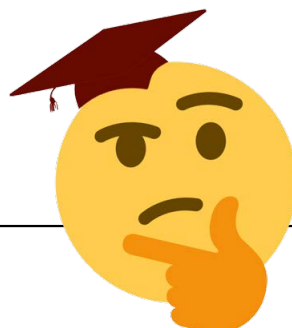
amount = mol [2]

2. the mass of one atom of the gas.

mass = kg [2]

(c) Use your answer in (b)(ii) **part 2** to determine the nucleon number A of an atom of the gas.

$A =$ [1]



8 - (9702/42_Winter_2018_Q3) - Thermal Properties Of Materials

(a) Define *specific latent heat of fusion*.

.....

[2]

(b) A student sets up the apparatus shown in Fig. 3.1 in order to investigate the melting of ice.

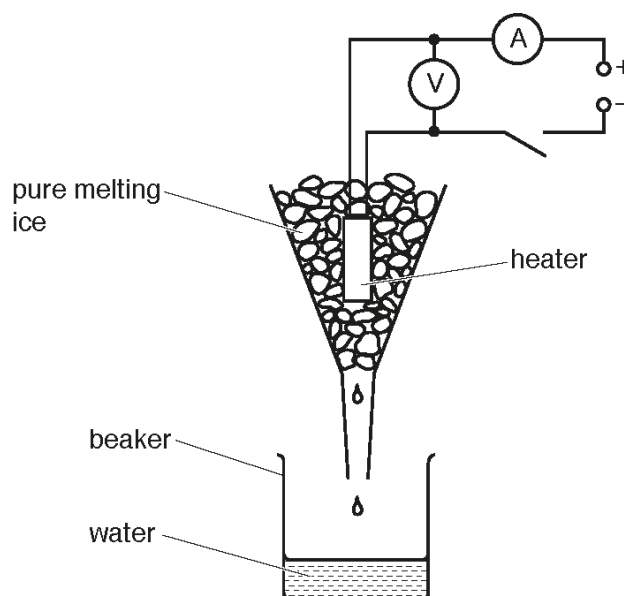


Fig. 3.1

The heater is switched on.

When the pure ice is melting at a constant rate, the data shown in Fig. 3.2 are collected.

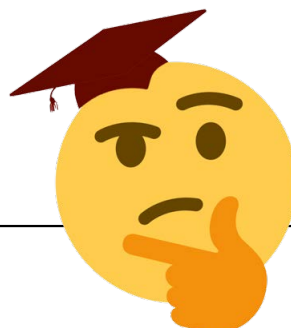
voltmeter reading /V	ammeter reading /A	initial mass of beaker plus water /g	final mass of beaker plus water /g	time of collection /minutes
12.8	4.60	121.5	185.0	5.00

Fig. 3.2

The specific latent heat of fusion of ice is 332 J g^{-1} .

(i) State what is observed by the student that shows that the ice is melting at a constant rate.

.....
[1]



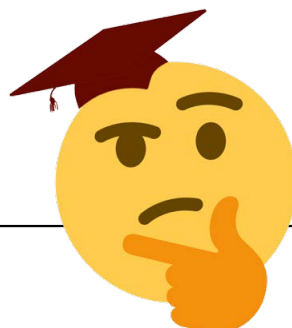
(II) Use the data in Fig. 3.2 to determine the rate at which

1. thermal energy is transferred to the melting ice,

rate = W

2. thermal energy is gained from the surroundings.

rate = W
[4]



9 - (9702/41_Summer_2019_Q2) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

A fixed mass of an ideal gas has volume 210 cm^3 at pressure $3.0 \times 10^5\text{ Pa}$ and temperature 270 K .

The volume of the gas is reduced at constant pressure to 140 cm^3 , as shown in Fig. 2.1.



Fig. 2.1

The final temperature of the gas is T .

(a) Determine:

(i) the amount of gas

amount = mol [3]

(ii) the final temperature T of the gas

$T =$ K [2]

(iii) the external work done on the gas.

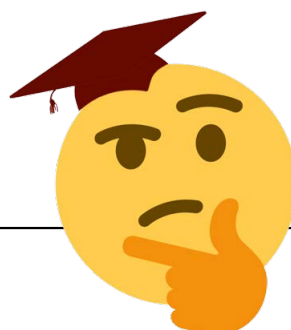
work done = J [2]



(b) For this change in volume and temperature of the gas, the thermal energy transferred is 53 J.

Determine ΔU , the change in internal energy of the gas.

$\Delta U = \dots\dots\dots$ J [3]



10 - (9702/42_Summer_2019_Q2) - *Ideal Gases, Thermal Properties Of Materials*

(a) The first law of thermodynamics may be expressed in the form

$$\Delta U = q + w.$$

(i) State, for a system, what is meant by:

1. $+q$

.....
.....

2. $+w$.

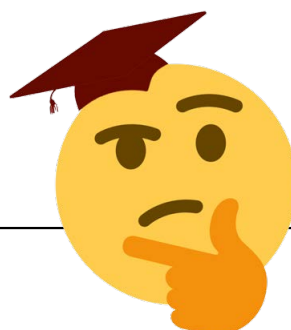
.....
.....

[2]

(ii) State what is represented by a negative value of ΔU .

.....
.....

[1]



(b) An ideal gas, sealed in a container, undergoes the cycle of changes shown in Fig. 2.1.

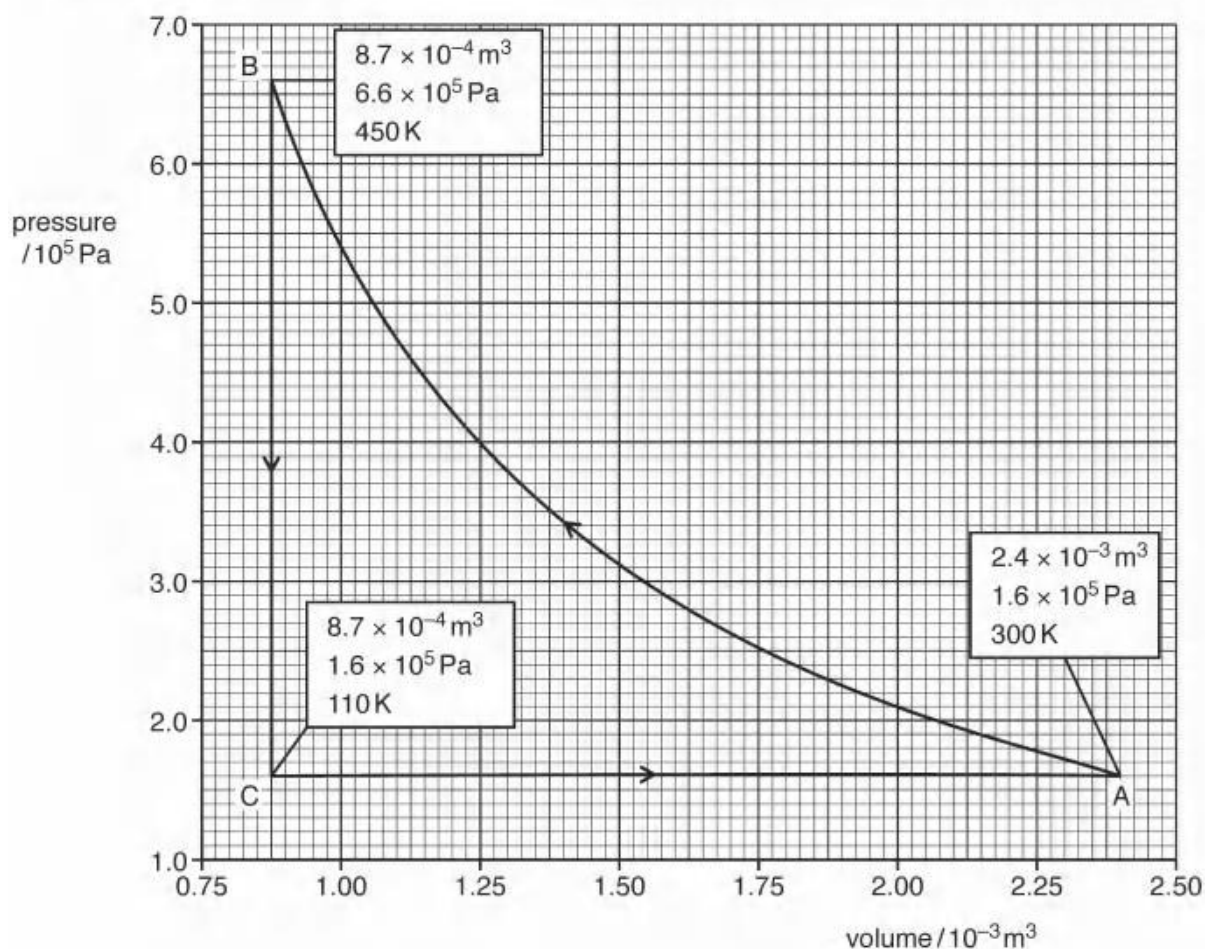


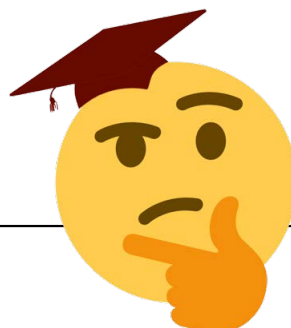
Fig. 2.1

At point A, the gas has volume $2.4 \times 10^{-3} \text{ m}^3$, pressure $1.6 \times 10^5 \text{ Pa}$ and temperature 300 K .

The gas is compressed suddenly so that no thermal energy enters or leaves the gas during the compression. The amount of work done is 480 J so that, at point B, the gas has volume $8.7 \times 10^{-4} \text{ m}^3$, pressure $6.6 \times 10^5 \text{ Pa}$ and temperature 450 K .

The gas is now cooled at constant volume so that, between points B and C, 1100 J of thermal energy is transferred. At point C, the gas has pressure $1.6 \times 10^5 \text{ Pa}$ and temperature 110 K .

Finally, the gas is returned to point A.



- (i) State and explain the total change in internal energy of the gas for one complete cycle ABCA.

.....

[2]

- (ii) Calculate the external work done on the gas during the expansion from point C to point A.

work done = J [2]

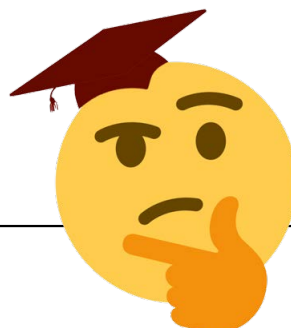
- (iii) Complete Fig. 2.2 for the changes from:

1. point A to point B
2. point B to point C
3. point C to point A.

change	+q/J	+w/J	$\Delta U/J$
A → B			
B → C			
C → A			

Fig. 2.2

[4]



11 - (9702/42_Winter_2019_Q2) - *Ideal Gases, Thermal Properties Of Materials*

- (a) Smoke particles are suspended in still air. Brownian motion of the smoke particles is seen through a microscope.

Describe:

- (i) what is seen through the microscope

.....
..... [1]

- (ii) how Brownian motion provides evidence for the nature of the movement of gas molecules.

.....
.....
..... [2]

- (b) A fixed mass of an ideal gas has volume $2.40 \times 10^3 \text{ cm}^3$ at pressure $3.51 \times 10^5 \text{ Pa}$ and temperature 290 K. The gas is heated at constant volume until the temperature is 310 K at pressure $3.75 \times 10^5 \text{ Pa}$, as illustrated in Fig. 2.1.

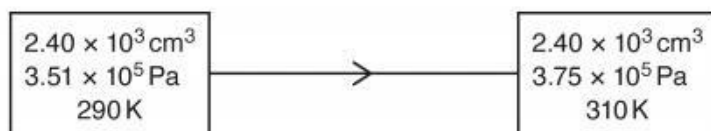


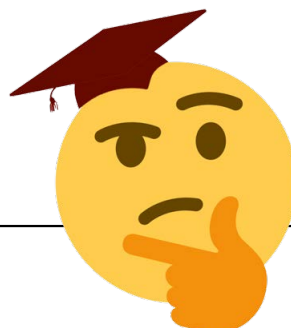
Fig. 2.1

The quantity of thermal energy required to raise the temperature of 1.00 mol of the gas by 1.00 K at constant volume is 12.5 J.

Calculate, to three significant figures:

- (i) the amount, in mol, of the gas

amount = mol [3]



- (ii) the thermal energy transfer during the change.

energy transfer = J [2]

- (c) For the change in the gas in (b), state:

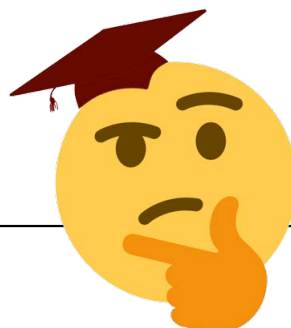
- (i) the quantity of external work done on the gas

work done = J [1]

- (ii) the change in internal energy, with the direction of this change.

change = J

direction [2]



12 - (9702/41_Winter_2019_Q3) - Temperature, Thermal Properties Of Materials

(a) State what is meant by *specific latent heat*.

.....

.....

..... [2]

(b) A student determines the specific latent heat of vaporisation of a liquid using the apparatus illustrated in Fig. 3.1.

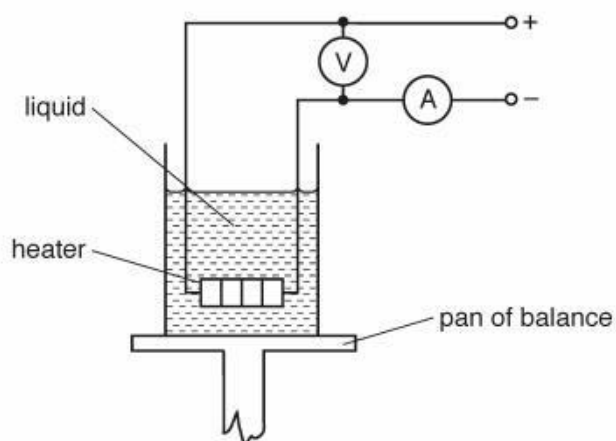
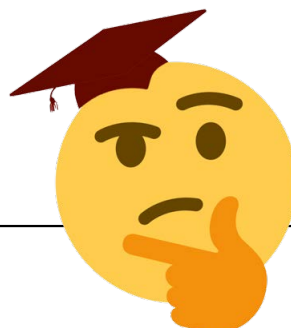


Fig. 3.1

The heater is switched on. When the liquid is boiling at a constant rate, the balance reading is noted at 2.0 minute intervals.

After 10 minutes, the current in the heater is reduced and the balance readings are taken for a further 12 minutes.



The readings of the ammeter and of the voltmeter are given in Fig. 3.2.

	ammeter reading /A	voltmeter reading /V
from time 0 to time 10 minutes	1.2	230
after time 10 minutes	1.0	190

Fig. 3.2

The variation with time of the balance reading is shown in Fig. 3.3.

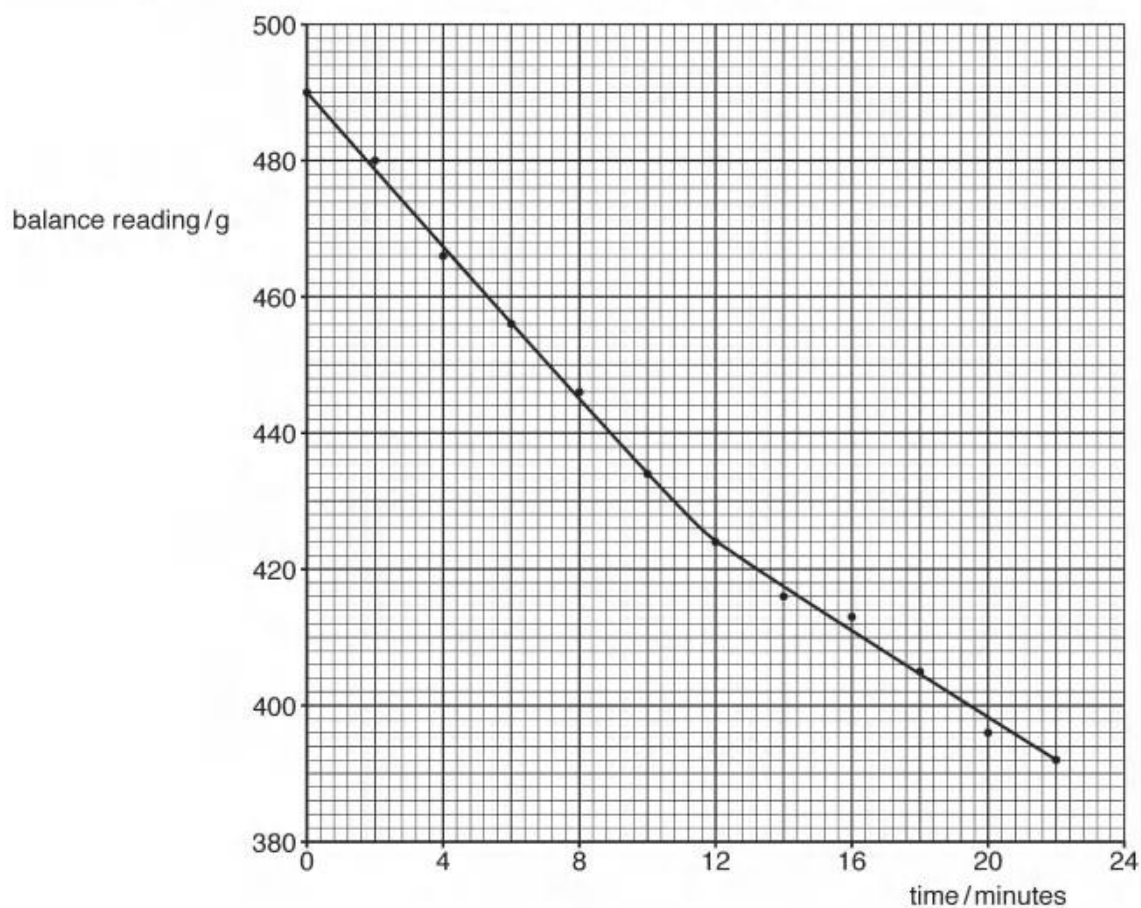
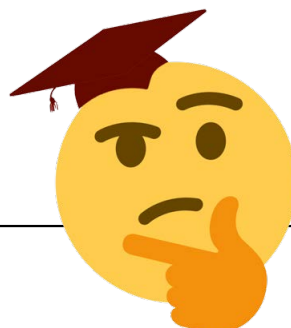


Fig. 3.3



- (i) From time 0 to time 10.0 minutes, the mass of liquid evaporated is 56 g.

Use Fig. 3.3 to determine the mass of liquid evaporated from time 12.0 minutes to time 22.0 minutes.

mass = g [1]

- (ii) Explain why, although the power of the heater is changed, the rate of loss of thermal energy to the surroundings may be assumed to be constant.

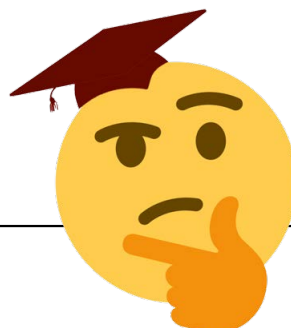
.....
..... [1]

- (iii) Determine a value for the specific latent heat of vaporisation L of the liquid.

$L = \dots\dots\dots \text{J g}^{-1}$ [4]

- (iv) Calculate the rate at which thermal energy is transferred to the surroundings.

rate = W [2]



13 - (9702/42_Winter_2019_Q3) - Thermal Properties Of Materials

(a) State what is meant by *specific latent heat*.

.....

.....

..... [2]

(b) A student uses the apparatus illustrated in Fig. 3.1 to determine a value for the specific latent heat of fusion of ice.

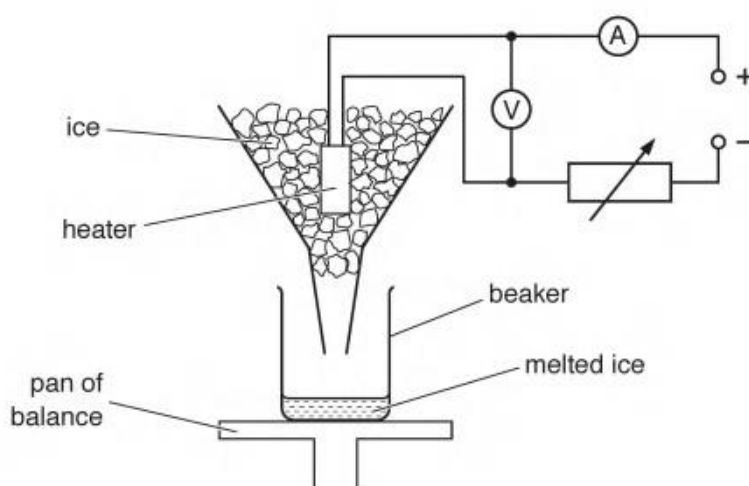
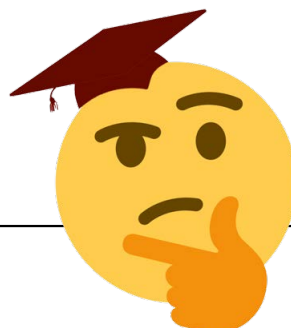


Fig. 3.1

The balance reading measures the mass of the beaker and the melted ice (water) in the beaker.

The heater is switched on and pieces of ice at 0°C are added continuously to the funnel so that the heater is always surrounded by ice.

When water drips out of the funnel at a constant rate, the balance reading is noted at 2.0 minute intervals. After 10 minutes, the current in the heater is increased and the balance readings are taken for a further 12 minutes.



The variation with time of the balance reading is shown in Fig. 3.2.

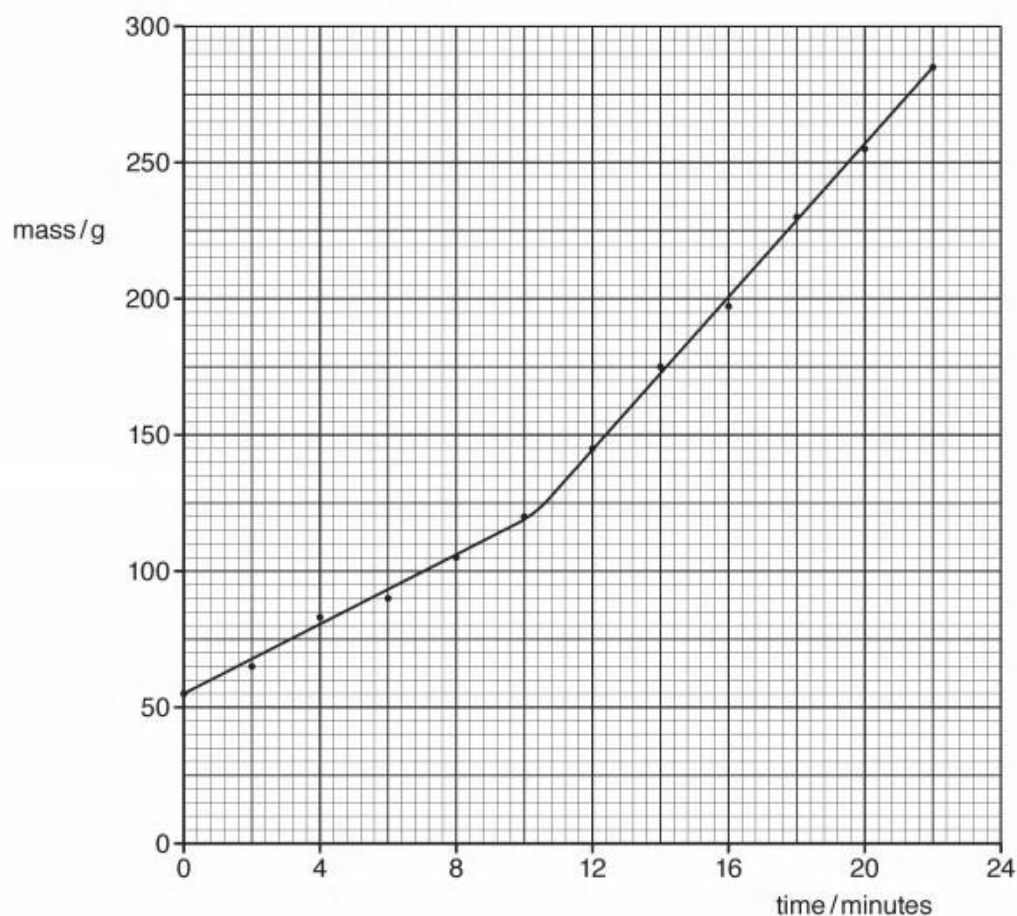
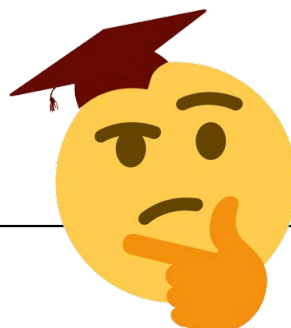


Fig. 3.2

The readings of the ammeter and of the voltmeter are shown in Fig. 3.3.

	ammeter reading /A	voltmeter reading /V
from time 0 to time 10 minutes	1.8	7.3
after time 10 minutes	3.6	15.1

Fig. 3.3



- (i) From time 0 to time 10.0 minutes, 65 g of ice is melted.

Use Fig. 3.2 to determine the mass of ice melted from time 12.0 minutes to time 22.0 minutes.

mass = g [1]

- (ii) Explain why, although the power of the heater is changed, the rate at which thermal energy is transferred from the surroundings to the ice is constant.

.....

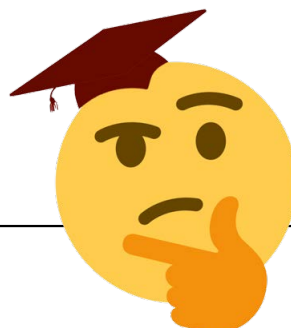
..... [1]

- (iii) Determine a value for the specific latent heat of fusion L of ice.

$L = \dots\dots\dots \text{Jg}^{-1}$ [4]

- (iv) Calculate the rate at which thermal energy is transferred from the surroundings to the ice.

rate = W [2]



14 - (9702/41_Summer_2020_Q2) - *Ideal Gases, Thermal Properties Of Materials*

(a) State what is meant by the *internal energy* of a system.

.....

.....

.....

..... [2]

(b) By reference to intermolecular forces, explain why the change in internal energy of an ideal gas is equal to the change in total kinetic energy of its molecules.

.....

.....

..... [2]

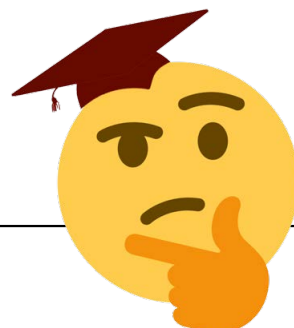
(c) State and explain the change, if any, in the internal energy of a solid metal ball as it falls under gravity in a vacuum.

.....

.....

.....

..... [3]



15 - (9702/42_Summer_2020_Q3) - *Thermal Properties Of Materials*

By reference to the first law of thermodynamics, state and explain the change, if any, in the internal energy of:

(a) a lump of solid lead as it melts at constant temperature

.....

.....

.....

.....

..... [3]

(b) some gas in a toy balloon when the balloon bursts and no thermal energy enters or leaves the gas.

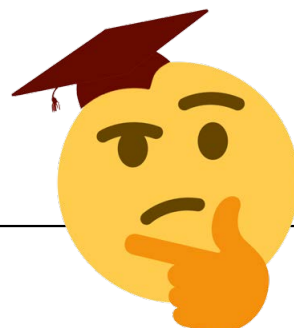
.....

.....

.....

.....

..... [3]



16 - (9702/41_Winter_2021_Q3) - *Thermal Properties Of Materials*

(a) Define *specific heat capacity*.

.....
.....
..... [2]

(b) A sealed container of fixed volume V contains N molecules, each of mass m , of an ideal gas at pressure p .

(i) State an expression, in terms of V , N , p and the Boltzmann constant k , for the thermodynamic temperature T of the gas.

..... [1]

(ii) Show that the mean translational kinetic energy E_k of a molecule of the gas is given by

$$E_k = \frac{3}{2}kT.$$

[2]

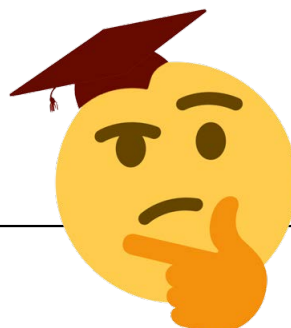
(iii) Explain why the internal energy of the gas is equal to the total kinetic energy of the molecules.

.....
.....
..... [2]

(c) The gas in (b) is supplied with thermal energy Q .

(i) Explain, with reference to the first law of thermodynamics, why the increase in internal energy of the gas is Q .

.....
.....
..... [2]



- (ii) Use the expression in (b)(ii) and the information in (c)(i) to show that the specific heat capacity c of the gas is given by

$$c = \frac{3k}{2m}.$$

[2]

- (d) The container in (b) is now replaced with one that does not have a fixed volume. Instead, the gas is able to expand, so that the pressure of the gas remains constant as thermal energy is supplied.

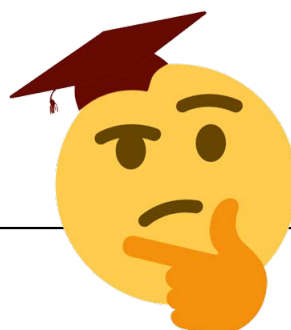
Suggest, with a reason, how the specific heat capacity of the gas would now compare with the value in (c)(ii).

.....

.....

.....

..... [2]



17 - (9702/41_Winter_2022_Q2) - *Thermal Properties Of Materials*

Fig. 2.1 shows a laboratory thermometer that is calibrated to measure temperature in degrees Celsius.

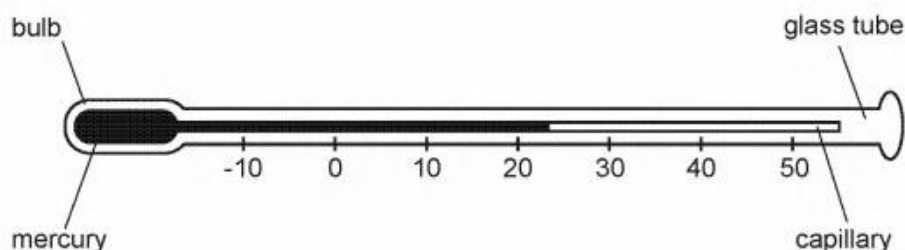


Fig. 2.1

The thermometer makes use of the fact that the density of mercury varies with temperature.

- (a) State **two** other physical properties of materials, apart from the density of a liquid, that can be used for measuring temperature.

1

2 [2]

- (b) The thermometer is initially at 23.0°C , as shown in Fig. 2.1. It is used to measure the temperature of an insulated beaker of water that is at 37.4°C . The bulb of the thermometer is inserted into the water, and the water is stirred until the reading on the thermometer becomes steady.

The mass of water in the beaker is 18.7 g .

The mass of mercury in the thermometer is 6.94 g .

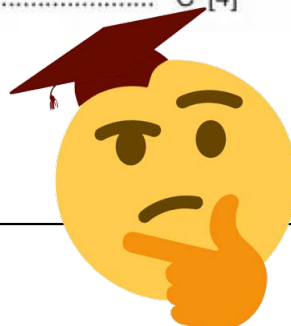
The specific heat capacity of water is $4.18\text{ J g}^{-1}\text{ K}^{-1}$.

The specific heat capacity of mercury is $0.140\text{ J g}^{-1}\text{ K}^{-1}$.

The glass of the thermometer and the beaker containing the water can be considered to have negligible heat capacity.

- (i) Calculate, to three significant figures, the final steady temperature indicated by the thermometer in the water.

temperature = $^{\circ}\text{C}$ [4]



- (ii) Suggest **one** change that could be made to the design of the thermometer that would enable it to give a more accurate measurement of temperature.

.....
..... [1]

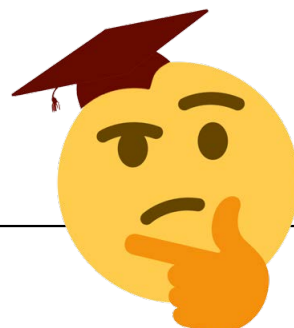
- (c) (i) Explain why the thermometer in Fig. 2.1 does **not** provide a direct measurement of thermodynamic temperature.

.....
.....
..... [2]

- (ii) Thermodynamic temperature T may be determined by the behaviour of a type of substance for which T is proportional to the product of pressure and volume.

State the name of this type of substance.

..... [1]



18 - (9702/42_Winter_2022_Q2) - Thermal Properties Of Materials

(a) Define specific heat capacity.

.....

.....

..... [2]

(b) A fixed mass of water in a beaker is at atmospheric pressure.**(i)** The initial temperature of the water is 0°C .

The water is supplied with thermal energy E , so that its temperature increases to 8°C .
There is no net change in the volume of the water.

Use the first law of thermodynamics to complete Table 2.1 for this process.

Table 2.1

work done on water	thermal energy supplied to water	increase in internal energy of water
	$+ E$	

[2]

(ii) The water is now heated so that its temperature increases by a further 8°C to a final temperature of 16°C . This process causes the volume of the water to increase so that work W is done.Assume that the change in internal energy is the same as in **(b)(i)**.

Use the first law of thermodynamics to complete Table 2.2 for this process.

Table 2.2

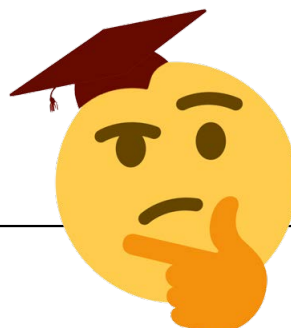
work done on water	thermal energy supplied to water	increase in internal energy of water

[2]

(c) Use the information in **(b)** to suggest, with a reason, how the average specific heat capacity of water between 8°C and 16°C compares with its average value between 0°C and 8°C .

.....

..... [1]



19 - (9702/41_Summer_2023_Q4) - *Ideal Gases, Temperature, Thermal Properties Of Materials*

(a) State **two** of the basic assumptions of the kinetic theory of gases.

- 1
-
- 2
-
- [2]

(b) An ideal gas has amount of substance n .

The gas is initially in state X, with pressure $2p$ and volume V .

The gas is cooled at constant volume to state Y, with pressure p .

The gas is then heated at constant pressure to state Z, with volume $2V$.

Finally, the gas returns at constant temperature to state X.

- (i) Determine an expression for the temperature T of the gas in state X, in terms of n , p and V .
Identify any other symbols that you use.

[2]

- (ii) On Fig. 4.1, sketch the variation with volume of pressure for the gas as the gas undergoes the three changes. The state X is labelled. Label states Y and Z.

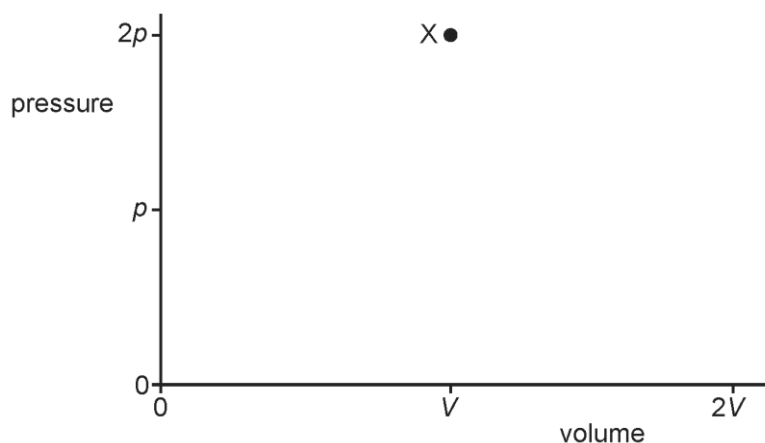
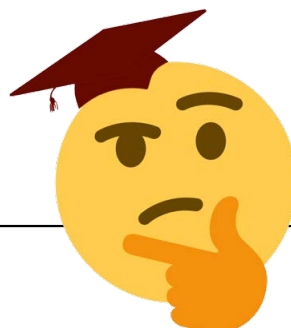


Fig. 4.1

[3]



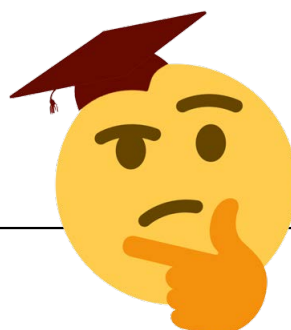
- (iii) During the change of state from Y to Z, the increase in internal energy of the gas is U .
During the change of state from Z to X, the work done on the gas is W .

Complete Table 4.1 to indicate, for each of the three changes of state, the increase in internal energy of the gas, the thermal energy transferred to the gas and the work done on the gas, in terms of p , V , U and W .

Table 4.1

change	increase in internal energy of gas	thermal energy transferred to gas	work done on gas
X to Y			
Y to Z	$+U$		
Z to X			$+W$

[5]



1 - (9702/41_Summer_2017_Q2) - Oscillations

A bar magnet of mass 180g is suspended from the free end of a spring, as illustrated in Fig. 2.1.

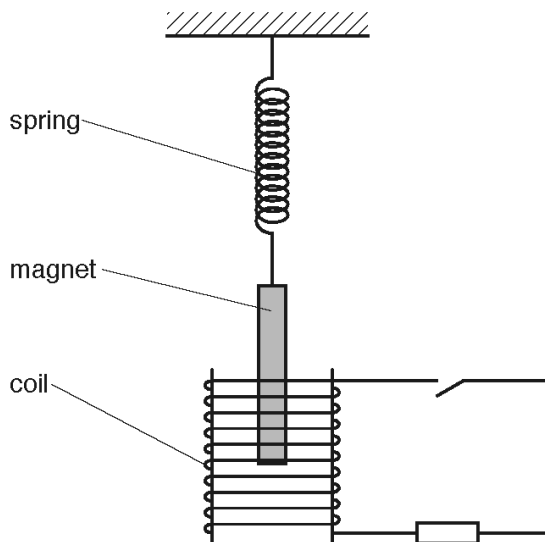


Fig. 2.1

The magnet hangs so that one pole is near the centre of a coil of wire.

The coil is connected in series with a resistor and a switch. The switch is open.

The magnet is displaced vertically and then allowed to oscillate with one pole remaining inside the coil. The other pole remains outside the coil.

At time $t = 0$, the magnet is oscillating freely as it passes through its equilibrium position. At time $t = 3.0$ s, the switch in the circuit is closed.

The variation with time t of the vertical displacement y of the magnet is shown in Fig. 2.2.

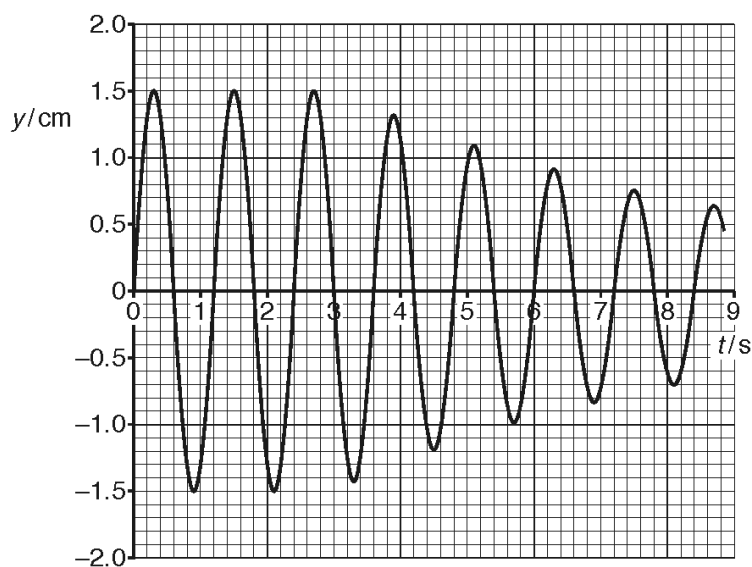
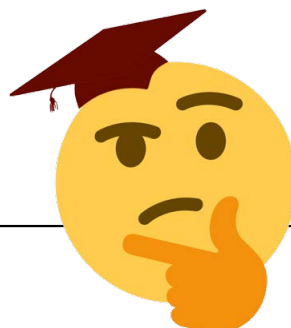


Fig. 2.2



- (a) Determine, to two significant figures, the frequency of oscillation of the magnet.

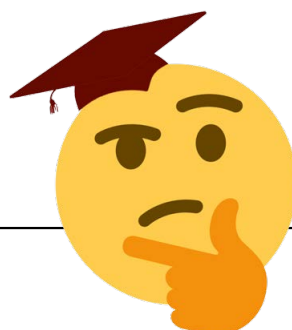
frequency = Hz [2]

- (b) State whether the closing of the switch gives rise to light, heavy or critical damping.

..... [1]

- (c) Calculate the change in the energy ΔE of oscillation of the magnet between time $t = 2.7$ s and time $t = 7.5$ s. Explain your working.

$\Delta E =$ J [6]



2 - (9702/42_Summer_2017_Q3) - Oscillations, Electromagnetic Induction

A bar magnet of mass 250g is suspended from the free end of a spring, as illustrated in Fig. 3.1.

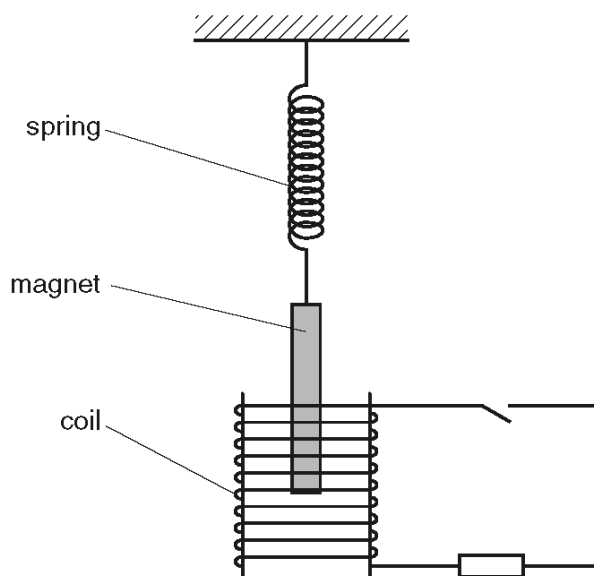


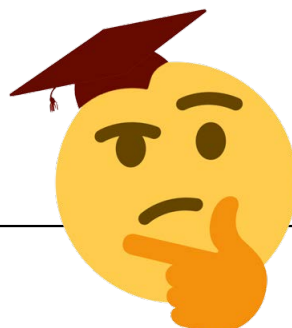
Fig. 3.1

The magnet hangs so that one pole is near the centre of a coil of wire.

The coil is connected in series with a resistor and a switch. The switch is open.

The magnet is displaced vertically and then allowed to oscillate with one pole remaining inside the coil. The other pole remains outside the coil.

At time $t = 0$, the magnet is oscillating freely as it passes through its equilibrium position. At time $t = 6.0\text{ s}$, the switch in the circuit is closed.



The variation with time t of the vertical displacement y of the magnet is shown in Fig. 3.2.

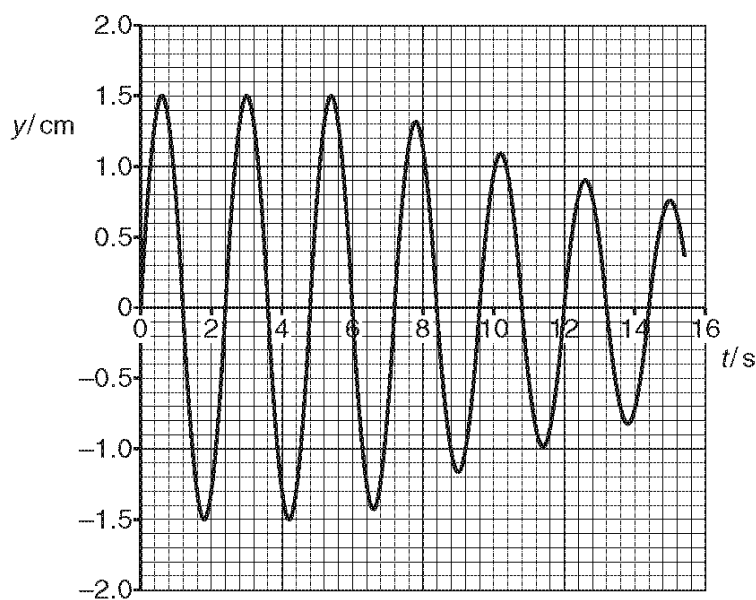


Fig. 3.2

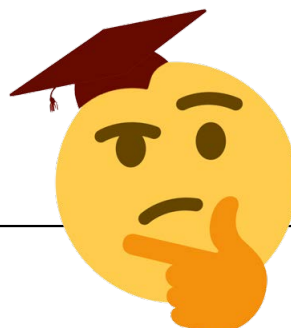
(a) For the oscillating magnet, use data from Fig. 3.2 to calculate, to two significant figures,

(i) the frequency f ,

$f = \dots\dots\dots$ Hz [2]

(ii) the energy of the oscillations during the time $t = 0$ to time $t = 6.0$ s.

energy = $\dots\dots\dots$ J [3]

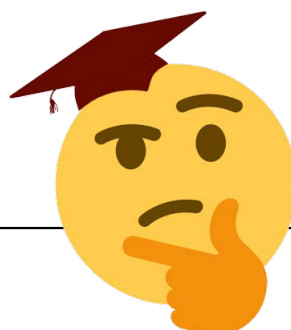


(b) (i) State Faraday's law of electromagnetic induction.

.....
.....
.....
.....[2]

(ii) Use Faraday's law and energy conservation to explain why the amplitude of the oscillations of the magnet reduces after time $t = 6.0\text{ s}$.

.....
.....
.....
.....
.....
.....
.....[3]



3 - (9702/41_Winter_2017_Q2) - Oscillations

- (a) State, by reference to simple harmonic motion, what is meant by *angular frequency*.

.....
..... [1]

- (b) A thin metal strip is clamped at one end so that it is horizontal. A load of mass M is attached to its free end. The load causes a displacement s of the end of the strip, as shown in Fig. 2.1.

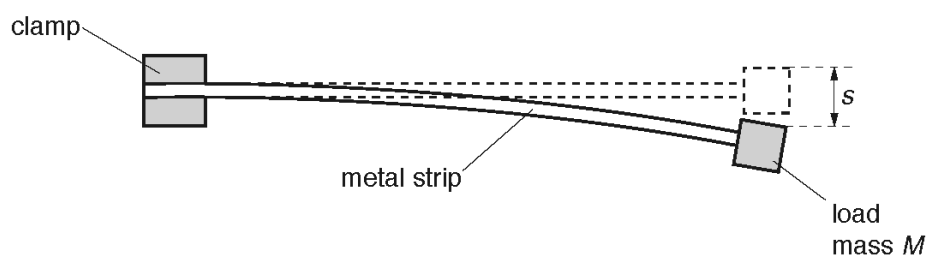


Fig. 2.1

The load is displaced vertically and then released. The load oscillates. The variation with the acceleration a of the displacement s of the load is shown in Fig. 2.2.

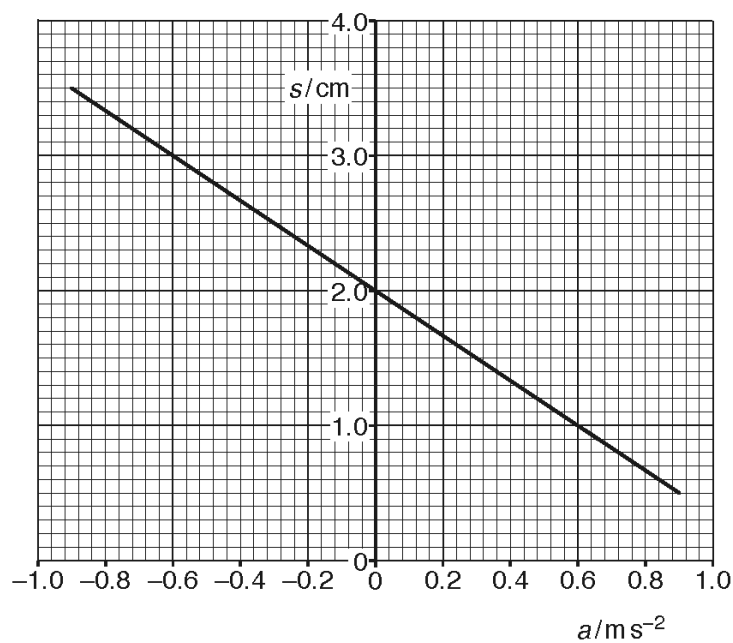
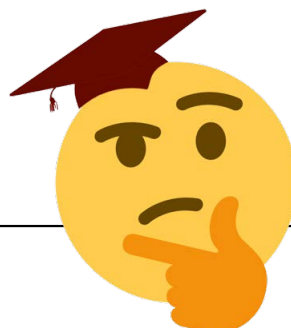


Fig. 2.2



(i) Use Fig. 2.2 to determine

1. the displacement of the load before it is made to oscillate,

displacement = cm

2. the amplitude of the oscillations of the load.

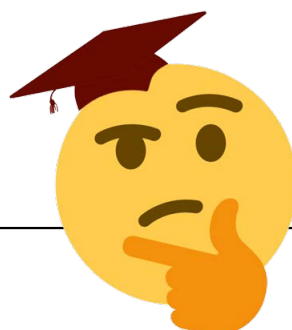
amplitude = cm
[2]

(ii) Show that the load is undergoing simple harmonic motion.

.....
.....
.....
..... [3]

(iii) Calculate the frequency of oscillation of the load.

frequency = Hz [3]



4 - (9702/42_Winter_2017_Q3) - Oscillations

(a) (i) Define the *radian*.

.....

[2]

(ii) State, by reference to simple harmonic motion, what is meant by *angular frequency*.

.....
[1]

(b) A thin metal strip, clamped horizontally at one end, has a load of mass M attached to its free end, as shown in Fig. 3.1.

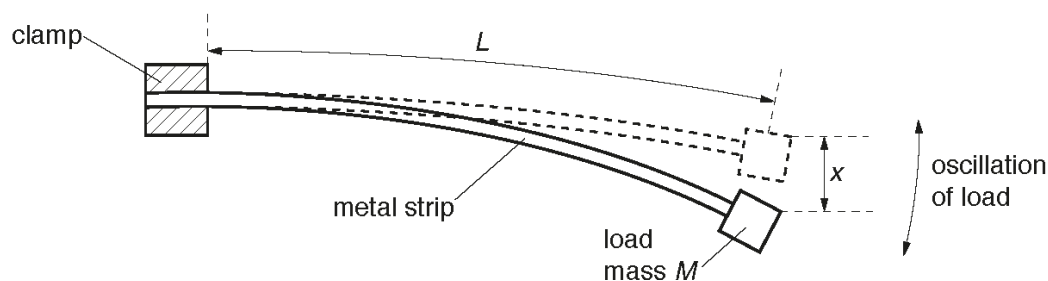


Fig. 3.1

The metal strip bends, as shown in Fig. 3.1.

When the free end of the strip is displaced vertically and then released, the mass oscillates in a vertical plane.

Theory predicts that the variation of the acceleration a of the oscillating load with the displacement x from its equilibrium position is given by

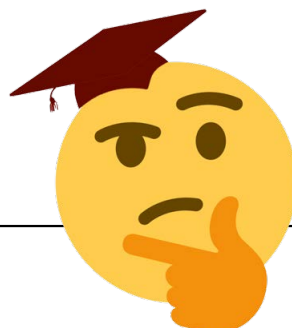
$$a = -\left(\frac{c}{ML^3}\right)x$$

where L is the effective length of the metal strip and c is a positive constant.

(i) Explain how the expression shows that the load is undergoing simple harmonic motion.

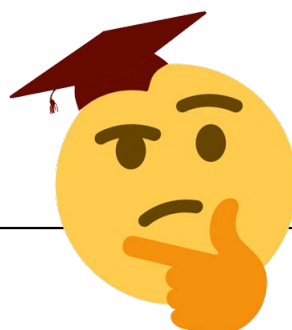
.....

[2]



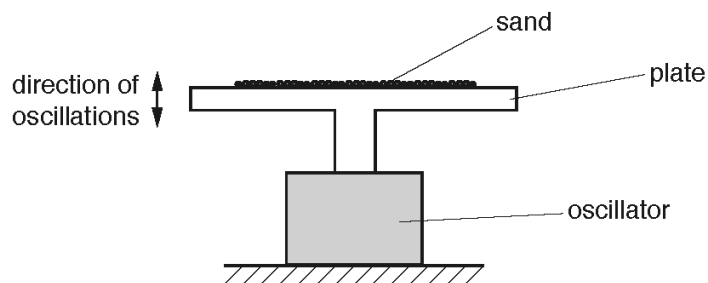
- (ii) For a metal strip of length $L = 65\text{ cm}$ and a load of mass $M = 240\text{ g}$, the frequency of oscillation is 3.2 Hz .
Calculate the constant c .

$c = \dots\dots\dots \text{ kg m}^3\text{ s}^{-2}$ [3]



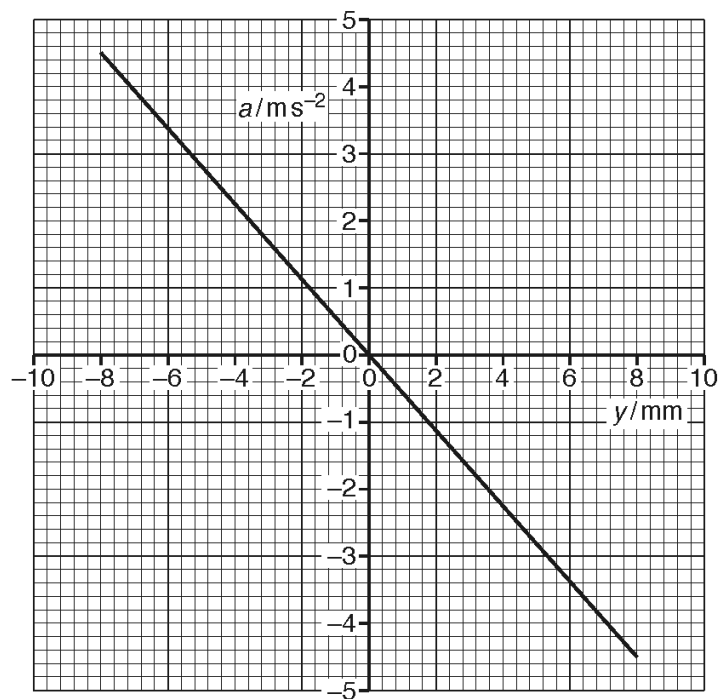
5 - (9702/41_Summer_2018_Q2) - Oscillations

A metal plate is made to vibrate vertically by means of an oscillator, as shown in Fig. 2.1.

**Fig. 2.1**

Some sand is sprinkled on to the plate.

The variation with displacement y of the acceleration a of the sand on the plate is shown in Fig. 2.2.

**Fig. 2.2**

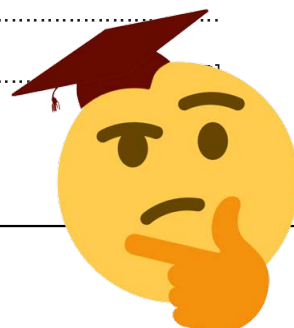
- (a) (i) Use Fig. 2.2 to show how it can be deduced that the sand is undergoing simple harmonic motion.

.....

.....

.....

.....



- (ii) Calculate the frequency of oscillation of the sand.

frequency = Hz [2]

- (b) The amplitude of oscillation of the plate is gradually increased beyond 8 mm. The frequency is constant.

At one amplitude, the sand is seen to lose contact with the plate.

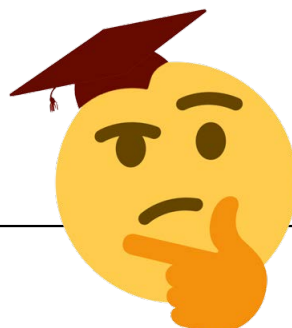
For the plate when the sand first loses contact with the plate,

- (i) state the position of the plate,

.....[1]

- (ii) calculate the amplitude of oscillation.

amplitude = mm [3]



6 - (9702/42_Summer_2018_Q4) - Oscillations

(a) State two conditions necessary for a mass to be undergoing simple harmonic motion.

1.
 2.
- [2]

(b) A trolley of mass 950 g is held on a horizontal surface by means of two springs attached to fixed points P and Q, as shown in Fig. 4.1.

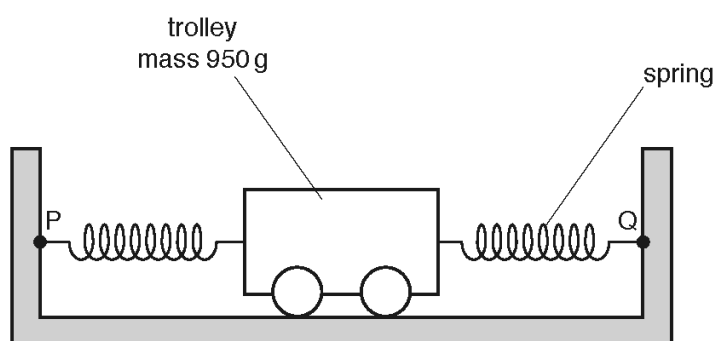


Fig. 4.1

The springs, each having a spring constant k of 230 N m^{-1} , are always extended.

The trolley is displaced along the line of the springs and then released.
The variation with time t of the displacement x of the trolley is shown in Fig. 4.2.

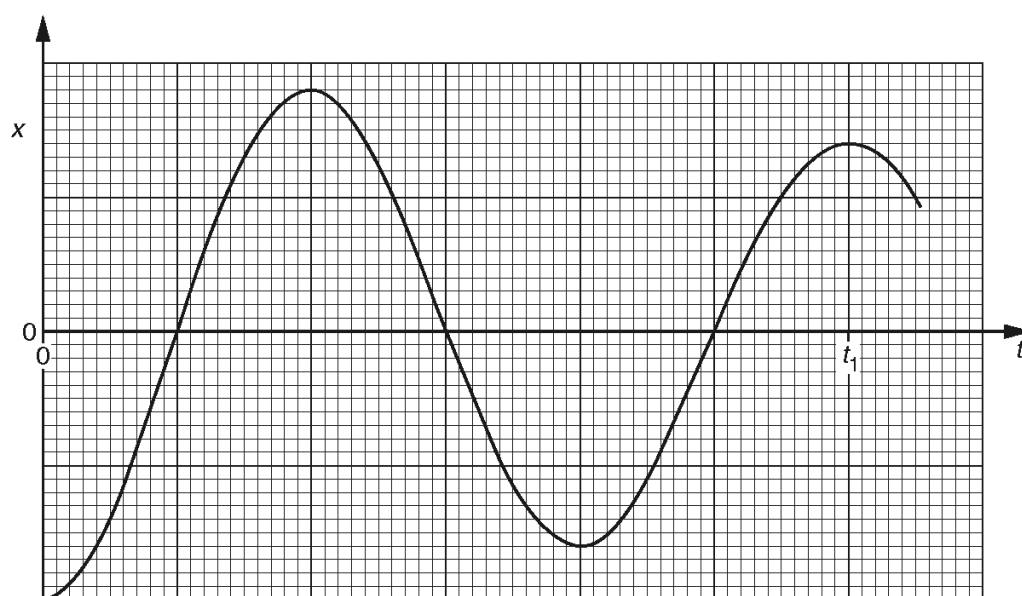
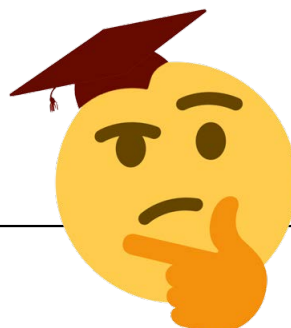


Fig. 4.2



- (i) 1. State and explain whether the oscillations of the trolley are heavily damped, critically damped or lightly damped.

.....
.....

2. Suggest the cause of the damping.

.....
.....
.....

[3]

- (ii) The acceleration a of the trolley of mass m may be assumed to be given by the expression

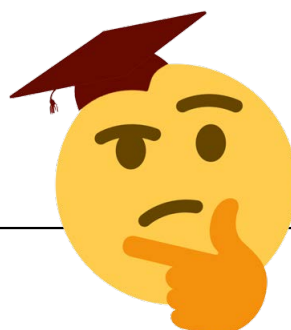
$$a = -\left(\frac{2k}{m}\right)x.$$

1. Calculate the angular frequency ω of the oscillations of the trolley.

$$\omega = \dots\dots\dots \text{rad s}^{-1} \quad [3]$$

2. Determine the time t_1 shown on Fig. 4.2.

$$t_1 = \dots\dots\dots \text{s} \quad [2]$$



7 - (9702/41_Winter_2018_Q3) - Oscillations

A U-tube contains liquid, as shown in Fig. 3.1.

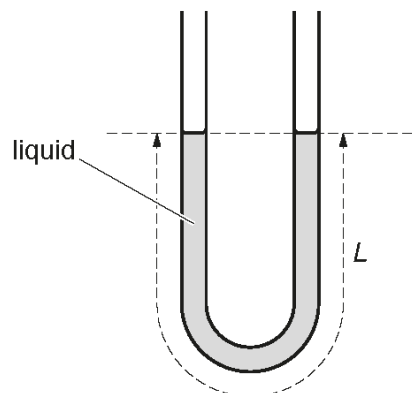


Fig. 3.1

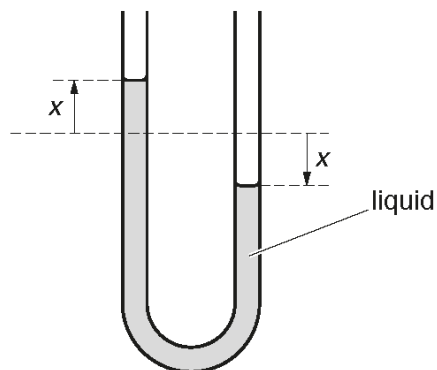


Fig. 3.2

The total length of the column of liquid in the tube is L .

The column of liquid is displaced so that the change in height of the liquid in each arm of the U-tube is x , as shown in Fig. 3.2.

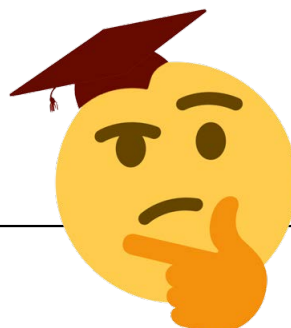
The liquid in the U-tube then oscillates with simple harmonic motion such that the acceleration a of the column is given by the expression

$$a = -\left(\frac{2g}{L}\right)x$$

where g is the acceleration of free fall.

(a) Calculate the period T of oscillation of the liquid column for a column length L of 19.0 cm.

$T = \dots\dots\dots$ s [3]



(b) The variation with time t of the displacement x is shown in Fig. 3.3.

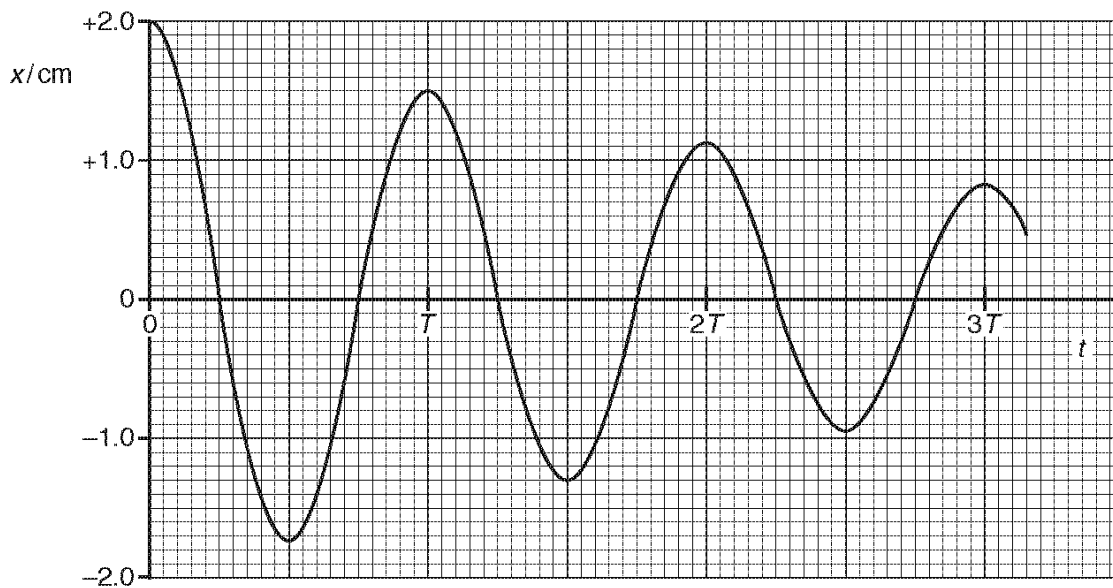


Fig. 3.3

The period of oscillation of the liquid column of mass 18.0 g is T .

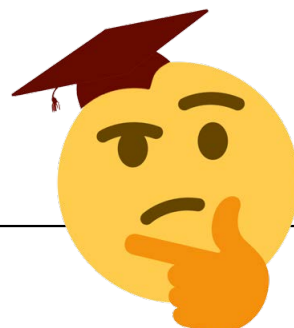
The oscillations are damped.

(i) Suggest one cause of the damping.

.....
[1]

(ii) Calculate the loss in total energy of the oscillations during the first 2.5 periods of the oscillations.

energy loss = J [3]



8 - (9702/42_Winter_2018_Q4) - Oscillations

A U-tube contains liquid, as shown in Fig. 4.1.

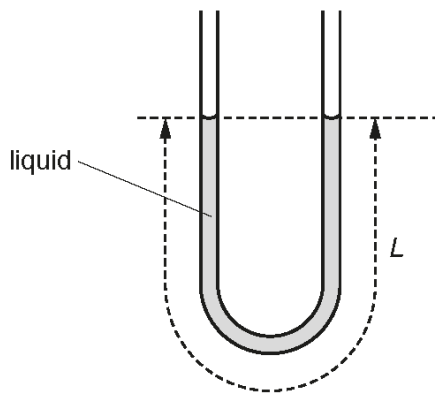


Fig. 4.1

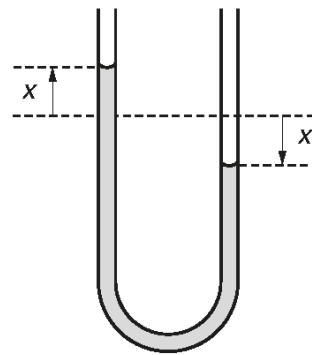


Fig. 4.2

The total length of the liquid column is L .

The column of liquid is displaced so that the change in height of the liquid level from the equilibrium position in each arm of the U-tube is x , as shown in Fig. 4.2.

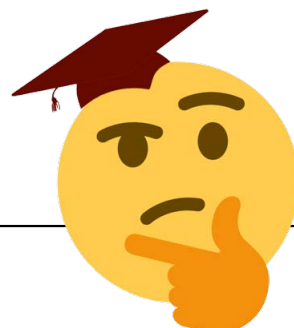
The liquid in the U-tube then oscillates such that its acceleration a is given by the expression

$$a = -\left(\frac{2g}{L}\right)x$$

where g is the acceleration of free fall.

(a) Show that the liquid column undergoes simple harmonic motion.

[2]



(b) The variation with time t of the displacement x is shown in Fig. 4.3.

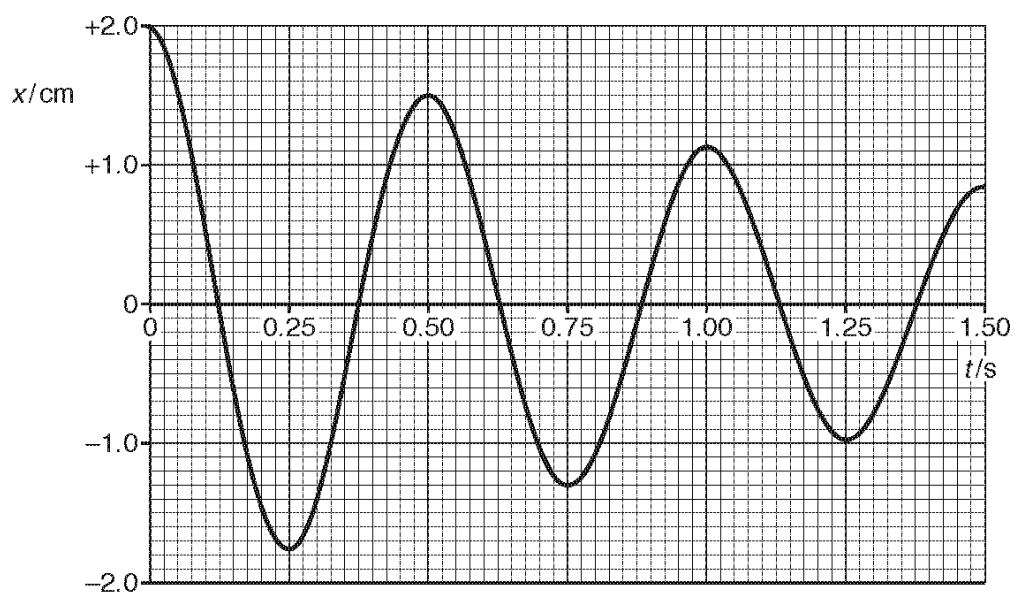
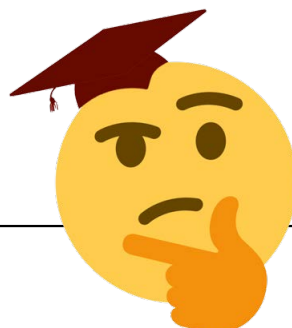


Fig. 4.3

Use data from Fig. 4.3 to determine the length L of the liquid column.

$L = \dots\dots\dots$ m [3]



(c) The oscillations shown in Fig. 4.3 are damped.

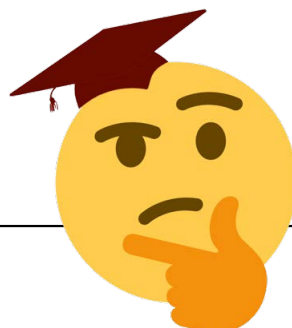
(i) Suggest one cause of this damping.

.....
.....[1]

(ii) Calculate the ratio

$$\frac{\text{total energy of oscillations after 1.5 complete oscillations}}{\text{total initial energy of oscillations}}$$

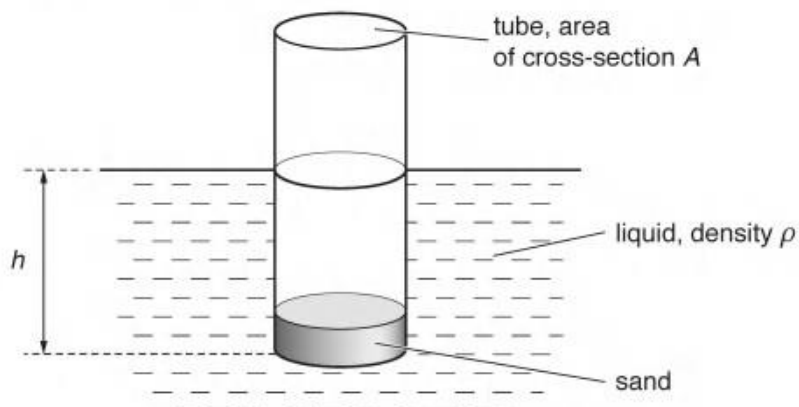
ratio = [2]



9 - (9702/41_Summer_2019_Q3) - Oscillations

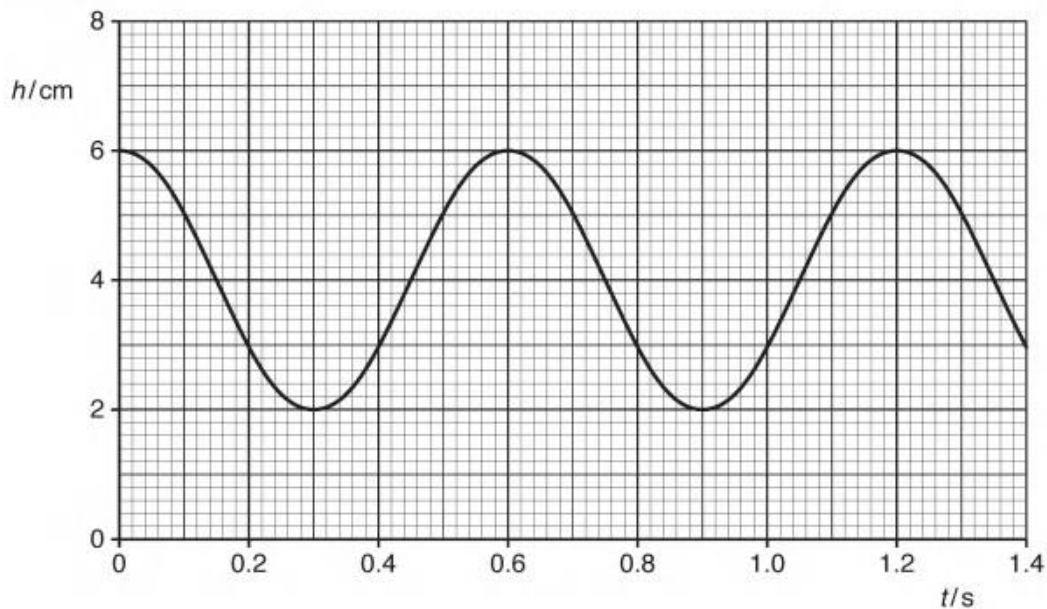
A hollow tube, sealed at one end, has a cross-sectional area A of 24 cm^2 . The tube contains sand so that the total mass M of the tube and sand is 0.23 kg .

The tube floats upright in a liquid of density ρ , as illustrated in Fig. 3.1.

**Fig. 3.1**

The depth of the bottom of the tube below the liquid surface is h .

The tube is displaced vertically and then released. The variation with time t of the depth h is shown in Fig. 3.2.

**Fig. 3.2**

(a) Determine:

- (i) the amplitude, in metres, of the oscillations

amplitude =



- (ii) the frequency of oscillation of the tube in the liquid

frequency =Hz [2]

- (iii) the acceleration of the tube when h is a maximum.

acceleration =ms⁻² [2]

- (b) The frequency f of oscillation of the tube is given by the expression

$$f = \frac{1}{2\pi} \sqrt{\left(\frac{A\rho g}{M}\right)}$$

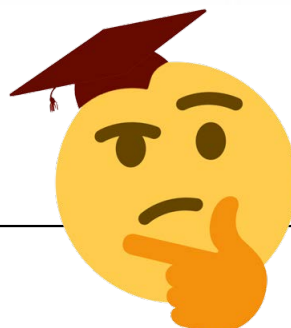
where g is the acceleration of free fall.

Calculate the density ρ of the liquid in which the tube is floating.

$\rho = \text{.....kg m}^{-3}$ [2]

- (c) The oscillations illustrated in Fig. 3.2 are undamped. In practice, the liquid does cause light damping.

On Fig. 3.2, draw a line to show light damping of the oscillations for time $t = 0$ to time $t = 1.4$ s. [3]



10 - (9702/42_Summer_2019_Q3) - Oscillations

A spring is hung vertically from a fixed point. A mass M is hung from the other end of the spring, as illustrated in Fig. 3.1.

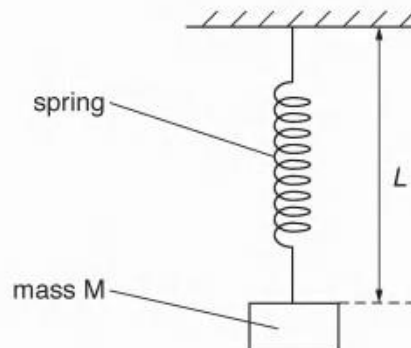


Fig. 3.1

The mass is displaced downwards and then released. The subsequent motion of the mass is simple harmonic.

The variation with time t of the length L of the spring is shown in Fig. 3.2.

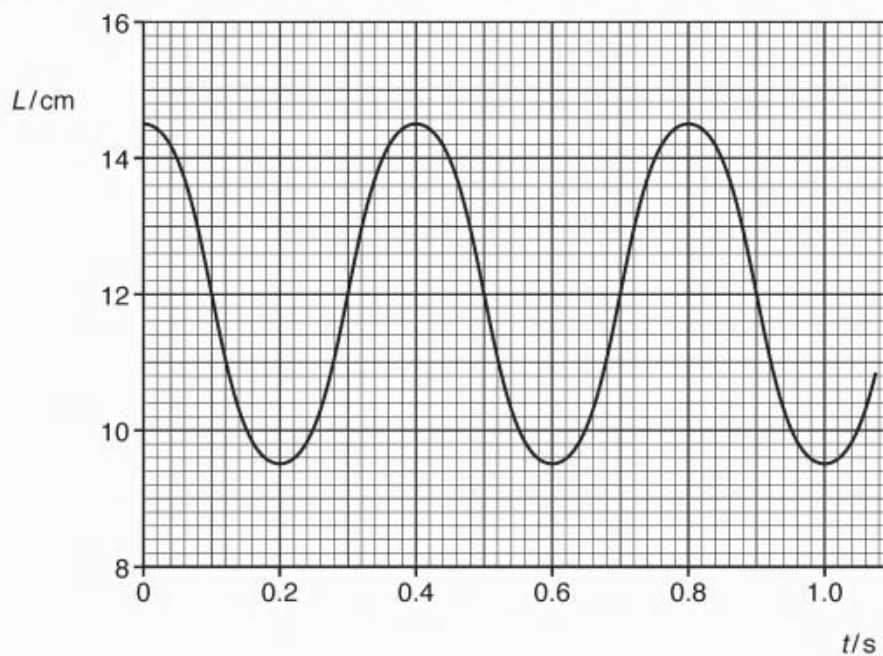


Fig. 3.2

(a) State:

- (i) one time at which the mass is moving with maximum speed

time = s [1]

- (ii) one time at which the spring has maximum elastic potential energy.

time =



(b) Use data from Fig. 3.2 to determine, for the motion of the mass:

(i) the angular frequency ω

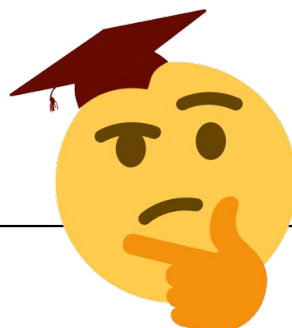
$$\omega = \dots\dots\dots \text{rad s}^{-1} \quad [2]$$

(ii) the maximum speed

$$\text{maximum speed} = \dots\dots\dots \text{m s}^{-1} \quad [2]$$

(iii) the magnitude of the maximum acceleration.

$$\text{maximum acceleration} = \dots\dots\dots \text{m s}^{-2} \quad [2]$$



- (c) The mass M is now suspended from two springs, each identical to that in Fig. 3.1, as shown in Fig. 3.3.

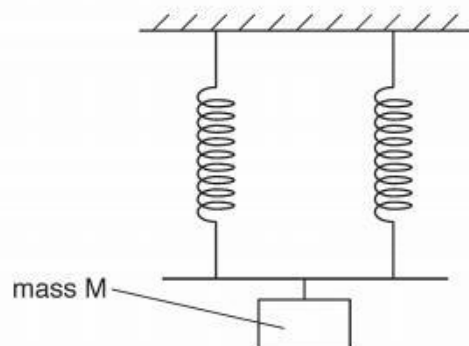


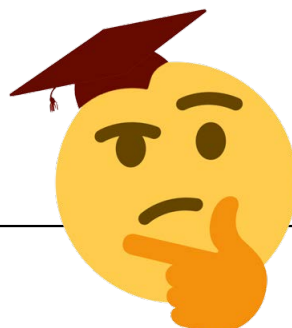
Fig. 3.3

Suggest and explain the change, if any, in the period of oscillation of the mass. A numerical answer is not required.

.....

.....

.....[2]



11 - (9702/41_Winter_2019_Q4) - Oscillations

A mass is suspended vertically from a fixed point by means of a spring, as illustrated in Fig. 4.1.

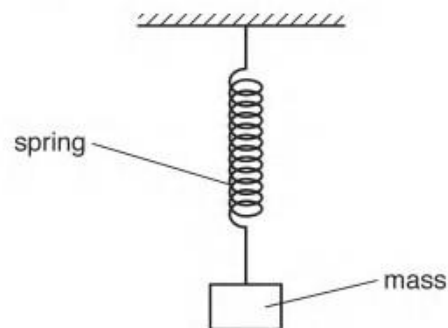


Fig. 4.1

The mass is oscillating vertically. The variation with displacement x of the acceleration a of the mass is shown in Fig. 4.2.

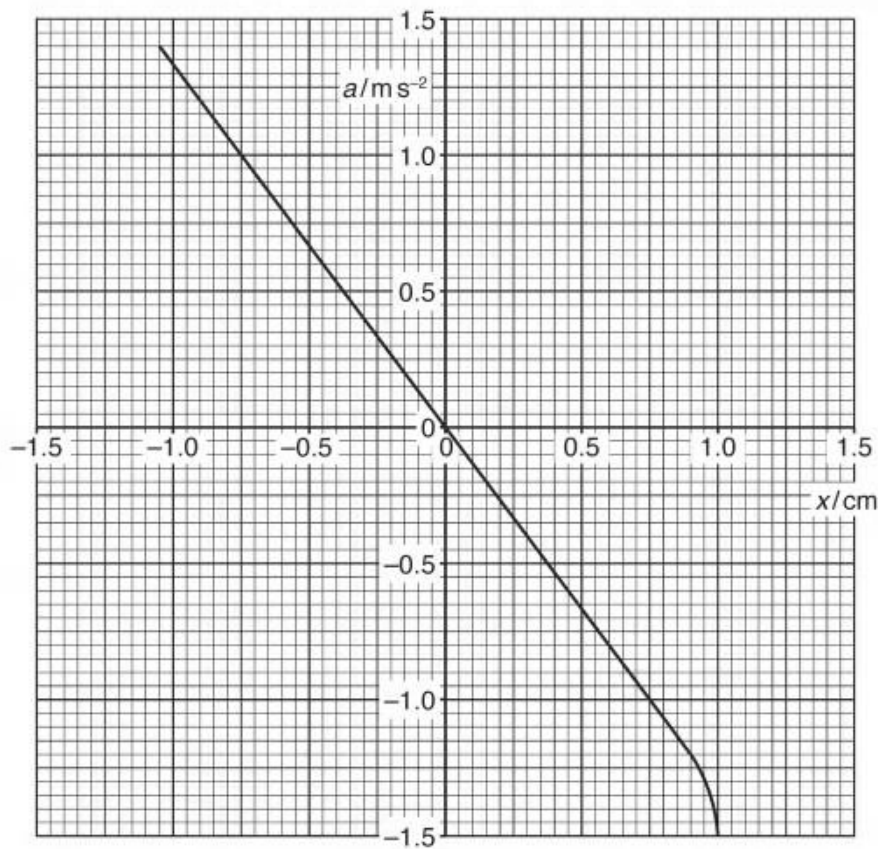
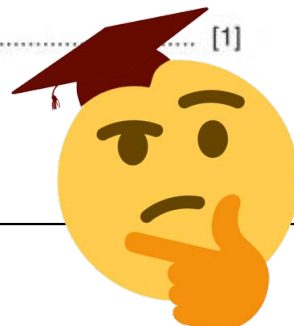


Fig. 4.2

(a) (i) State what is meant by the *displacement* of the mass on the spring.

.....

..... [1]



- (ii) Suggest how Fig. 4.2 shows that the mass is not performing simple harmonic motion.

.....
 [1]

- (b) (i) The amplitude of oscillation of the mass may be changed.

State the maximum amplitude x_0 for which the oscillations are simple harmonic.

$x_0 =$ cm [1]

- (ii) For the simple harmonic oscillations of the mass, use Fig. 4.2 to determine the frequency of the oscillations.

frequency = Hz [3]

- (c) The maximum speed of the mass when oscillating with simple harmonic motion of amplitude x_0 is v_0 .

On Fig. 4.3, show the variation with displacement x of the velocity v of the mass for displacements from $+x_0$ to $-x_0$.

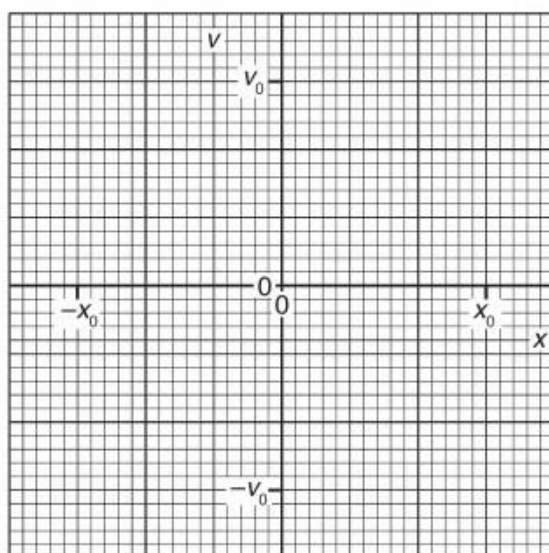
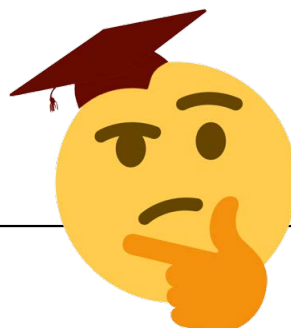


Fig. 4.3

[2]



12 - (9702/42_Winter_2019_Q4) - Oscillations

A ball of mass M is held on a horizontal surface by two identical extended springs, as illustrated in Fig. 4.1.

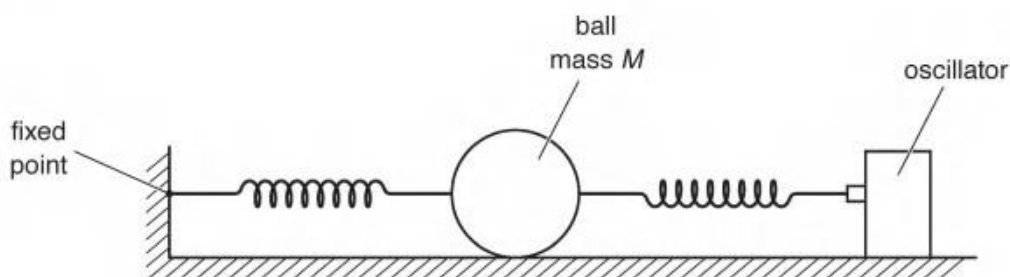


Fig. 4.1

One spring is attached to a fixed point. The other spring is attached to an oscillator.

The oscillator is switched off. The ball is displaced sideways along the axis of the springs and is then released. The variation with time t of the displacement x of the ball is shown in Fig. 4.2.

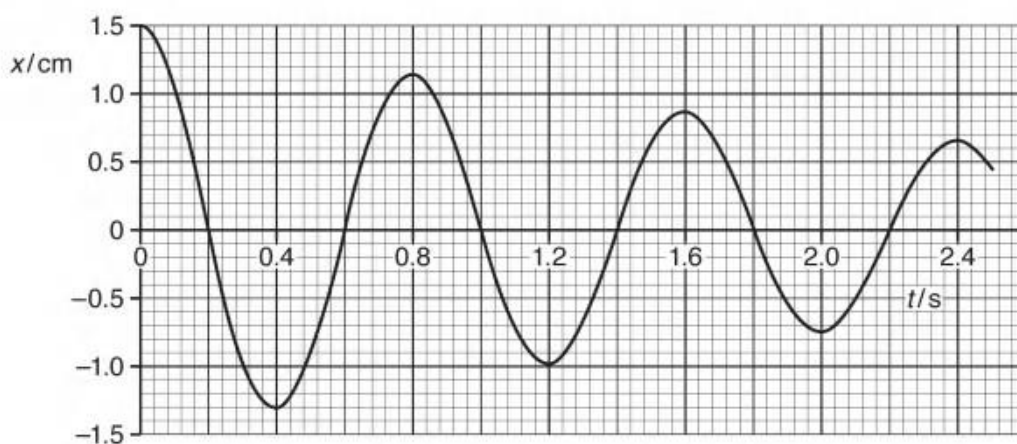


Fig. 4.2

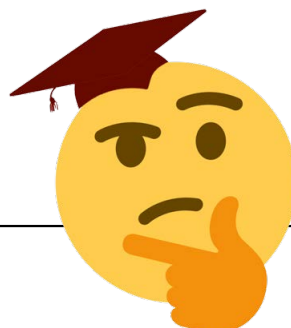
(a) State:

(i) what is meant by *damping*

.....
..... [1]

(ii) the evidence provided by Fig. 4.2 that the motion of the ball is damped.

.....
..... [1]



- (b) The acceleration a and the displacement x of the ball are related by the expression

$$a = -\left(\frac{2k}{M}\right)x$$

where k is the spring constant of one of the springs.

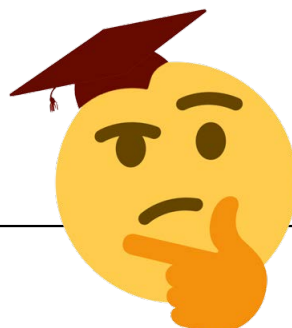
The mass M of the ball is 1.2 kg.

- (i) Use data from Fig. 4.2 to determine the angular frequency ω of the oscillations of the ball.

$$\omega = \dots\dots\dots \text{rads}^{-1} \quad [2]$$

- (ii) Use your answer in (i) to determine the value of k .

$$k = \dots\dots\dots \text{Nm}^{-1} \quad [2]$$



- (c) The oscillator is switched on. The amplitude of oscillation of the oscillator is constant.

The angular frequency of the oscillations is gradually increased from 0.7ω to 1.3ω , where ω is the angular frequency calculated in (b)(i).

- (i) On the axes of Fig. 4.3, show the variation with angular frequency of the amplitude A of oscillation of the ball.

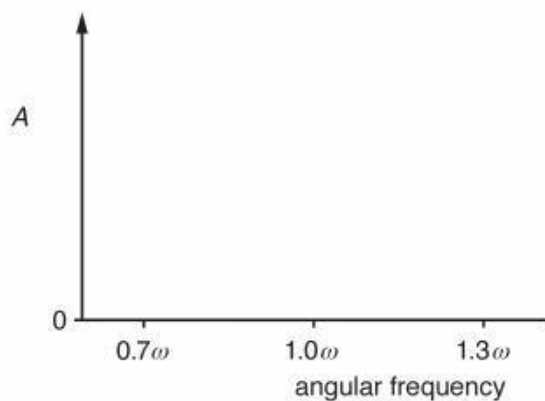


Fig. 4.3

[2]

- (ii) Some sand is now sprinkled on the horizontal surface.

The angular frequency of the oscillations is again gradually increased from 0.7ω to 1.3ω .

State **two** changes that occur to the line you have drawn on Fig. 4.3.

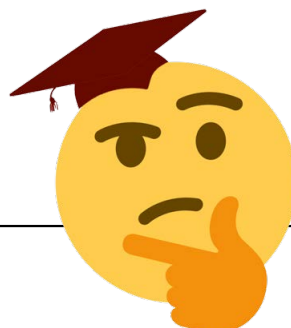
1.

.....

2.

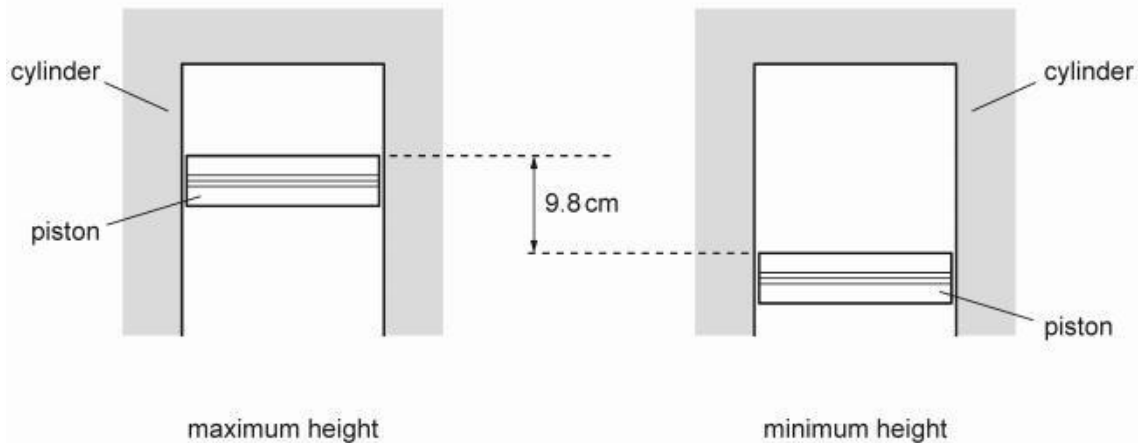
.....

[2]



13 - (9702/41_Summer_2020_Q3) - Oscillations

The piston in the cylinder of a car engine moves in the cylinder with simple harmonic motion. The piston moves between a position of maximum height in the cylinder to a position of minimum height, as illustrated in Fig. 3.1.

**Fig. 3.1**

The distance moved by the piston between the positions shown in Fig. 3.1 is 9.8 cm.

The mass of the piston is 640 g.

At one particular speed of the engine, the piston completes 2700 oscillations in 1.0 minute.

(a) For the oscillations of the piston in the cylinder, determine:

(i) the amplitude

amplitude = cm [1]

(ii) the frequency

frequency = Hz [1]

(iii) the maximum speed

maximum speed =



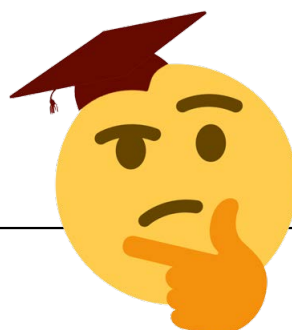
(iv) the speed when the top of the piston is 2.3 cm below its maximum height.

speed = ms^{-1} [2]

(b) The acceleration of the piston varies.

Determine the resultant force on the piston that gives rise to its maximum acceleration.

force = N [3]



14 - (9702/42_Summer_2020_Q4) - Oscillations

A dish is made from a section of a hollow glass sphere.

The dish, fixed to a horizontal table, contains a small solid ball of mass 45 g, as shown in Fig. 4.1.

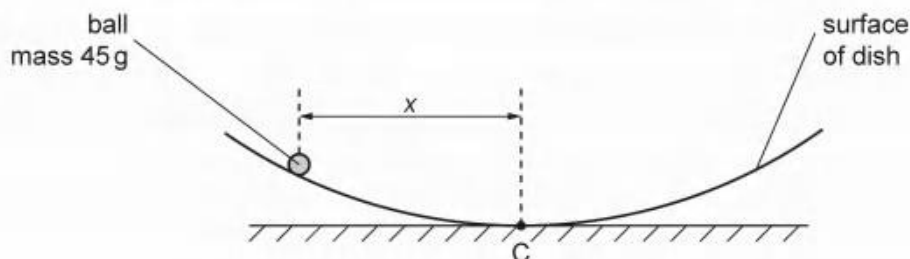


Fig. 4.1

The horizontal displacement of the ball from the centre C of the dish is x .

Initially, the ball is held at rest with distance $x = 3.0$ cm.

The ball is then released. The variation with time t of the horizontal displacement x of the ball from point C is shown in Fig. 4.2.

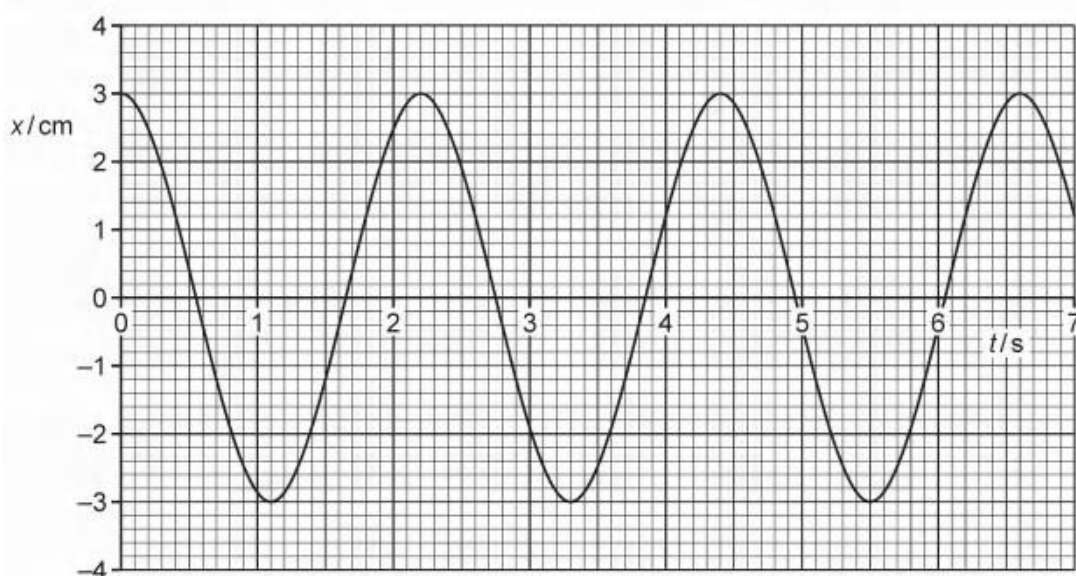
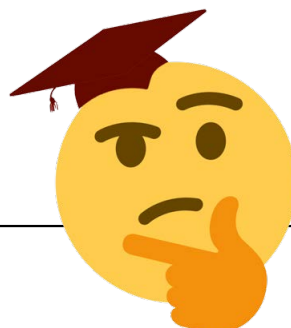


Fig. 4.2

The motion of the ball in the dish is simple harmonic with its acceleration a given by the expression

$$a = -\left(\frac{g}{R}\right)x$$

where g is the acceleration of free fall and R is a constant that depends on the dimensions of the dish and the ball.



- (a) Use Fig. 4.2 to show that the angular frequency ω of oscillation of the ball in the dish is 2.9 rad s^{-1} .

[1]

- (b) Use the information in (a) to:

- (i) determine R

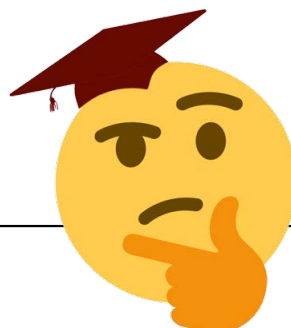
$R = \dots\dots\dots \text{ m}$ [2]

- (ii) calculate the speed of the ball as it passes over the centre C of the dish.

speed = $\dots\dots\dots \text{ ms}^{-1}$ [2]

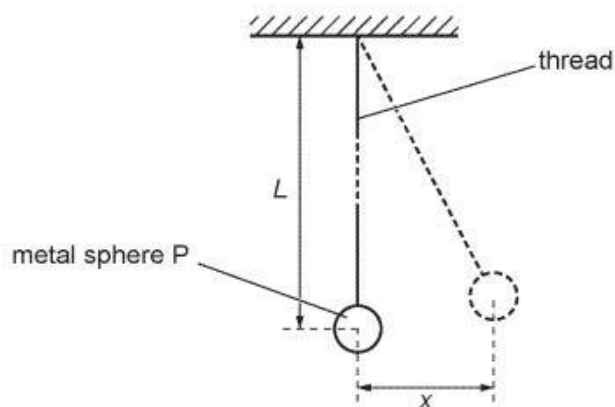
- (c) Some moisture collects on the surface of the dish so that the motion of the ball becomes lightly damped.

On the axes of Fig. 4.2, draw a line to show the lightly damped motion of the ball for the first 5.0 s after the release of the ball. [3]



15 - (9702/41_Winter_2020_Q3) - Oscillations

A pendulum consists of a metal sphere P suspended from a fixed point by means of a thread, as illustrated in Fig. 3.1.

**Fig. 3.1**

The centre of gravity of sphere P is a distance L from the fixed point.

The sphere is pulled to one side and then released so that it oscillates. The sphere may be assumed to oscillate with simple harmonic motion.

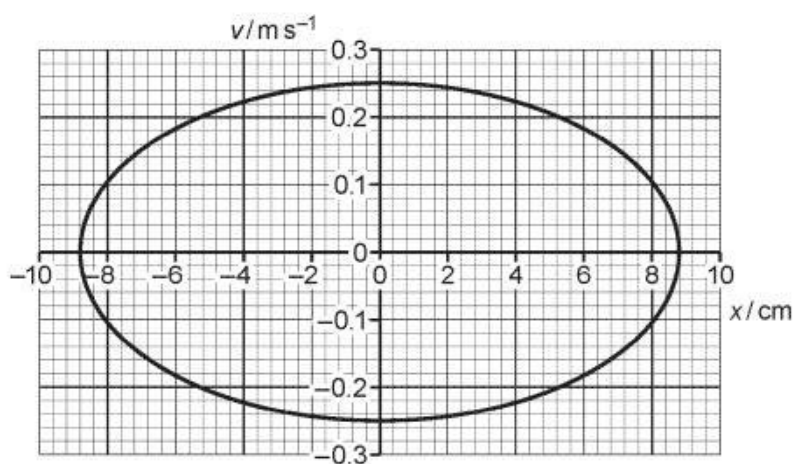
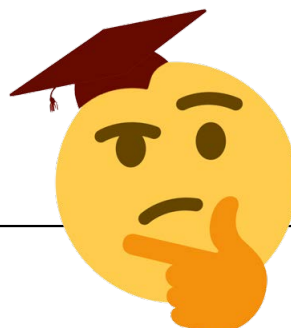
(a) State what is meant by *simple harmonic motion*.

.....

.....

..... [2]

(b) The variation of the velocity v of sphere P with the displacement x from its mean position is shown in Fig. 3.2.

**Fig. 3.2**

Use Fig. 3.2 to determine the frequency f of the oscillations of sphere P.

$$f = \dots\dots\dots \text{ Hz [3]}$$

- (c) The period T of the oscillations of sphere P is given by the expression

$$T = 2\pi\sqrt{\left(\frac{L}{g}\right)}$$

where g is the acceleration of free fall.

Use your answer in (b) to determine the length L .

$$L = \dots\dots\dots \text{ m [2]}$$

- (d) Another pendulum consists of a sphere Q suspended by a thread. Spheres P and Q are identical. The thread attached to sphere Q is longer than the thread attached to sphere P.

Sphere Q is displaced and then released. The oscillations of sphere Q have the same amplitude as the oscillations of sphere P.

On Fig. 3.2, sketch the variation of the velocity v with displacement x for sphere Q. [2]

[Total: 9]



16 - (9702/42_Winter_2020_Q3) - Oscillations

A simple pendulum consists of a metal sphere suspended from a fixed point by means of a thread, as illustrated in Fig. 3.1.

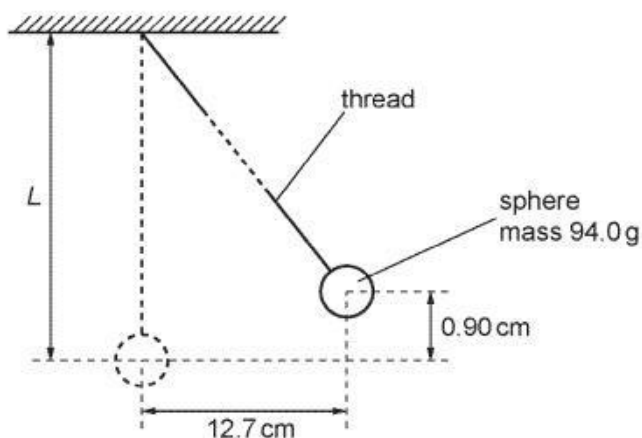


Fig. 3.1 (not to scale)

The sphere of mass 94.0 g is displaced to one side through a horizontal distance of 12.7 cm. The centre of gravity of the sphere rises vertically by 0.90 cm.

The sphere is released so that it oscillates. The sphere may be assumed to oscillate with simple harmonic motion.

(a) State what is meant by *simple harmonic motion*.

.....

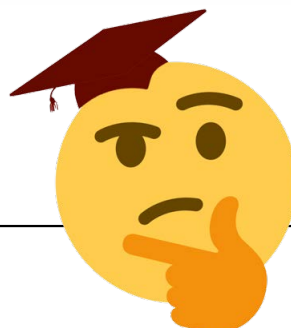
 [2]

(b) (i) State the kinetic energy of the sphere when the sphere returns to the displaced position shown in Fig. 3.1.

kinetic energy = J [1]

(ii) Calculate the total energy E_T of the oscillations.

$E_T = \dots\dots\dots$ J [2]



- (iii) Use your answer in (ii) to show that the angular frequency ω of the oscillations of the pendulum is 3.3 rad s^{-1} .

[2]

- (c) The period T of oscillation of the pendulum is given by the expression

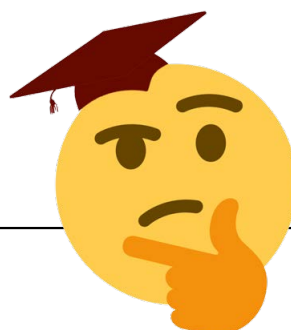
$$T = 2\pi\sqrt{\frac{L}{g}}$$

where g is the acceleration of free fall and L is the length of the pendulum.

Use data from (b) to determine L .

$L = \dots\dots\dots \text{m}$ [3]

[Total: 10]



17 - (9702/41_Summer_2021_Q3) - Oscillations

- (a) State what is meant by *simple harmonic motion*.

.....

 [2]

- (b) A trolley of mass m is held on a horizontal surface by means of two springs. One spring is attached to a fixed point P. The other spring is connected to an oscillator, as shown in Fig. 3.1.

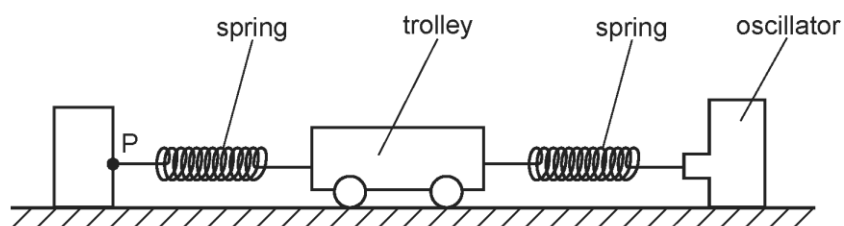


Fig. 3.1

The springs, each having spring constant k of 130 N m^{-1} , are always extended.

The oscillator is switched off. The trolley is displaced along the line of the springs and then released. The resulting oscillations of the trolley are simple harmonic.

The acceleration a of the trolley is given by the expression

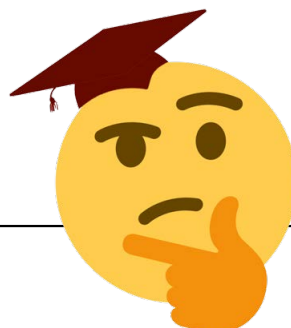
$$a = -\left(\frac{2k}{m}\right)x$$

where x is the displacement of the trolley from its equilibrium position.

The mass of the trolley is 840 g .

Calculate the frequency f of oscillation of the trolley.

$f = \dots\dots\dots \text{ Hz}$ [3]



- (c) The oscillator in (b) is switched on. The frequency of oscillation of the oscillator is varied, keeping its amplitude of oscillation constant.

The amplitude of oscillation of the trolley is seen to vary. The amplitude is a maximum at the frequency calculated in (b).

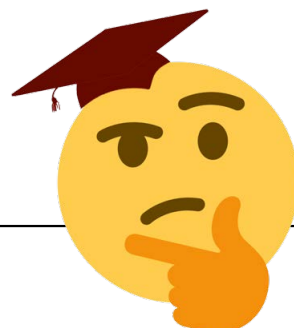
- (i) State the name of the effect giving rise to this maximum.

..... [1]

- (ii) At any given frequency, the amplitude of oscillation of the trolley is constant.

Explain how this indicates that there are resistive forces opposing the motion of the trolley.

.....
.....
..... [2]



18 - (9702/42_Summer_2021_Q3) - Oscillations

A U-shaped tube contains some liquid. The liquid column in each half of the tube has length L , as shown in Fig. 3.1.

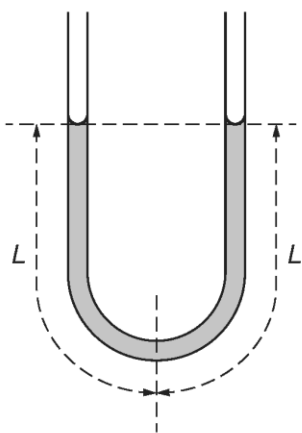


Fig. 3.1

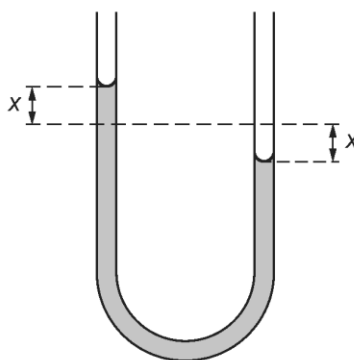


Fig. 3.2

The liquid columns are displaced vertically. The liquid then oscillates in the tube. The liquid levels are displaced from the equilibrium positions as shown in Fig. 3.2.

The acceleration a of the liquid in the tube is related to the displacement x by the expression

$$a = -\left(\frac{g}{L}\right)x$$

where g is the acceleration of free fall.

- (a) Explain how the expression shows that the liquid in the tube is undergoing simple harmonic motion.

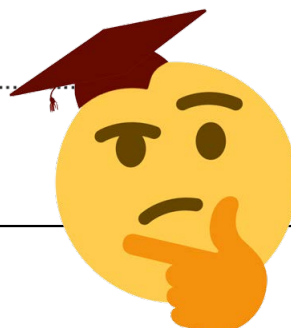
.....

 [3]

- (b) The length L of each liquid column is 18 cm.

Determine the period T of the oscillations.

$T =$

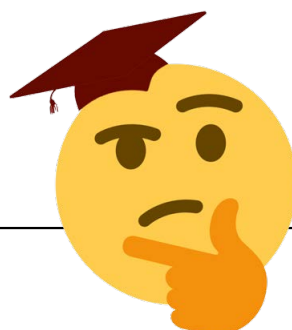


- (c) The oscillations of the liquid in the tube are damped.
In any one complete cycle of the oscillations, the amplitude decreases by 6.0% of its value at the beginning of the oscillation.

Determine the ratio

$$\frac{\text{energy of oscillations after 3 cycles}}{\text{initial energy of oscillations}}.$$

ratio = [3]



19 - (9702/41_Winter_2021_Q4) - Oscillations

A trolley on a track is attached by springs to fixed blocks X and Y, as shown in Fig. 4.1. The track contains many small holes through which air is blown vertically upwards. This results in the trolley resting on a cushion of air rather than being in direct contact with the track.

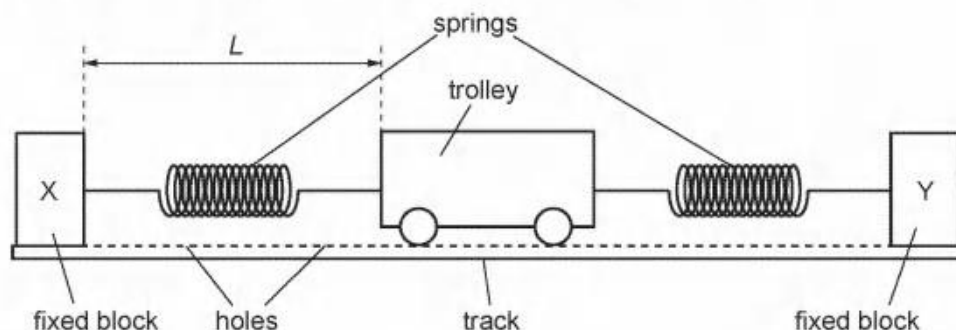


Fig. 4.1

The trolley is pulled to one side of its equilibrium position and then released so that it oscillates initially with simple harmonic motion. After a short time, the air blower is switched off. The variation with time t of the distance L of the trolley from block X is shown in Fig. 4.2.

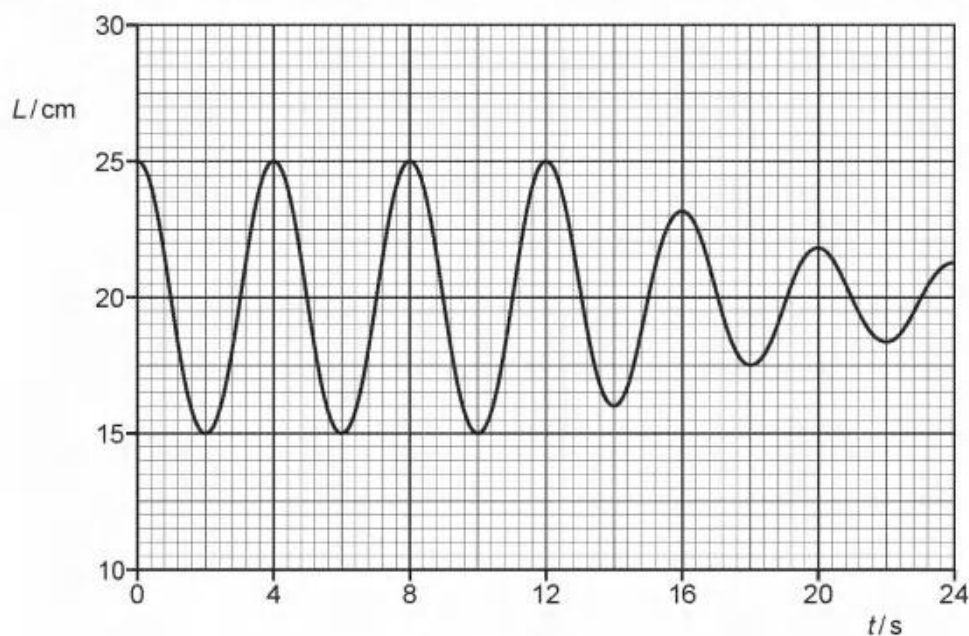
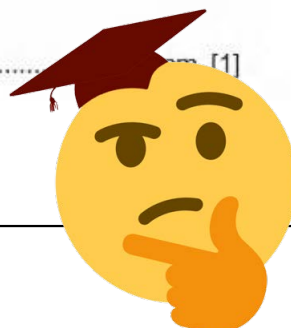


Fig. 4.2

(a) Use Fig. 4.2 to determine:

(i) the initial amplitude of the oscillations

amplitude = [1]



- (ii) the angular frequency ω of the oscillations

$$\omega = \dots\dots\dots \text{rad s}^{-1} \quad [2]$$

- (iii) the maximum speed v_0 , in cm s^{-1} , of the oscillating trolley.

$$v_0 = \dots\dots\dots \text{cm s}^{-1} \quad [2]$$

- (b) Apart from the quantities in (a), describe what may be deduced from Fig. 4.2 about the motion of the trolley between time $t = 0$ and time $t = 24$ s. No calculations are required.

.....
.....
.....
.....
..... [3]

- (c) On Fig. 4.3, sketch the variation with L of the velocity v of the trolley for its first complete oscillation.

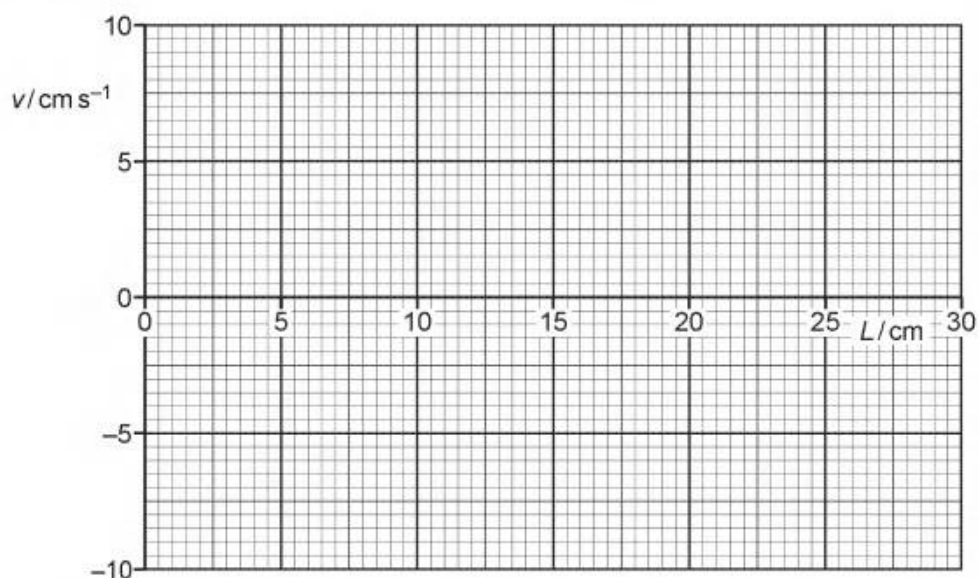


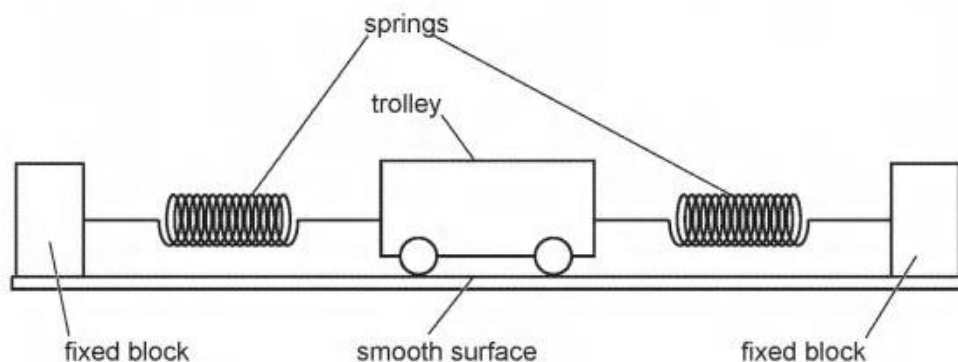
Fig. 4.3

[3]

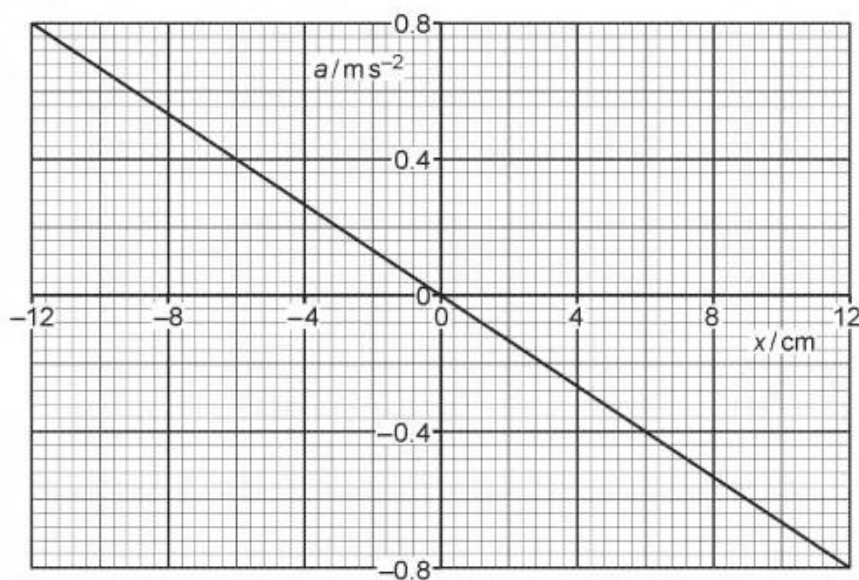


20 – (9702/42_Winter_2021_Q4) – Oscillations

A trolley on a smooth surface is attached by springs to fixed blocks as shown in Fig. 4.1.

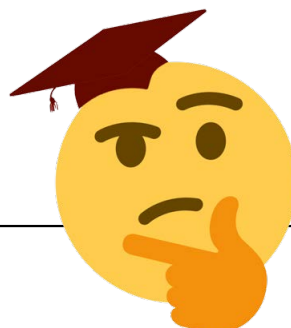
**Fig. 4.1**

The trolley oscillates horizontally about its equilibrium position with an amplitude of 12 cm. Fig. 4.2 shows the variation of the acceleration a of the trolley with displacement x from its equilibrium position. Friction between the trolley and the surface can be assumed to be negligible.

**Fig. 4.2**

- (a) Describe the features of the line in Fig. 4.2 that demonstrate that the motion of the trolley is simple harmonic.

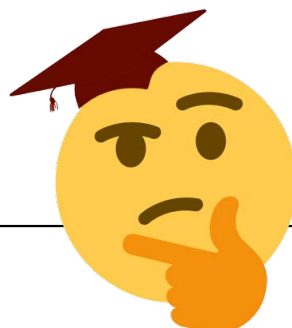
.....
.....
..... [2]



(b) Use Fig. 4.2 to determine the period T of the oscillations of the trolley.

$T = \dots\dots\dots$ s [3]

- (c) (i) On the line of the graph of Fig. 4.2, label with the letter P one point where the kinetic energy of the trolley is zero. [1]
- (ii) On the line of the graph of Fig. 4.2, label with the letter Q an approximate position of one point where the kinetic energy of the trolley is equal to the potential energy stored in the springs. [1]



21 - (9702/41_Summer_2022_Q4) - Oscillations

A pendulum consists of a bob (small metal sphere) attached to the end of a piece of string. The other end of the string is attached to a fixed point. The bob oscillates with small oscillations about its equilibrium position, as shown in Fig. 4.1.

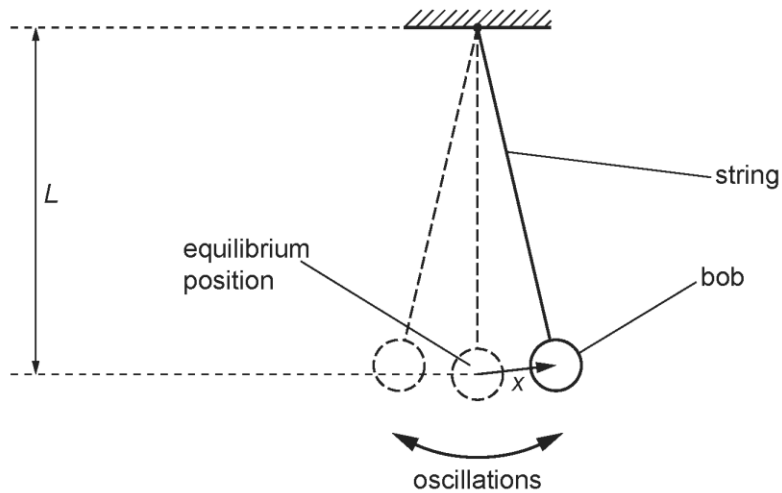


Fig. 4.1 (not to scale)

The length L of the pendulum, measured from the fixed point to the centre of the bob, is 1.24 m.

The acceleration a of the bob varies with its displacement x from the equilibrium position as shown in Fig. 4.2.

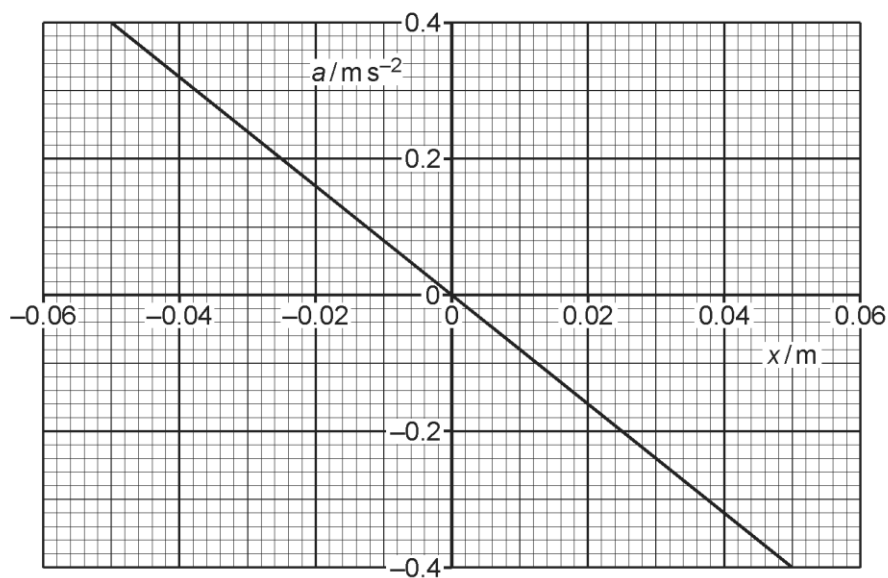
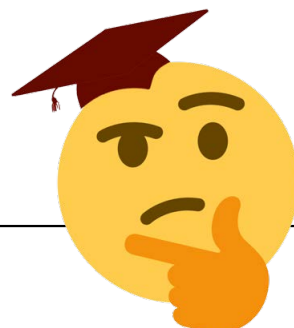


Fig. 4.2



- (a) State how Fig. 4.2 shows that the motion of the pendulum is simple harmonic.

.....
.....
..... [2]

- (b) (i) Use Fig. 4.2 to determine the angular frequency ω of the oscillations.

$$\omega = \dots\dots\dots \text{rad s}^{-1} \quad [2]$$

- (ii) The angular frequency ω is related to the length L of the pendulum by

$$\omega = \sqrt{\frac{k}{L}}$$

where k is a constant.

Use your answer in (b)(i) to determine k . Give a unit with your answer.

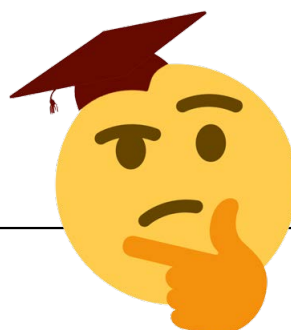
$$k = \dots\dots\dots \text{unit} \dots\dots\dots [2]$$

- (c) While the pendulum is oscillating, the length of the string is increased in such a way that the total energy of the oscillations remains constant.

Suggest and explain the qualitative effect of this change on the amplitude of the oscillations.

.....
.....
..... [2]

[Total: 8]



22 - (9702/42_Summer_2022_Q4) - Oscillations

(a) State what is meant by resonance.

.....
.....
..... [2]

(b) Fig. 4.1 shows a heavy pendulum and a light pendulum, both suspended from the same piece of string. This string is secured at each end to fixed points.

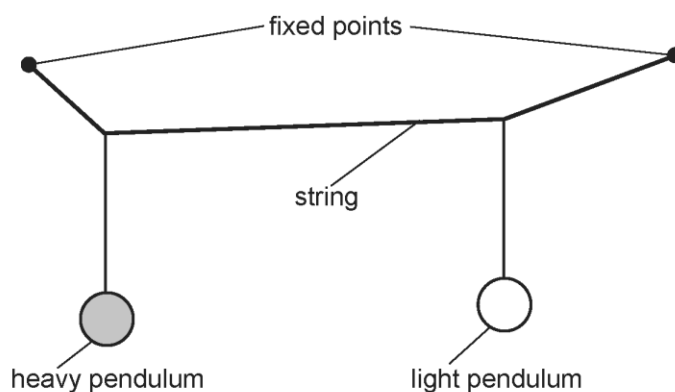


Fig. 4.1

Both pendulums have the same natural frequency.

The heavy pendulum is set oscillating perpendicular to the plane of the diagram. As it oscillates, it causes the light pendulum to oscillate.

Fig. 4.2 shows the variation with time t of the displacements of the two pendulums for three oscillations.

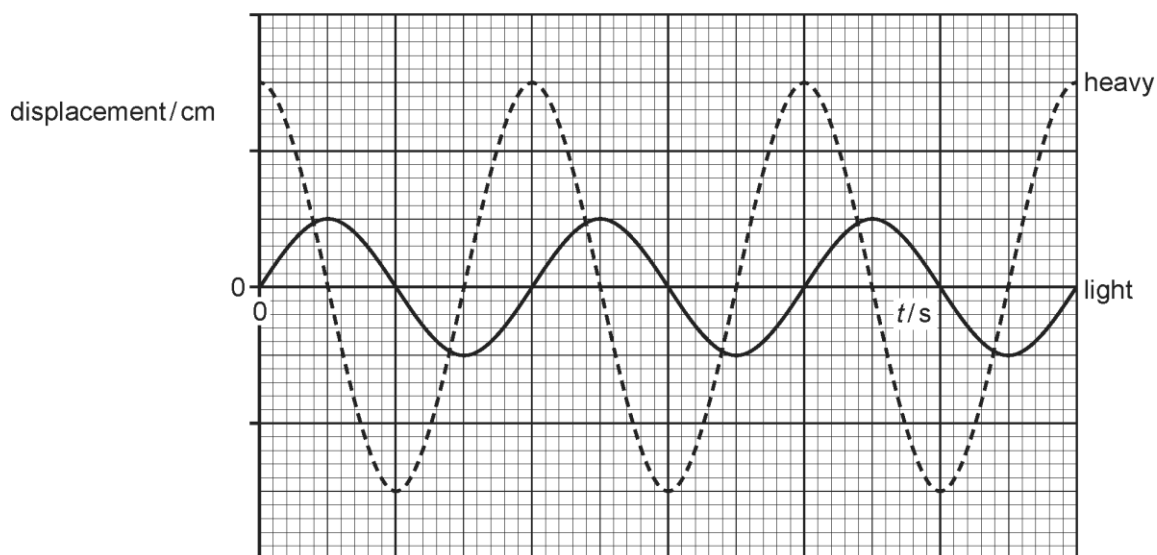
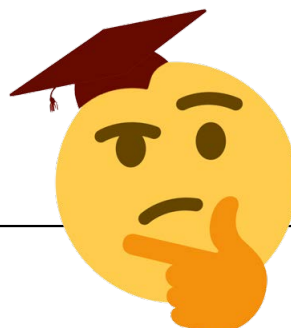


Fig. 4.2



The variation with t of the displacement x of the light pendulum is given by

$$x = 0.25 \sin 5.0\pi t$$

where x is in centimetres and t is in seconds.

- (i) Calculate the period T of the oscillations.

$$T = \dots\dots\dots \text{ s [2]}$$

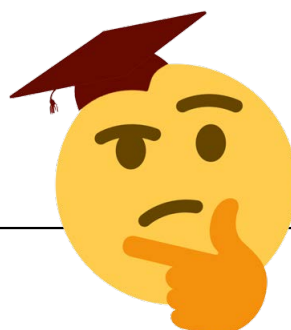
- (ii) On Fig. 4.2, label both of the axes with the correct scales. Use the space below for any additional working that you need.

[2]

- (iii) Determine the magnitude of the phase difference ϕ between the oscillations of the light and heavy pendulums. Give a unit with your answer.

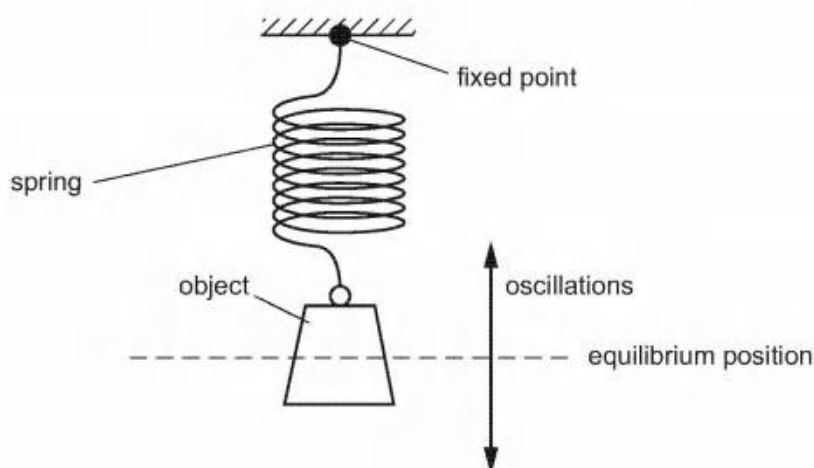
$$\phi = \dots\dots\dots \text{ unit } \dots\dots\dots [2]$$

[Total: 8]



23 - (9702/41_Winter_2022_Q3) - Oscillations

An object is suspended from a spring that is attached to a fixed point as shown in Fig. 3.1.

**Fig. 3.1**

The object oscillates vertically with simple harmonic motion about its equilibrium position.

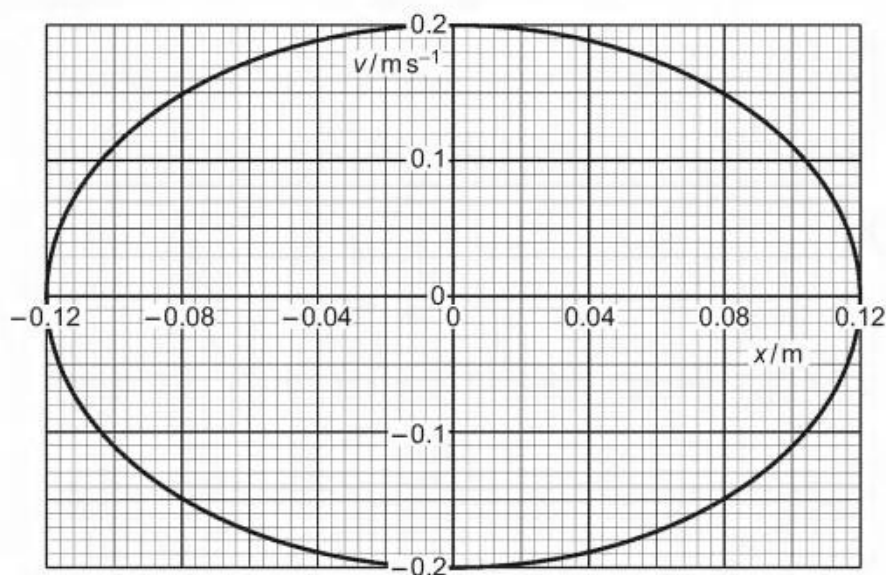
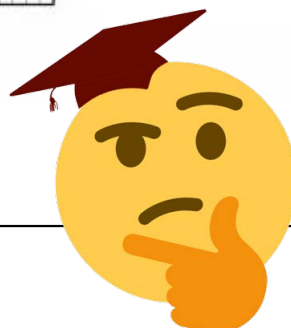
- (a) State the defining equation for simple harmonic motion. Identify the meaning of each of the symbols used to represent physical quantities.

.....

.....

..... [2]

- (b) The variation with displacement x from the equilibrium position of the velocity v of the object is shown in Fig. 3.2.

**Fig. 3.2**

The variation with x of the potential energy E_p of the oscillations of the object is shown in Fig. 3.3.

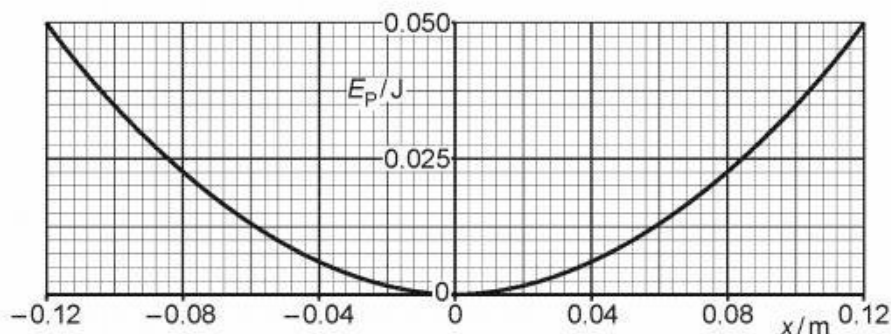


Fig. 3.3

Use Fig. 3.2 and Fig. 3.3 to:

- (i) determine the amplitude x_0 of the oscillations

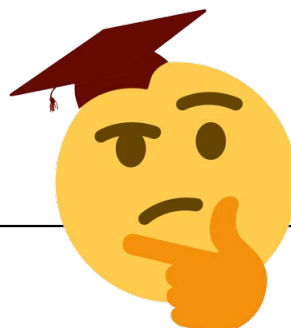
$$x_0 = \dots\dots\dots \text{ m [1]}$$

- (ii) show that the angular frequency of the oscillations is 1.7 rad s^{-1}

[2]

- (iii) determine the mass M of the object.

$$M = \dots\dots\dots \text{ kg [2]}$$



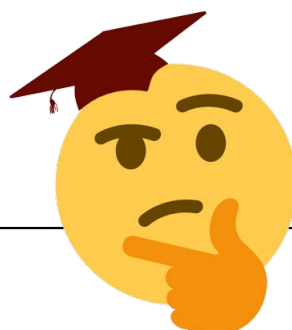
(c) The oscillations of the object are now lightly damped.

(i) State what is meant by damping.

.....
.....
..... [2]

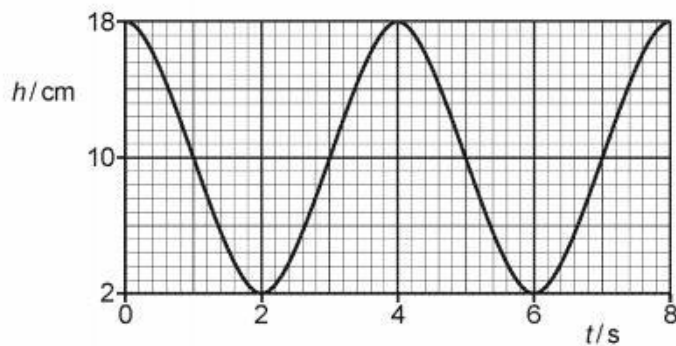
(ii) Assume that the damping does not change the angular frequency of the oscillations.

On Fig. 3.2, sketch the variation with x of v when the amplitude of the oscillations is 0.060 m. [2]



24 – (9702/42_Winter_2022_Q4) – Oscillations

Fig. 4.1 shows the variation with time t of the height h above the ground of an object of mass 36 kg that is undergoing vertical simple harmonic motion.

**Fig. 4.1**

(a) For the oscillations of the object:

(i) determine the amplitude x_0 , in cm

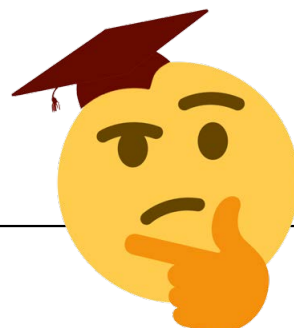
$x_0 = \dots\dots\dots$ cm [1]

(ii) show that the angular frequency ω is 1.6 rad s^{-1}

[2]

(iii) determine the total energy E .

$E = \dots\dots\dots$ J [3]



(b) On Fig. 4.2, sketch the variation with h of the kinetic energy E_K of the object.

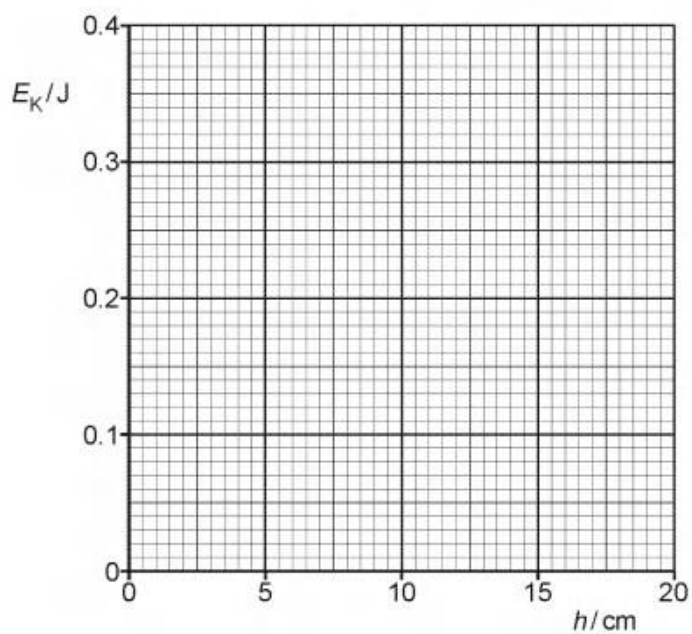
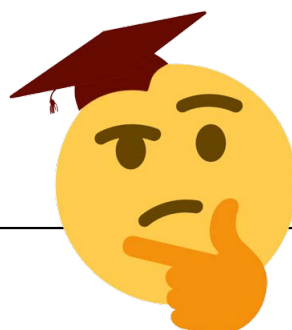


Fig. 4.2

[4]



25 - (9702/42_Summer_2023_Q4) - Oscillations

A small steel sphere is oscillating vertically on the end of a spring, as shown in Fig. 4.1.

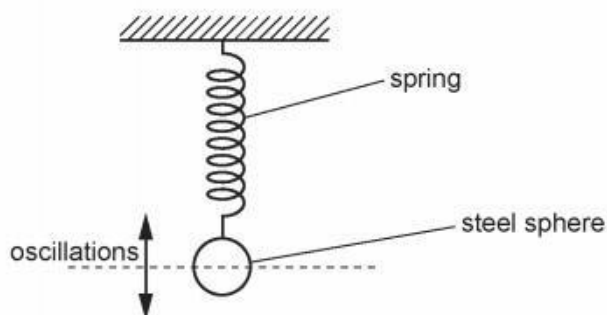


Fig. 4.1

The velocity v of the sphere varies with displacement x from its equilibrium position according to

$$v = \pm 9.7\sqrt{(11.6 - x^2)}$$

where v is in cm s^{-1} and x is in cm.

(a) (i) Calculate the frequency of the oscillations.

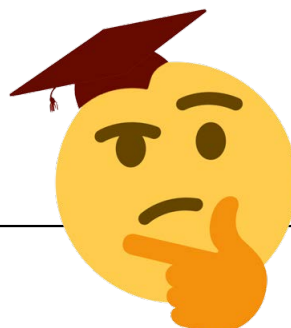
frequency = Hz [2]

(ii) Show that the amplitude of the oscillations is 3.4 cm.

[1]

(iii) Calculate the maximum acceleration a_0 of the sphere.

$a_0 = \dots \text{ms}^{-2}$ [2]



(b) On Fig. 4.2, sketch the variation with x of the acceleration a of the sphere.

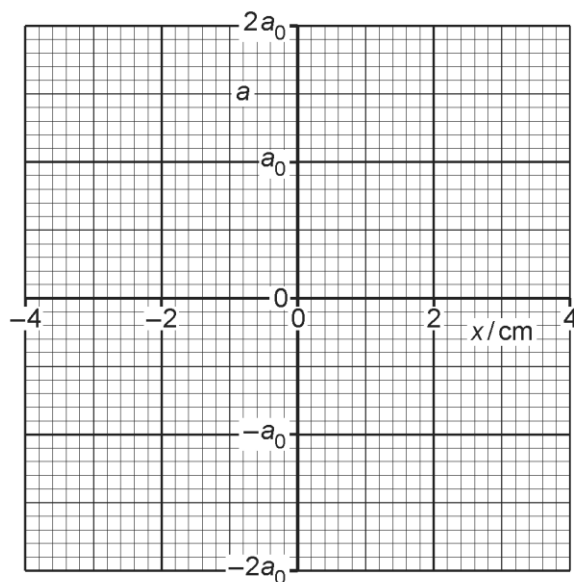
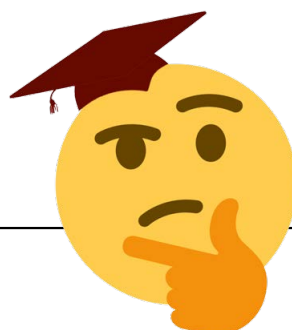


Fig. 4.2

[3]

(c) Describe, without calculation, the interchange between the potential energy and the kinetic energy of the oscillations.

.....
.....
.....
.....
..... [3]



26 – (9702/41_Winter_2023_Q4) – Oscillations, Motion In A Circle

A heavy metal sphere of mass 0.81 kg is suspended from a string. The sphere is undergoing small oscillations from side to side, as shown in Fig. 4.1.

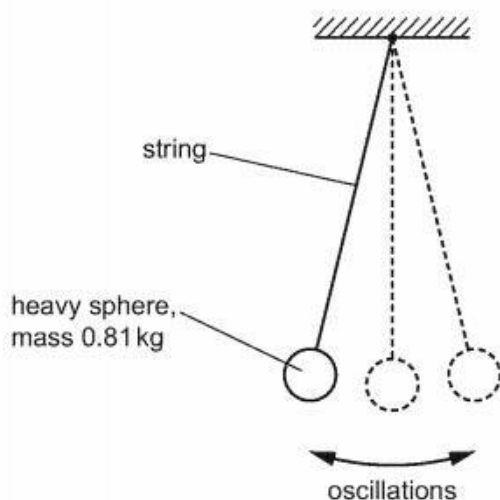


Fig. 4.1

The oscillations of the sphere may be considered to be simple harmonic with amplitude 0.036 m and period 3.0 s.

(a) State what is meant by simple harmonic motion.

.....

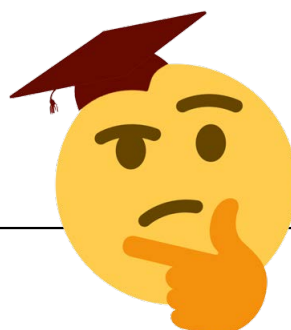
.....

..... [2]

(b) Calculate:

(i) the angular frequency of the oscillations

angular frequency = rad s^{-1} [2]



(ii) the total energy of the oscillations.

total energy = J [2]

- (c) The suspended sphere is now lowered into water. The sphere is given a sideways displacement of +0.036 m from its equilibrium position and is then released at time $t = 0$. The water causes the motion of the sphere to be critically damped.

On Fig. 4.2, sketch the variation of the displacement x of the sphere from its equilibrium position with t from $t = 0$ to $t = 6.0$ s.

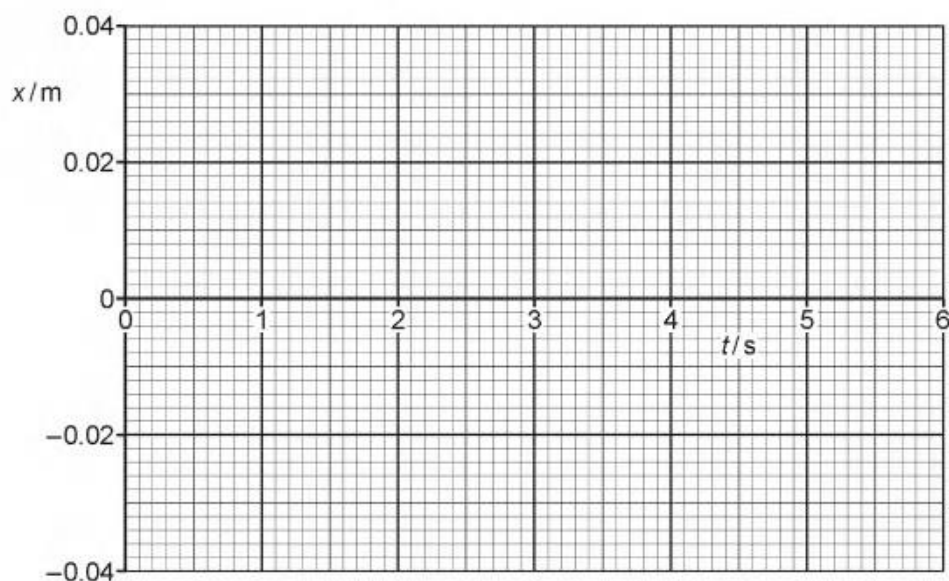
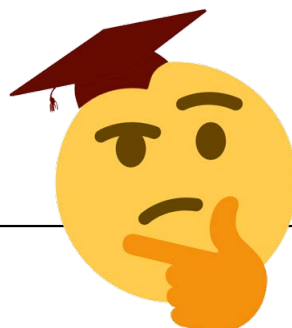


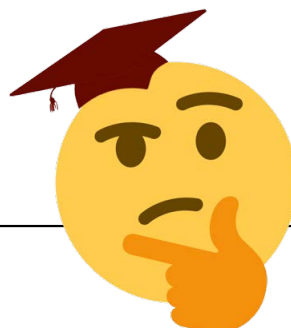
Fig. 4.2

[3]



(a) Explain the main principles behind the **use** of ultrasound to obtain diagnostic information about internal body structures.

[6]



- (b) A parallel beam of ultrasound has intensity I_0 as it enters a muscle of thickness 4.6 cm, as illustrated in Fig. 4.1.

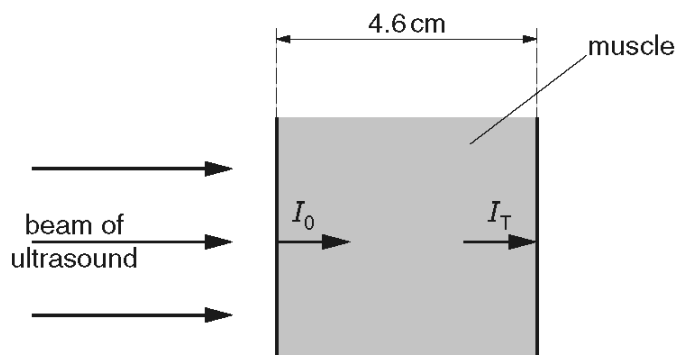


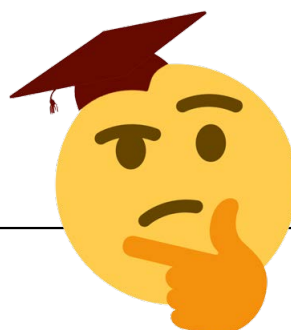
Fig. 4.1

The intensity of the beam just before it leaves the muscle is I_T .

The ratio I_0/I_T is found to be 2.9.

Calculate the linear attenuation (absorption) coefficient μ of the ultrasound in the layer of muscle.

$$\mu = \dots\dots\dots \text{cm}^{-1} [3]$$



2 - (9702/42_Winter_2017_Q4) - *Waves*

(a) Explain the principles behind the **generation** of ultrasound waves for diagnosis in medicine.

[5]

(b) Ultrasound frequencies as high as 10 MHz are used in medical diagnosis. Suggest one advantage of the use of high-frequency ultrasound rather than lower-frequency ultrasound.

[1]



3 - (9702/41_Summer_2018_Q4) - Waves

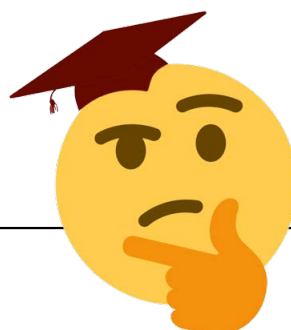
Piezo-electric transducers are used for the generation of ultrasonic waves.

(a) State one other use, apart from in ultrasound, of piezo-electric transducers.

.....
.....[1]

(b) Explain the main principles behind the **use** of ultrasound to obtain diagnostic information about internal body structures.

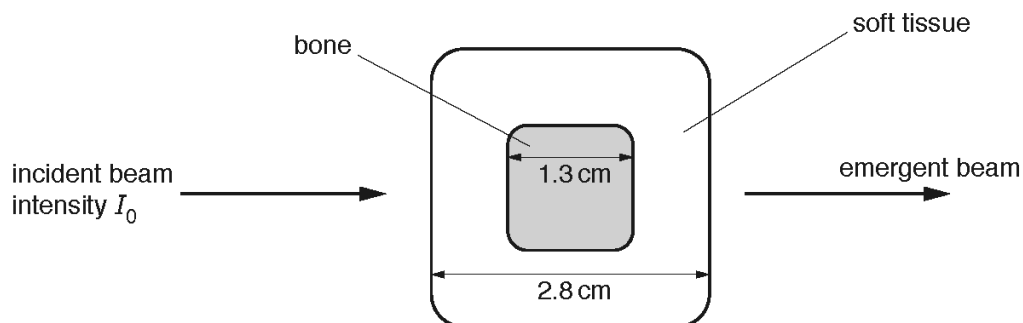
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.....
.....[6]



4 - (9702/41_Summer_2018_Q12) - Waves

An X-ray beam is used to produce an image of a model of a thumb.

A parallel beam of X-ray radiation of intensity I_0 is incident on the model, as illustrated in Fig. 12.1.

**Fig. 12.1**

Data for the attenuation (absorption) coefficient μ in bone and in soft tissue are shown in Fig. 12.2.

	μ/cm^{-1}
bone	3.0
soft tissue	0.90

Fig. 12.2

(a) Calculate, in terms of the incident intensity I_0 of the X-ray beam, the intensity of the beam after passing through

(i) a thickness of 2.8 cm of soft tissue,

intensity = I_0 [2]



(ii) the bone and soft tissue, as shown in Fig. 12.1.

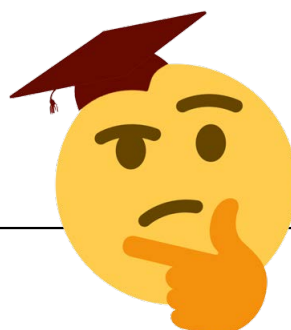
intensity = I_0 [2]

(b) (i) State what is meant by the *contrast* of an X-ray image.

.....
.....
.....[2]

(ii) By reference to your answers in (a), suggest whether the X-ray image of the model has good contrast.

.....
.....
.....[1]



5 - (9702/41_Winter_2018_Q4) - Waves

- (a) Explain the main principles behind the **use** of ultrasound to obtain diagnostic information about internal body structures.

[6]

- (b) (i) Define *specific acoustic impedance*.

[2]

- (ii) The fraction of the incident intensity of an ultrasound beam that is reflected at a boundary between two media depends on the specific acoustic impedances Z_1 and Z_2 of the media.

Discuss qualitatively how the relative magnitudes of the two specific acoustic impedances affect the reflected intensity.

.....[2]



6 - (9702/41_Summer_2023_Q8) - Waves

- (a) Table 8.1 shows some data relating to the properties of air, gel and body tissue. The data are given to three significant figures.

Table 8.1

material	density / kg m^{-3}	speed of sound / m s^{-1}	specific acoustic impedance / $\text{kg m}^{-2} \text{s}^{-1}$
air		340	440
gel	1200	1400	
tissue	1090		1.68×10^6

- (i) Show that the specific acoustic impedance of gel is $1.68 \times 10^6 \text{ kg m}^{-2} \text{s}^{-1}$.

[1]

- (ii) Complete Table 8.1 by calculating the missing values to three significant figures. Use the space below for any working that you need.

[2]

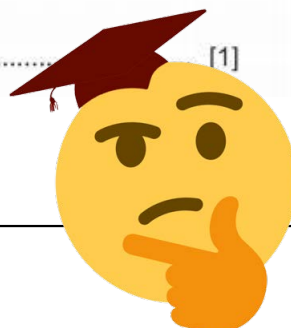
- (b) Use the information in (a) to calculate the intensity reflection coefficient for:

- (i) an air–tissue boundary

intensity reflection coefficient = [2]

- (ii) a gel–tissue boundary.

intensity reflection coefficient = [1]

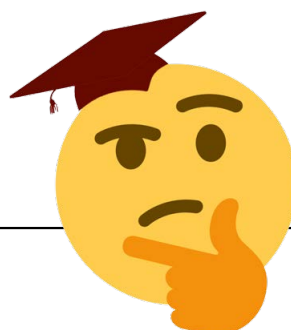


(c) Use your answers in (b) to explain why gel is applied to the skin during ultrasound scanning.

.....

.....

..... [2]



1 - (9702/41_Summer_2017_Q3) - Communication

The digital transmission of speech may be illustrated using the block diagram of Fig. 3.1.

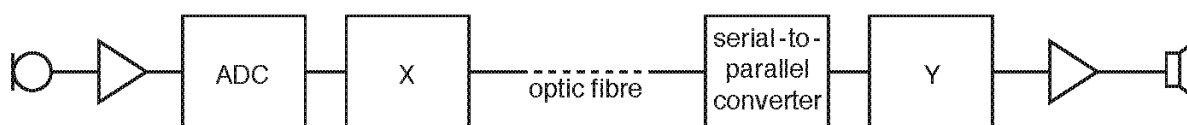


Fig. 3.1

(a) (i) State what is meant by a *digital signal*.

.....
 [1]

(ii) State the names of the components labelled X and Y on Fig. 3.1.

X:
 Y: [2]

(iii) Describe the function of the ADC.

.....

 [2]

(b) The optic fibre has length 84 km and the attenuation per unit length in the fibre is 0.19 dB km^{-1} .

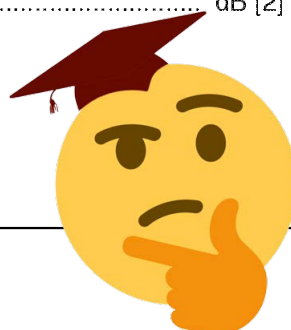
The input power to the optic fibre is 9.7 mW. At the output from the optic fibre, the signal-to-noise ratio is 28 dB.

Calculate

(i) in dB, the ratio

$$\frac{\text{input power to optic fibre}}{\text{noise power at output of optic fibre}}$$

ratio = dB [2]



(ii) the noise power at the output of the optic fibre.

noise power = W [3]



2 - (9702/42_Summer_2017_Q5) - Communication

(a) State two advantages of the transmission of data in digital form rather than in analogue form.

1.

.....

2.

.....

[2]

(b) An analogue signal S_I is converted into a digital signal D using an analogue-to-digital converter (ADC). After transmission of the digital signal, it is converted back to an analogue signal S_T using a digital-to-analogue converter (DAC), as illustrated in Fig. 5.1.

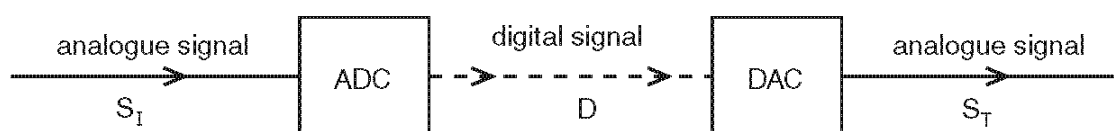


Fig. 5.1

(i) Outline the process by which the ADC converts the analogue signal S_I into the digital signal D .

.....

.....

.....[2]

(ii) The ADC and the DAC operate with the same sampling rate and the same number of bits in each digital number.

State the effect on the transmitted analogue signal S_T when, for the ADC and the DAC,

1. the sampling rate is increased,

.....

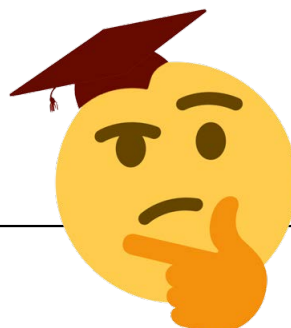
.....

2. the number of bits in each digital number is increased.

.....

.....

[2]



3 - (9702/41_Winter_2017_Q4) - Communication

A coaxial cable is frequently used to connect an aerial to a television receiver. Such a cable is illustrated in Fig. 4.1.

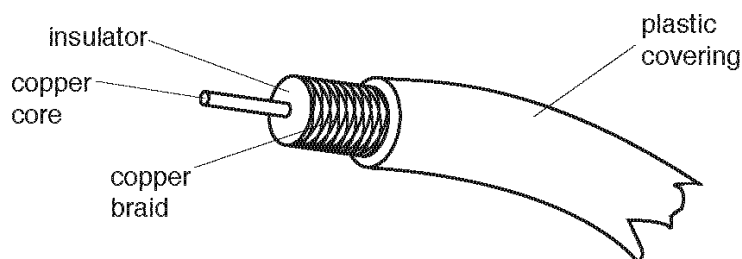


Fig. 4.1

(a) Suggest two functions of the copper braid.

1.
.....
 2.
.....
- [2]

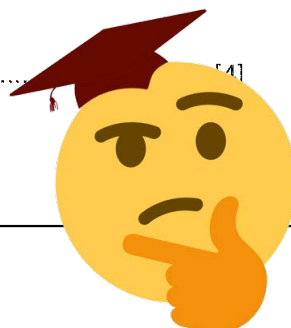
(b) Suggest two reasons why a wire pair is not usually used to connect the aerial to the receiver.

1.
.....
 2.
.....
- [2]

(c) The coaxial cable connecting an aerial to a receiver has length 14 m.
The cable has an attenuation per unit length of 190 dB km^{-1} .

Calculate the fractional **loss** in signal power during transmission of the signal along the cable.

fractional loss = [1]



4 - (9702/42_Winter_2017_Q5) - Communication

The analogue signal from a microphone is to be transmitted in digital form.
The variation with time t of part of the signal from the microphone is shown in Fig. 5.1.

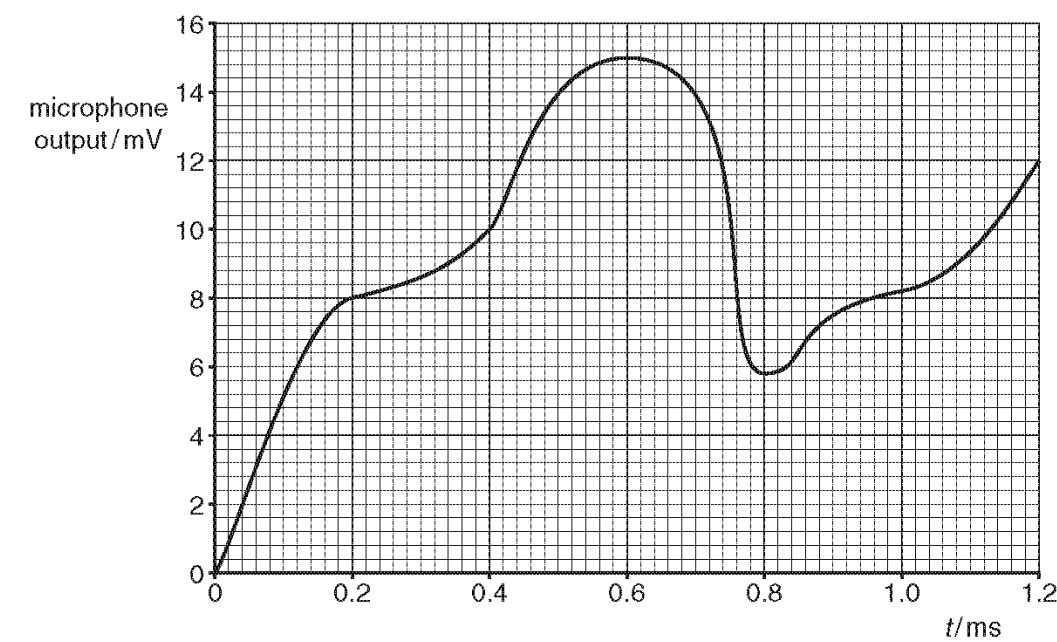


Fig. 5.1

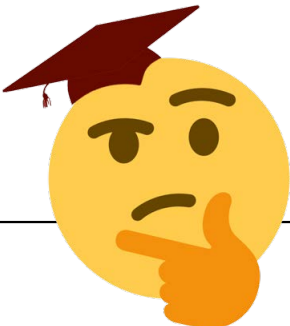
The microphone output is sampled at a frequency of 5.0 kHz by an analogue-to-digital converter (ADC).
The output from the ADC is a series of 4-bit numbers. The smallest bit represents 1.0 mV.
The first sample is taken at time $t = 0$.

(a) Use Fig. 5.1 to complete Fig. 5.2.

time t /ms	microphone output/mV	ADC output
0.2		
0.8		

Fig. 5.2

[2]



- (b) After transmission of the digital signal, it is converted back to an analogue signal using a digital-to-analogue converter (DAC).

Using data from Fig. 5.1, draw, on the axes of Fig. 5.3, the output level from the DAC for the transmitted signal from time $t = 0$ to time $t = 1.2\text{ ms}$.

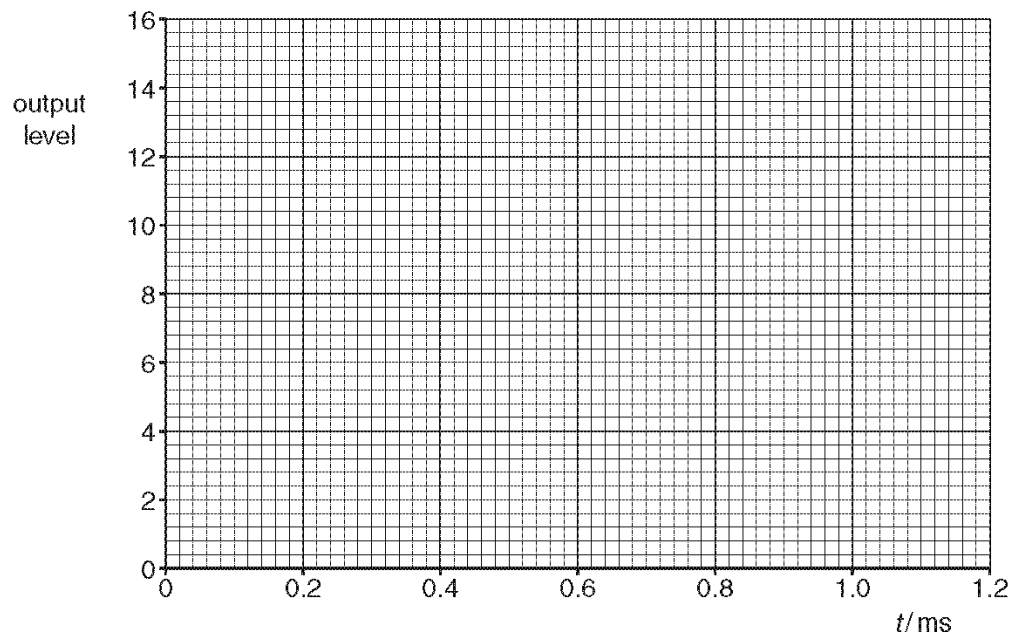


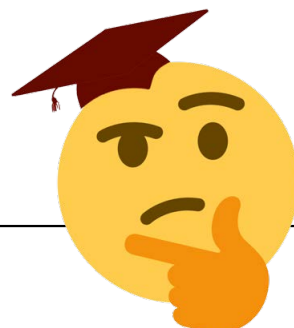
Fig. 5.3

[4]

- (c) It is usual in modern telecommunication systems for the ADC and the DAC to have more than four bits in each sample.

State and explain the effect on the transmitted analogue signal of such an increase.

.....
.....
.....
.....[2]



5 - (9702/41_Summer_2018_Q5) - Communication

A geostationary satellite orbits the Earth with a period of 24 hours.

(a) State

(i) the direction of the orbit about the Earth,

.....[1]

(ii) the position of the satellite relative to the Earth's surface,

.....[1]

(iii) a typical frequency for communication between the satellite and Earth.

frequency = Hz [1]

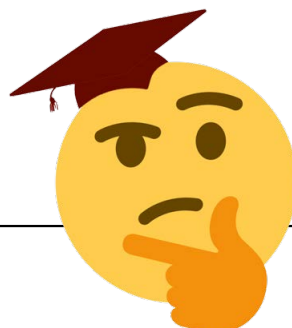
(b) A signal transmitted from Earth to a satellite has an initial power of 3.0 kW.
The signal power received by the satellite is attenuated by 195 dB.

(i) Calculate the signal power received by the satellite.

power = W [3]

(ii) By reference to your answer in (i), explain why different frequencies are used for the up-link and the down-link in communication with the satellite.

.....
.....
.....
.....[2]



6 - (9702/42_Summer_2018_Q5) - Communication

- (a) In radio communication, the bandwidth of an FM transmission is greater than the bandwidth of an AM transmission.

State

- (i) what is meant by *bandwidth*,

.....
.....[1]

- (ii) one advantage and one disadvantage of a greater bandwidth.

advantage:

.....

disadvantage:

.....
[2]

- (b) A carrier wave has a frequency of 650 kHz and is measured to have an amplitude of 5.0 V.

The carrier wave is frequency modulated by a signal of frequency 10 kHz and amplitude 3.0 V.
The frequency deviation of the carrier wave is 8.0 kHz V^{-1} .

Determine, for the frequency modulated carrier wave,

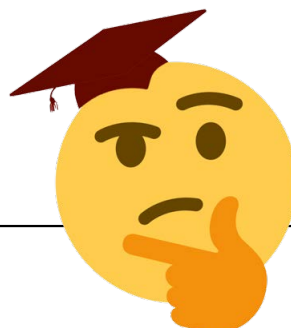
- (i) the measured amplitude,

amplitude = V [1]

- (ii) the maximum and the minimum frequencies,

maximum frequency = kHz

minimum frequency = kHz
[2]



(iii) the minimum time between a maximum and a minimum transmitted frequency.

time =s [1]



7 - (9702/41_Winter_2018_Q5) - Communication

- (a) State two advantages of the transmission of data in digital form, compared with the transmission in analogue form.

1

=====

.....

[2]

- (b)** The digital numbers shown in Fig. 5.1 are transmitted at a sampling rate of 500 Hz.

0111 1011 1001 0100 1110 0101 0010

← end of transmission ← start of transmission

Fig. 5.1

The digital numbers are received, after transmission, by a digital-to-analogue converter (DAC).

On Fig. 5.2, complete the graph to show the variation with time t of the signal level from the DAC.

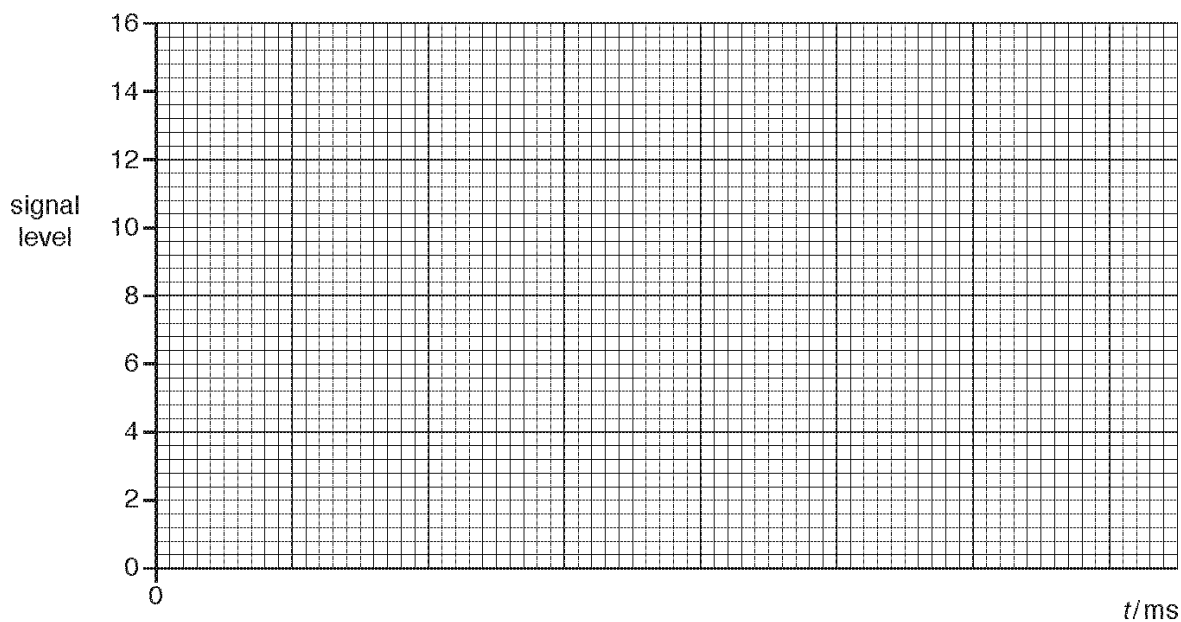


Fig. 5.2

[4]



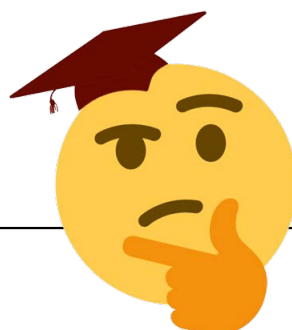
(c) State the effect on the transmitted analogue signal when

(i) the sampling rate of the analogue-to-digital converter (ADC) and of the DAC is increased,

.....
.....[1]

(ii) the number of bits in each sample is increased.

.....
.....[1]



8 - (9702/42_Winter_2018_Q5) - Communication

- (a) In radio communication, the radio wave is usually modulated.

State what is meant by *amplitude modulation (AM)*.

.....
.....
.....[2]

- (b) A sinusoidal radio carrier wave has a frequency of 900 kHz and an unmodulated amplitude measured to be 4.0 V.

The carrier wave is amplitude modulated by a signal of frequency 5.0 kHz.

For the amplitude modulated wave,

- (i) determine the wavelength,

wavelength = m [1]

- (ii) describe the amplitude variation,

.....
.....
.....[2]

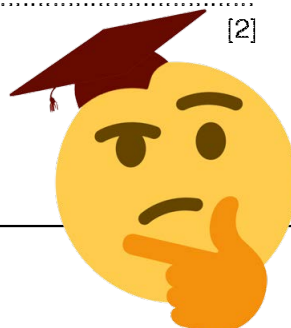
- (iii) state the bandwidth.

bandwidth = Hz [1]

- (c) Communication is sometimes made using satellites in geostationary orbits that have a period of rotation about the Earth of 24 hours.

- (i) State two other features, apart from the period, of a geostationary orbit.

1.
.....
2.
.....
.....[2]



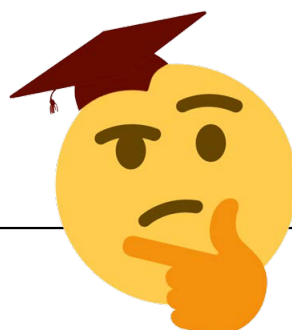
(II) Suggest why

1. frequencies of the order of gigahertz are used for satellite communication,

.....
.....[1]

2. the uplink frequency to the satellite is different from the downlink frequency.

.....
.....
.....[2]



9 - (9702/41_Summer_2019_Q4) - Communication

(a) During the transmission of a signal, attenuation occurs and noise is picked up.

State what is meant by:

(i) *attenuation*

.....
..... [1]

(ii) *noise*.

.....
.....
..... [2]

(b) By reference to (a)(ii), explain the advantage of the transmission of the signal in digital form rather than in analogue form.

.....
..... [1]

(c) Part of an analogue signal is shown in Fig. 4.1.

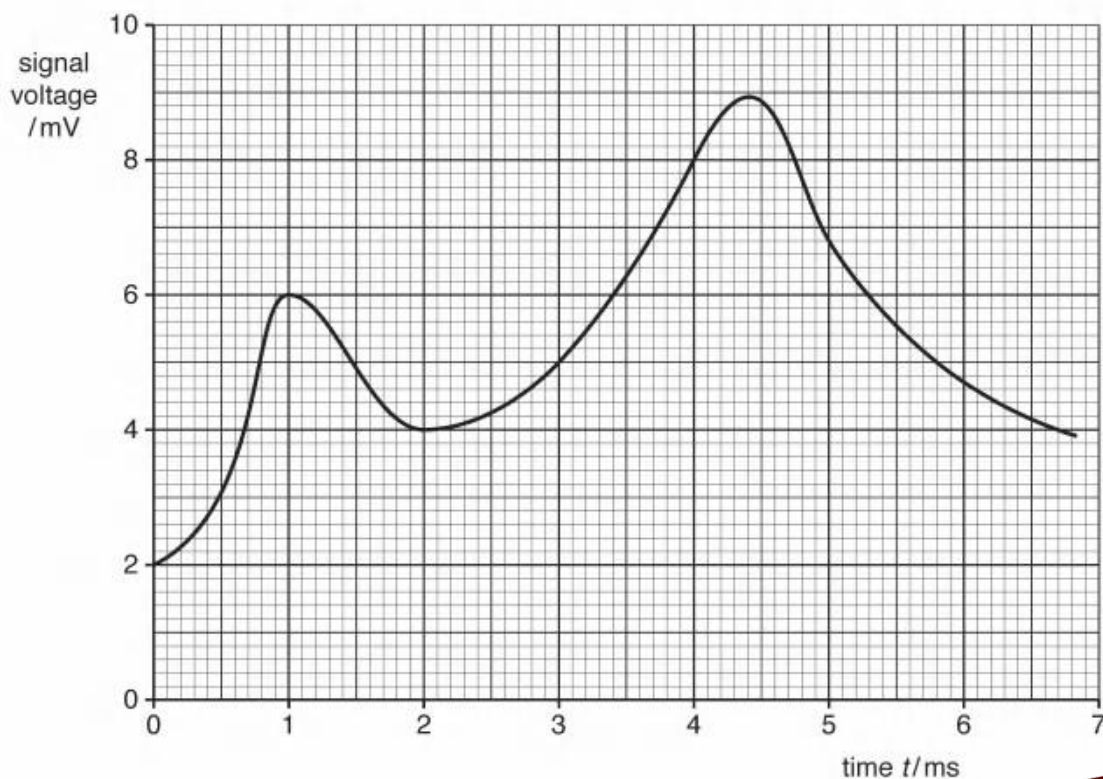


Fig. 4.1



The signal is to be transmitted in digital form.

The analogue signal is sampled at a frequency of $1.0 \times 10^3 \text{ Hz}$ using an analogue-to-digital converter (ADC). The ADC produces 4-bit numbers.

The times t at which the analogue signal is sampled are shown in Fig. 4.2.

time t/ms	0	1.0	2.0	3.0	4.0	5.0	6.0
digital number	0010	0110	0100	0101	.....	.....	.....

Fig. 4.2

On Fig. 4.2:

- (i) for the digital number at time $t = 3.0 \text{ ms}$, underline the least significant bit (LSB) [1]
- (ii) state the digital numbers corresponding to the sampling times between time $t = 4.0 \text{ ms}$ and time $t = 6.0 \text{ ms}$. [2]
- (d) The transmitted digital signal is converted back to an analogue signal using a digital-to-analogue converter (DAC).

On Fig. 4.3, show the variation with time t of the output levels of the DAC for time $t = 0$ to time $t = 4.0 \text{ ms}$. Assume that there is negligible time delay in the transmission line.

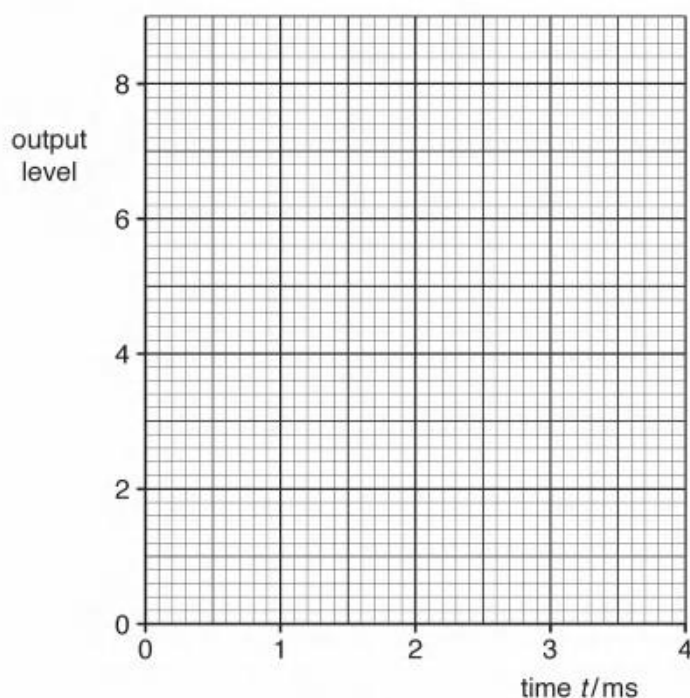
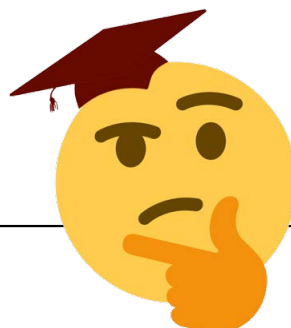


Fig. 4.3

[3]



10 - (9702/42_Summer_2019_Q4) - Communication

- (a) State what is meant by the *specific acoustic impedance* of a medium.

.....

[2]

- (b) A parallel beam of ultrasound of intensity I_0 is incident on the boundary between two media A and B, as illustrated in Fig. 4.1.

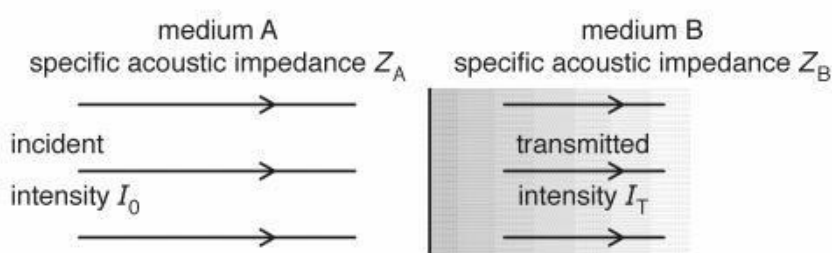


Fig. 4.1

The two media A and B have specific acoustic impedances Z_A and Z_B respectively. The intensity of the beam transmitted through the boundary is I_T .

State how the ratio

$$\frac{\text{intensity } I_T \text{ of transmitted beam}}{\text{intensity } I_0 \text{ of incident beam}}$$

depends on the relative magnitudes of Z_A and Z_B .

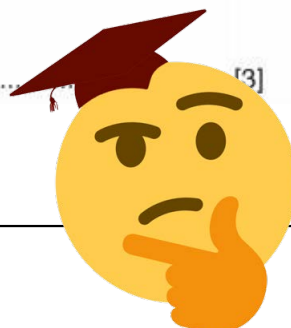
.....

[2]

- (c) The linear absorption (attenuation) coefficient μ of medium B is 23 m^{-1} .

Calculate the thickness of medium B required to reduce the intensity of the ultrasound beam to 34% of its initial intensity in medium B.

thickness =[3]



11 - (9702/42_Summer_2019_Q5) - Communication, Electronics

(a) For a signal transmitted along an optic fibre, state what is meant by:

(i) *attenuation*

.....
 [1]

(ii) *noise*.

.....

 [2]

(b) The initial section of the transmission line for a signal from a telephone exchange is illustrated in Fig. 5.1.

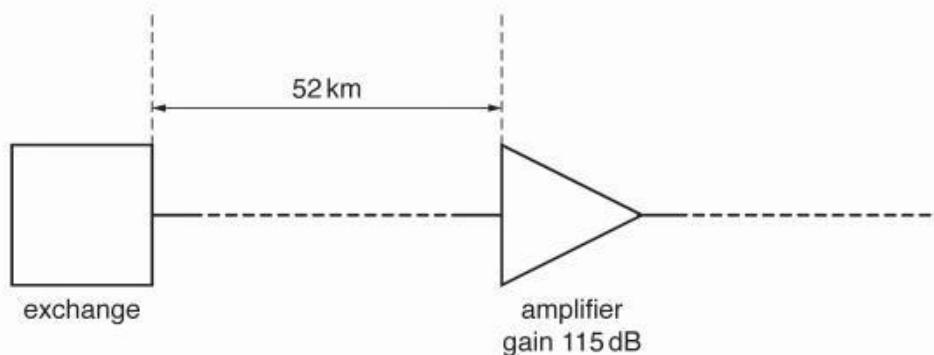


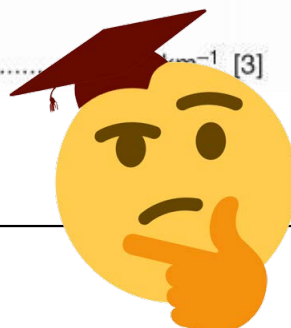
Fig. 5.1

At the exchange, the input signal to the transmission line has a power of $2.5 \times 10^{-3} \text{ W}$.

After the signal has travelled a distance of 52 km along the transmission line, the power of the signal is $7.8 \times 10^{-16} \text{ W}$. The signal is then amplified.

(i) Calculate the attenuation per unit length, in dB km^{-1} , in the transmission line.

attenuation per unit length = dB km^{-1} [3]



- (ii) The gain of the amplifier is 115 dB.

Calculate the power of the signal at the output of the amplifier.

power = W [2]



12 - (9702/41_Winter_2019_Q5) - Communication

- (a) A section of a coaxial cable is shown in Fig. 5.1.

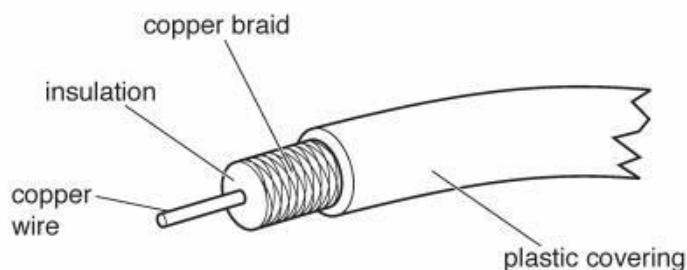


Fig. 5.1

- (i) Suggest **two** functions of the copper braid.

1.

.....

2.

.....

[2]

- (ii) Suggest **one** application of a coaxial cable for the transmission of electrical signals.

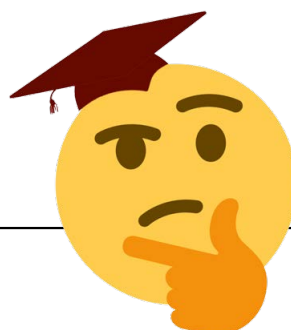
.....

..... [1]

- (b) (i) The constant noise power in a transmission cable is $7.6\mu\text{W}$. The minimum acceptable signal-to-noise ratio is 32 dB.

Calculate the minimum acceptable signal power P_{MIN} in the cable.

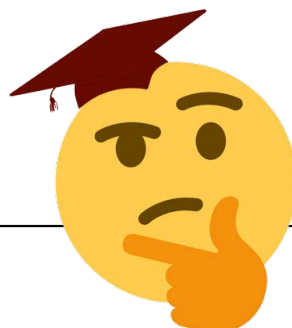
$P_{\text{MIN}} = \dots\dots\dots\text{W}$ [2]



- (ii) The input power of the signal to the transmission cable is 2.6 W. The attenuation per unit length of the cable is 6.3 dB km^{-1} .

Use your answer in (i) to determine the maximum uninterrupted length L of cable along which the signal may be transmitted.

$L = \dots\dots\dots \text{ km [2]}$



13 - (9702/42_Winter_2019_Q5) - Communication

- (a) (i) State what is meant by the *specific acoustic impedance* of a medium.

.....

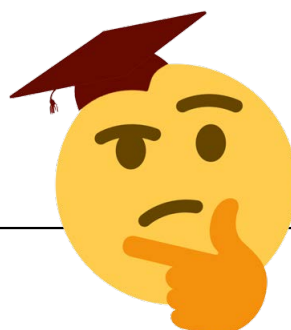
.....

..... [2]

- (ii) The density of a sample of bone is 1.8 g cm^{-3} and the speed of ultrasound in the bone is $4.1 \times 10^3 \text{ m s}^{-1}$.

Calculate the specific acoustic impedance Z_B of the sample of bone.

$$Z_B = \dots\dots\dots \text{ kg m}^{-2} \text{ s}^{-1} \quad [1]$$



(b) A parallel beam of ultrasound passes normally through a layer of fat and of muscle, as illustrated in Fig. 5.1.

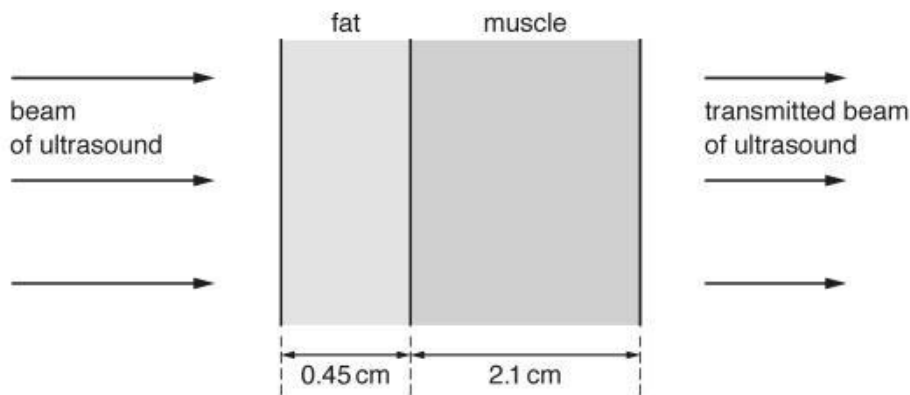


Fig. 5.1 (not to scale)

The fat has thickness 0.45 cm and the muscle has thickness 2.1 cm.

Data for fat and for muscle are given in Fig. 5.2.

	specific acoustic impedance $Z/10^6 \text{ kg m}^{-2} \text{ s}^{-1}$	linear attenuation (absorption) coefficient μ/cm^{-1}
fat	1.3	0.24
muscle	1.7	0.23

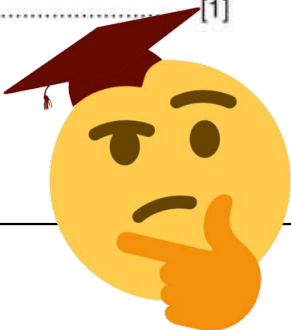
Fig. 5.2

The intensity reflection coefficient α at a boundary between two media of specific acoustic impedances Z_1 and Z_2 is given by the expression

$$\alpha = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}.$$

Calculate the fraction of the intensity of the ultrasound that is **transmitted** through the boundary between the fat and the muscle.

fraction transmitted = [1]



- (c) (i) State what is meant by *attenuation* of an ultrasound wave.

.....
.....
..... [2]

- (ii) Data for linear attenuation coefficients are given in Fig. 5.2.

Determine the ratio

$$\frac{\text{intensity of ultrasound transmitted through the medium}}{\text{intensity of ultrasound entering the medium}}$$

for:

1. the layer of fat of thickness 0.45 cm

ratio =

2. the layer of muscle of thickness 2.1 cm.

ratio = [3]

- (d) Use your answers in (b) and (c)(ii) to determine the fraction of the intensity entering the layer of fat that is transmitted through the layer of muscle.

fraction transmitted = [1]



14 - (9702/42_Winter_2019_Q6) - Communication

The variation with time of the displacement of an amplitude-modulated (AM) wave is shown in Fig. 6.1.

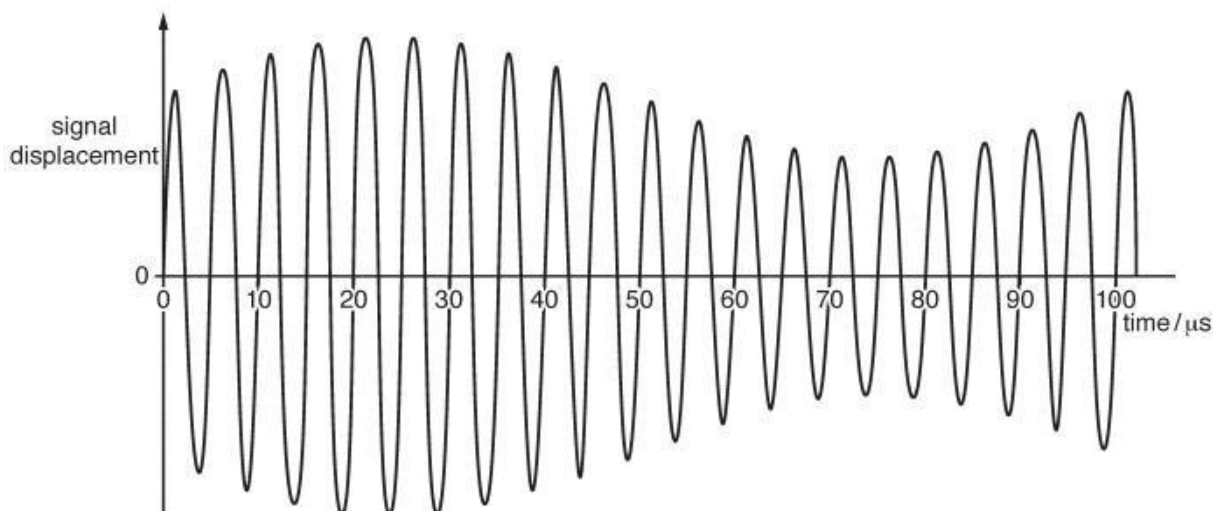


Fig. 6.1

The sinusoidal information signal has frequency 10 kHz.

(a) Determine the frequency of the carrier wave.

frequency = Hz [1]

(b) On the axes of Fig. 6.2, sketch the frequency spectrum of the modulated wave.

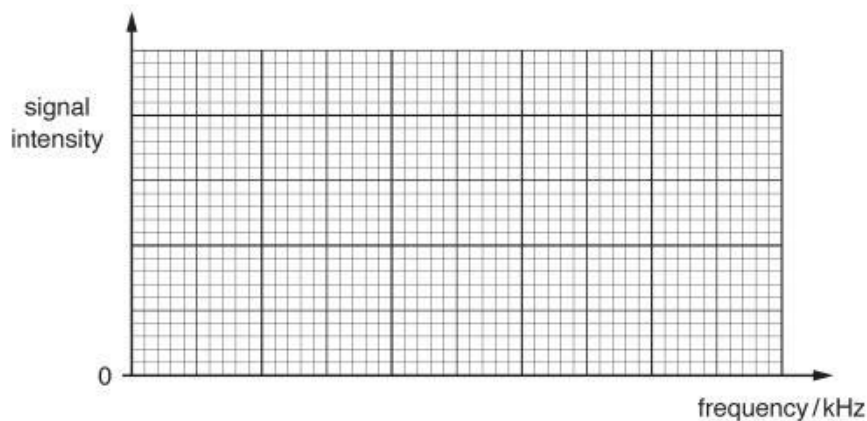
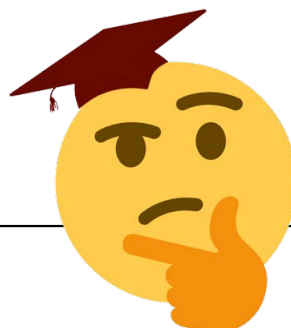


Fig. 6.2

[3]



15 - (9702/41_Summer_2020_Q4) - Communication

- (a) (i) By reference to an ultrasound wave, explain what is meant by *specific acoustic impedance*.

.....
.....
..... [2]

- (ii) An ultrasound wave is incident normally on the boundary between two media. The media have specific acoustic impedances Z_1 and Z_2 .

State how the ratio

$$\frac{\text{intensity of ultrasound reflected from boundary}}{\text{intensity of ultrasound incident on boundary}}$$

depends on the relative magnitudes of Z_1 and Z_2 .

.....
.....
.....
..... [2]

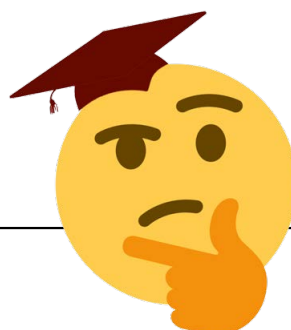
- (b) (i) State what is meant by the *attenuation* of an ultrasound wave.

.....
..... [1]

- (ii) A parallel beam of ultrasound is passing through a medium.
The incident intensity I_0 is reduced to $0.35I_0$ on passing through a thickness of 0.046 m of the medium.

Calculate the linear attenuation coefficient μ of the ultrasound beam in the medium.

$$\mu = \dots\dots\dots \text{m}^{-1} \quad [2]$$



16 - (9702/42_Summer_2020_Q5) - Communication

(a) Explain the principles of the **detection** of ultrasound waves for medical diagnosis.

.....

.....

.....

.....

.....

.....

.....

..... [4]

(b) By reference to specific acoustic impedance, explain why there is very little transmission of ultrasound waves from air into skin.

.....

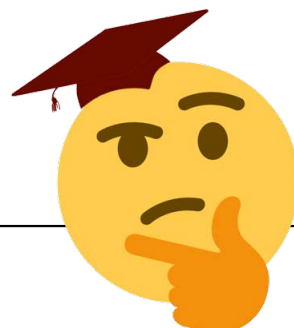
.....

.....

.....

.....

..... [3]



17 - (9702/41_Summer_2020_Q6) - Communication

- (a) The transmission of signals using optic fibres has, to a great extent, replaced the use of coaxial cables.

Advantages of optic fibres include greater bandwidth and very little crosslinking.

- (i) Suggest an advantage of greater bandwidth.

.....
..... [1]

- (ii) State what is meant by *crosslinking*.

.....
.....
..... [2]

- (b) In telecommunications, a signal power of 1.0 mW is used as a reference power. Signal powers relative to this reference power and expressed in dB are said to be measured in 'dBm'.

Show that a signal power of 13 dBm is equivalent to 20 mW.

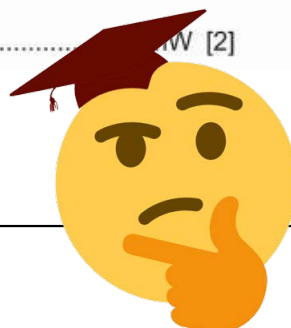
[2]

- (c) A signal of input power 20 mW is transmitted along an optic fibre for an uninterrupted distance of 45 km.

The optic fibre has an attenuation per unit length of 0.18 dB km^{-1} .

Calculate the output power P from the optic fibre.

$P = \dots\dots\dots \text{ mW}$ [2]



18 - (9702/42_Summer_2020_Q6) - Communication

- (a) Telephone signals may be transmitted either by means of an optic fibre or by means of a wire pair.

State **three** advantages of the use of an optic fibre rather than a wire pair.

1.
.....
 2.
.....
 3.
.....
- [3]

- (b) It is proposed to transmit a signal over a distance of 4.5×10^3 km by means of an optic fibre.

The input signal has a power of 9.8 mW.

The minimum signal that can be detected at the output has a power of 6.3×10^{-17} W. For this signal power, the signal-to-noise ratio is 21 dB.

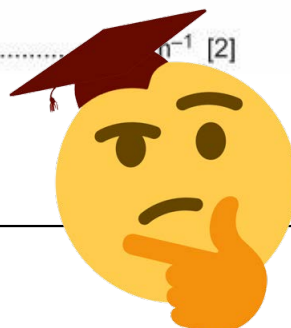
Calculate:

- (i) the power of the background noise

power = W [2]

- (ii) the maximum attenuation per unit length of the optic fibre that allows for uninterrupted transmission of the signal.

attenuation per unit length = dB km^{-1} [2]



19 - (9702/41_Winter_2020_Q4) - Communication

- (a) Explain the principles of the **generation** of ultrasound waves for use in medical diagnosis.

.....

.....

.....

.....

.....

.....

.....

..... [4]

- (b) The linear attenuation (absorption) coefficient for a parallel beam of ultrasound waves in air is 1.2 cm^{-1} .

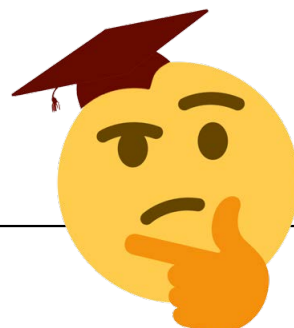
The parallel beam passes through a layer of air of thickness 3.5 cm.

Calculate the ratio, in dB,

$$\frac{\text{intensity of beam after passing through the layer of air}}{\text{intensity of beam entering the layer of air}}.$$

ratio = dB [4]

[Total: 8]



20 – (9702/42_Winter_2020_Q4) – Communication

(a) State **two** advantages of the transmission of data in digital, rather than analogue, form.

1.
2.

[2]

(b) An analogue signal is to be transmitted in digital form.

The transmission system may be represented in block form as in Fig. 4.1.



Fig. 4.1

The variation with time t of part of the input analogue signal is shown in Fig. 4.2.

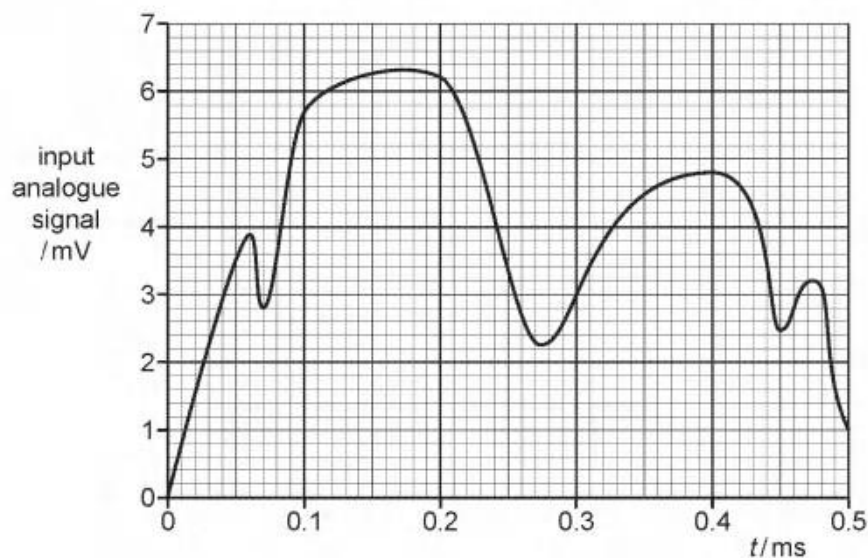


Fig. 4.2

The analogue signal is sampled at time intervals of 0.10 ms. The first sample is taken at time $t = 0$.

Some values of the sampled analogue signal and the corresponding digital signals are shown in Table 4.1.

Each digitised number contains four bits.

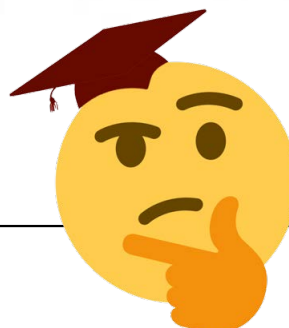


Table 4.1

time t/ms	0	0.10	0.20	0.30	0.40	0.50
analogue signal /mV	0	5.7	6.2	.....	.....	.....
digital signal	0000	0101	0110	.....	.....	.....

- (i)

In Table 4.1, underline the least significant bit (LSB) in the digital signal for the time of 0.20 ms.

[1]
- (ii)

Complete Table 4.1.

[3]
- (c)

A single bit from the output of the digital-to-analogue converter corresponds to an output analogue signal of 1.0 mV.

Assume that the conversion and transmission do not introduce a time delay.

On the axes of Fig. 4.3, show the variation with time t of the output from the digital-to-analogue converter.

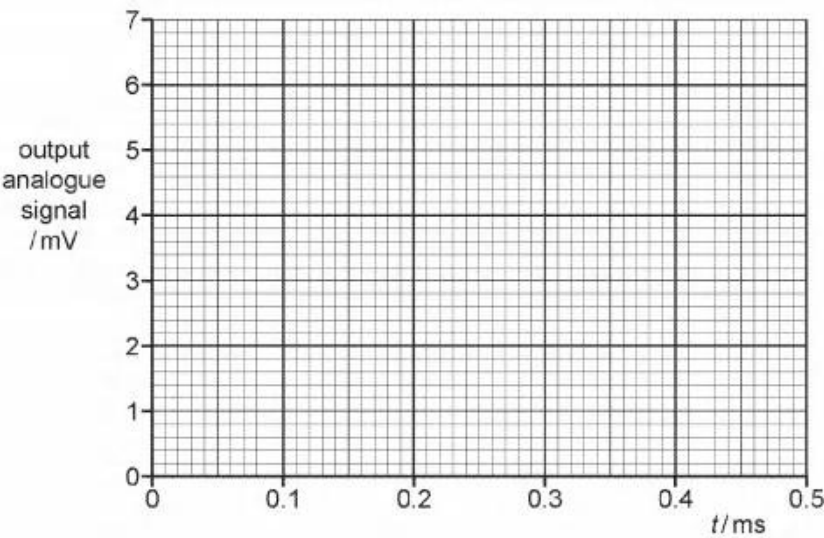
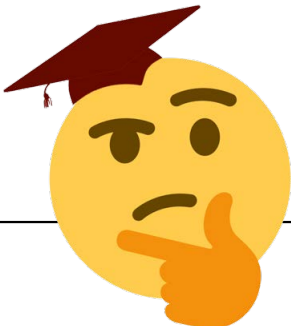


Fig. 4.3

[3]

[Total: 9]



21 - (9702/42_Winter_2020_Q7) - Communication

Electrons in a beam are travelling at high speed in a vacuum. The electrons are incident on a metal target, causing X-ray radiation to be emitted.

The variation with wavelength λ of the intensity I of the emitted X-ray radiation is shown in Fig. 7.1.

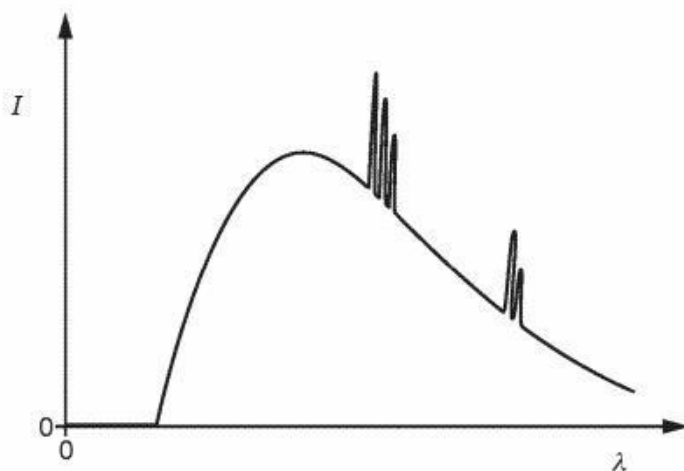


Fig. 7.1

Explain why:

(a) there is a continuous distribution of wavelengths

.....

.....

.....

.....

..... [3]

(b) at certain wavelengths, there are narrow peaks of increased intensity.

.....

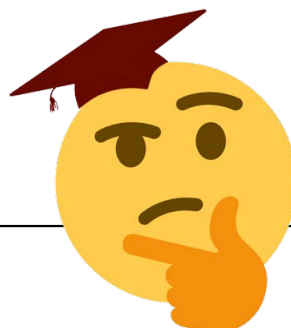
.....

.....

.....

..... [3]

[Total: 6]



22 - (9702/42_Summer_2021_Q4) - Communication

- (a) A sinusoidal carrier wave has a constant amplitude and a frequency of 1.2 MHz. The carrier wave is modulated by a signal wave such that a 1.0 V displacement of the signal wave causes a change in frequency of 25 kHz.

The signal wave has frequency 8.0 kHz and amplitude 2.0 V.

- (i) State the name of this type of modulation of the carrier wave.

..... [1]

- (ii) For this modulated carrier wave, determine the variation, if any, in:

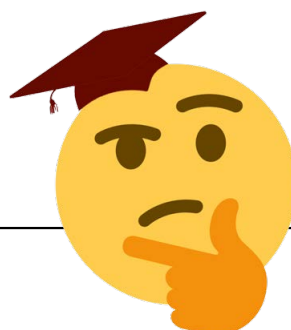
1. its amplitude

.....
.....

2. its frequency.

.....
.....
.....

[3]



- (b) An audio signal is transmitted by means of a modulated radio wave.

The variation with frequency of the amplitude of the radio wave is shown in Fig. 4.1.

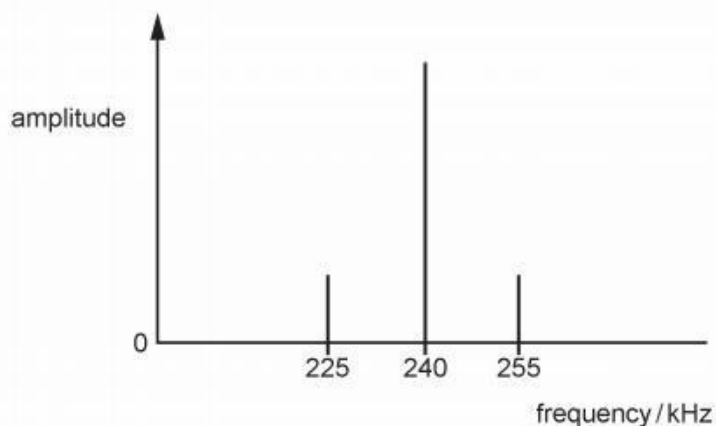


Fig. 4.1

For this transmission, determine:

- (i) the wavelength, in km, of the carrier wave

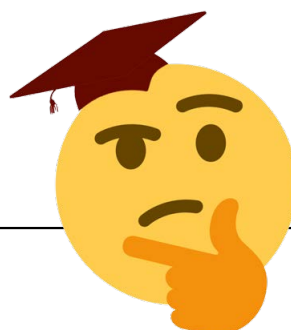
wavelength = km [2]

- (ii) the bandwidth

bandwidth = kHz [1]

- (iii) the frequency of the audio signal.

frequency = kHz [1]



23 - (9702/41_Summer_2021_Q5) - Communication

(a) State what is meant by the *amplitude modulation (AM)* of a radio wave.

.....
.....
..... [2]

(b) A radio wave is modulated by an audio signal.

The variation with frequency f of the amplitude of the modulated wave is shown in Fig. 5.1.

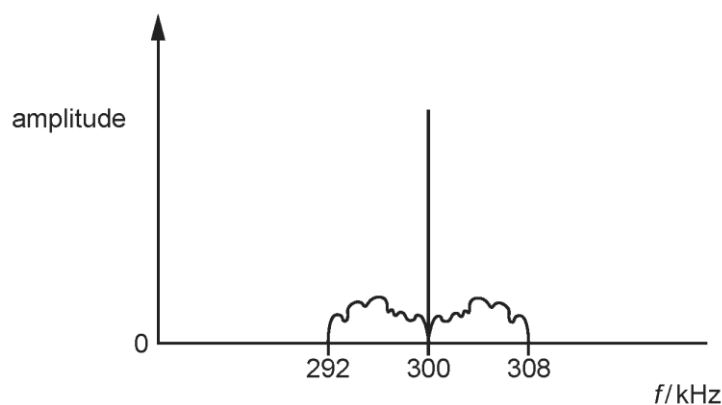


Fig. 5.1

Determine:

(i) the wavelength of the carrier wave

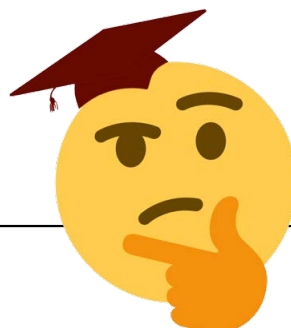
wavelength = m [1]

(ii) the bandwidth of the modulated wave

bandwidth = kHz [1]

(iii) the maximum frequency of the audio signal.

maximum frequency = kHz [1]



- (c) The power of a radio signal at a transmitter is P_T .
At a receiver, the received power P_R is given by the expression

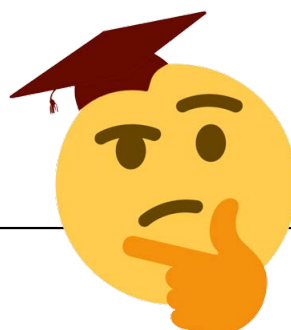
$$P_R = \frac{0.082 P_T}{x^2}$$

where x is the distance, in metres, between the transmitter and the receiver.

For the transmission of this signal, the attenuation is 73 dB.

Determine the distance x .

$x = \dots\dots\dots$ m [3]



24 - (9702/41_Winter_2021_Q5) - Communication

An analogue signal is to be transmitted to a receiver. Before transmission, the signal passes through an analogue-to-digital converter (ADC). After transmission it passes through a digital-to-analogue converter (DAC) before finally reaching the receiver, as shown in Fig. 5.1.

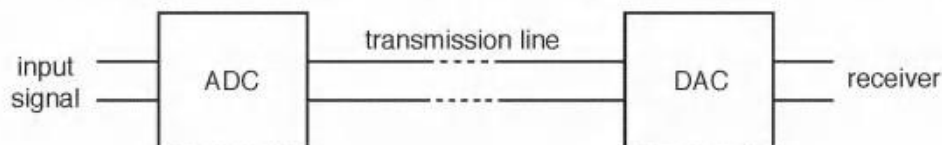


Fig. 5.1

(a) State **two** advantages of converting the signal into digital form for transmission.

1.

.....

2.

.....

[2]

(b) The variation with time of the potential difference (p.d.) of the input signal is shown in Fig. 5.2.

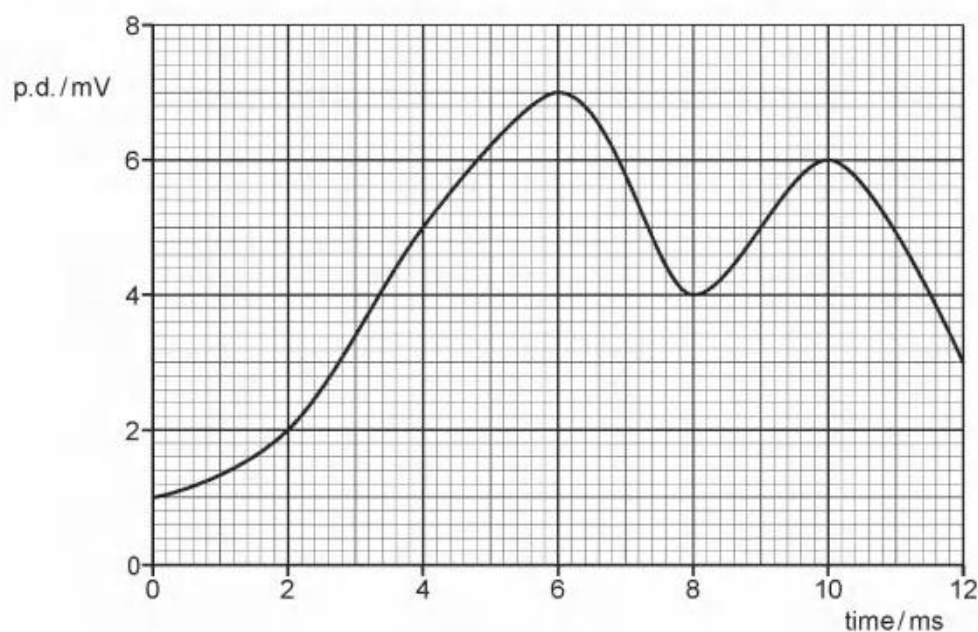
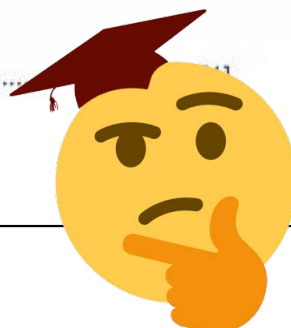


Fig. 5.2

The ADC has a sampling frequency of 250 Hz and uses 4-bit sampling, with the least significant bit corresponding to 1 mV. The signal is first sampled at time 0, when the sampled bits are 0001.

(i) State the sampled bits at time 4 ms and time 8 ms.

4 ms: 8 ms:



- (ii) Part of the signal received by the receiver, after the sampled signal has passed through the DAC, is shown in Fig. 5.3.

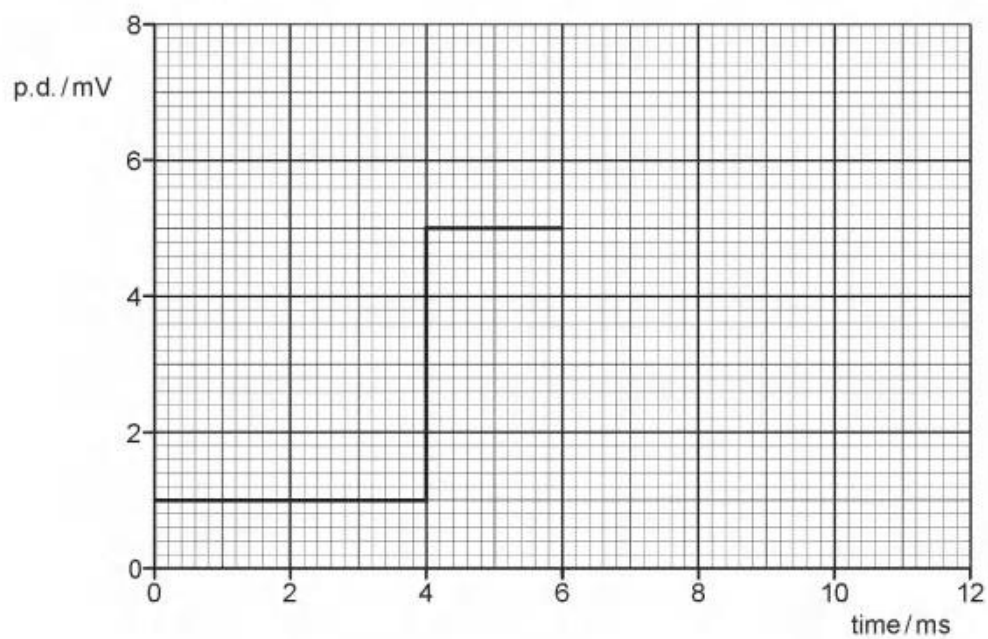
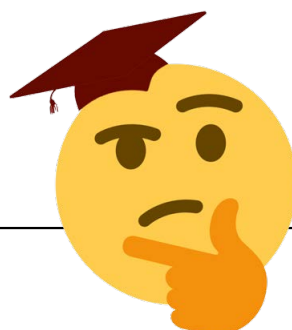


Fig. 5.3

On Fig. 5.3, complete the line to show the received signal for time 0 to time 12 ms. [2]



- (c) The ADC in (b) is replaced with one that has a sampling frequency of 500 Hz and uses 3-bit sampling, with the least significant bit corresponding to 2 mV.

On Fig. 5.4, sketch the signal that is now received, after passing through the DAC, from time 0 to time 12 ms.

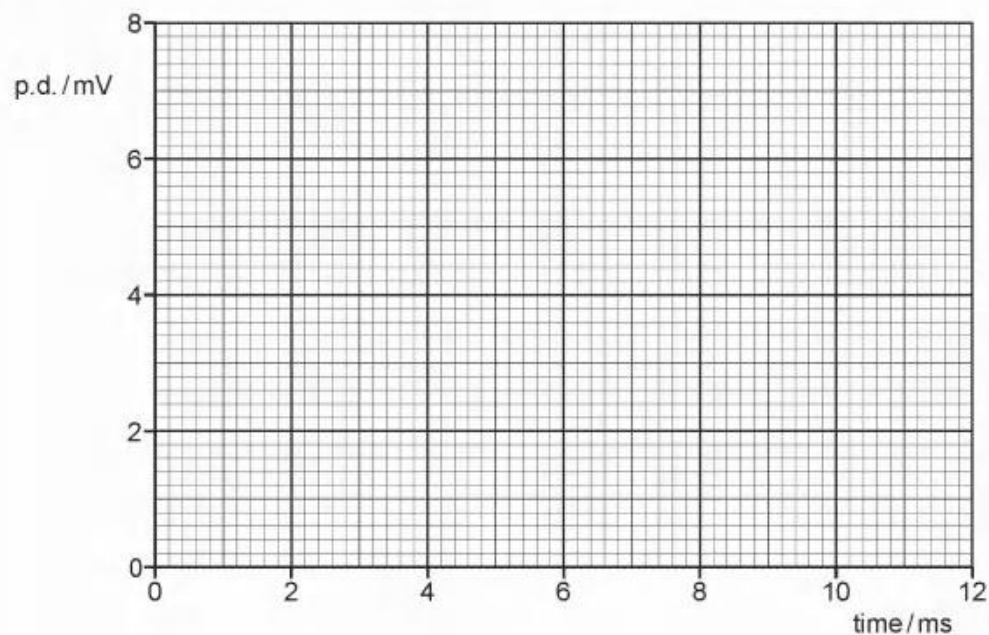
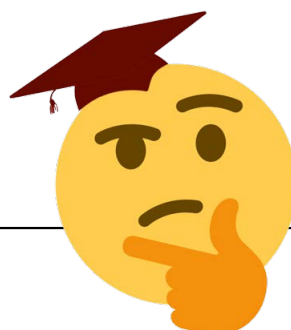


Fig. 5.4

[3]



25 – (9702/42_Winter_2021_Q5) – Communication

- (a) (i) When audio signals are transmitted over long distances, modulation of radio waves is used.

Suggest a reason why modulation is used.

.....
 [1]

- (ii) State a technical advantage and a technical disadvantage of using frequency modulation rather than amplitude modulation.

advantage:

.....

disadvantage:

..... [2]

- (b) An audio signal of amplitude $2.0\ \mu\text{V}$ and frequency $4.2\ \text{kHz}$ is to be transmitted using a carrier wave of amplitude $10.0\ \text{mV}$ and frequency $100\ \text{kHz}$.

Either amplitude modulation or frequency modulation may be used.

The amplitude modulation is at a rate of $1\ \text{mV}\ \mu\text{V}^{-1}$.

The frequency modulation is at a rate of $5\ \text{kHz}\ \mu\text{V}^{-1}$.

Complete Table 5.1 to show the maximum and minimum values of the amplitude and of the frequency of the modulated wave for each type of modulation.

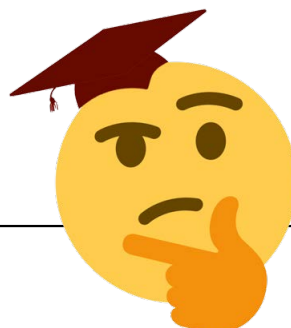
Table 5.1

	amplitude / mV		frequency / kHz	
	minimum	maximum	minimum	maximum
amplitude modulation				
frequency modulation				

[4]

- (c) For the amplitude modulated wave in (b), determine the bandwidth.

bandwidth = kHz [1]



1 - (9702/42_Summer_2017_Q6) - *Electric Fields, Current Of Electricity*

(a) State Coulomb's law.

.....

.....

.....[2]

(b) Two charged metal spheres A and B are situated in a vacuum, as illustrated in Fig. 6.1.

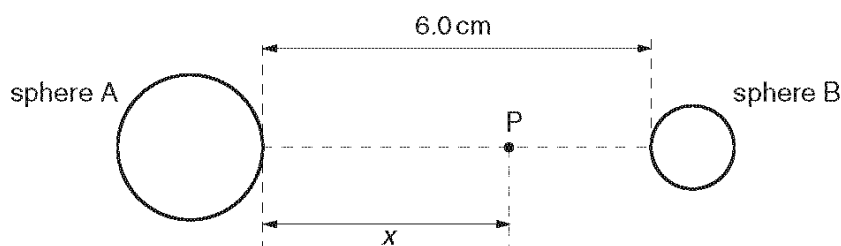


Fig. 6.1

The shortest distance between the surfaces of the spheres is 6.0 cm.

A movable point P lies along the line joining the centres of the two spheres, a distance x from the surface of sphere A.

The variation with distance x of the electric field strength E at point P is shown in Fig. 6.2.

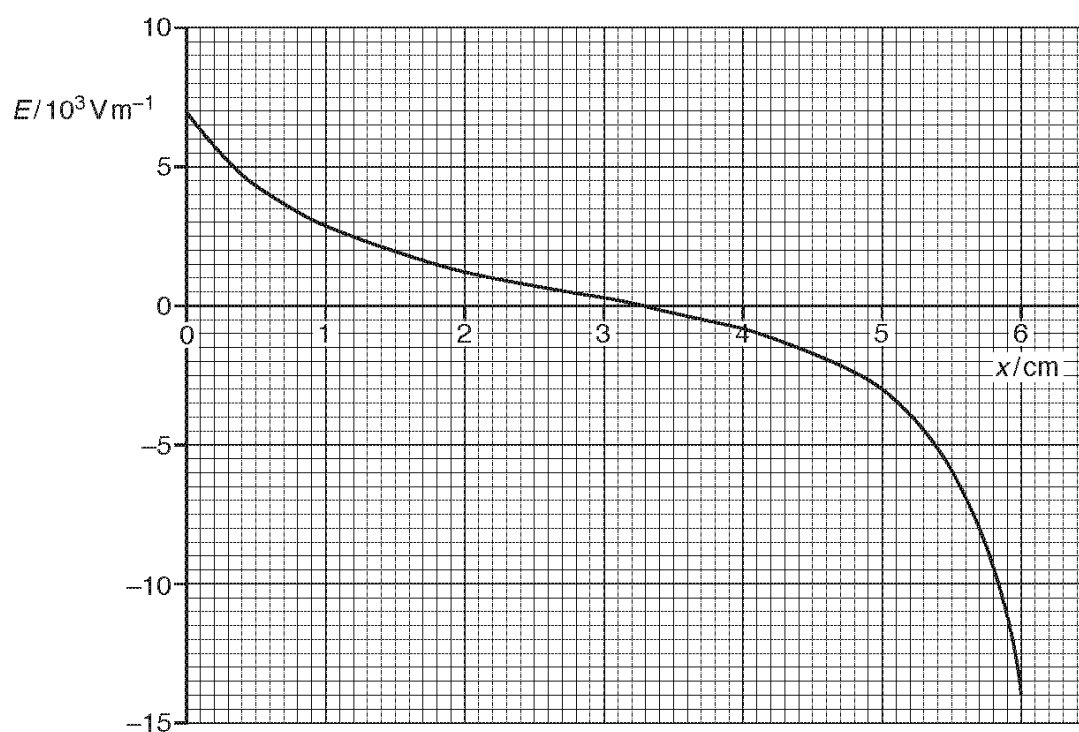
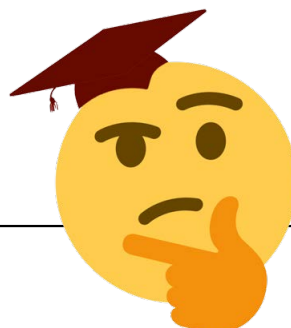


Fig. 6.2



- (i) Use Fig. 6.2 to explain whether the two spheres have charges of the same, or opposite, sign.

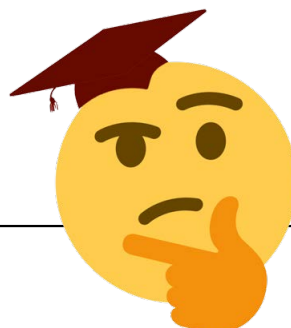
.....
.....
.....
.....[2]

- (ii) A proton is at point P where $x = 5.0$ cm.
Use data from Fig. 6.2 to determine the acceleration of the proton.

acceleration = ms^{-2} [3]

- (c) Use data from Fig. 6.2 to state the value of x at which the rate of change of electric potential is maximum. Give the reason for the value you have chosen.

.....
.....
.....[2]



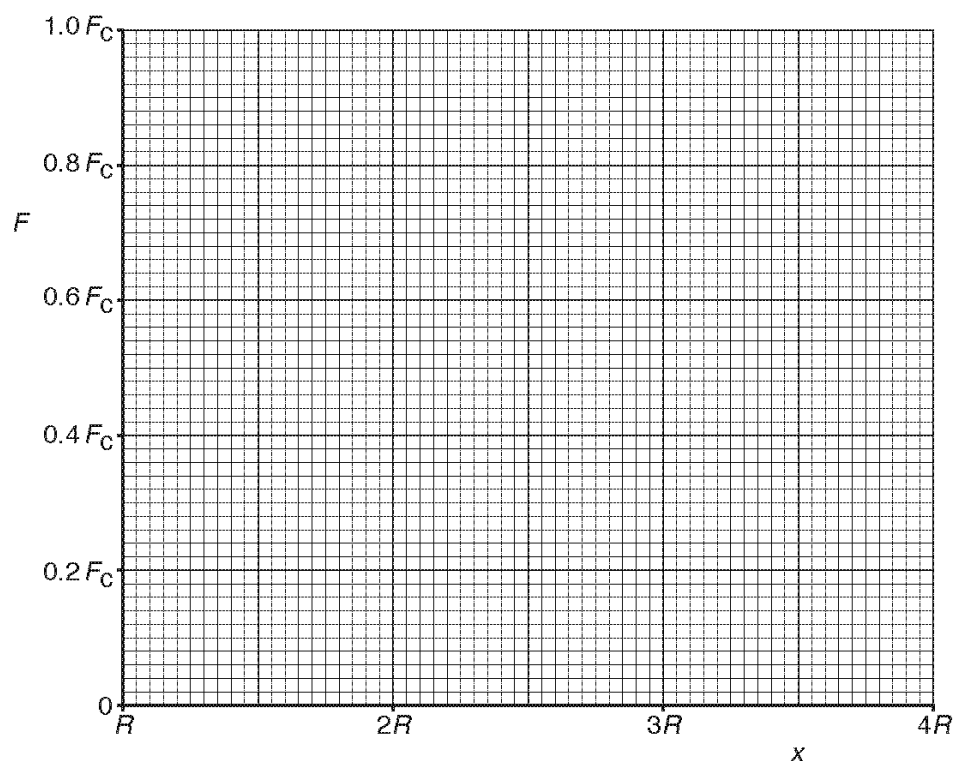
2 - (9702/41_Winter_2017_Q5) - *Electric Fields, Electromagnetic Induction*

- (a) (i) State Coulomb's law for the force between two point charges.

.....
..... [1]

- (ii) Two point charges are situated in a vacuum and separated by a distance R . The force between the charges is F_C .

On Fig. 5.1, sketch a graph to show the variation of the force F between the charges with separation x for values of x from $x = R$ to $x = 4R$.



[3]

Fig. 5.1

- (b) Two coils C and D are placed close to one another, as shown in Fig. 5.2.

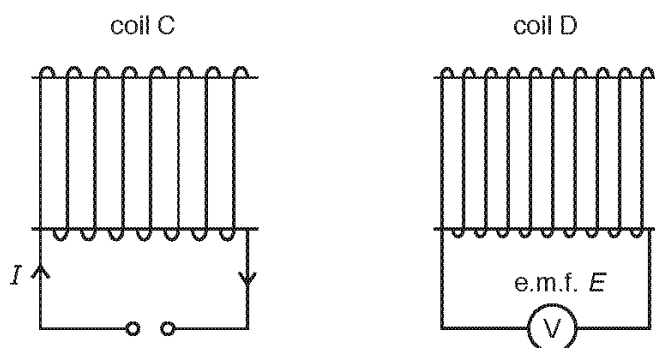
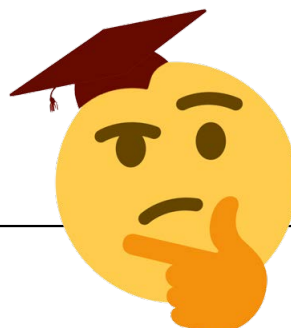


Fig. 5.2



The variation with time t of the current I in coil C is shown in Fig. 5.3.

On Fig. 5.4, show the variation with time t of the e.m.f. E induced in coil D for time $t = 0$ to time $t = t_5$.

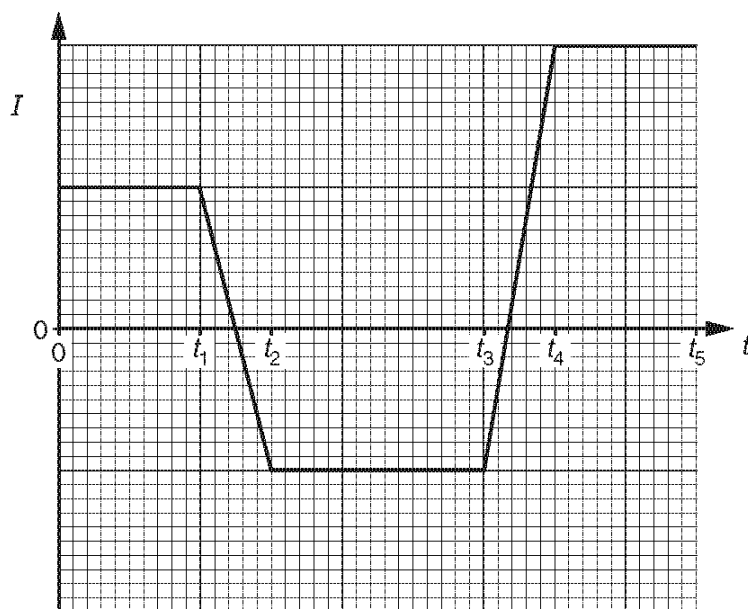


Fig. 5.3

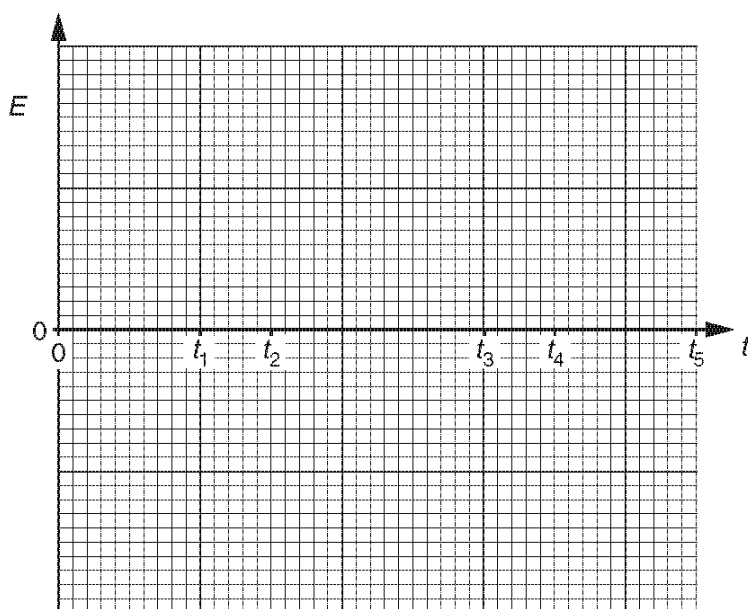
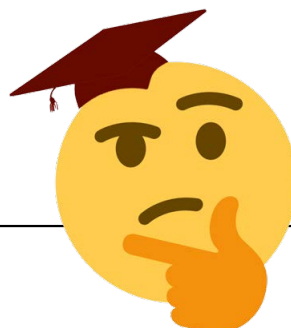


Fig. 5.4

[4]



3 - (9702/42_Winter_2017_Q6) - *Electric Fields*

- (a) For any point outside a spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre. By reference to electric field lines, explain this.

.....
.....
.....
.....[2]

- (b) An isolated spherical conductor has charge q , as shown in Fig. 6.1.

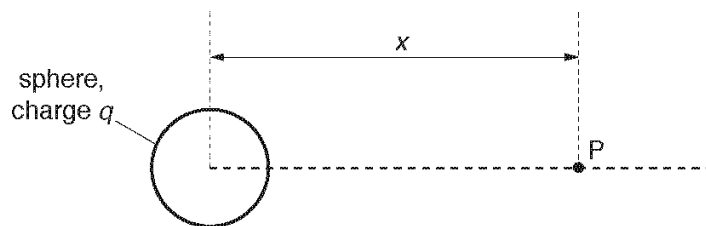


Fig. 6.1

Point P is a movable point that, at any one time, is a distance x from the centre of the sphere.

The variation with distance x of the electric potential V at point P due to the charge on the sphere is shown in Fig. 6.2.

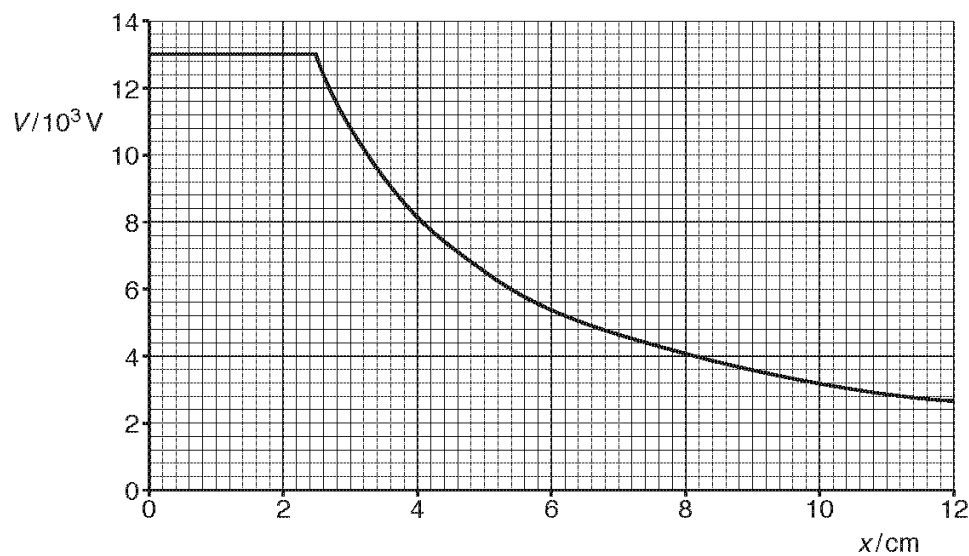


Fig. 6.2



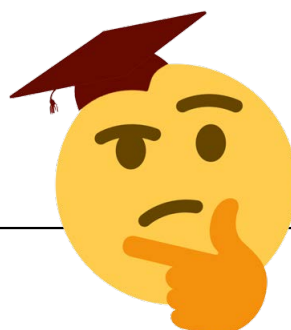
Use Fig. 6.2 to determine

- (i) the electric field strength E at point P where $x = 6.0\text{ cm}$,

$$E = \dots\dots\dots \text{ NC}^{-1} \text{ [3]}$$

- (ii) the radius R of the sphere. Explain your answer.

$$R = \dots\dots\dots \text{ cm [2]}$$



4 - (9702/41_Summer_2018_Q6) - *Electric Fields*

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

.....
.....[1]

(b) An isolated metal sphere A of radius 26 cm is positively charged. Sphere A is shown in Fig. 6.1.

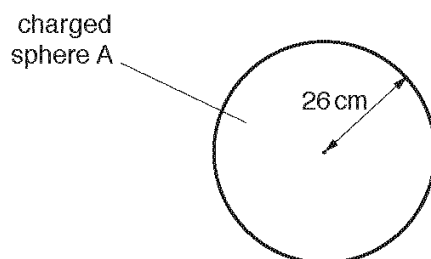


Fig. 6.1

Electrical breakdown (a spark) occurs when the electric field strength at the surface of the sphere exceeds $2.0 \times 10^4 \text{ Vm}^{-1}$.

Calculate the maximum charge Q that can be stored on the sphere.

$Q = \dots\dots\dots \text{C}$ [2]

(c) A second isolated metal sphere B, also with charge $+Q$, has a radius of 52 cm.

Calculate the additional charge, in terms of Q , that may be stored on this sphere before electrical breakdown occurs.

additional charge = [2]



5 - (9702/41_Winter_2018_Q6) - *Electric Fields*

(a) (i) Define *electric potential* at a point.

.....
.....
.....[2]

(ii) State the relationship between electric potential and electric field strength at a point.

.....
.....
.....[2]

(b) Two parallel metal plates A and B are situated a distance 1.2 cm apart in a vacuum, as shown in Fig. 6.1.

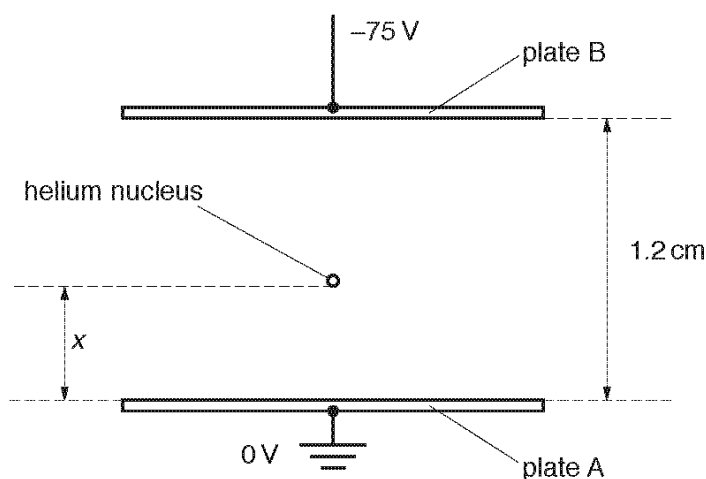


Fig. 6.1

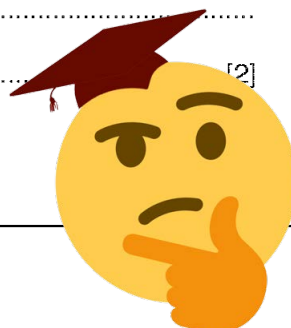
Plate A is earthed and plate B is at a potential of -75 V .

A helium nucleus is situated between the plates, a distance x from plate A.

Initially, the helium nucleus is at rest on plate A where $x = 0$.

(i) The helium nucleus is free to move between the plates. By considering energy changes of the helium nucleus, explain why the speed at which it reaches plate B is independent of the separation of the plates.

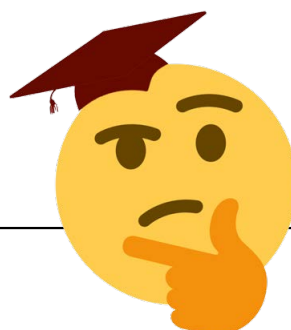
.....
.....
.....
.....[2]



- (ii) As the helium nucleus (${}^4_2\text{He}$) moves from plate A towards plate B, its distance x from plate A increases.

Calculate the speed of the nucleus after it has moved a distance $x = 0.40\text{ cm}$ from plate A.

speed = ms^{-1} [3]



6 - (9702/42_Winter_2018_Q6) - *Electric Fields*

(a) State

(i) what is meant by the *electric potential* at a point,

.....
.....
.....[2]

(ii) the relationship between electric potential at a point and electric field strength at the point.

.....
.....
.....[2]

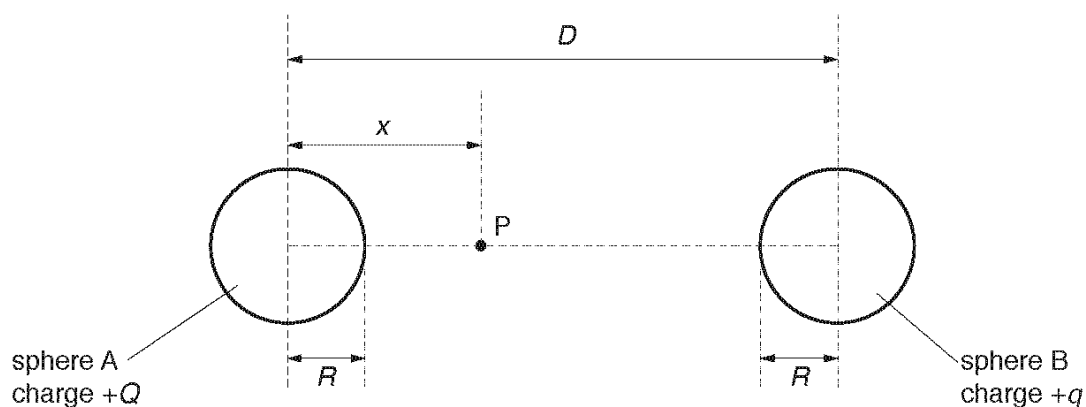
(b) Two similar solid metal spheres A and B, each of radius R , are situated in a vacuum such that the separation of their centres is D , as shown in Fig. 6.1.

Fig. 6.1

The charge $+Q$ on sphere A is larger than the charge $+q$ on sphere B.

A movable point P is located on the line joining the centres of the two spheres.
The point P is a distance x from the centre of sphere A.



On Fig. 6.2, sketch a graph to show the variation with x of the electric potential V between the centres of the two spheres.

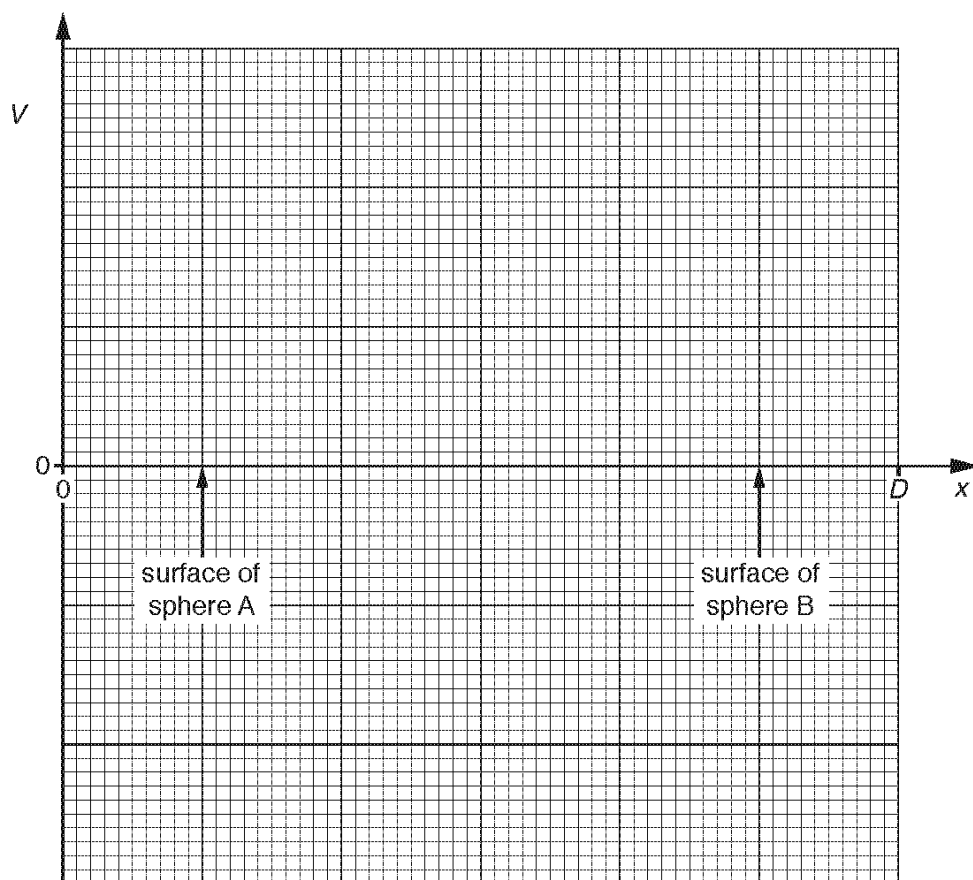
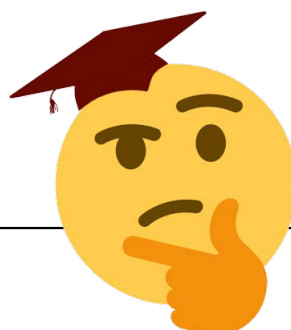


Fig. 6.2

[4]



7 - (9702/41_Summer_2019_Q5) - *Electric Fields*

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

.....

.....

..... [2]

(b) Two point charges A and B are situated a distance 15 cm apart in a vacuum, as illustrated in Fig. 5.1.

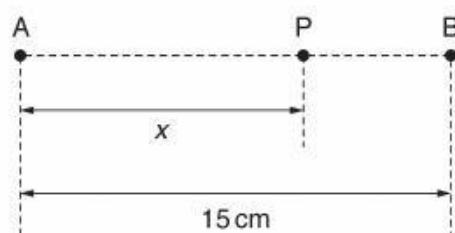


Fig. 5.1

Point P lies on the line joining the charges and is a distance x from charge A.

The variation with distance x of the electric field strength E at point P is shown in Fig. 5.2.

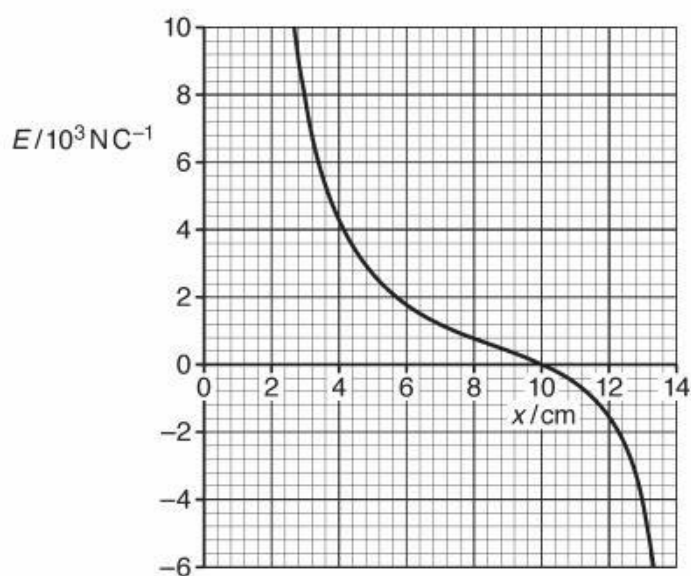
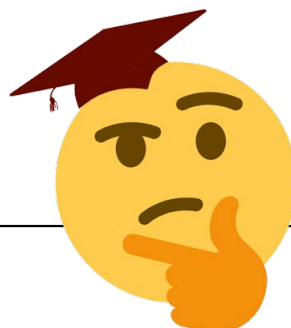


Fig. 5.2



- (i) By reference to the direction of the electric field, state and explain whether the charges A and B have the same, or opposite, signs.

.....
.....
..... [2]

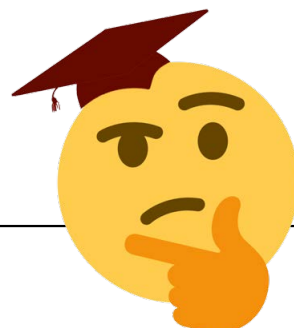
- (ii) State why, although charge A is a point charge, the electric field strength between $x = 3\text{ cm}$ and $x = 7\text{ cm}$ does not obey an inverse-square law.

.....
..... [1]

- (iii) Use Fig. 5.2 to determine the ratio

$$\frac{\text{magnitude of charge A}}{\text{magnitude of charge B}} .$$

ratio = [3]



8 - (9702/42_Summer_2019_Q6) - *Electric Fields*

- (a) State what is meant by *electric potential* at a point.

.....
.....
.....[2]

- (b) Two parallel metal plates A and B are held a distance d apart in a vacuum, as illustrated in Fig. 6.1.

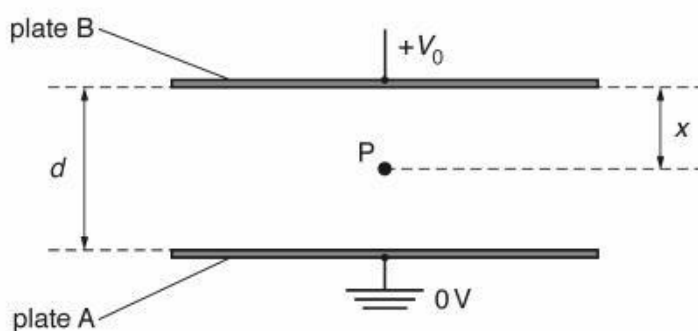


Fig. 6.1

Plate A is earthed and plate B is at a potential of $+V_0$.

Point P is situated in the centre region between the plates at a distance x from plate B.
The potential at point P is V .

On Fig. 6.2, show the variation with x of the potential V for values of x from $x = 0$ to $x = d$.

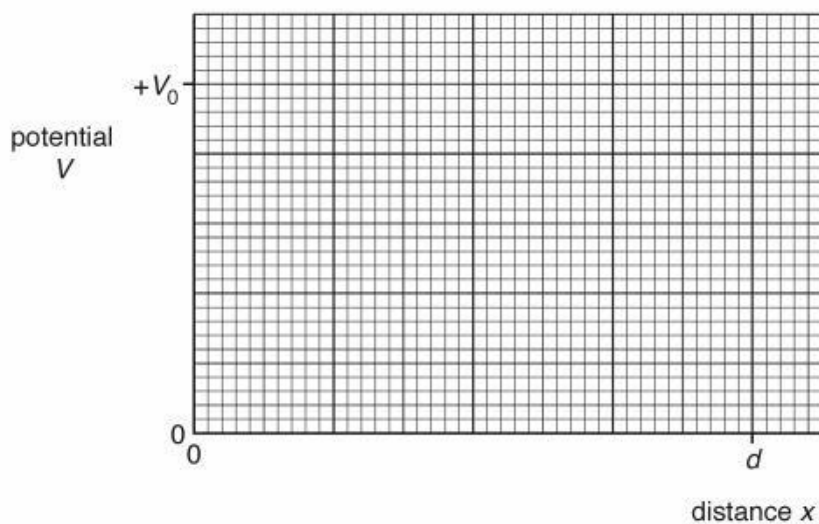
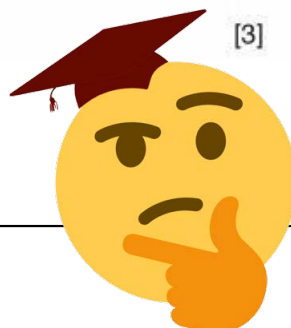


Fig. 6.2

[3]



- (c) Two isolated solid metal spheres M and N, each of radius R , are situated in a vacuum. Their centres are a distance D apart, as illustrated in Fig. 6.3.

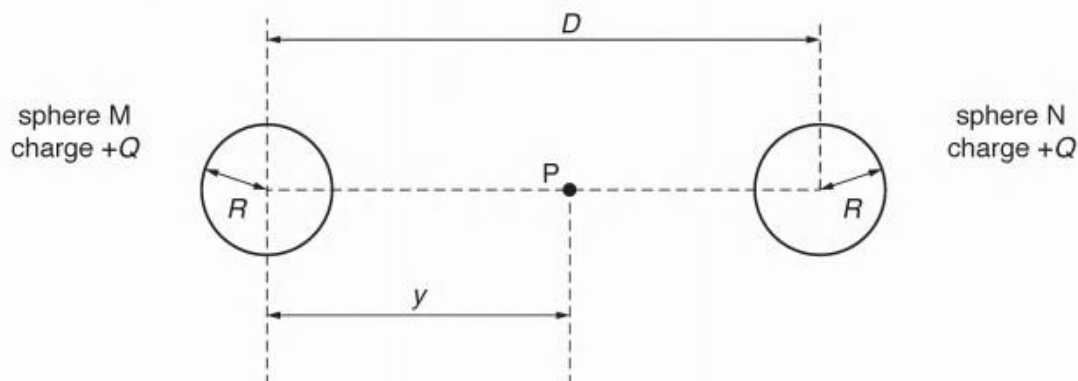


Fig. 6.3

Each sphere has charge $+Q$.

Point P lies on the line joining the centres of the two spheres, and is a distance y from the centre of sphere M.

On Fig. 6.4, show the variation with distance y of the electric potential at point P, for values of y from $y = 0$ to $y = D$.

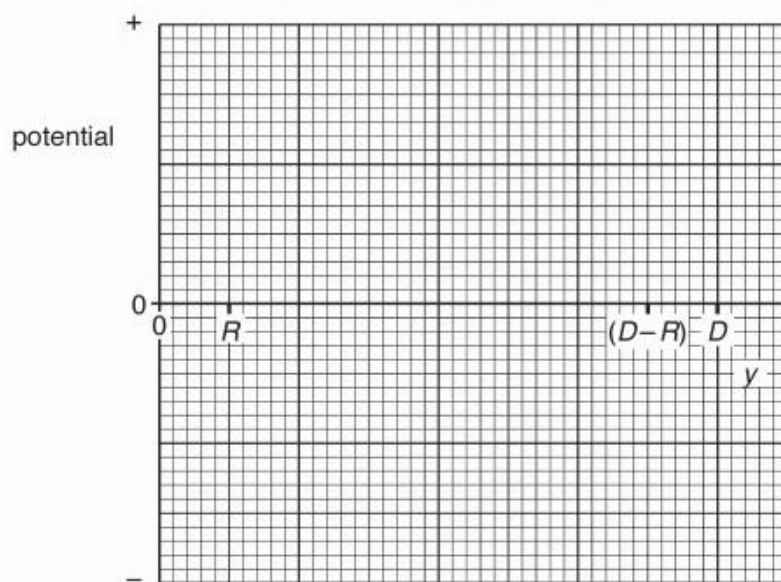
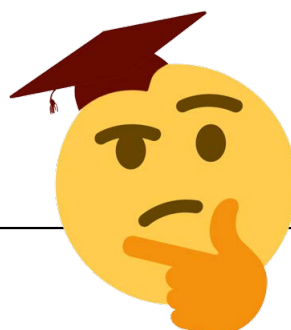


Fig. 6.4

[4]



9 - (9702/41_Winter_2019_Q6) - *Electric Fields*

- (a) State an expression for the electric field strength E at a distance r from a point charge Q in a vacuum.
State the name of any other symbol used.

.....
.....
..... [2]

- (b) Two point charges A and B are situated a distance 10.0 cm apart in a vacuum, as illustrated in Fig. 6.1.

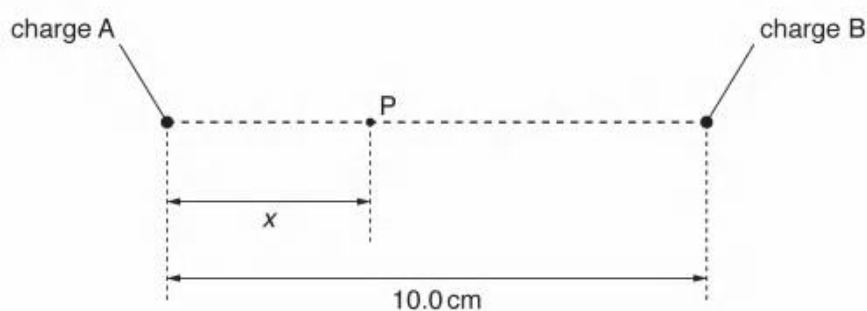


Fig. 6.1

A point P lies on the line joining the charges A and B. Point P is a distance x from A.

The variation with distance x of the electric field strength E at point P is shown in Fig. 6.2.

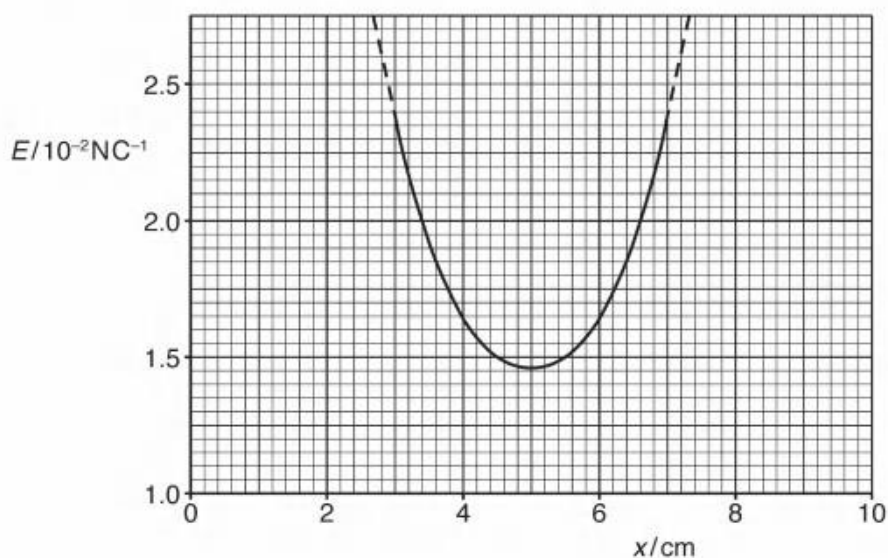
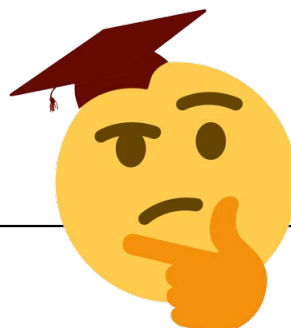


Fig. 6.2



State and explain whether the charges A and B:

(i) have the same, or opposite, signs

.....
.....
..... [2]

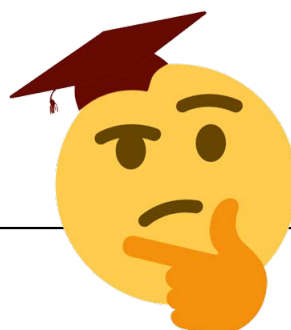
(ii) have the same, or different, magnitudes.

.....
.....
..... [2]

(c) An electron is situated at point P.

Without calculation, state and explain the variation in the magnitude of the acceleration of the electron as it moves from the position where $x = 3\text{ cm}$ to the position where $x = 7\text{ cm}$.

.....
.....
.....
.....
.....
..... [4]



10 – (9702/42_Winter_2019_Q9) – *Electric Fields*

- (a) Define what is meant by *electric potential* at a point.

.....
.....
..... [2]

- (b) In an α -particle scattering experiment, α -particles are directed towards a thin film of gold, as illustrated in Fig. 9.1.

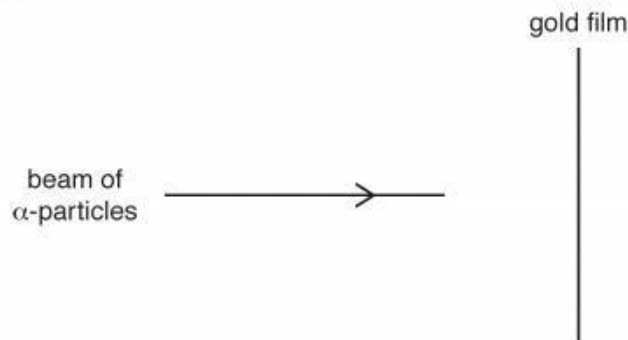


Fig. 9.1

The apparatus is in a vacuum.

The gold-197 ($^{197}_{79}\text{Au}$) nuclei in the film may be considered to be fixed point charges.

The α -particles emitted from the source each have an energy of 4.8 MeV.

Calculate:

- (i) the initial kinetic energy E_K , in J, of an α -particle emitted from the source

$E_K = \dots\dots\dots$ J [1]

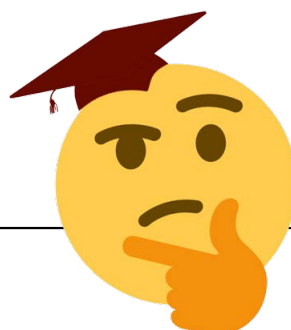


(ii) the distance d of closest approach of an α -particle to a gold nucleus.

$d = \dots\dots\dots$ m [4]

(c) Use your answer in (b)(ii) to comment on the possible diameter of a gold nucleus.

$\dots\dots\dots$
 $\dots\dots\dots$ [1]



11 - (9702/41_Summer_2020_Q5) - *Electric Fields*

- (a) State **one** similarity and **one** difference between the fields of force produced by an isolated point charge and by an isolated point mass.

similarity:

.....

difference:

.....

[2]

- (b) An isolated solid metal sphere A of radius R has charge $+Q$, as illustrated in Fig. 5.1.

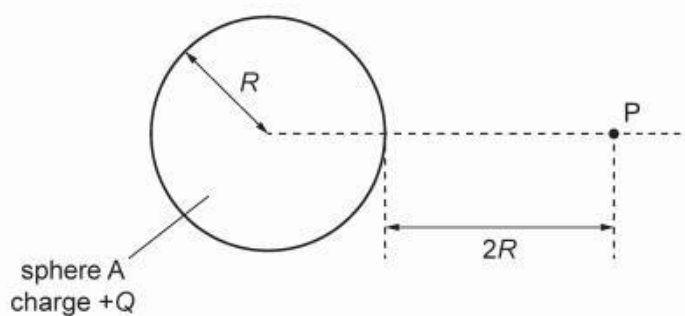
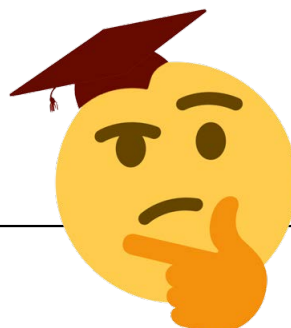


Fig. 5.1

A point P is distance $2R$ from the surface of the sphere.

Determine an expression that includes the terms R and Q for the electric field strength E at point P.

$E =$ [2]



- (c) A second identical solid metal sphere B is now placed near sphere A. The centres of the spheres are separated by a distance $6R$, as shown in Fig. 5.2.

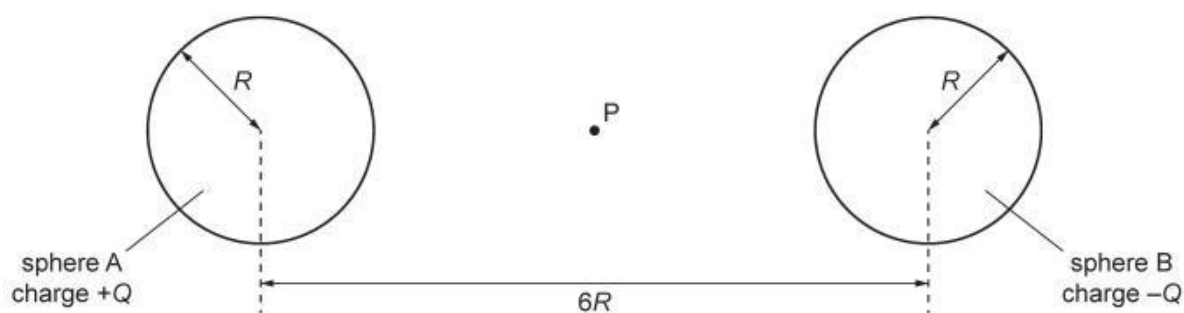


Fig. 5.2

Point P lies midway between spheres A and B.

Sphere B has charge $-Q$.

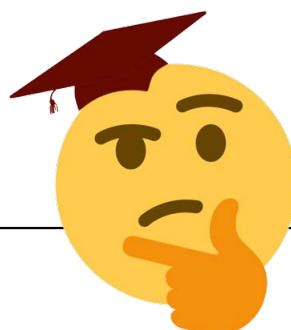
Explain why:

- (i) the magnitude of the electric field strength at P is given by the sum of the magnitudes of the field strengths due to each sphere

.....
..... [1]

- (ii) the electric field strength at point P due to the charged metal spheres is not, in practice, equal to $2E$, where E is the electric field strength determined in (b).

.....
.....
..... [2]



12 - (9702/42_Summer_2020_Q7) - *Electric Fields*

A metal sphere of radius R is isolated in space.

Point P is a distance x from the centre of the sphere, as illustrated in Fig. 7.1.

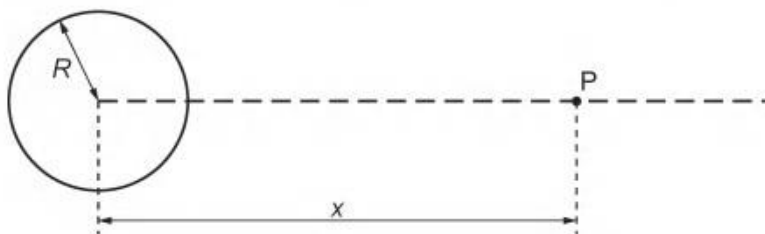


Fig. 7.1

The variation with distance x of the electric field strength E due to the charge on the sphere is shown in Fig. 7.2.

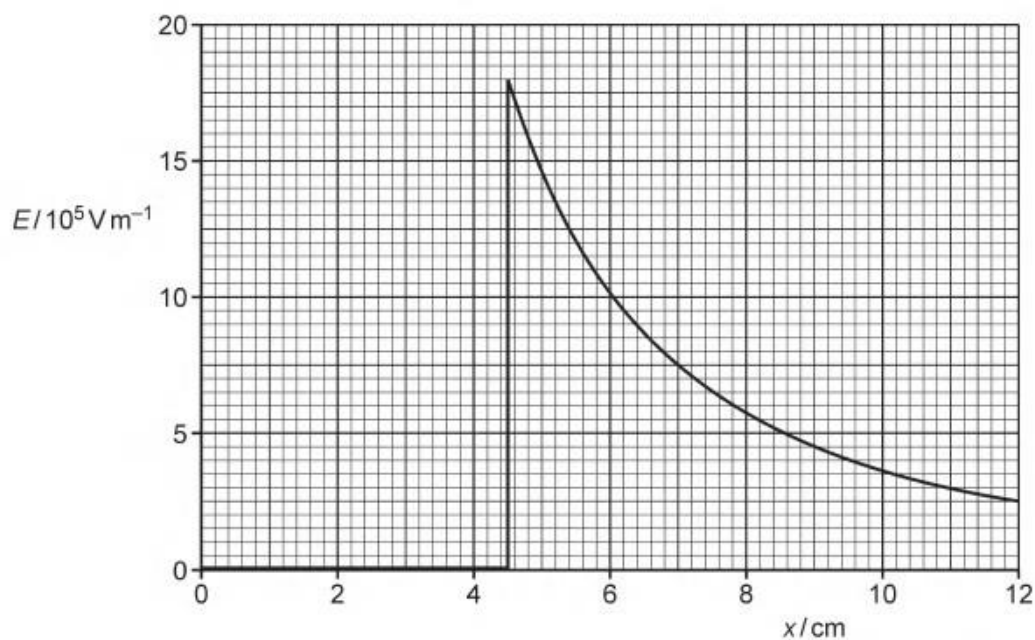


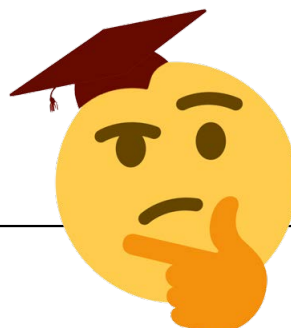
Fig. 7.2

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

.....

.....

..... [2]



(b) (i) Use Fig. 7.2 to determine the radius R of the sphere. Explain your working.

$R = \dots\dots\dots$ cm [2]

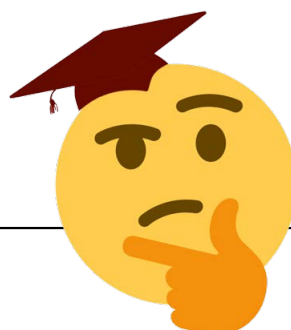
(ii) Use Fig. 7.2 to determine the charge Q on the sphere.

$Q = \dots\dots\dots$ C [3]

(c) An α -particle is situated a distance 8.0 cm from the centre of the sphere.

Calculate the acceleration of the α -particle.

acceleration = $\dots\dots\dots$ ms⁻² [3]



13 - (9702/41_Winter_2020_Q5) - Electric Fields

(a) Define *electric potential* at a point.

.....

.....

..... [2]

(b) Two point charges A and B are separated by a distance of 12.0 cm in a vacuum, as illustrated in Fig. 5.1.

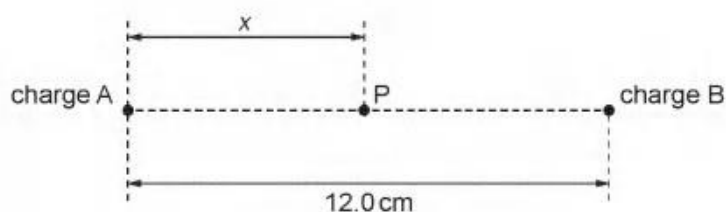


Fig. 5.1

The charge of A is $+2.0 \times 10^{-9} \text{ C}$.

A point P lies on the line joining charges A and B. Its distance from charge A is x .

The variation with distance x of the electric potential V at point P is shown in Fig. 5.2.

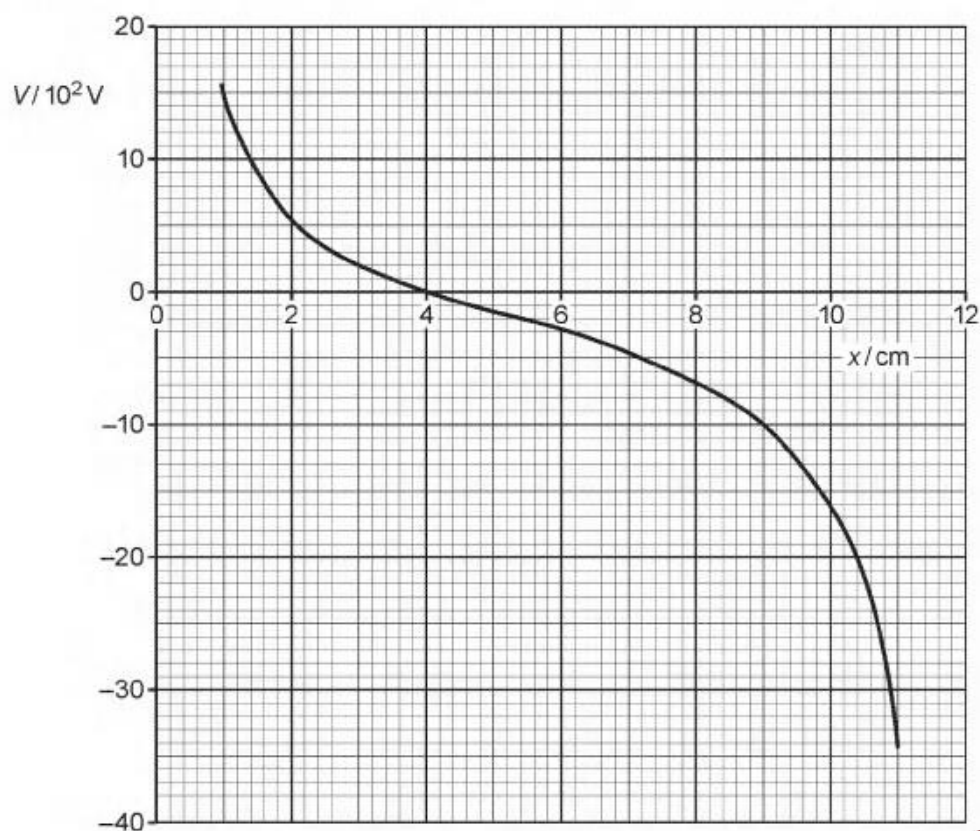


Fig. 5.2



Use Fig. 5.2 to determine:

- (i) the charge of B

charge = C [3]

- (ii) the change in electric potential when point P moves from the position where $x = 9.0$ cm to the position where $x = 3.0$ cm.

change = V [1]

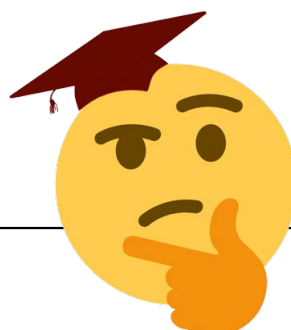
- (c) An α -particle moves along the line joining point charges A and B in Fig. 5.1.

The α -particle moves from the position where $x = 9.0$ cm and just reaches the position where $x = 3.0$ cm.

Use your answer in (b)(ii) to calculate the speed v of the α -particle at the position where $x = 9.0$ cm.

$v =$ ms^{-1} [3]

[Total: 9]



14 - (9702/42_Winter_2020_Q5) - *Electric Fields*

- (a) (i) State what is meant by a *field of force*.

.....
.....
..... [2]

- (ii) State **one** similarity and **one** difference between the electric field due to a point charge and the gravitational field due to a point mass.

similarity:
.....
.....
difference:
.....
..... [2]

- (b) An isolated solid metal sphere of radius 0.15 m is situated in a vacuum, as illustrated in Fig. 5.1.

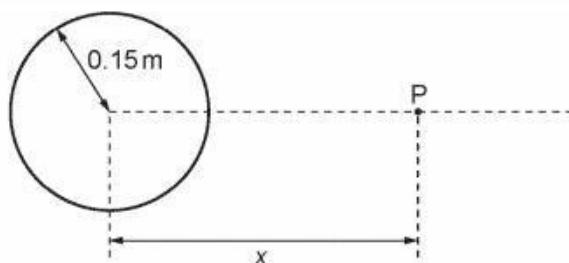


Fig. 5.1

The electric field strength at the surface of the sphere is 84 V m^{-1} .

Determine:

- (i) the charge Q on the sphere

$Q =$



- (ii) the electric field strength at point P, a distance $x = 0.45$ m from the centre of the sphere.

electric field strength = V m^{-1} [2]

- (c) Use information from (b) to show, on the axes of Fig. 5.2, the variation of the electric field strength E with distance x from the centre of the sphere for values of x from $x = 0$ to $x = 0.45$ m.

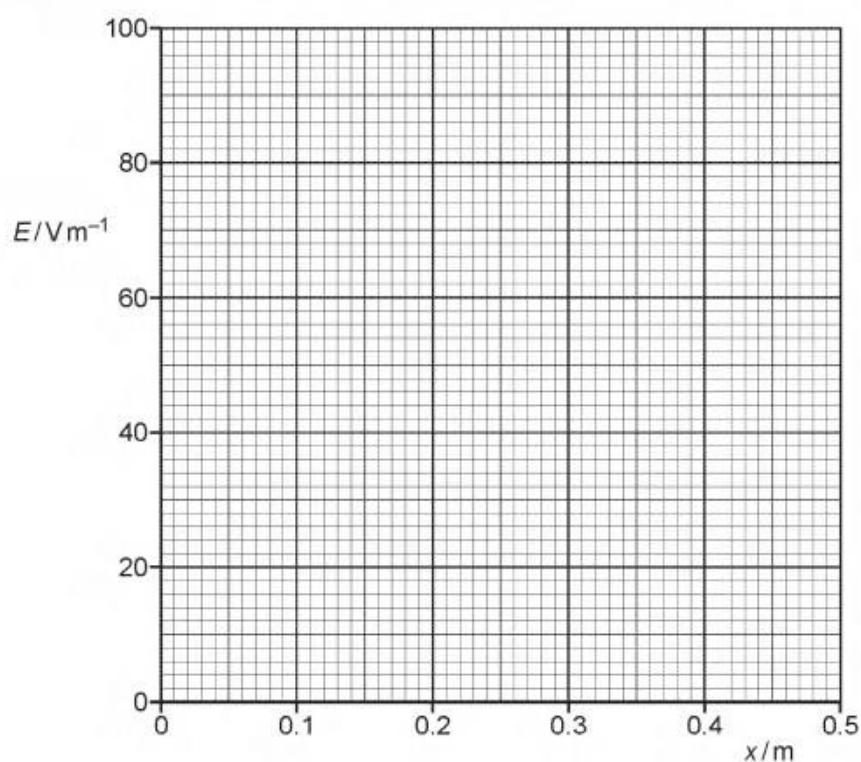
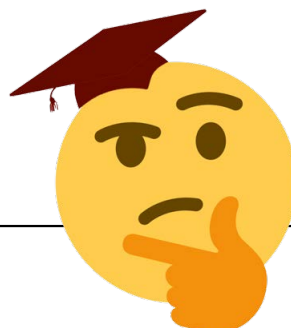


Fig. 5.2

[3]

[Total: 11]



15 - (9702/43_Winter_2020_Q5) - *Electric Fields*

(a) Define *electric potential* at a point.

.....

.....

..... [2]

(b) Two point charges A and B are separated by a distance of 12.0 cm in a vacuum, as illustrated in Fig. 5.1.

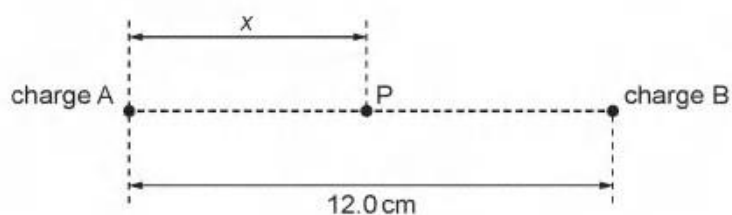


Fig. 5.1

The charge of A is $+2.0 \times 10^{-9} \text{ C}$.

A point P lies on the line joining charges A and B. Its distance from charge A is x .

The variation with distance x of the electric potential V at point P is shown in Fig. 5.2.

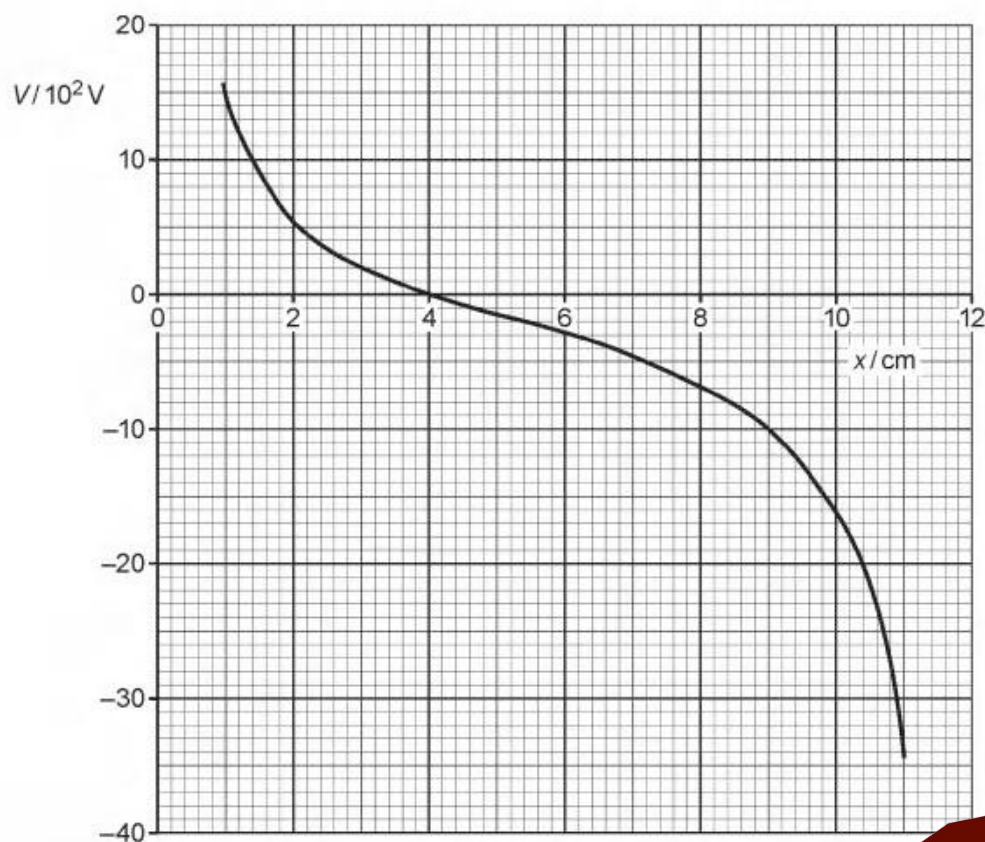
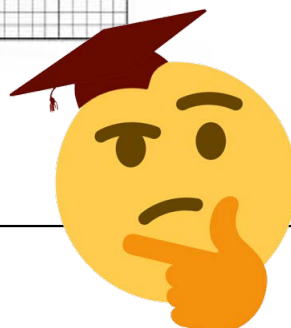


Fig. 5.2



Use Fig. 5.2 to determine:

- (i) the charge of B

charge = C [3]

- (ii) the change in electric potential when point P moves from the position where $x = 9.0\text{ cm}$ to the position where $x = 3.0\text{ cm}$.

change = V [1]

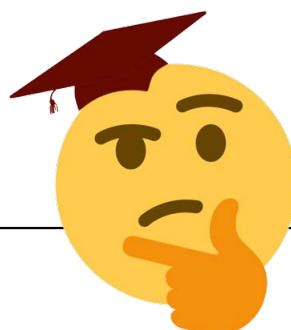
- (c) An α -particle moves along the line joining point charges A and B in Fig. 5.1.

The α -particle moves from the position where $x = 9.0\text{ cm}$ and just reaches the position where $x = 3.0\text{ cm}$.

Use your answer in (b)(ii) to calculate the speed v of the α -particle at the position where $x = 9.0\text{ cm}$.

$v = \dots\dots\dots \text{ ms}^{-1}$ [3]

[Total: 9]



16 - (9702/42_Summer_2021_Q5) - *Electric Fields*

- (a) An isolated metal sphere of radius r is charged so that the electric potential at its surface is V_0 .

On Fig. 5.1, sketch the variation with distance x from the centre of the sphere of the electric potential. Your graph should extend from $x = 0$ to $x = 3r$.

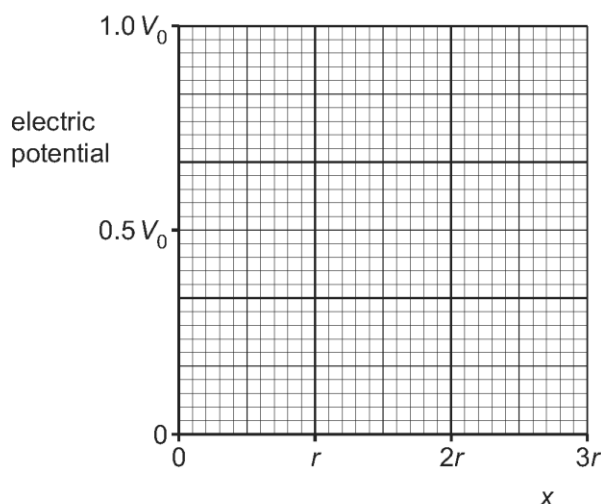


Fig. 5.1

[3]

- (b) Photons having wavelength λ are incident on a metal surface. The maximum wavelength for which there is emission of electrons is λ_0 . For photons of wavelength $\frac{\lambda_0}{2}$, the maximum kinetic energy of the emitted electrons is E_{MAX} .

On Fig. 5.2, sketch the variation with wavelength λ of the maximum kinetic energy for values of wavelength between $\lambda = \frac{\lambda_0}{3}$ and $\lambda = \lambda_0$.

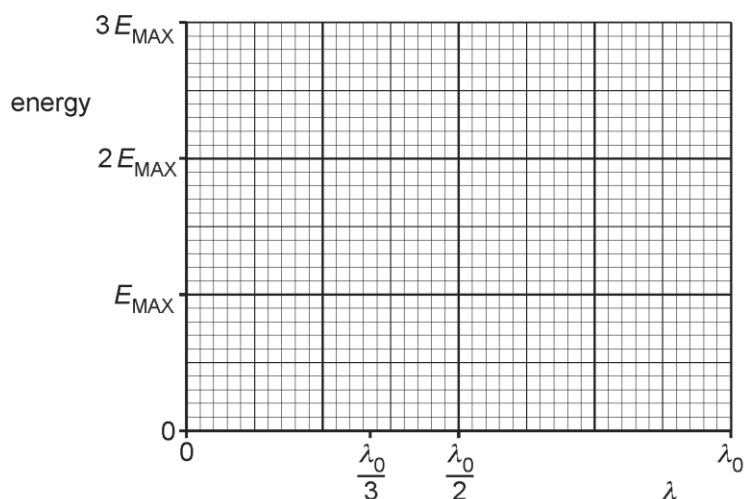
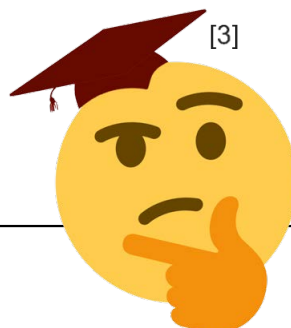


Fig. 5.2

[3]



- (c) A pure sample of a radioactive isotope contains N_0 nuclei. The half-life of the isotope is $T_{\frac{1}{2}}$. The product of the radioactive decay is stable.

The variation with time t of the number N of nuclei of the radioactive isotope is shown in Fig. 5.3.

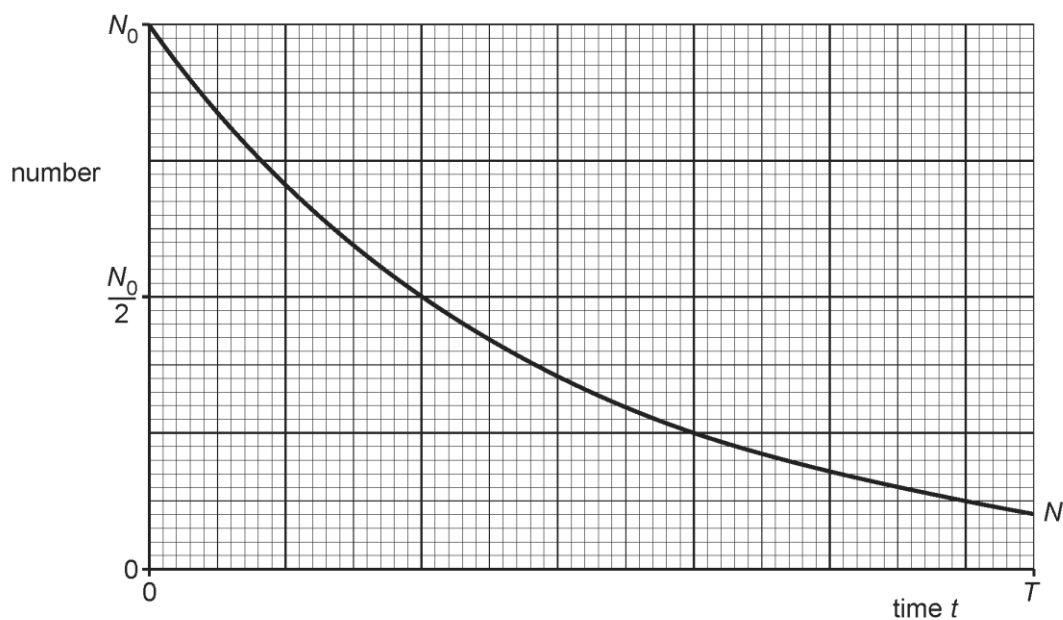
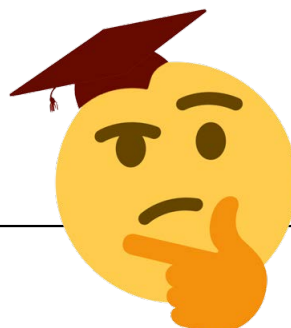


Fig. 5.3

On Fig. 5.3:

- label, on the time axis, the time $t = 1.0T_{\frac{1}{2}}$ and the time $t = 2.0T_{\frac{1}{2}}$
- sketch the variation with time t of the number of nuclei of the decay product for time $t = 0$ to time $t = T$.

[3]



17 - (9702/41_Summer_2021_Q6) - *Electric Fields, Quantum Physics, Particle & Nuclear Physics*

- (a) An isolated metal sphere of radius r is charged so that the electric field strength at its surface is E_0 .

On Fig. 6.1, sketch the variation of the electric field strength E with distance x from the centre of the sphere. Your sketch should extend from $x = 0$ to $x = 3r$.

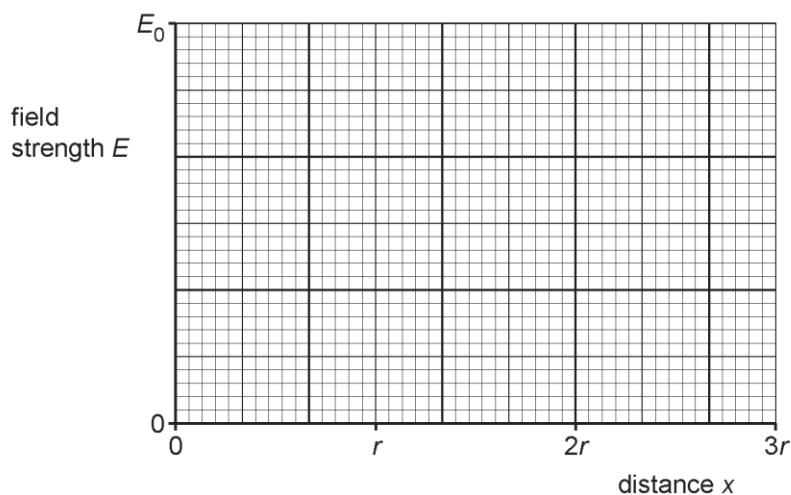


Fig. 6.1

[3]

- (b) The de Broglie wavelength of a particle is λ_0 when its momentum is p_0 .

On Fig. 6.2, sketch the variation with momentum p of the de Broglie wavelength λ of the particle for values of momentum from $\frac{p_0}{2}$ to p_0 .

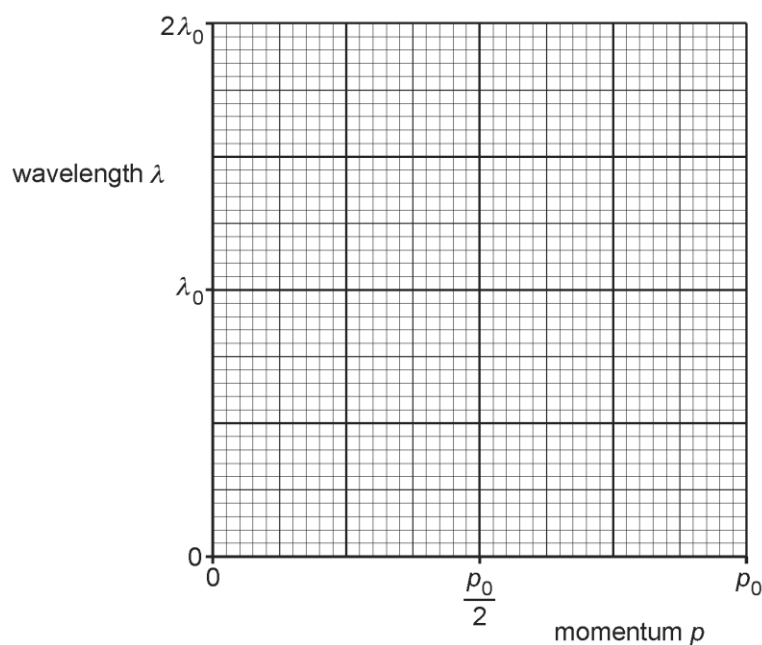
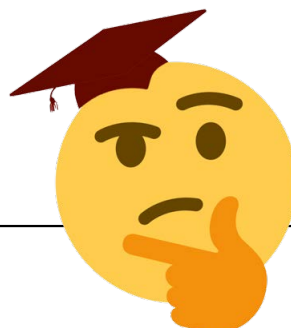


Fig. 6.2



(c) A radioactive isotope decays with a half-life of 15 s to form a stable product.

A fresh sample of the radioactive isotope at time $t = 0$ contains N_0 nuclei and no nuclei of the stable product.

On Fig. 6.3, sketch the variation with t of the number n of nuclei of the stable product for time $t = 0$ to time $t = 45$ s.

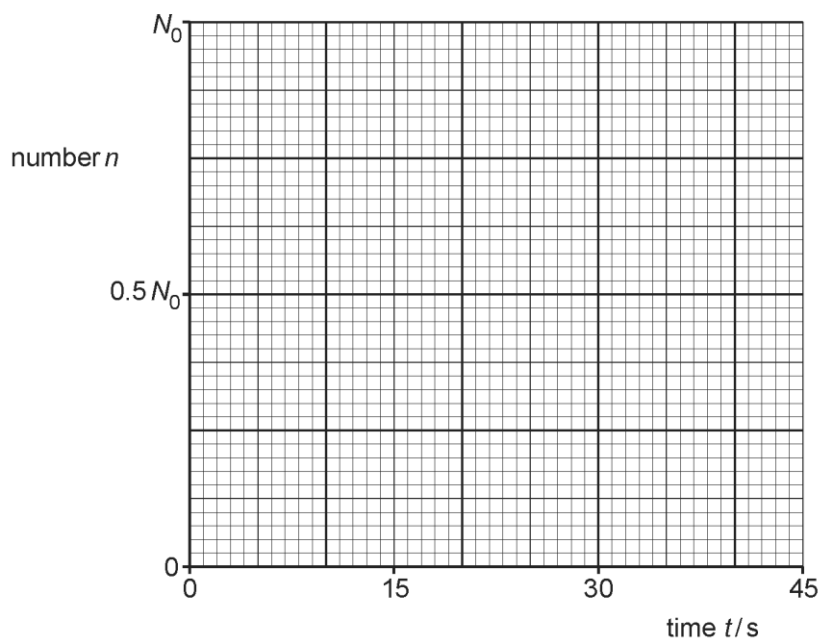
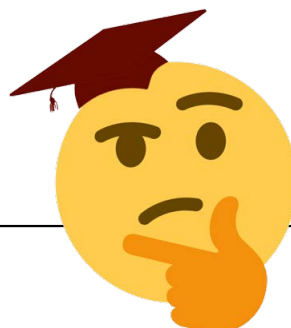


Fig. 6.3

[3]



18 - (9702/41_Summer_2022_Q2) - *Electric Fields*

A sphere of mass $1.6 \times 10^{-10} \text{ kg}$ has a charge of $+0.27 \text{ nC}$. The sphere is in a uniform electric field that acts vertically upwards, as shown in the side view in Fig. 2.1.

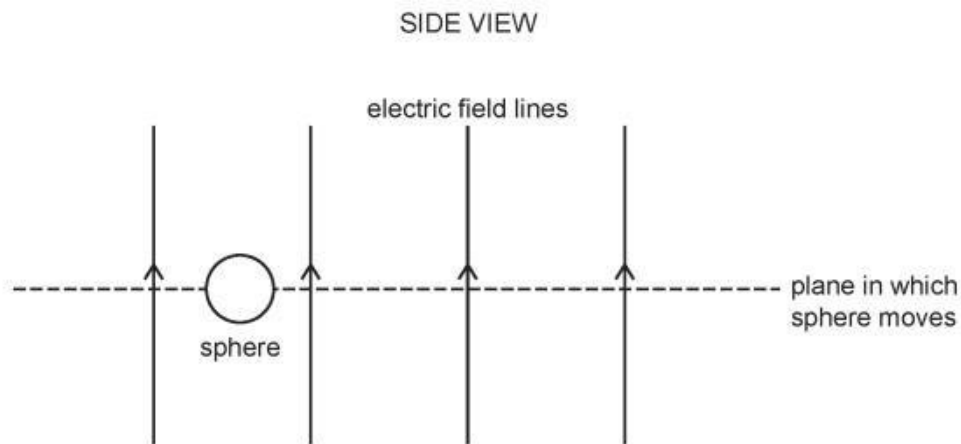


Fig. 2.1

The force exerted on the sphere by the electric field causes the sphere to remain at a fixed vertical height in a horizontal plane.

There is a uniform magnetic field in the region of the electric field. The sphere moves at a speed of 0.78 m s^{-1} in the horizontal plane. The magnetic field causes the sphere to move in a circular path of radius 3.4 m , as shown in the view from above in Fig. 2.2.

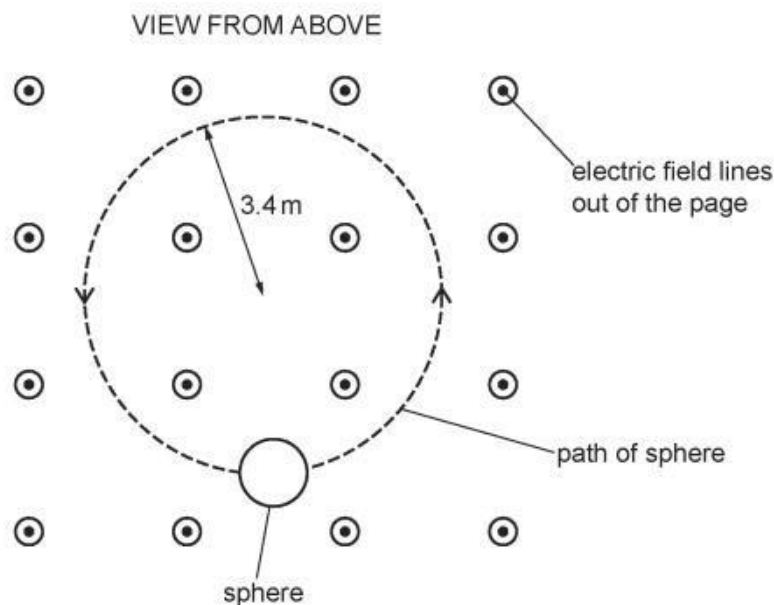


Fig. 2.2



- (a) (i) Determine the direction of the uniform magnetic field.

..... [1]

- (ii) Explain why the motion of the sphere in the horizontal plane is circular.

.....

.....

..... [2]

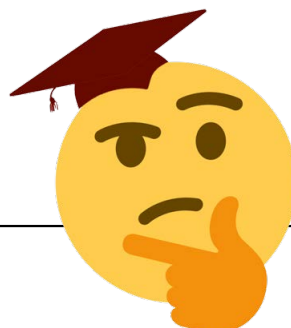
- (b) Calculate the strength of the uniform electric field.

electric field strength = NC^{-1} [2]

- (c) By considering the magnetic force on the sphere, show that the flux density of the uniform magnetic field is 0.14 T.

[3]

[Total: 8]



19 - (9702/42_Summer_2022_Q2) - *Electric Fields*

(a) State Coulomb's law.

.....

.....

..... [2]

(b) Positronium is a system in which an electron and a positron orbit, with the same period, around their common centre of mass, as shown in Fig. 2.1.

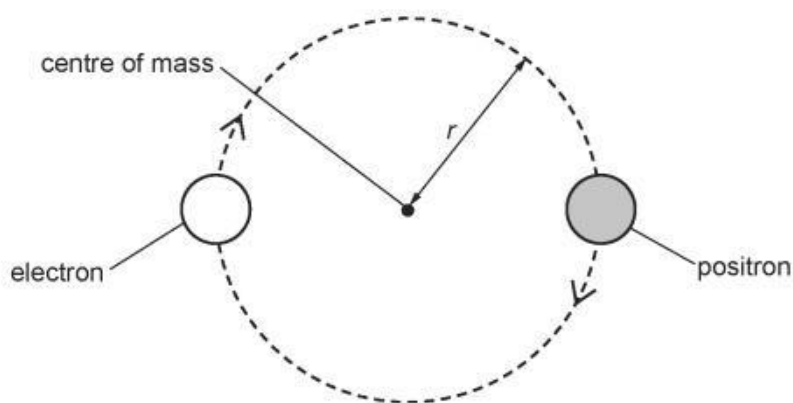


Fig. 2.1 (not to scale)

The radius r of the orbit of both particles is $1.59 \times 10^{-10} \text{ m}$.

(i) Explain how the electric force between the electron and the positron causes the path of the moving particles to be circular.

.....

.....

..... [2]

(ii) Show that the magnitude of the electric force between the electron and the positron is $2.28 \times 10^{-9} \text{ N}$.



- (iii) Use the information in (b)(ii) to determine the period of the circular orbit of the two particles.

period = s [3]

- (c) Positronium is highly unstable, and after a very short period of time it becomes gamma radiation.

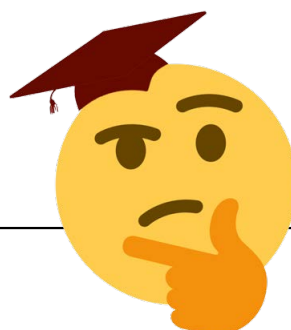
- (i) Describe how gamma radiation is formed from the two particles in positronium.

.....
.....
.....
..... [3]

- (ii) State **one** medical application of the process described in (c)(i).

..... [1]

[Total: 13]



20 - (9702/42_Summer_2022_Q5) - *Electric Fields*

- (a) Define the capacitance of a parallel plate capacitor.

.....

.....

..... [2]

- (b) Two capacitors, of capacitances C_1 and C_2 , are connected in parallel to a power supply of electromotive force (e.m.f.) E , as shown in Fig. 5.1.

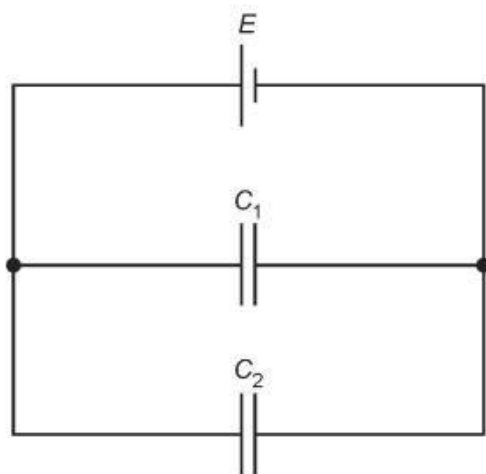


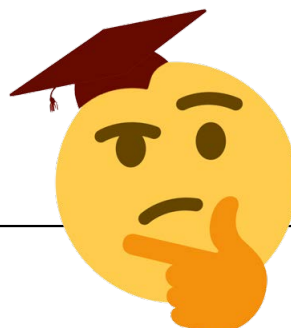
Fig. 5.1

Show that the combined capacitance C_T of the two capacitors is given by

$$C_T = C_1 + C_2.$$

Explain your reasoning. You may draw on Fig. 5.1 if you wish.

[3]



- (c) Two capacitors of capacitances $22\mu\text{F}$ and $47\mu\text{F}$, and a resistor of resistance $2.7\text{M}\Omega$, are connected into the circuit of Fig. 5.2.

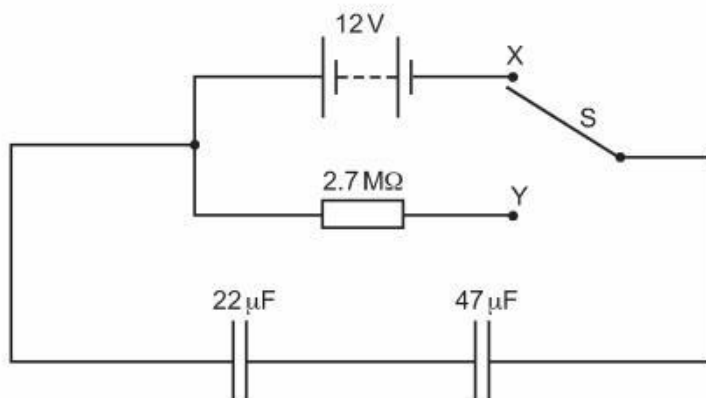


Fig. 5.2

The battery has an e.m.f. of 12 V.

- (i) Show that the combined capacitance of the two capacitors is $15\mu\text{F}$.

[1]

- (ii) The two-way switch S is initially at position X, so that the capacitors are fully charged.

Use the information in (c)(i) to calculate the total energy stored in the two capacitors.

total energy = J [2]

- (iii) The two-way switch is now moved to position Y.

Determine the time taken for the potential difference (p.d.) across the $22\mu\text{F}$ capacitor to become 6.0 V.

time = s [3]

[Total: 11]



21 - (9702/41_Winter_2022_Q4) - *Electric Fields*

- (a) State what is indicated by the direction of an electric field line.

.....
..... [2]

- (b) Fig. 4.1 shows a pair of parallel metal plates with a potential difference (p.d.) of 2400 V between them.

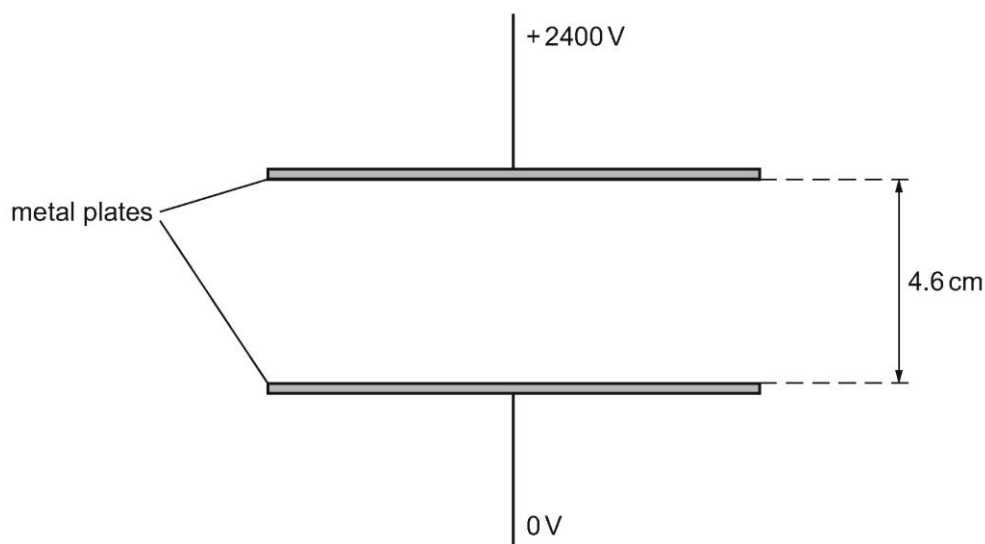
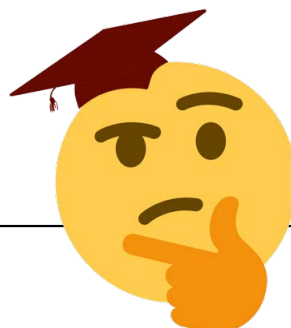


Fig. 4.1

The plates are separated by a distance of 4.6 cm. The plates are in a vacuum.

- (i) On Fig. 4.1, draw five lines to represent the electric field in the region between the plates. [3]
- (ii) Calculate the strength of the electric field between the plates.

electric field strength = NC^{-1} [2]



(c) A moving proton enters the region between the plates from the left, as shown in Fig. 4.2.

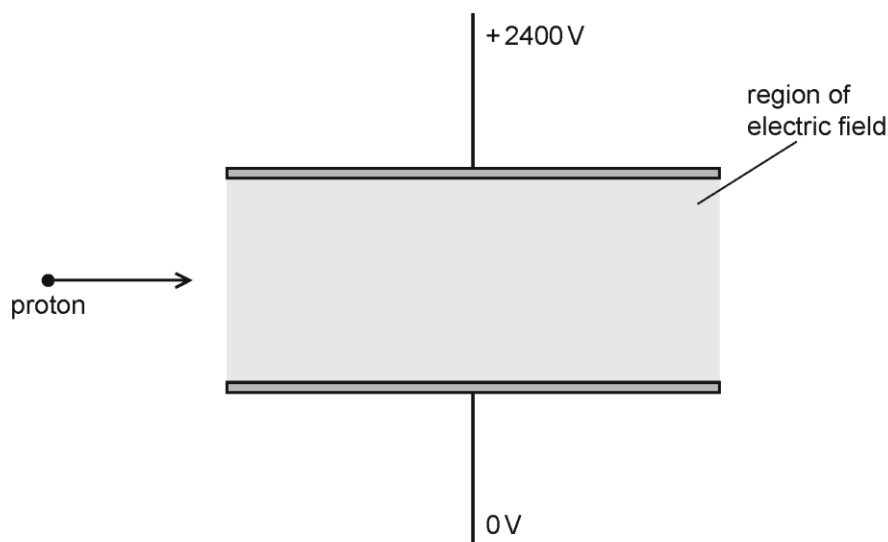


Fig. 4.2

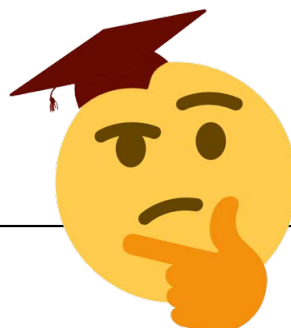
- (i) The proton is deflected by the electric field.

On Fig. 4.2, draw a line to show the path of the proton as it moves through and out of the region of the electric field. [2]

- (ii) A helium nucleus (${}^4_2\text{He}$) now enters the region of the electric field along the same initial path as the proton and travelling at the same initial speed.

State and explain how the final speed of the helium nucleus compares with the final speed of the proton after leaving the region of the electric field.

.....
.....
.....
.....
..... [3]



22 - (9702/42_Winter_2022_Q5) - *Electric Fields*

(a) Define electric potential at a point.

.....
.....
..... [2]

(b) An isolated conducting sphere is charged. Fig. 5.1 shows the variation of the potential V due to the sphere with displacement x from its centre.

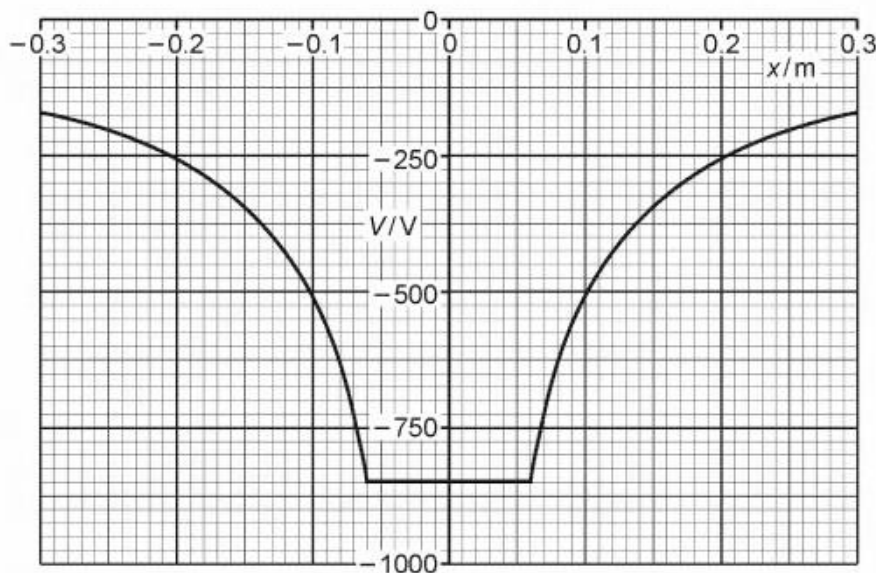


Fig. 5.1

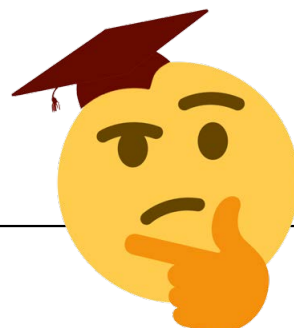
Use Fig. 5.1 to determine:

(i) the radius of the sphere

radius = m [1]

(ii) the charge on the sphere.

charge = C [2]



- (c) Two spheres are identical to the sphere in (b). Each sphere has the same charge as the sphere in (b).

The spheres are held in a vacuum so that their centres are separated by a distance of 0.46 m. Assume that the charge on each sphere is a point charge at the centre of the sphere.

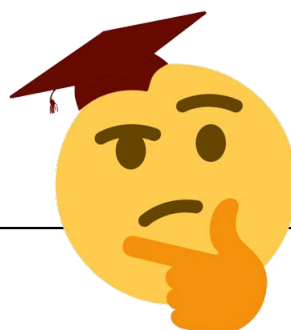
- (i) Calculate the electric potential energy E_p of the two spheres.

$$E_p = \dots\dots\dots \text{ J [2]}$$

- (ii) The two spheres are now released simultaneously so that they are free to move.

Describe and explain the subsequent motion of the spheres.

.....
.....
.....
..... [3]



23 – (9702/41_Winter_2023_Q5) – *Electric Fields*

(a) Define electric potential at a point.

.....

.....

..... [2]

(b) Two isolated charged metal spheres X and Y are situated near to each other in a vacuum with their centres a distance of 24 m apart. Point P is at a variable distance x from the centre of sphere X on the line joining the centres of the spheres.

Fig. 5.1 shows the variation with x of the electric potential V due to the spheres at point P.

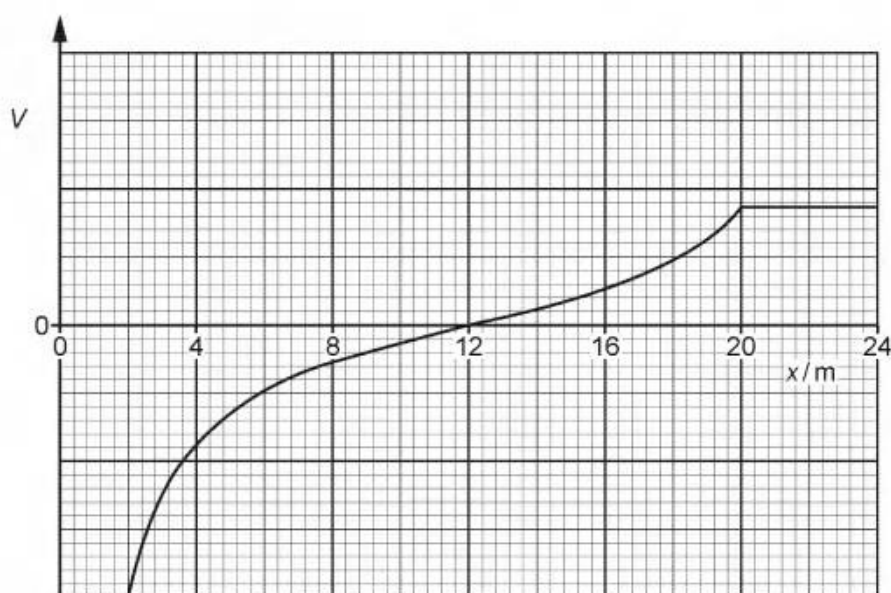


Fig. 5.1

State **three** conclusions that can be drawn about the spheres from Fig. 5.1. The conclusions may be qualitative or quantitative.

1

.....

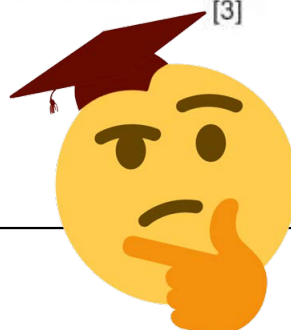
2

.....

3

.....

[3]



- (c) A positively charged particle is placed at point P in (b), such that $x = 12\text{ m}$. The particle is released.

Describe and explain the subsequent motion of the particle.

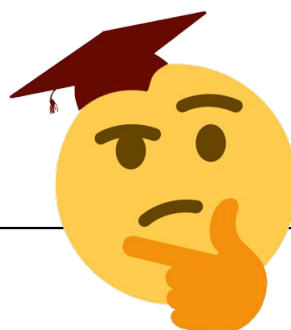
.....

.....

.....

.....

..... [3]



24 - (9702/42_Winter_2023_Q5) - *Electric Fields*

(a) State Coulomb's law.

.....
.....
..... [2]

(b) Two identical oil droplets are in a vacuum. The centres of the droplets are a distance of $3.8 \times 10^{-6} \text{ m}$ apart. The droplets have equal charge and exert an electric force on each other of magnitude $6.3 \times 10^{-17} \text{ N}$.

Determine the magnitude of the charge on each droplet.

charge = C [2]

(c) One of the oil droplets in (b) is now placed between two horizontal metal plates, as shown in Fig. 5.1.

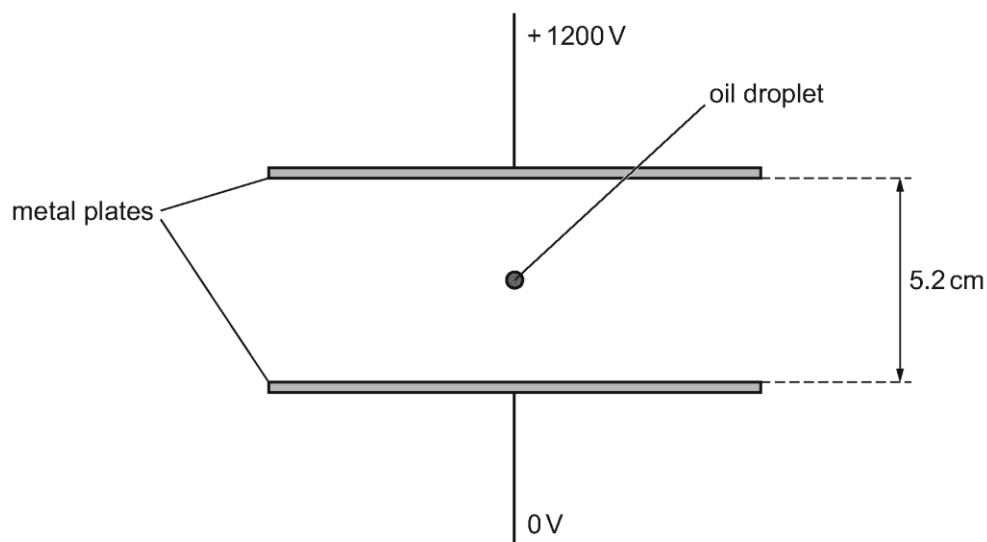
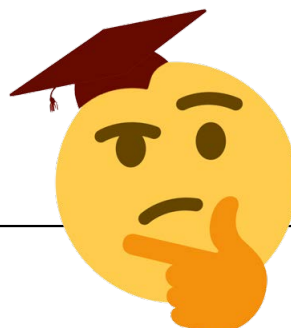


Fig. 5.1 (not to scale)

A potential difference (p.d.) of 1200 V is applied between the plates, with the top plate at the higher potential. The oil droplet is stationary and in equilibrium.



- (i) State the sign of the charge on the oil droplet.

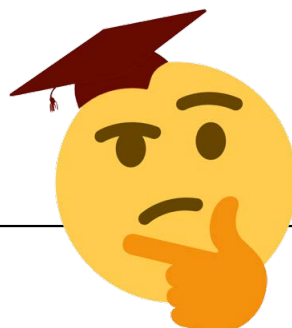
..... [1]

- (ii) On Fig. 5.1, draw four lines to represent the electric field between the plates. [3]

- (iii) The distance between the plates is 5.2 cm.

Determine the mass of the oil droplet.

mass = kg [3]



1 - (9702/42_Summer_2017_Q7) - Capacitance

A capacitor consists of two parallel metal plates, separated by an insulator, as shown in Fig. 7.1.

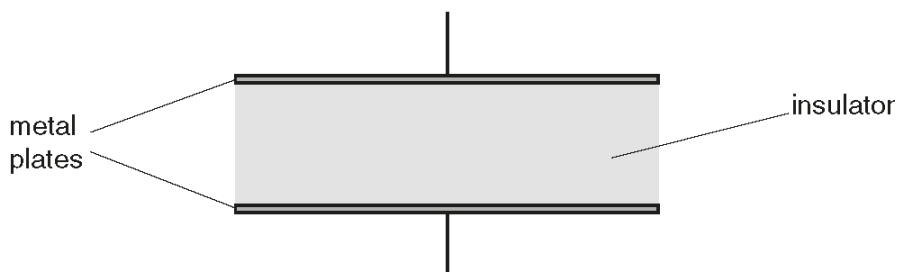


Fig. 7.1

- (a) Suggest why, when the capacitor is connected across the terminals of a battery, the capacitor stores energy, not charge.

.....
.....
.....[2]

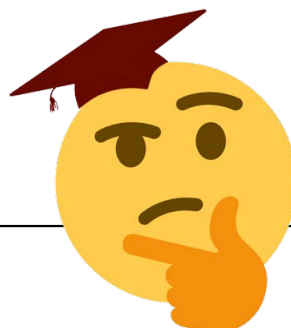
- (b) Define the *capacitance* of the capacitor.

.....
.....
.....[2]

- (c) The capacitor is charged so that the potential difference between its plates is V_0 . The capacitor is then connected across a resistor for a short time. It is then disconnected. The energy stored in the capacitor is reduced to $\frac{1}{16}$ of its initial value.

Determine, in terms of V_0 , the potential difference across the capacitor.

potential difference =[2]



2 - (9702/41_Winter_2017_Q6) - Capacitance

Two capacitors P and Q, each of capacitance C , are connected in series with a battery of e.m.f. 9.0 V , as shown in Fig. 6.1.

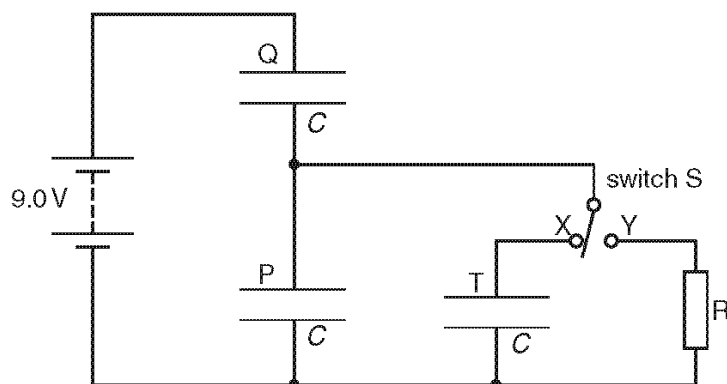


Fig. 6.1

A switch S is used to connect either a third capacitor T, also of capacitance C , or a resistor R, in parallel with capacitor P.

(a) Switch S is in position X.

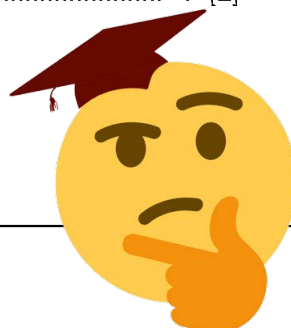
Calculate

(i) the combined capacitance, in terms of C , of the three capacitors,

capacitance = [2]

(ii) the potential difference across capacitor Q. Explain your working.

potential difference = V [2]



- (b) Switch S is now moved to position Y.
State what happens to the potential difference across capacitor P and across capacitor Q.

capacitor P:

.....

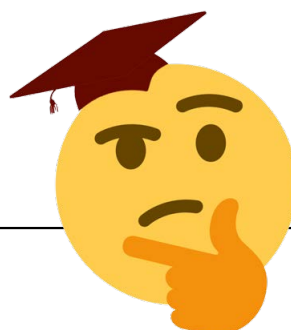
.....

capacitor Q:

.....

.....

[4]



3 - (9702/42_Summer_2018_Q6) - Capacitance

(a) Explain what is meant by the *capacitance* of a parallel plate capacitor.

.....

.....

.....

.....[3]

(b) Three parallel plate capacitors each have a capacitance of $6.0\ \mu\text{F}$.

Draw circuit diagrams, one in each case, to show how the capacitors may be connected together to give a combined capacitance of

(i) $9.0\ \mu\text{F}$,

[1]

(ii) $4.0\ \mu\text{F}$.

[1]

(c) Two capacitors of capacitances $3.0\ \mu\text{F}$ and $2.0\ \mu\text{F}$ are connected in series with a battery of electromotive force (e.m.f.) $8.0\ \text{V}$, as shown in Fig. 6.1.

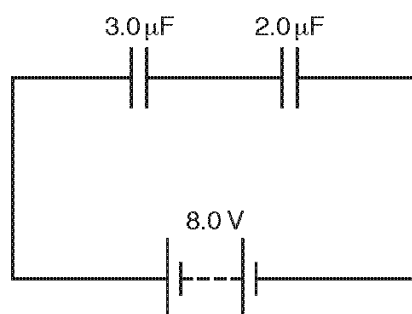
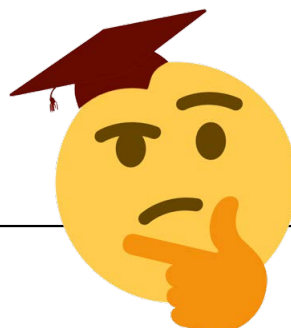


Fig. 6.1



- (i) Calculate the combined capacitance of the capacitors.

capacitance = μF [1]

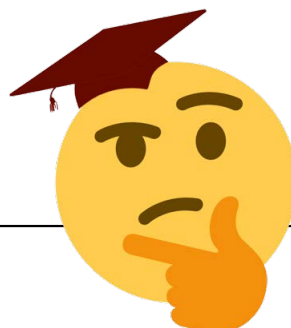
- (ii) Use your answer in (i) to determine, for the capacitor of capacitance $3.0\mu\text{F}$,

1. the charge on one plate of the capacitor,

charge = μC

2. the energy stored in the capacitor.

energy = J
[4]



4 - (9702/41_Summer_2018_Q7) - Capacitance

(a) Explain what is meant by the *capacitance* of a parallel plate capacitor.

.....

.....

.....

.....[3]

(b) A parallel plate capacitor C is connected into the circuit shown in Fig. 7.1.

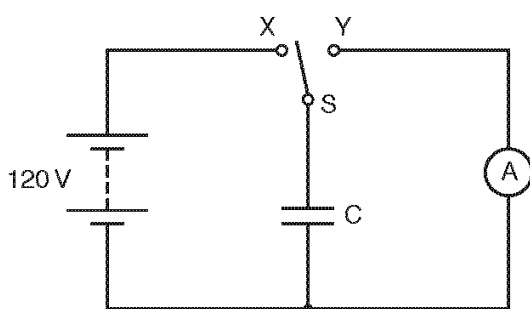


Fig. 7.1

When switch S is at position X , the battery of electromotive force 120 V and negligible internal resistance is connected to capacitor C .

When switch S is at position Y , the capacitor C is discharged through the sensitive ammeter.

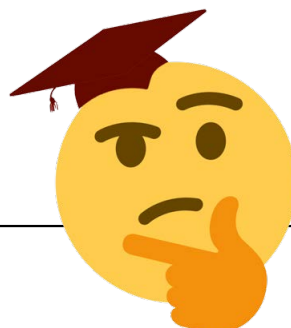
The switch vibrates so that it is first in position X , then moves to position Y and then back to position X fifty times each second.

The current recorded on the ammeter is $4.5\text{ }\mu\text{A}$.

Determine

(i) the charge, in coulomb, passing through the ammeter in 1.0 s ,

charge = C [1]



(ii) the charge on one plate of the capacitor, each time that it is charged,

charge = C [1]

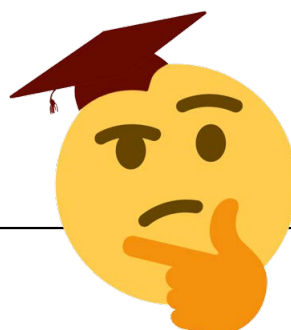
(iii) the capacitance of capacitor C.

capacitance = F [2]

(c) A second capacitor, having a capacitance equal to that of capacitor C, is now placed in series with C.

Suggest and explain the effect on the current recorded on the ammeter.

.....
.....
.....[2]



5 - (9702/41_Summer_2019_Q6) - Capacitance

(a) State **two** different functions of capacitors in electrical circuits.

1.

.....

2.

.....

[2]

(b) Three uncharged capacitors of capacitances C_1 , C_2 and C_3 are connected in series with a battery of electromotive force (e.m.f.) E and a switch, as shown in Fig. 6.1.

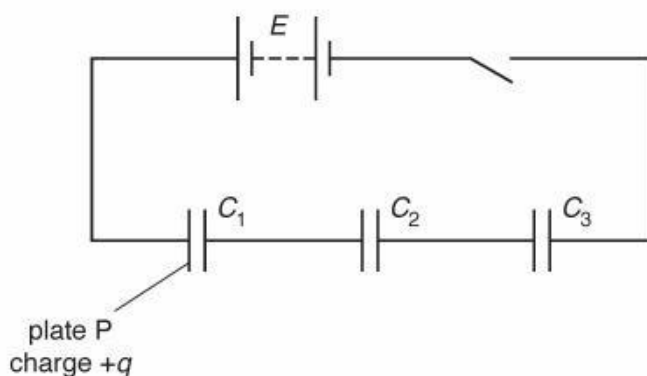


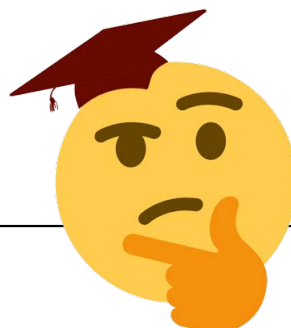
Fig. 6.1

When the switch is closed, there is a charge $+q$ on plate P of the capacitor of capacitance C_1 .

Show that the combined capacitance C of the three capacitors is given by the expression

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}.$$

[3]



(c) A student has available four capacitors, each of capacitance $20\ \mu\text{F}$.

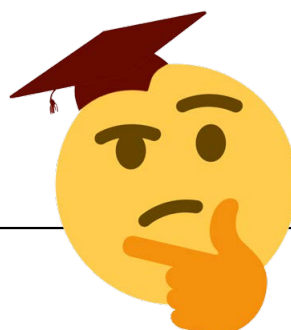
Draw circuit diagrams, one in each case, to show how the student may connect some or all of the capacitors to produce a combined capacitance of:

(i) $60\ \mu\text{F}$

[1]

(ii) $15\ \mu\text{F}$

[1]



6 - (9702/41_Winter_2020_Q6) - Capacitance

(a) (i) Define the *capacitance* of a parallel plate capacitor.

.....
.....
..... [2]

(ii) State **three** functions of capacitors in electrical circuits.

1.
2.
3. [3]

(b) A student has available four capacitors, each of capacitance $24\ \mu\text{F}$.

The capacitors are connected as shown in Fig. 6.1.

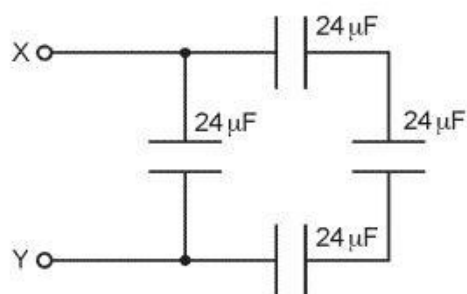
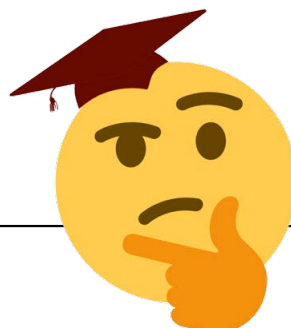


Fig. 6.1

Calculate the combined capacitance between the terminals X and Y.

capacitance = μF [2]

[Total: 7]



7 - (9702/42_Winter_2020_Q6) - Capacitance

(a) (i) Define the *capacitance* of a parallel plate capacitor.

.....

.....

..... [2]

(ii) State **three** functions of capacitors in electrical circuits.

1.
2.
3. [3]

(b) A student has available **three** capacitors, each of capacitance $12\ \mu\text{F}$.

Draw diagrams, one in each case, to show how the student connects the capacitors to give a combined capacitance between the terminals of:

(i) $18\ \mu\text{F}$



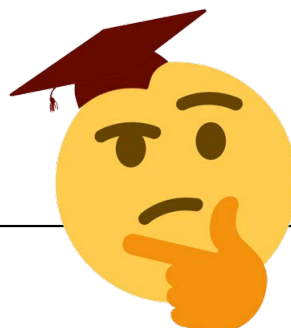
[1]

(ii) $8\ \mu\text{F}$.



[1]

[Total: 7]



8 - (9702/42_Summer_2021_Q6) - Capacitance

- (a) Two flat metal plates are held a small distance apart by means of insulating pads, as shown in Fig. 6.1.

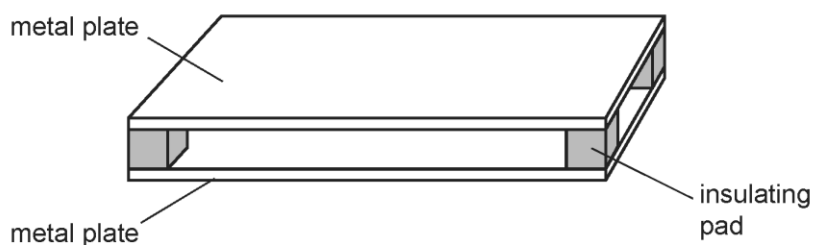


Fig. 6.1

Explain how the plates could act as a capacitor.

.....
.....
..... [2]

- (b) The arrangement in Fig. 6.1 has capacitance C .
The arrangement is connected into the circuit of Fig. 6.2.

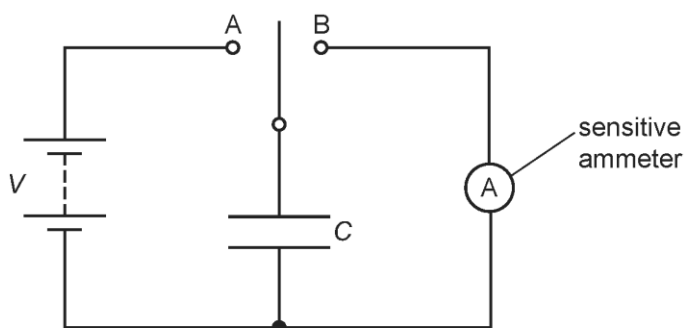
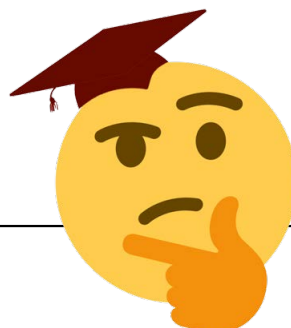


Fig. 6.2

When the two-way switch is moved to position A, the capacitor is charged so that the potential difference across it is V . When the switch moves to position B, the capacitor fully discharges through the sensitive ammeter.

The switch moves repeatedly between A and B so that the capacitor charges and then discharges with frequency f .



- (i) Show that the average current I in the ammeter is given by

$$I = CVf.$$

[2]

- (ii) For a potential difference V of 180 V and a frequency f of switching of 50 Hz, the average current I in the ammeter is $2.5\text{ }\mu\text{A}$.

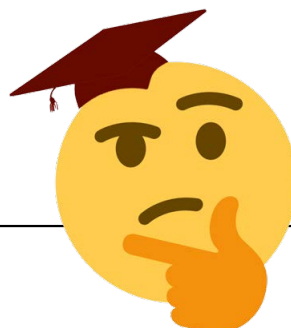
Calculate the capacitance, in pF, of the parallel plates.

capacitance = pF [2]

- (c) A second capacitor is connected into the circuit of Fig. 6.2.
The two capacitors are connected in parallel.

State and explain the change, if any, in the average current in the ammeter.

.....
.....
..... [2]



9 - (9702/41_Summer_2021_Q7) - Capacitance

- (a) State what is meant by the *capacitance* of a parallel plate capacitor.

.....
.....
..... [2]

- (b) A capacitor of capacitance C is connected into the circuit shown in Fig. 7.1.

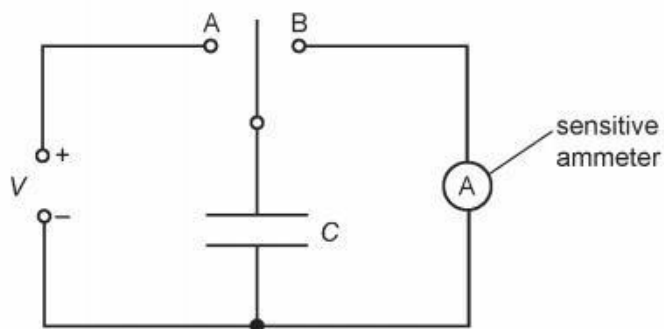


Fig. 7.1

When the two-way switch is in position A, the capacitor is charged so that the potential difference across it is V .

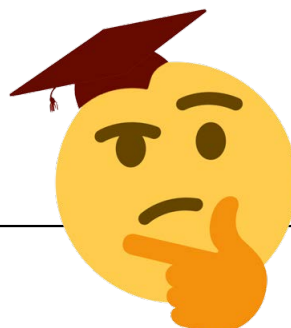
The switch moves to position B and the capacitor fully discharges through the sensitive ammeter.

The switch moves repeatedly between A and B so that the capacitor charges and then discharges with frequency f .

- (i) Show that the average current I in the ammeter is given by the expression

$$I = fCV.$$

[2]



- (ii) For a potential difference V of 150 V and a frequency f of 60 Hz, the average current in the ammeter is $4.8 \mu\text{A}$.

Calculate the capacitance, in pF, of the capacitor.

capacitance = pF [2]

- (c) A second capacitor, having the same capacitance as the capacitor in (b), is connected into the circuit of Fig. 7.1. The two capacitors are connected in series.

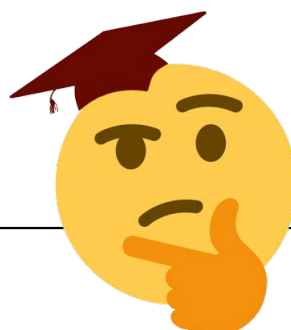
State and explain the new reading on the ammeter.

new reading = μA

.....

.....

..... [3]



10 - (9702/41_Winter_2021_Q6) - Capacitance

- (a) A capacitor consists of two parallel metal plates, separated by air, at a variable distance x apart, as shown in Fig. 6.1. The capacitance C is inversely proportional to x .

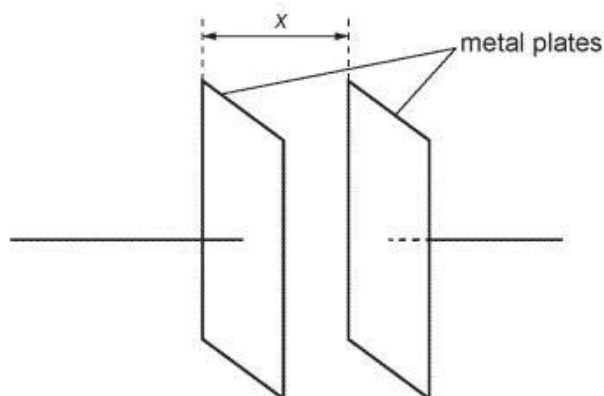


Fig. 6.1

The capacitor is charged by a supply so that there is a potential difference (p.d.) V between the plates.

State expressions, in terms of C and V , for the charge Q on one of the plates and for the energy E stored in the capacitor.

$Q = \dots\dots\dots$ $E = \dots\dots\dots$ [1]

- (b) The charged capacitor in (a) is now disconnected from the supply. The plates of the capacitor are initially separated by distance L . They are then moved closer together by a distance D , as shown in Fig. 6.2.

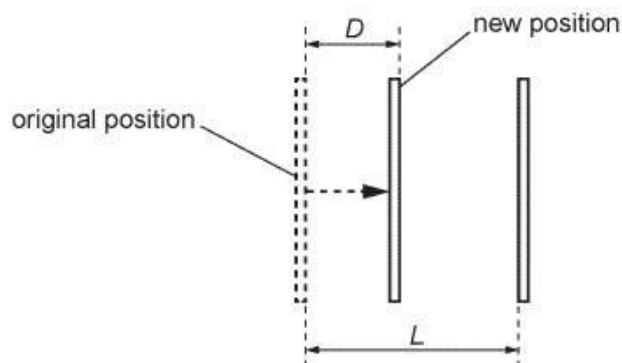
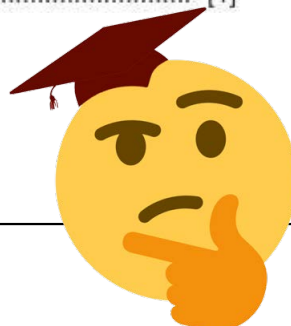


Fig. 6.2

State expressions, in terms of C , V , L and D , for:

- (i) the new capacitance C_N

$C_N = \dots\dots\dots$ [1]



(ii) the new charge Q_N on one of the plates

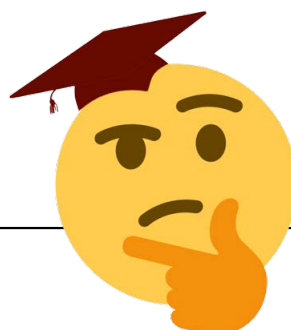
$$Q_N = \dots\dots\dots [1]$$

(iii) the new p.d. V_N between the plates.

$$V_N = \dots\dots\dots [1]$$

(c) Explain whether reducing the separation of the plates in (b) results in an increase or decrease in the energy stored in the capacitor.

.....
.....
..... [1]



11 – (9702/42_Winter_2021_Q6) – Capacitance

(a) Define *electric potential*.

.....
.....
..... [2]

(b) An isolated conducting sphere in a vacuum has radius r and is initially uncharged. It is then charged by friction so that it carries a final charge Q . This charge can be considered to be acting at the centre of the sphere.

By considering the electric potential at its surface, show that the capacitance C of the sphere is given by

$$C = 4\pi\epsilon_0 r$$

where ϵ_0 is the permittivity of free space.

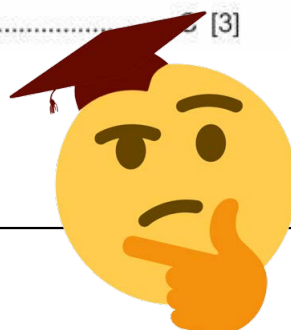
[2]

(c) The dome of an electrostatic generator is a spherical conductor of radius 13 cm. It is initially charged so that the electric potential at the surface is 4.5 kV.

A smaller isolated sphere of radius 5.2 cm, initially uncharged, is brought near to the dome. Sparking causes a current between the two spheres until they reach the same potential. Assume that any charge on a sphere may be considered to act as a point charge at its centre.

Calculate the charge that is transferred between the two spheres.

charge = [3]



12 - (9702/41_Winter_2022_Q5) - Capacitance

A capacitor of capacitance $470\,\mu\text{F}$ is connected to a battery of electromotive force (e.m.f.) $24\,\text{V}$ in the circuit of Fig. 5.1.

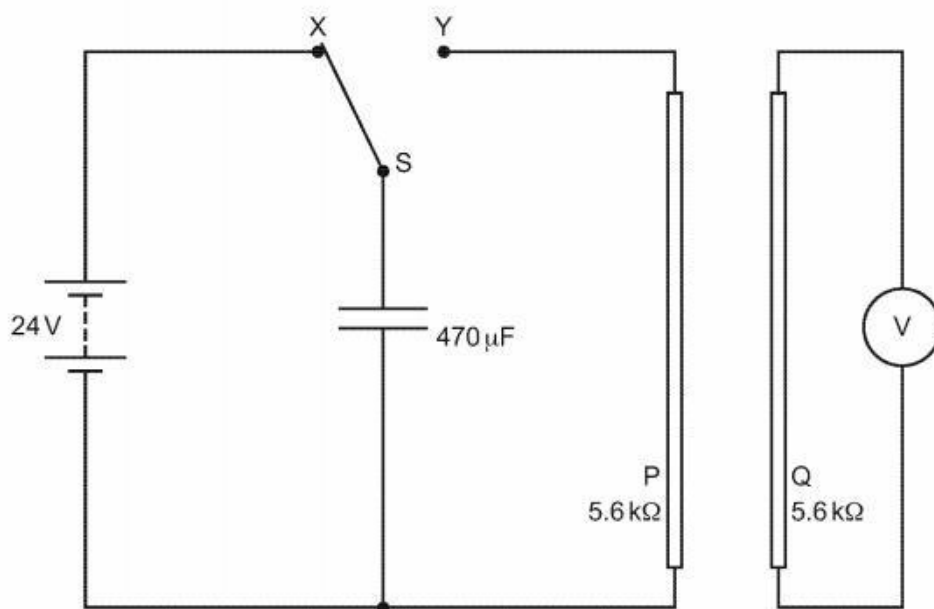


Fig. 5.1

The two-way switch S is initially at position X.

P and Q are identical long straight wires, each with a resistance of $5.6\,\text{k}\Omega$. These wires are placed near to, and parallel to, each other. Wire Q is connected to a voltmeter.

At time $t = 0$, switch S is moved to position Y so that the capacitor discharges through wire P.

(a) (i) Calculate the charge Q_0 on the capacitor at time $t = 0$.

$$Q_0 = \dots\dots\dots \text{C} \quad [2]$$

(ii) Calculate the current I_0 in wire P at time $t = 0$.

$$I_0 = \dots\dots\dots \text{A} \quad [1]$$



- (iii) Calculate the time constant τ of the discharge circuit.

$$\tau = \dots\dots\dots \text{ s } [2]$$

- (iv) On Fig. 5.2, sketch a line to show the variation with t of the current I in wire P as the capacitor discharges.



Fig. 5.2

[2]

- (b) (i) Explain why there is an induced e.m.f. across wire Q during the discharge of the capacitor.

.....

.....

.....

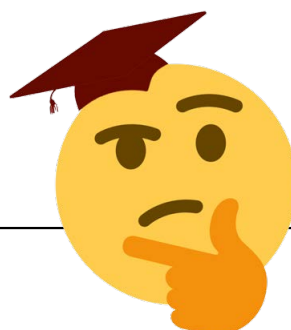
..... [3]

- (ii) On Fig. 5.3, sketch a line to suggest the variation with t of the voltmeter reading V .



Fig. 5.3

[1]



13 - (9702/42_Winter_2022_Q6) - Capacitance

A capacitor of capacitance C and a resistor of resistance R are connected as shown in Fig. 6.1.

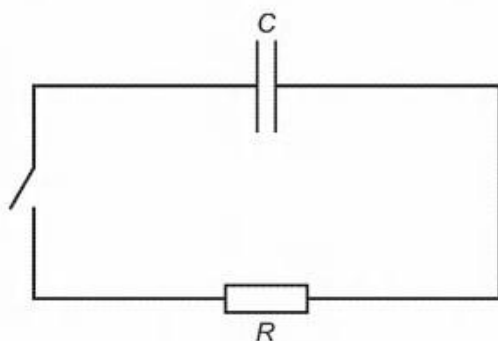


Fig. 6.1

Initially, the capacitor is charged and the switch is open.

The switch is closed at time $t = 0$.

Fig. 6.2 and Fig. 6.3 show, respectively, the variations with t of the charge Q on the capacitor and the potential difference (p.d.) V across the resistor.

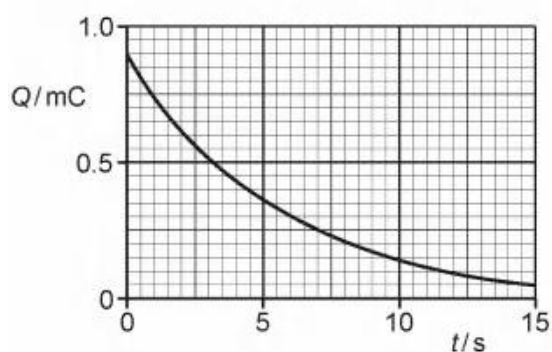


Fig. 6.2

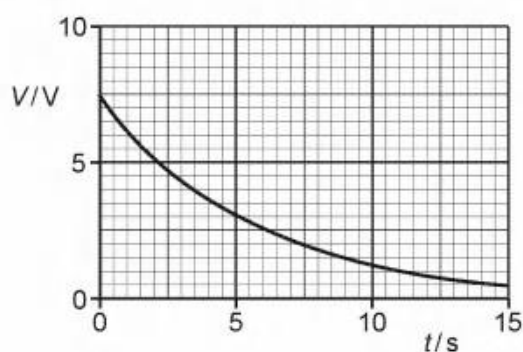


Fig. 6.3

(a) Explain the shape of the line in Fig. 6.3 representing the variation of V with t .

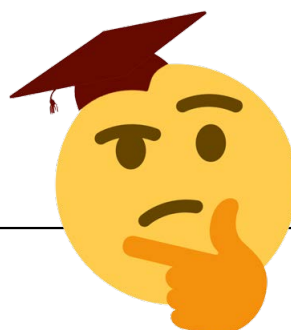
.....

.....

.....

.....

..... [3]



(b) Use Fig. 6.2 to show that the time constant of the circuit in Fig. 6.1 is 5.5 s.

[3]

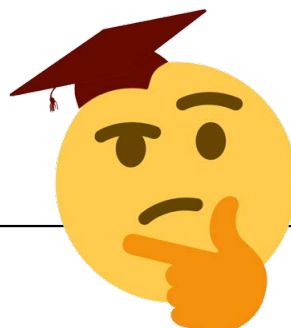
(c) Use Fig. 6.2, Fig. 6.3 and the information in **(b)** to determine:

(i) capacitance C , in μF

$C = \dots\dots\dots \mu\text{F}$ [2]

(ii) resistance R , in $\text{k}\Omega$.

$R = \dots\dots\dots \text{k}\Omega$ [2]



14 - (9702/42_Summer_2023_Q5) - Capacitance

Two capacitors A and B are connected into the circuit shown in Fig. 5.1.

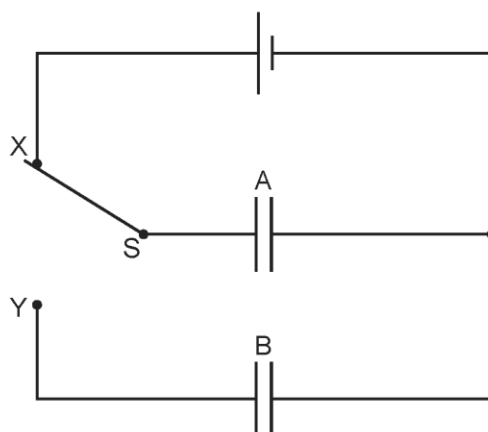


Fig. 5.1

Capacitor A has capacitance C and capacitor B has capacitance $3C$.

The electromotive force (e.m.f.) of the cell is V .

The two-way switch S is initially at position X, and capacitor B is initially uncharged.

(a) State, in terms of V and C , expressions for:

(i) the initial charge Q_A on the plates of capacitor A

$$Q_A = \dots\dots\dots [1]$$

(ii) the initial energy E_A stored in capacitor A.

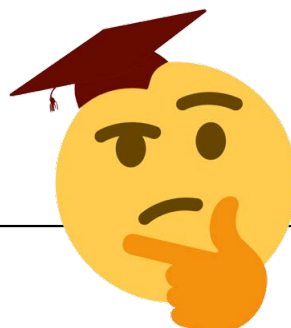
$$E_A = \dots\dots\dots [1]$$

(b) The two-way switch S is now moved to position Y.

(i) State and explain what happens to the charge that was initially on the plates of capacitor A.

.....

 [2]



- (ii) Show that the final potential difference (p.d.) V_B across capacitor B is given by

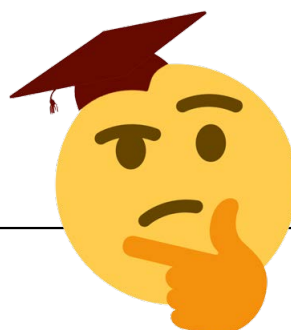
$$V_B = \frac{V}{4}.$$

Explain your reasoning.

[3]

- (iii) Determine an expression, in terms of V and C , for the decrease ΔE in the total energy that is stored in the capacitors as a result of the change of the position of the switch.

$$\Delta E = \dots\dots\dots [2]$$



15 - (9702/43_Summer_2023_Q5) - Capacitance

Part of an electric circuit is shown in Fig. 5.1.

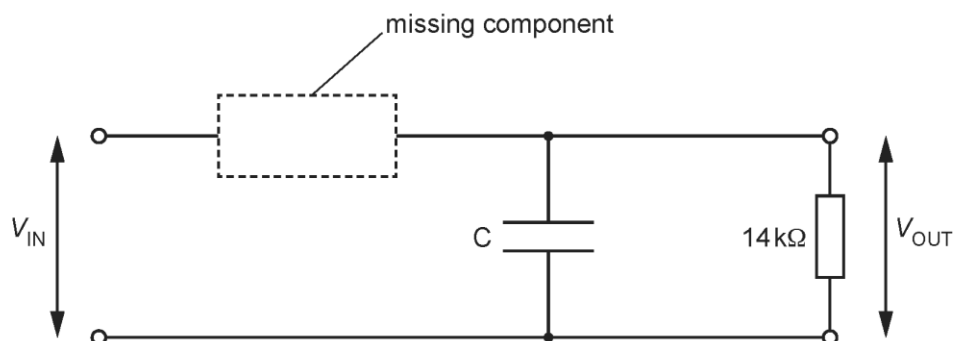


Fig. 5.1

The circuit is used to produce half-wave rectification of an alternating voltage of potential difference (p.d.) V_{IN} .

The output p.d. across the $14\text{ k}\Omega$ resistor is V_{OUT} .

- (a) (i) A component is missing from the circuit of Fig. 5.1.

Complete the circuit diagram in Fig. 5.1 by adding the circuit symbol for the missing component, correctly connected. [1]

- (ii) A capacitor C is shown in the circuit of Fig. 5.1.

State the effect on V_{OUT} of including the capacitor in the circuit.

..... [1]

- (b) Fig. 5.2 shows the variation with time t of V_{IN} .

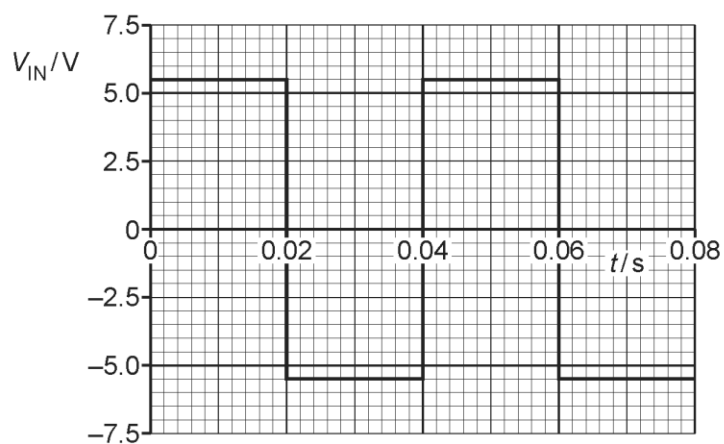


Fig. 5.2

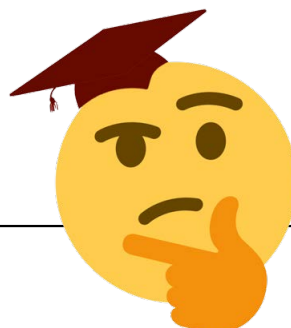


Fig. 5.3 shows the variation with t of V_{OUT} .

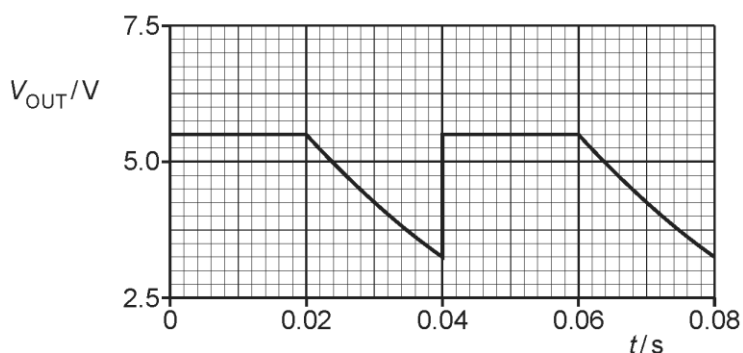


Fig. 5.3

- (i) Determine the frequency of V_{IN} .

frequency = Hz [1]

- (ii) Show that the time constant τ for the discharge of the capacitor through the resistor is 0.038 s.

[2]

- (iii) Calculate the capacitance of C. Give a unit with your answer.

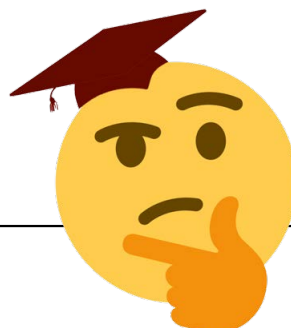
capacitance = unit [2]

- (c) The circuit of Fig. 5.1 is modified so that it produces full-wave rectification of an input voltage.

Suggest, with a reason, how V_{OUT} now varies with time when V_{IN} is as shown in Fig. 5.2.

.....

 [2]



16 - (9702/42_Winter_2023_Q6) - Capacitance

A capacitor C is charged so that the potential difference (p.d.) V across its terminals is 8.0 V . The capacitor is connected into the circuit of Fig. 6.1.

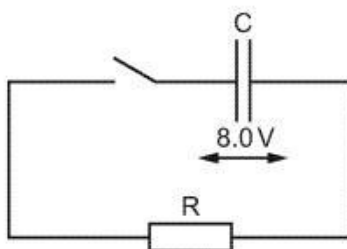


Fig. 6.1

The switch is initially open. The switch is closed at time $t = 0$.

- (a) Fig. 6.2 shows the variation of V with the charge Q on the plates of capacitor C as the capacitor discharges.

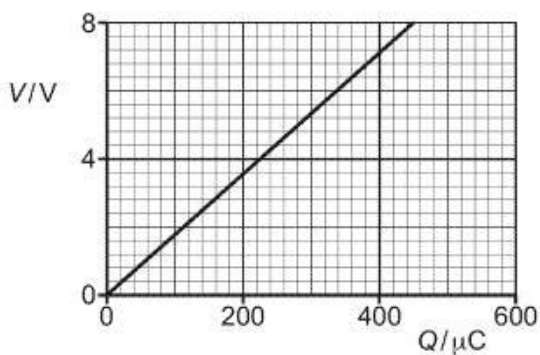


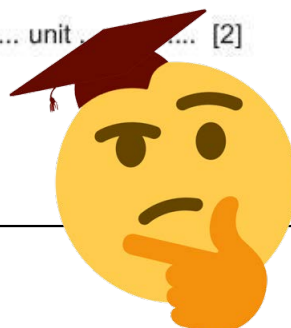
Fig. 6.2

- (i) Show that the energy stored in capacitor C at time $t = 0$ is 1.8 mJ .

[2]

- (ii) Determine the capacitance of capacitor C . Give a unit with your answer.

capacitance = unit [2]



(b) Fig. 6.3 shows the variation with t of $-\ln\left(\frac{V}{8.0\text{V}}\right)$.

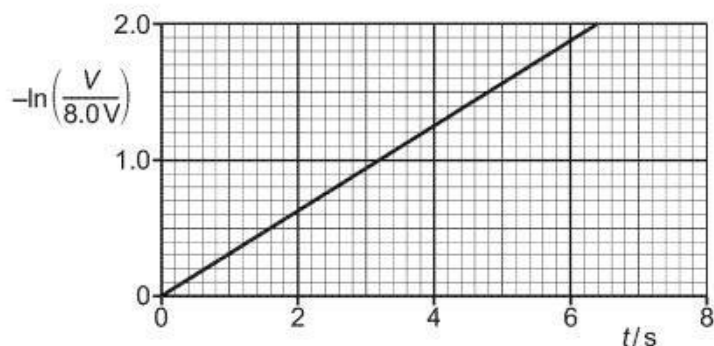


Fig. 6.3

(i) Show that, when t is equal to one time constant, the value of $-\ln\left(\frac{V}{8.0\text{V}}\right)$ is equal to 1.0.

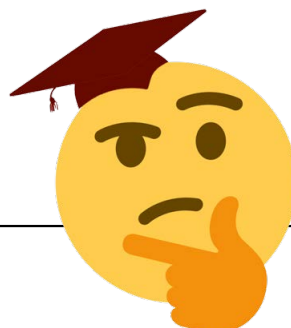
[2]

(ii) Determine the time constant τ of the circuit in Fig. 6.1.

$\tau = \dots\dots\dots \text{s}$ [1]

(iii) Calculate the resistance of resistor R.

resistance = $\dots\dots\dots \Omega$ [2]



1 – (9702/42_Summer_2017_Q6) – *Electric Fields, Current Of Electricity*

(a) State Coulomb's law.

.....
.....
.....[2]

(b) Two charged metal spheres A and B are situated in a vacuum, as illustrated in Fig. 6.1.

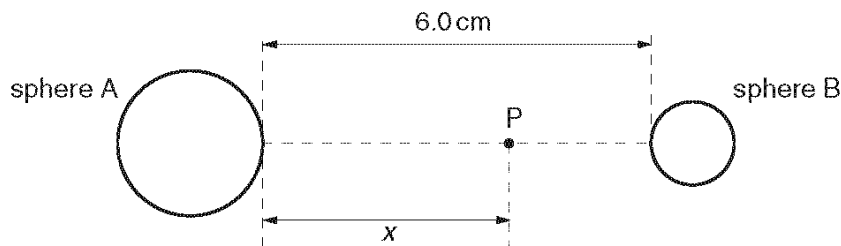


Fig. 6.1

The shortest distance between the surfaces of the spheres is 6.0 cm.

A movable point P lies along the line joining the centres of the two spheres, a distance x from the surface of sphere A.

The variation with distance x of the electric field strength E at point P is shown in Fig. 6.2.

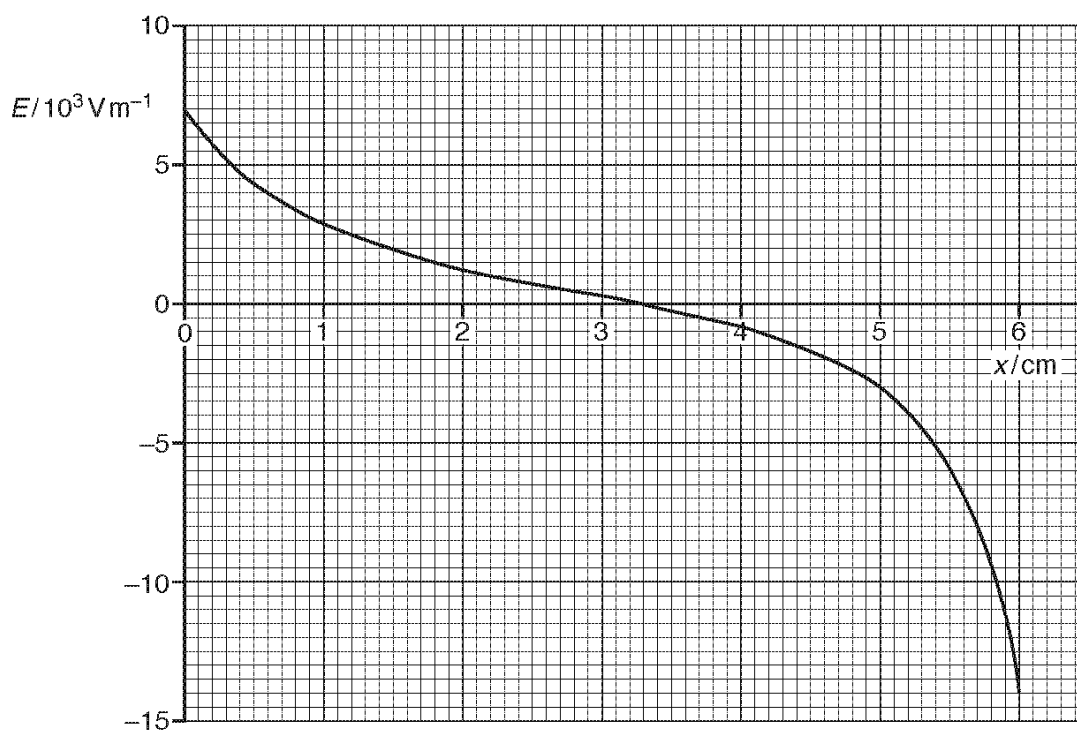


Fig. 6.2



- (i) Use Fig. 6.2 to explain whether the two spheres have charges of the same, or opposite, sign.

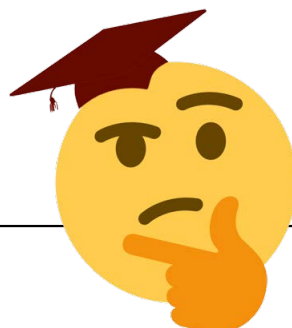
.....
.....
.....
.....[2]

- (ii) A proton is at point P where $x = 5.0$ cm.
Use data from Fig. 6.2 to determine the acceleration of the proton.

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

- (c) Use data from Fig. 6.2 to state the value of x at which the rate of change of electric potential is maximum. Give the reason for the value you have chosen.

.....
.....
.....[2]



2 - (9702/41_Summer_2021_Q8) - Current Of Electricity

The variation with temperature of the resistance of a thermistor is shown in Fig. 8.1.

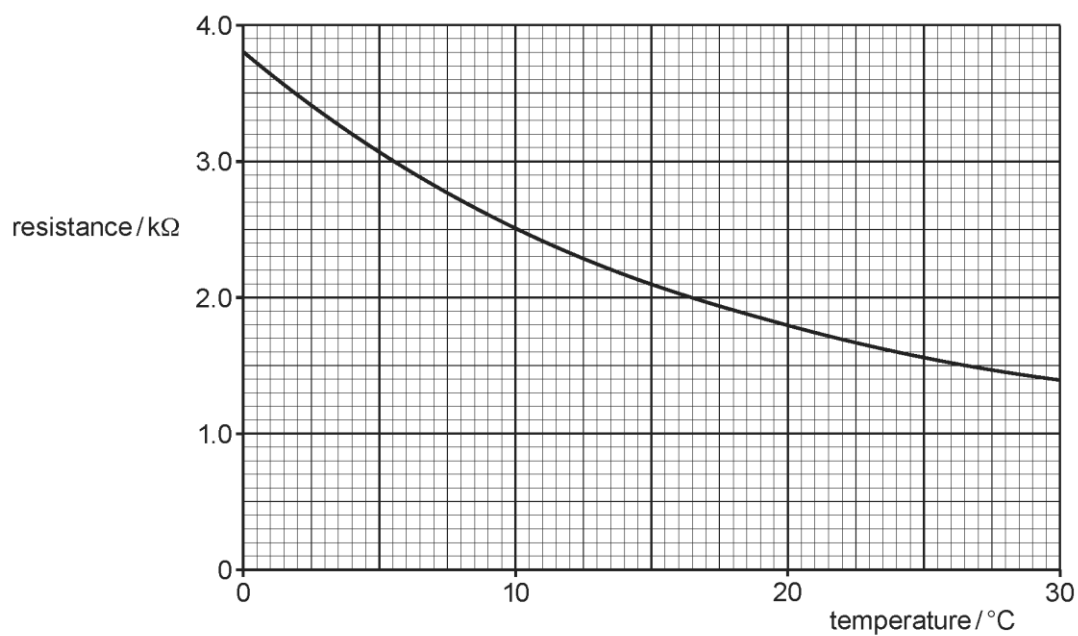


Fig. 8.1

A student includes the thermistor and an ideal operational amplifier (op-amp) in the circuit of Fig. 8.2.

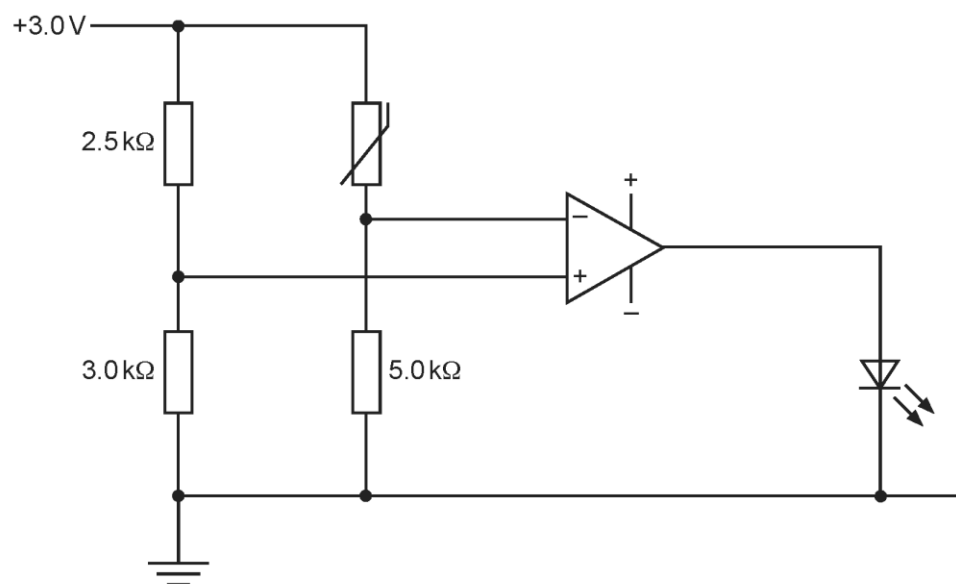
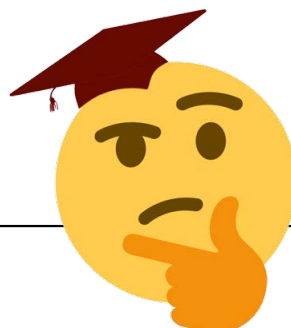


Fig. 8.2



- (a) Calculate the potential V^+ at the non-inverting input of the op-amp.

$$V^+ = \dots\dots\dots \text{ V [2]}$$

- (b) At 10°C , the resistance of the thermistor is $2.5\text{ k}\Omega$.

State and explain whether the light-emitting diode (LED) is emitting light.

.....
.....
..... [2]

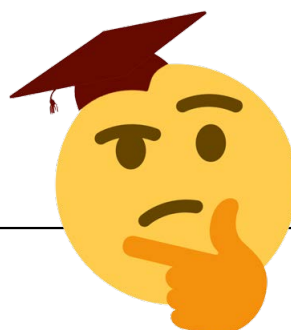
- (c) Explain why the student's circuit will not indicate any change in temperature above 0°C .

.....
.....
..... [2]

- (d) The resistor of resistance $5.0\text{ k}\Omega$ is changed to a resistor of resistance R so that the LED switches on or off at a temperature of 20°C .

Determine R in $\text{k}\Omega$.

$$R = \dots\dots\dots \text{ k}\Omega [3]$$



3 - (9702/41_Summer_2023_Q5) - Current Of Electricity

Part of an electric circuit is shown in Fig. 5.1.

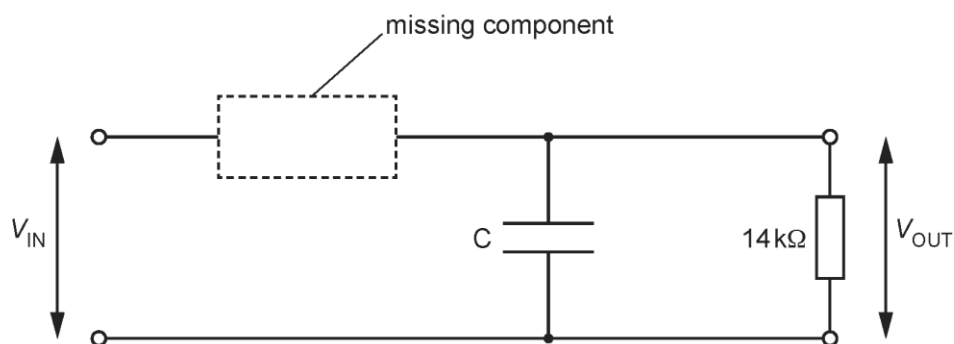


Fig. 5.1

The circuit is used to produce half-wave rectification of an alternating voltage of potential difference (p.d.) V_{IN} .

The output p.d. across the $14\text{ k}\Omega$ resistor is V_{OUT} .

- (a) (i)** A component is missing from the circuit of Fig. 5.1.

Complete the circuit diagram in Fig. 5.1 by adding the circuit symbol for the missing component, correctly connected. [1]

- (ii)** A capacitor C is shown in the circuit of Fig. 5.1.

State the effect on V_{OUT} of including the capacitor in the circuit.

..... [1]

- (b)** Fig. 5.2 shows the variation with time t of V_{IN} .

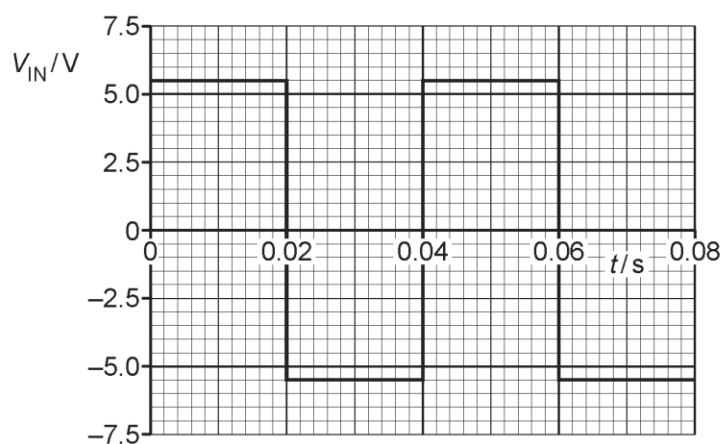


Fig. 5.2

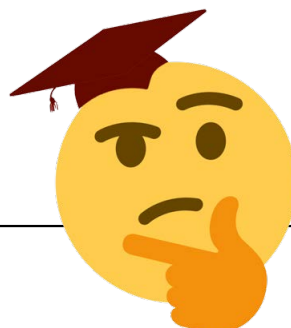


Fig. 5.3 shows the variation with t of V_{OUT} .

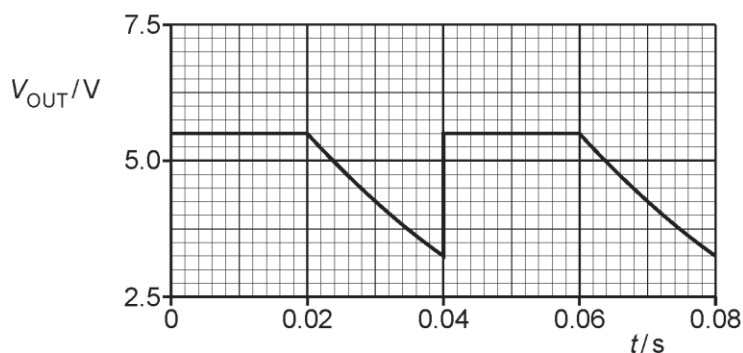


Fig. 5.3

- (i) Determine the frequency of V_{IN} .

frequency = Hz [1]

- (ii) Show that the time constant τ for the discharge of the capacitor through the resistor is 0.038 s.

[2]

- (iii) Calculate the capacitance of C. Give a unit with your answer.

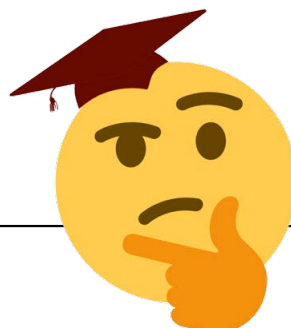
capacitance = unit [2]

- (c) The circuit of Fig. 5.1 is modified so that it produces full-wave rectification of an input voltage.

Suggest, with a reason, how V_{OUT} now varies with time when V_{IN} is as shown in Fig. 5.2.

.....

 [2]



1 - (9702/41_Summer_2017_Q6) - D.c. Circuits, Electronics

A comparator circuit is designed to switch on a mains lamp when the ambient light level reaches a set value.

An incomplete diagram of the circuit is shown in Fig. 6.1.

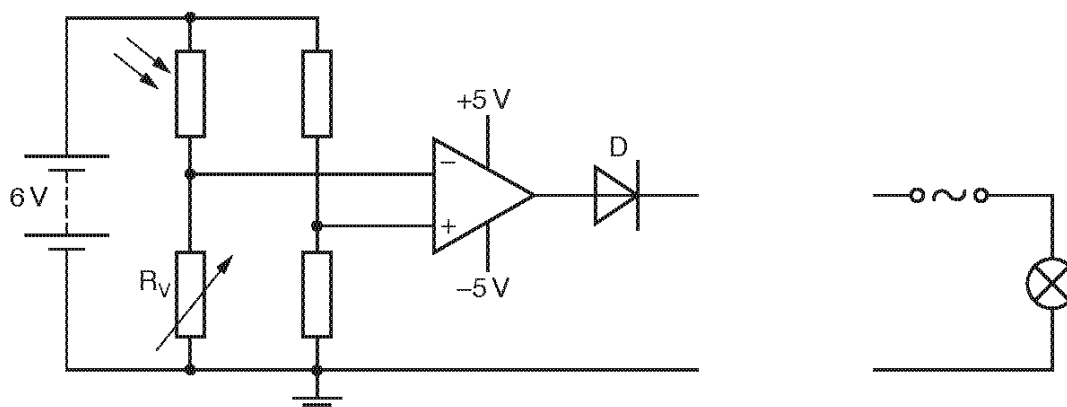


Fig. 6.1

- (a) (i) A relay is required as part of the output device. This is not shown in Fig. 6.1. Explain why a relay is required.

.....

[2]

- (ii) On Fig. 6.1, draw the symbol for a relay connected in the circuit as part of the output device. [2]

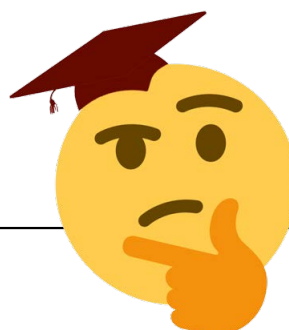
- (b) Describe the function of

- (i) the variable resistor R_V .

.....
[1]

- (ii) the diode D.

.....
[1]



- (c) State whether the lamp will switch on as the light level increases or as it decreases. Explain your answer.

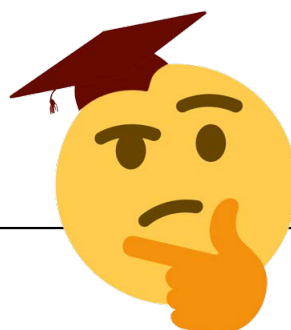
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.....

.....[3]



2 - (9702/43_Summer_2021_Q8) - Current Of Electricity, D.c. Circuits

The variation with temperature of the resistance of a thermistor is shown in Fig. 8.1.

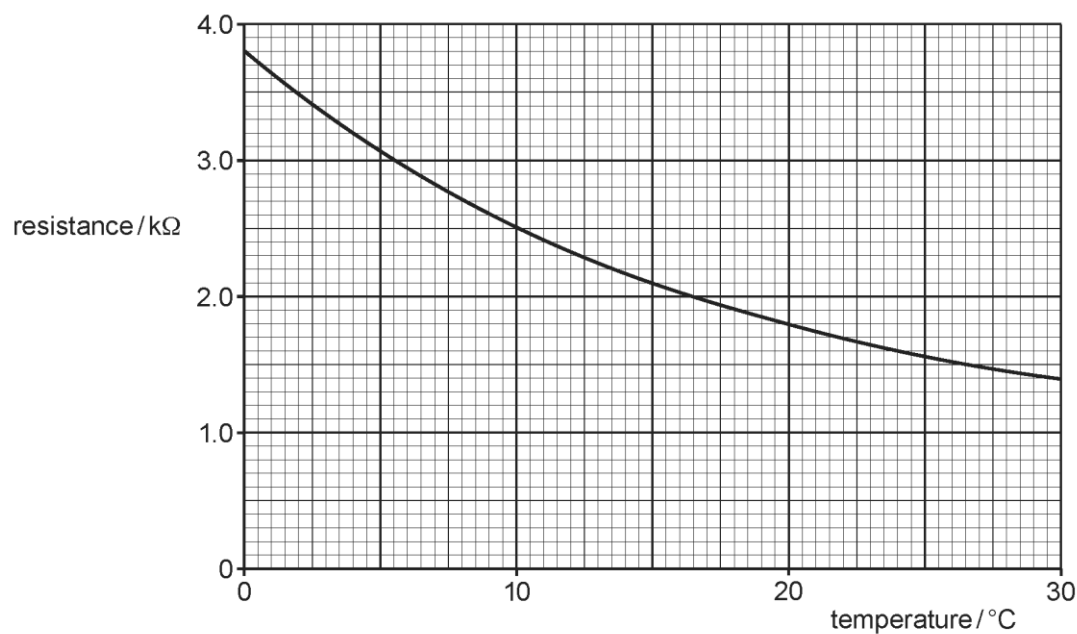


Fig. 8.1

A student includes the thermistor and an ideal operational amplifier (op-amp) in the circuit of Fig. 8.2.

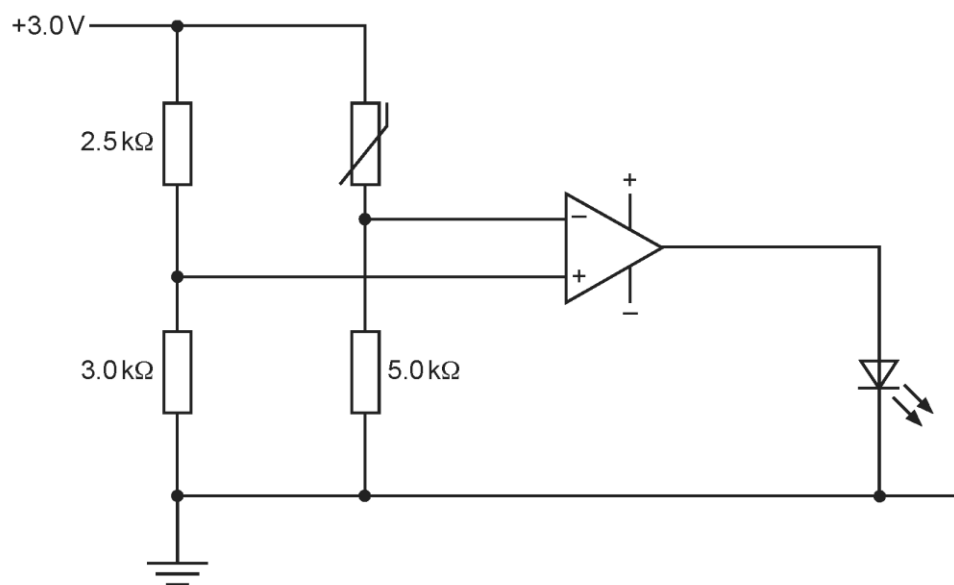
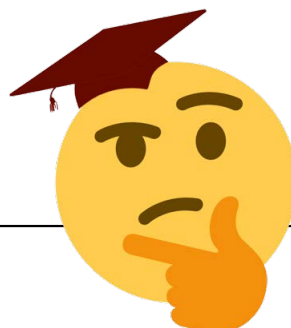


Fig. 8.2



- (a) Calculate the potential V^+ at the non-inverting input of the op-amp.

$$V^+ = \dots\dots\dots \text{ V [2]}$$

- (b) At 10°C , the resistance of the thermistor is $2.5\text{ k}\Omega$.

State and explain whether the light-emitting diode (LED) is emitting light.

.....
.....
..... [2]

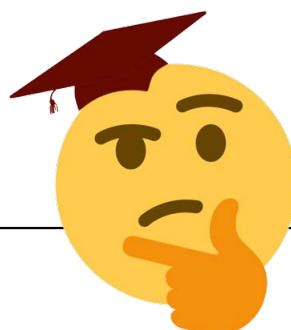
- (c) Explain why the student's circuit will not indicate any change in temperature above 0°C .

.....
.....
..... [2]

- (d) The resistor of resistance $5.0\text{ k}\Omega$ is changed to a resistor of resistance R so that the LED switches on or off at a temperature of 20°C .

Determine R in $\text{k}\Omega$.

$$R = \dots\dots\dots \text{ k}\Omega [3]$$



1 - (9702/41_Summer_2017_Q6) - D.c. Circuits, Electronics

A comparator circuit is designed to switch on a mains lamp when the ambient light level reaches a set value.

An incomplete diagram of the circuit is shown in Fig. 6.1.

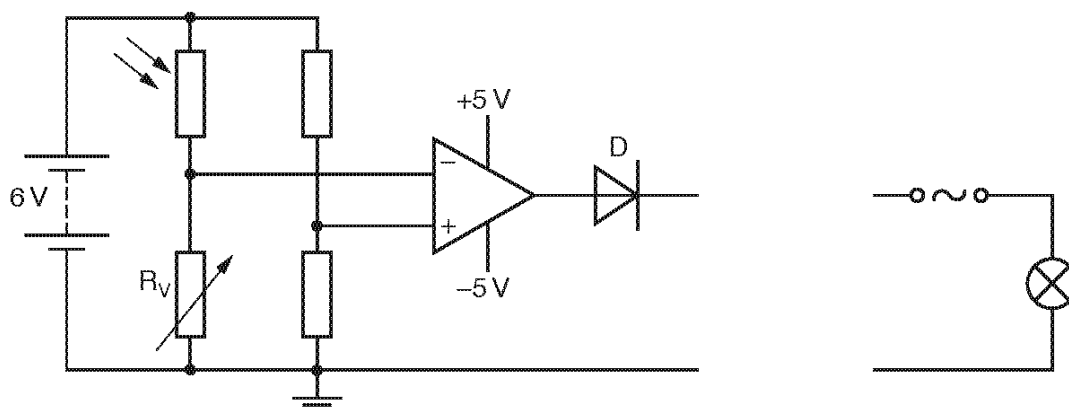


Fig. 6.1

- (a) (i) A relay is required as part of the output device. This is not shown in Fig. 6.1. Explain why a relay is required.

.....

[2]

- (ii) On Fig. 6.1, draw the symbol for a relay connected in the circuit as part of the output device. [2]

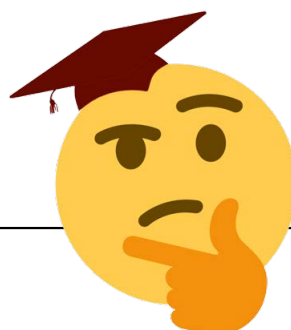
- (b) Describe the function of

- (i) the variable resistor R_V .

.....
[1]

- (ii) the diode D.

.....
[1]



- (c) State whether the lamp will switch on as the light level increases or as it decreases. Explain your answer.

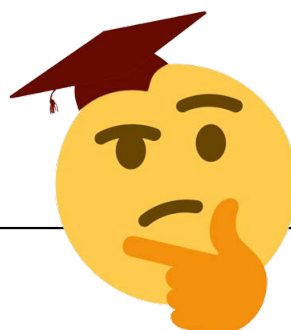
.....

.....

.....

.....

.....[3]



2 - (9702/42_Summer_2017_Q8) - Electronics

A student designs a circuit incorporating an operational amplifier (op-amp) as shown in Fig. 8.1.

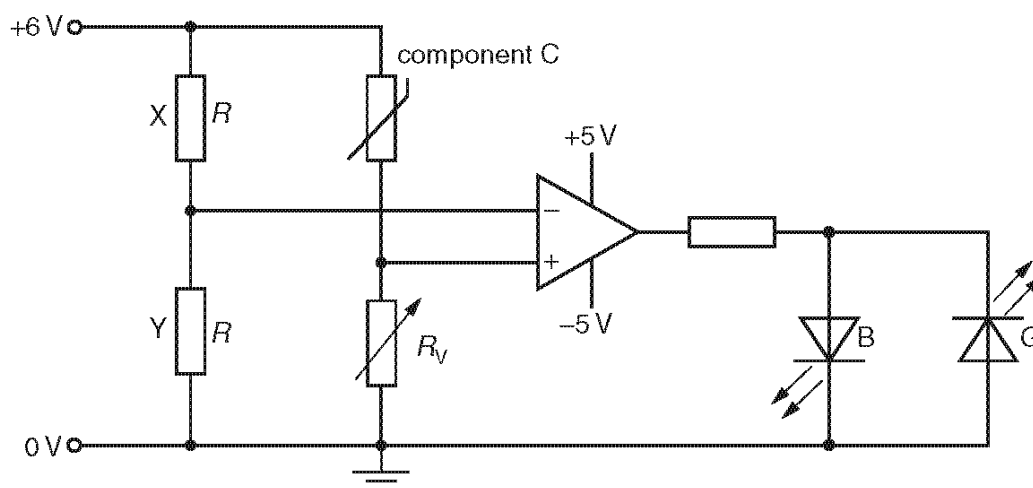


Fig. 8.1

- (a) (i) On Fig. 8.1, draw a circle around the output device. [1]

- (ii) State the purpose of this circuit.

.....

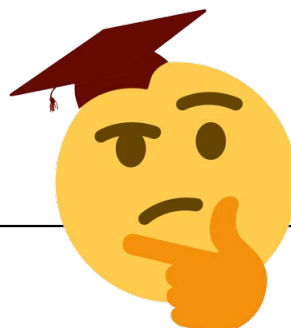
[2]

- (b) The resistors X and Y each have resistance R .
 When conducting, the LED labelled B emits blue light and the LED labelled G emits green light.

- (i) State whether blue light or green light is emitted when the resistance of component C is greater than the resistance R_V of the variable resistor. Explain your answer.

.....

[3]



(ii) State and explain what is observed as the resistance of component C is reduced.

.....

.....

.....

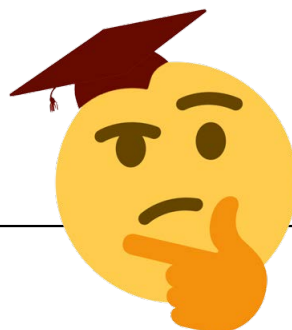
.....

.....[3]

(c) Suggest the function of the variable resistor.

.....

.....[1]



3 - (9702/41_Winter_2017_Q7) - Electronics

The circuit of an amplifier incorporating an ideal operational amplifier (op-amp) is shown in Fig. 7.1.

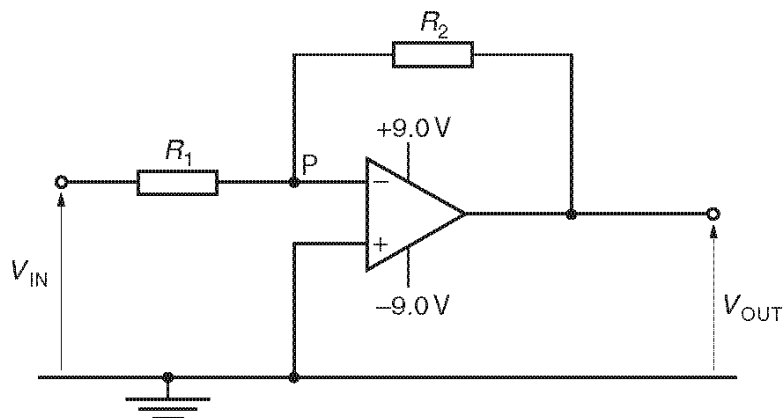


Fig. 7.1

(a) By reference to the properties of an ideal op-amp,

(i) explain why point P is referred to as a *virtual earth*,

.....

.....

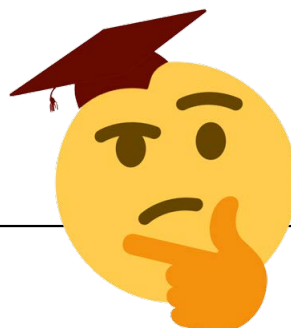
.....

.....

..... [4]

(ii) derive an expression, in terms of the resistances R_1 and R_2 , for the gain of the amplifier circuit.

[4]



- (b) In the circuit of Fig. 7.1, the ratio $\frac{R_2}{R_1}$ is 4.5.

The variation with time t of the input potential V_{IN} is shown in Fig. 7.2.

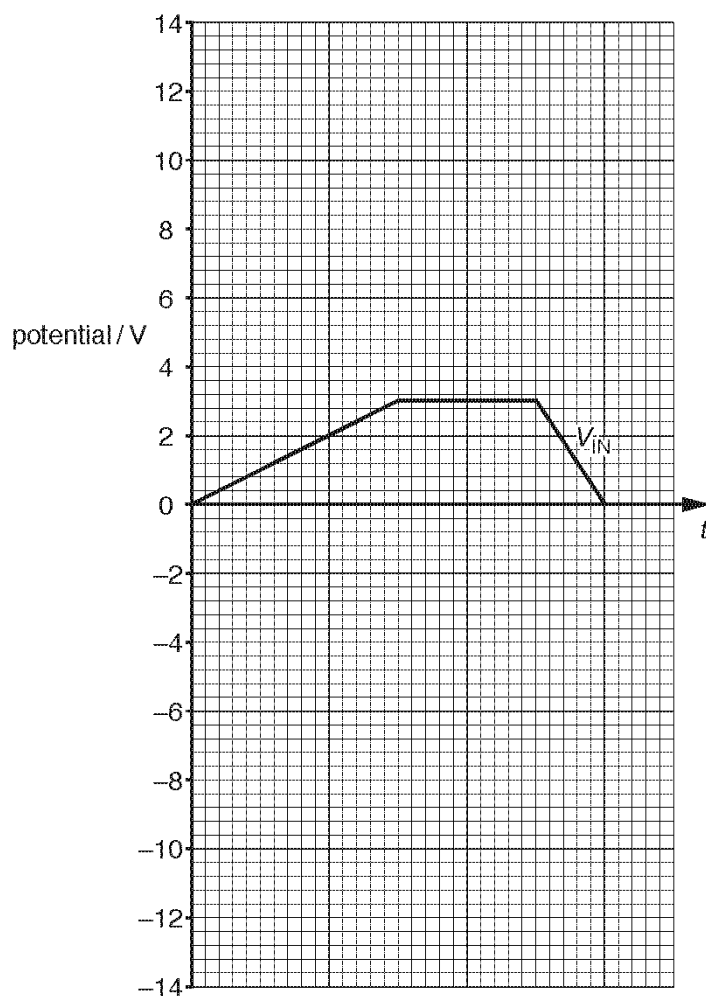
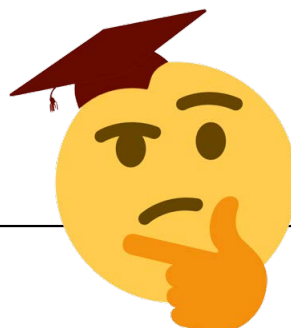


Fig. 7.2

On Fig. 7.2, show the variation with time t of the output potential V_{OUT} .

[3]



4 - (9702/42_Winter_2017_Q7) - Electronics

(a) Feedback is used frequently in amplifier circuits.

State

(i) what is meant by *feedback*,

.....
.....
..... [2]

(ii) two benefits of negative feedback in an amplifier circuit.

1.
.....
2.
..... [2]

(b) An amplifier circuit incorporating an ideal operational amplifier (op-amp) is used to amplify the output of a microphone. The circuit is shown in Fig. 7.1.

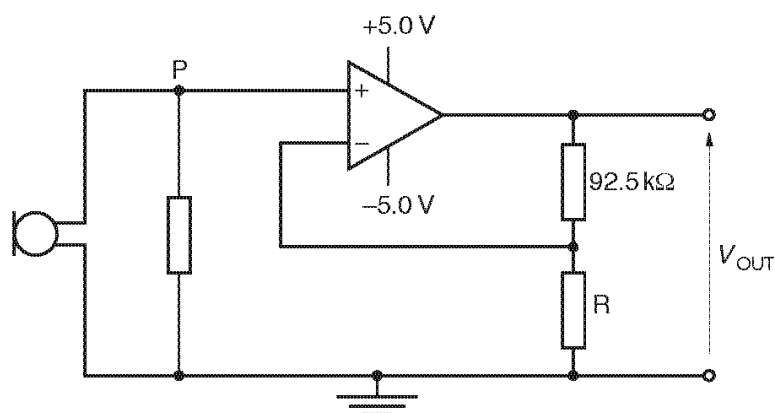
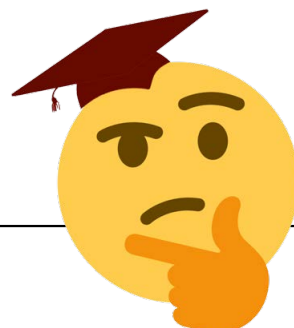


Fig. 7.1



When the potential at point P is 48 mV, the output potential difference V_{OUT} is 3.6 V.

(i) Determine

1. the gain of the amplifier circuit,

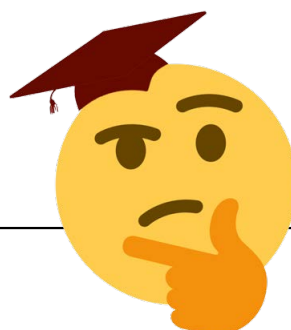
gain = [2]

2. the resistance of resistor R.

resistance = Ω [2]

(ii) State and explain the effect on the amplifier output when the potential at P exceeds 68 mV.

.....
.....
..... [2]



5 - (9702/42_Summer_2018_Q7) - Electronics

(a) Negative feedback is often used in amplifiers.

State

(i) what is meant by *negative feedback*,

.....

[2]

(ii) two effects of negative feedback on the gain of an amplifier.

1.

 2.
[2]

(b) An ideal operational amplifier (op-amp) is incorporated into the circuit shown in Fig. 7.1.

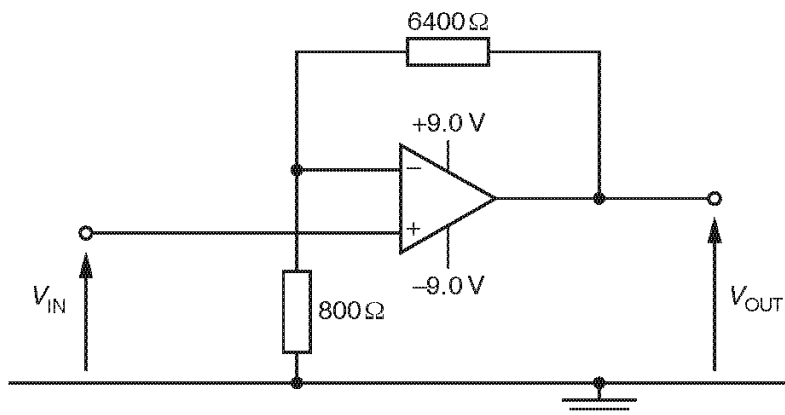
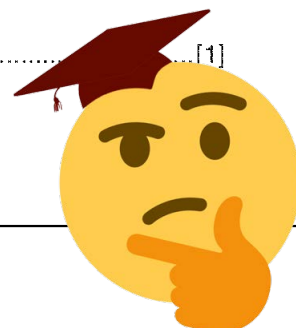


Fig. 7.1

(i) Calculate the gain G of the amplifier circuit.
 $G =$ [1]


(ii) Determine the output potential difference V_{OUT} for an input potential difference V_{IN} of

1. $+0.60 \text{ V}$,

$V_{\text{OUT}} = \dots\dots\dots \text{ V}$

2. -2.1 V .

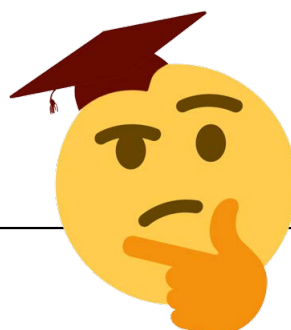
$V_{\text{OUT}} = \dots\dots\dots \text{ V}$
[2]

(iii) The gain of the amplifier shown in Fig. 7.1 is constant.

State one change that may be made to the circuit of Fig. 7.1 so that the amplifier circuit monitors temperature with the gain decreasing as the temperature rises.

.....

.....[1]



6 - (9702/41_Summer_2018_Q8) - Electronics

(a) Negative feedback is often used in amplifiers incorporating an operational amplifier (op-amp).

State

(i) what is meant by *negative feedback*,

.....

[2]

(ii) two effects of negative feedback on the gain of an amplifier.

1.

 2.
[2]

(b) An ideal op-amp is incorporated into the amplifier circuit shown in Fig. 8.1.

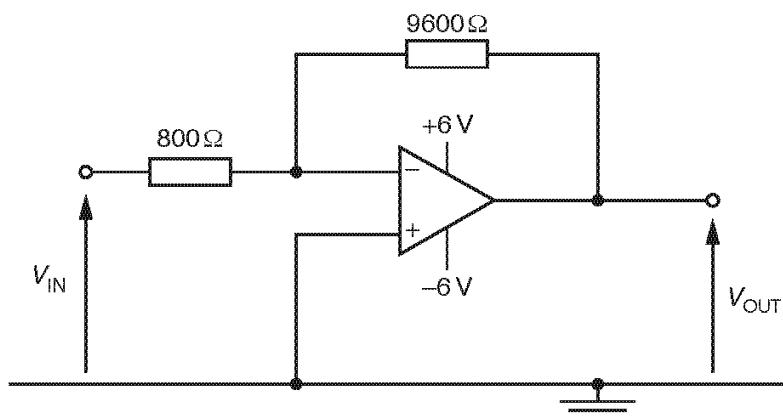
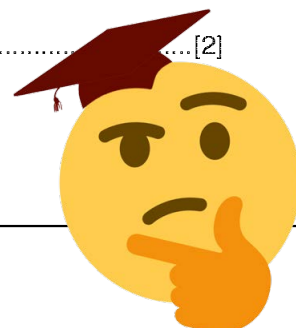


Fig. 8.1

(i) Calculate the gain G of the amplifier circuit.

$G =$ [2]



(ii) Determine the output potential difference V_{OUT} for input potential differences V_{IN} of

1. -0.10 V ,

$$V_{\text{OUT}} = \dots\dots\dots \text{ V}$$

2. $+1.3 \text{ V}$.

$$V_{\text{OUT}} = \dots\dots\dots \text{ V}$$

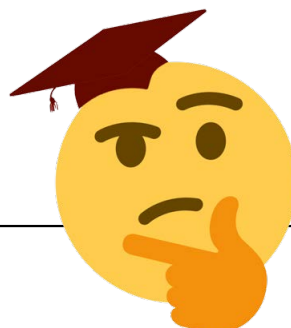
[2]

(iii) The gain of the amplifier shown in Fig. 8.1 is constant.

State one change that can be made to the circuit of Fig. 8.1 so that the amplifier circuit monitors light intensity levels, with the magnitude of the gain decreasing as light intensity increases.

.....

.....[1]



7 - (9702/41_Winter_2018_Q7) - Electronics

- (a) An ideal operational amplifier (op-amp) has infinite bandwidth and infinite slew rate.

State what is meant by

- (i) *infinite bandwidth*,

.....
.....
.....[2]

- (ii) *infinite slew rate*.

.....
.....
.....[2]

- (b) An incomplete circuit for a non-inverting amplifier incorporating an ideal operational amplifier is shown in Fig. 7.1.

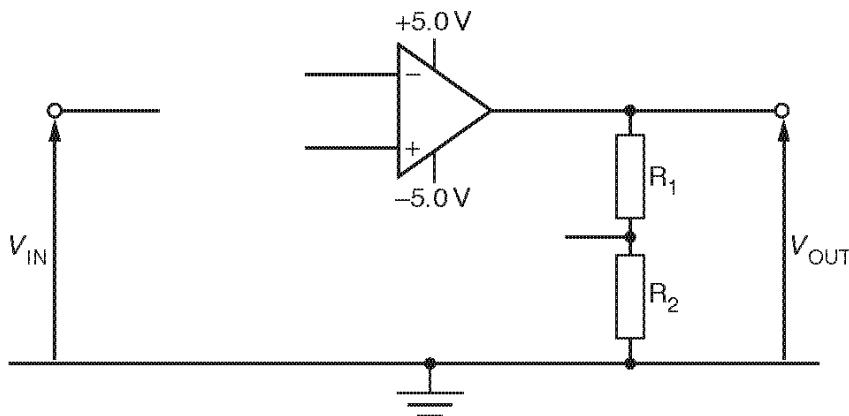
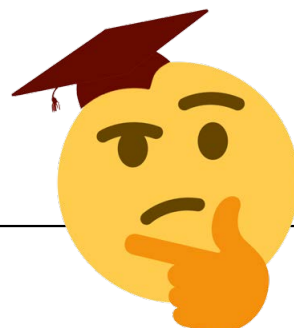


Fig. 7.1

On Fig. 7.1, draw lines to show the connections between the components to complete the circuit. [2]



(c) The completed amplifier of Fig. 7.1 has a voltage gain of 10.

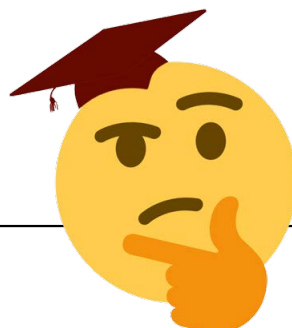
State the output voltage V_{OUT} for an input voltage V_{IN} of

(i) -0.36 V ,

$V_{\text{OUT}} = \dots\dots\dots \text{V} [1]$

(ii) 0.56 V .

$V_{\text{OUT}} = \dots\dots\dots \text{V} [1]$



8 - (9702/42_Winter_2018_Q7) - Electronics

A circuit incorporating an ideal operational amplifier (op-amp) is shown in Fig. 7.1.

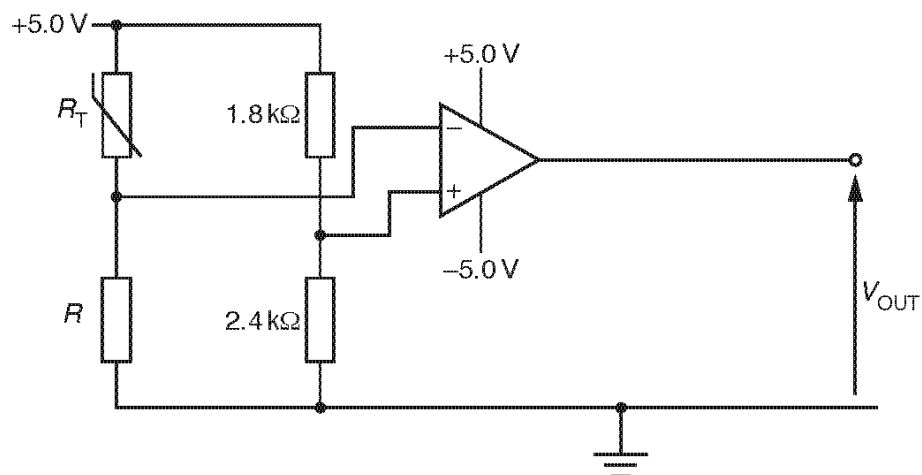


Fig. 7.1

The variation with temperature θ of the resistance R_T of the thermistor is shown in Fig. 7.2.

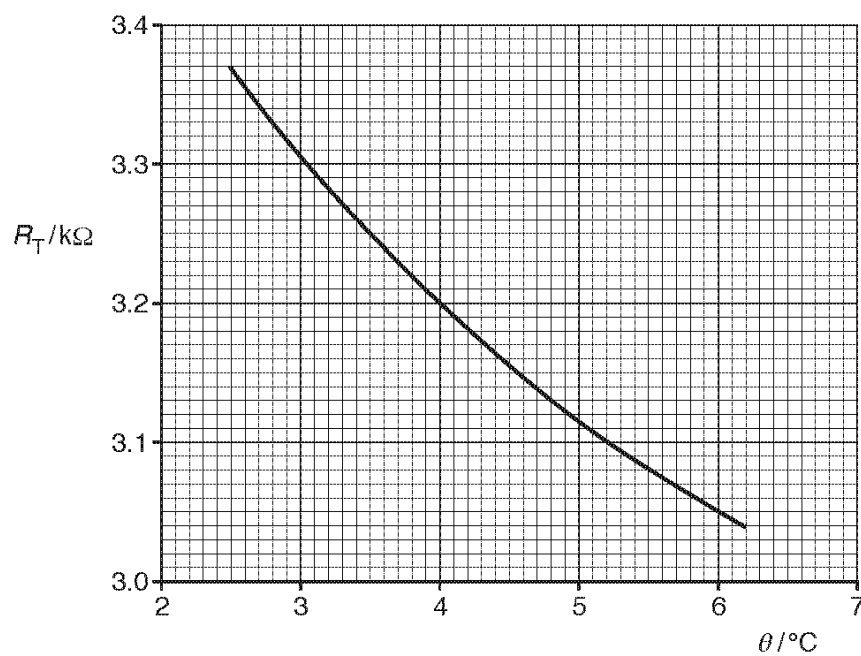
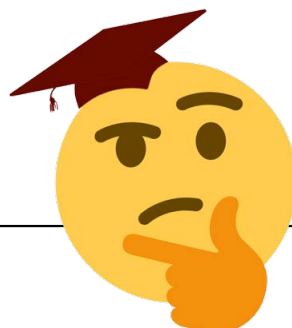


Fig. 7.2



- (a) The output potential V_{OUT} of the op-amp circuit changes sign when the temperature of the thermistor is 4.0°C .
Calculate the resistance R .

$R = \dots\dots\dots \text{ k}\Omega$ [2]

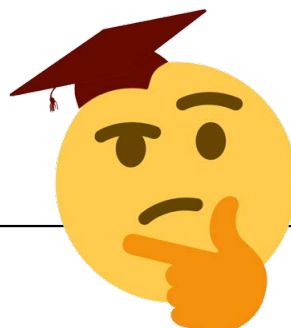
- (b) State and explain whether the output potential V_{OUT} is $+5.0\text{ V}$ or -5.0 V for a thermistor temperature of 2.5°C .

.....
.....
.....
.....[3]

- (c) The output of the op-amp is to be displayed using two light-emitting diodes (LEDs) labelled G and B.

When the temperature of the thermistor is below 4.0°C , only the LED labelled G emits light.
The LED labelled B emits light only when the temperature of the thermistor is above 4.0°C .

On Fig. 7.1, draw and label the symbols for the two LEDs. [3]



9 - (9702/42_Summer_2019_Q5) - Communication, Electronics

(a) For a signal transmitted along an optic fibre, state what is meant by:

(i) *attenuation*

.....
 [1]

(ii) *noise*.

.....

 [2]

(b) The initial section of the transmission line for a signal from a telephone exchange is illustrated in Fig. 5.1.

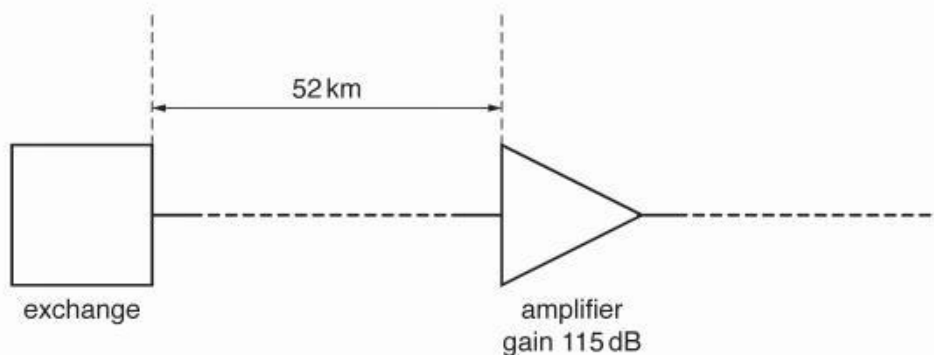


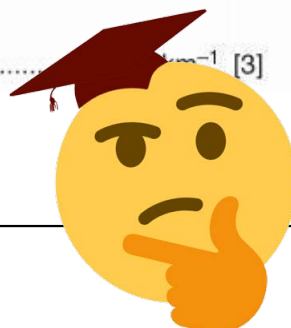
Fig. 5.1

At the exchange, the input signal to the transmission line has a power of $2.5 \times 10^{-3} \text{ W}$.

After the signal has travelled a distance of 52 km along the transmission line, the power of the signal is $7.8 \times 10^{-16} \text{ W}$. The signal is then amplified.

(i) Calculate the attenuation per unit length, in dB km^{-1} , in the transmission line.

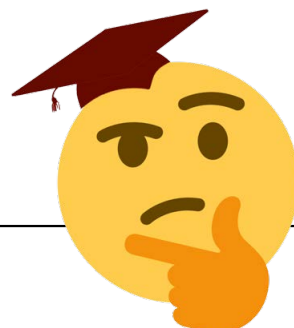
attenuation per unit length = dB km^{-1} [3]



- (ii) The gain of the amplifier is 115 dB.

Calculate the power of the signal at the output of the amplifier.

power = W [2]



10 - (9702/41_Summer_2019_Q7) - Electronics

The circuit for an inverting amplifier incorporating an ideal operational amplifier (op-amp) is shown in Fig. 7.1.

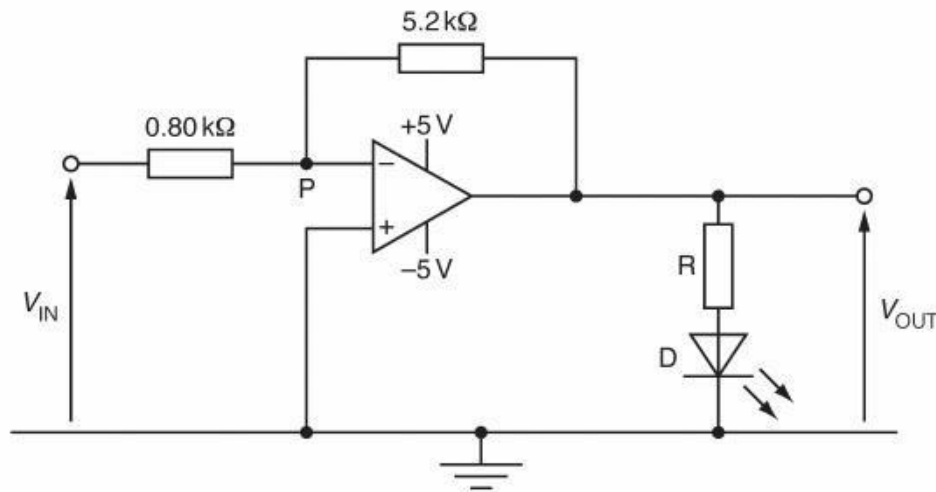


Fig. 7.1

(a) For the circuit of Fig. 7.1:

(i) explain why point P is known as a *virtual earth*

.....

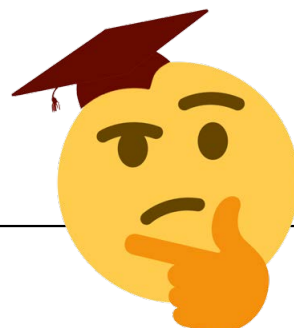
.....

.....

..... [3]

(ii) calculate the gain of the amplifier.

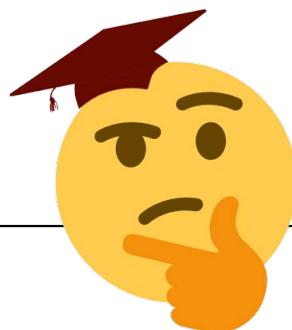
gain = [2]



(b) When the op-amp is saturated, the potential difference across the LED is 2.3 V.

Calculate the minimum resistance of resistor R so that the current in the LED is limited to 30 mA.

resistance = Ω [3]



11 - (9702/42_Summer_2019_Q9) - Electronics

Part of a circuit incorporating an operational amplifier (op-amp) is shown in Fig. 9.1.

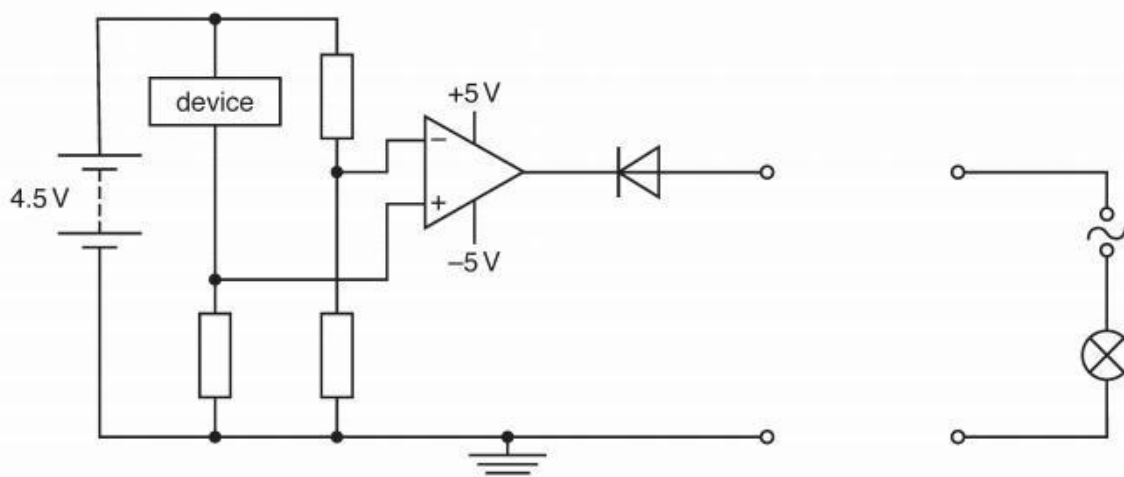


Fig. 9.1

- (a) A relay is connected to the output of the op-amp circuit so that a lamp may be switched on or off.

(i) Complete Fig. 9.1 to show the relay connected into the circuit. [2]

(ii) State and explain whether the output of the op-amp is positive or negative for the lamp to be switched on.

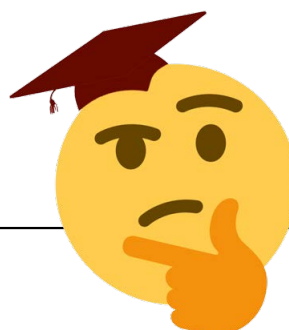
.....

 [2]

- (b) State the device in Fig. 9.1 that could be used so that the circuit indicates a change in:

(i) the bending of a rod
 [1]

(ii) the level of daylight to switch on a street light.
 [1]



12 - (9702/41_Winter_2019_Q7) - Electronics

- (a) An ideal operational amplifier (op-amp) has infinite bandwidth and zero output impedance.

State what is meant by:

- (i) *infinite bandwidth*

.....
..... [1]

- (ii) *zero output impedance.*

.....
..... [1]

- (b) The circuit for a non-inverting amplifier incorporating an ideal op-amp is shown in Fig. 7.1.

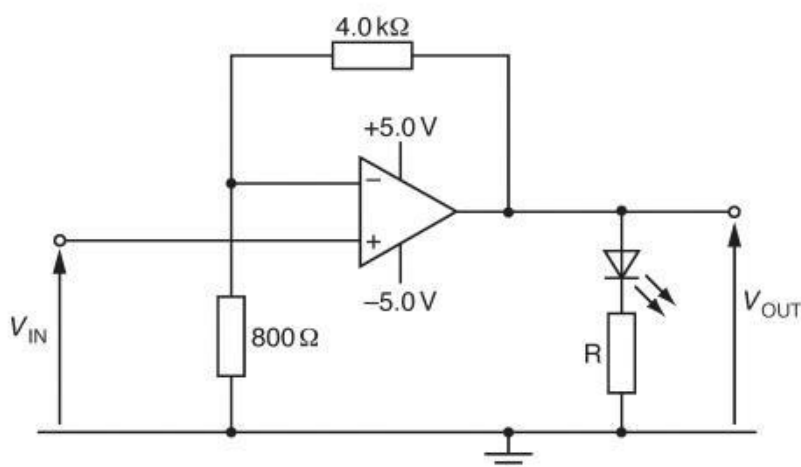


Fig. 7.1

The light-emitting diode (LED) emits light when the potential difference across it is at least 2.0 V.

The current in the LED must not be greater than 20 mA.

- (i) Calculate the gain of the amplifier circuit.

gain = [2]



- (ii) Determine the value of V_{IN} for which the value of V_{OUT} is +2.0 V.

$V_{IN} = \dots\dots\dots$ V [1]

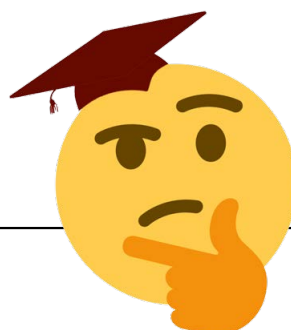
- (iii) State the maximum value of the output potential V_{OUT} .

maximum potential = $\dots\dots\dots$ V [1]

- (iv) When the op-amp is saturated, the potential difference across the LED is 2.2 V.

Calculate the minimum resistance of resistor R so that the current in the LED is limited to 20 mA.

resistance = $\dots\dots\dots$ Ω [2]



13 - (9702/42_Winter_2019_Q10) - *Electronics, Quantum Physics*

- (a) The upper electron energy bands in an intrinsic semiconductor material are illustrated in Fig. 10.1.

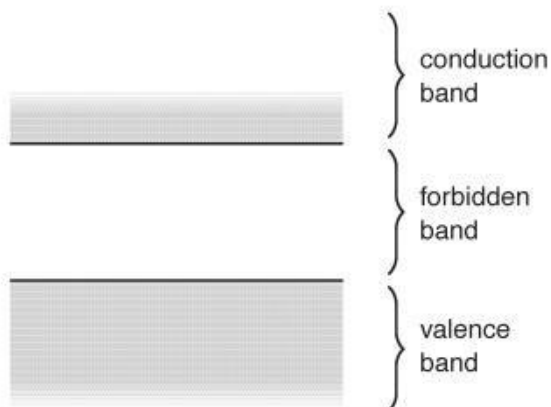


Fig. 10.1

Use band theory to explain why the resistance of an intrinsic semiconductor material decreases as its temperature increases.

.....

.....

.....

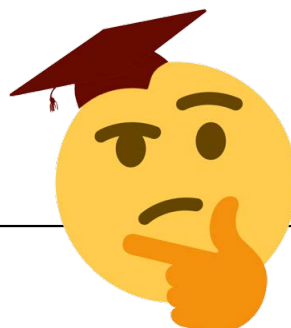
.....

.....

.....

.....

..... [4]



(b) A comparator circuit incorporating an ideal operational amplifier (op-amp) is shown in Fig. 10.2.

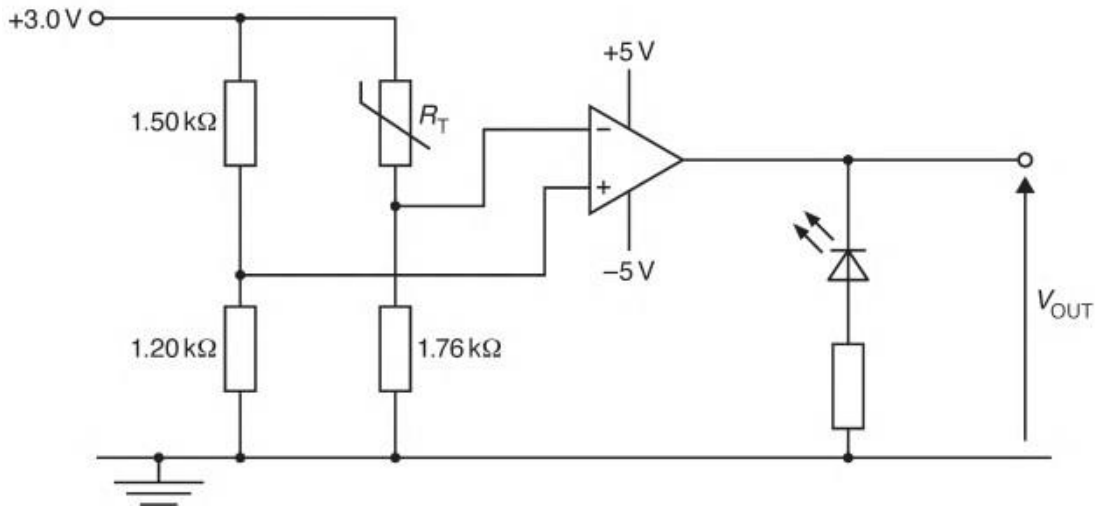


Fig. 10.2

The variation with temperature θ of the resistance R_T of the thermistor is shown in Fig. 10.3.

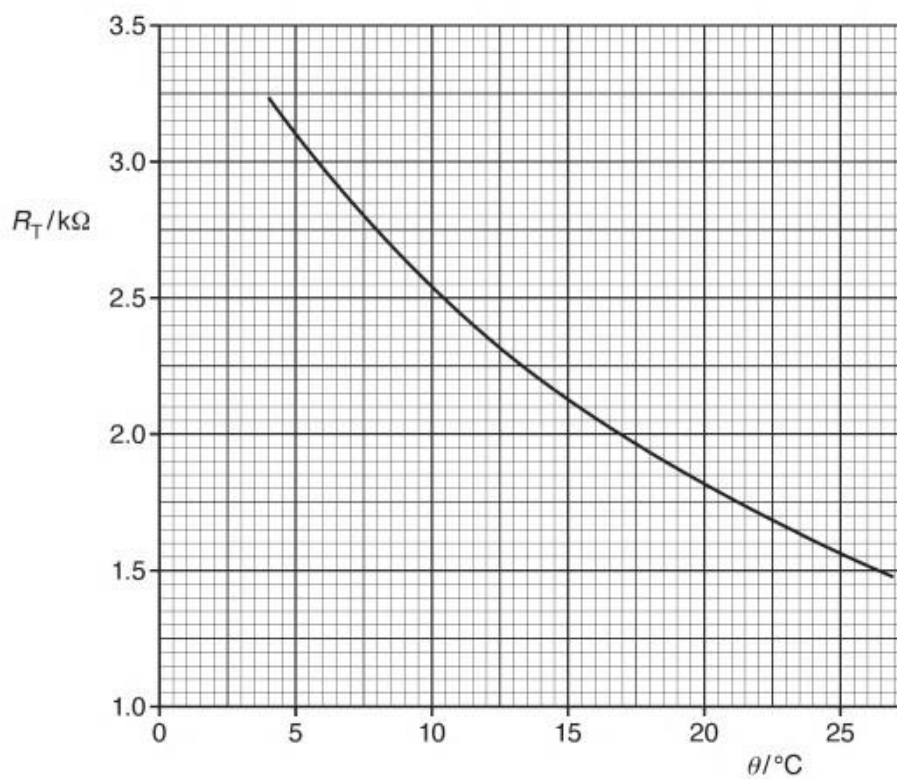


Fig. 10.3

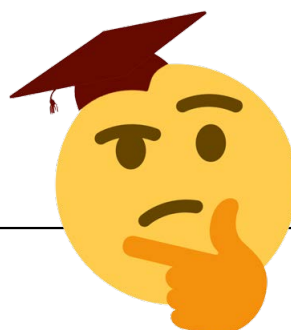


- (i) Determine the temperature at which the light-emitting diode (LED) in Fig. 10.2 switches on or off.

temperature = °C [4]

- (ii) State and explain whether the thermistor is above or below the temperature calculated in (i) for the LED to emit light.

.....
.....
.....
..... [3]



14 - (9702/41_Summer_2020_Q7) - Electronics

The output of a microphone is processed using a non-inverting amplifier. The amplifier incorporates an operational amplifier (op-amp).

- (a) State, by reference to the input and output signals, the function of a non-inverting amplifier.

.....
.....
..... [2]

- (b) The circuit for the microphone and amplifier is shown in Fig. 7.1.

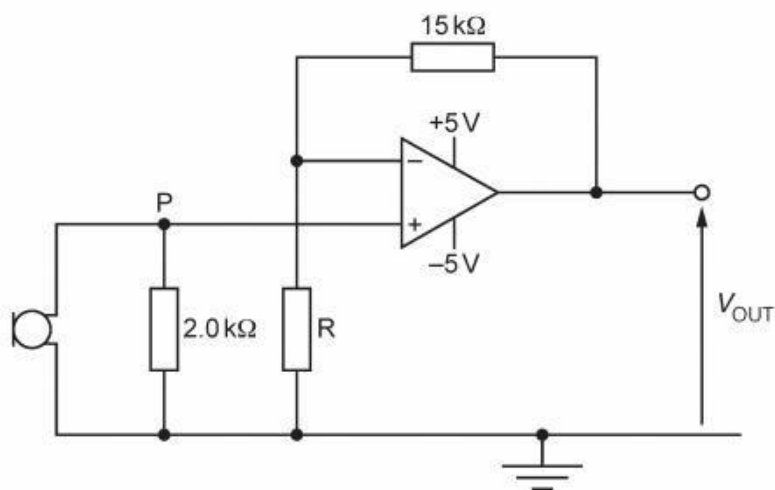


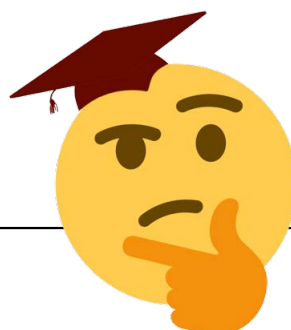
Fig. 7.1

The output potential difference V_{OUT} is 2.6 V when the potential at point P is 84 mV .

Determine:

- (i) the gain of the amplifier circuit

gain = [1]



- (ii) the resistance of resistor R.

resistance = Ω [2]

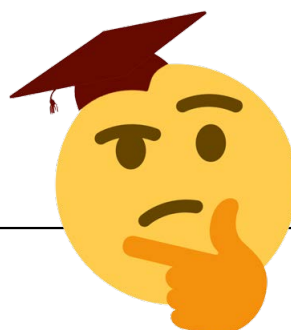
- (c) For the circuit of Fig. 7.1:

- (i) suggest a suitable device to connect to the output such that the shape of the waveform of the sound received by the microphone may be examined

..... [1]

- (ii) state and explain the effect on the output potential difference V_{OUT} of increasing the resistance of resistor R.

.....
.....
..... [2]



15 - (9702/42_Summer_2020_Q8) - Electronics

- (a) An ideal operational amplifier (op-amp) is connected to a load resistor. The op-amp is assumed to have infinite bandwidth and zero output resistance.

State:

- (i) what is meant by *infinite bandwidth*

.....
 [1]

- (ii) the effect, if any, on the output voltage of increasing the load resistance.

.....
 [1]

- (b) A student designs the circuit shown in Fig. 8.1 in order to indicate changes in temperature of the thermistor T.

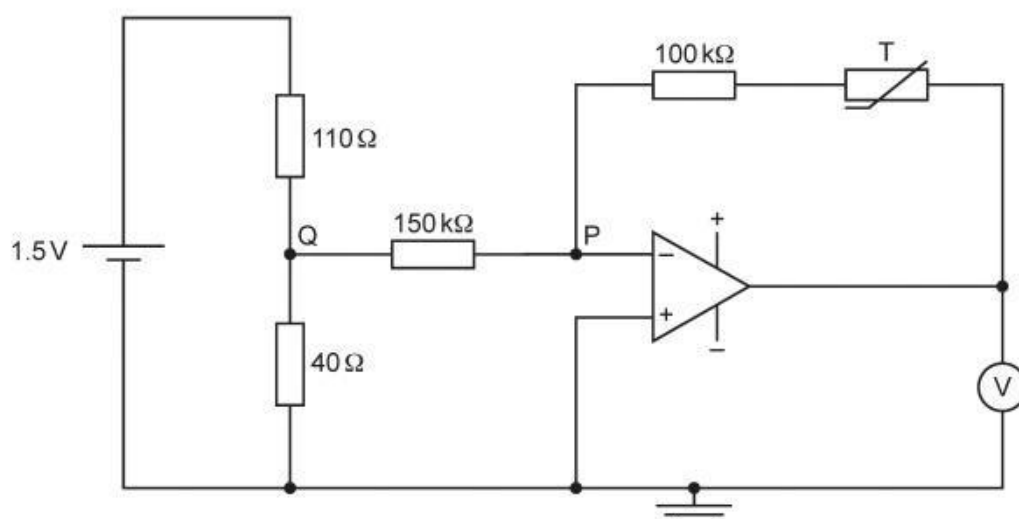
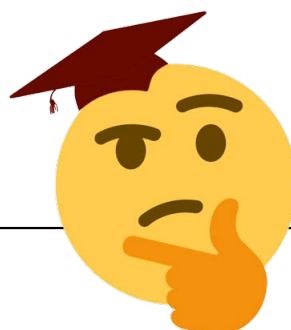


Fig. 8.1

- (i) Explain why point P is known as a *virtual earth*.

.....

 [3]



- (ii) Calculate the potential at point Q.

potential = V [2]

- (iii) At a temperature of 13°C , the resistance of the thermistor T is $230\text{ k}\Omega$.

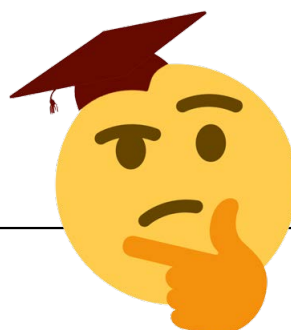
Show that the potential difference measured with the voltmeter is 0.88 V .

[2]

- (c) The resistance of the thermistor T in (b) decreases as its temperature rises.

Explain the effect of this change in temperature on the potential difference measured with the voltmeter.

.....
.....
..... [2]



16 - (9702/41_Winter_2020_Q7) - Electronics

An ideal operational amplifier (op-amp) is to be used in a comparator circuit. Part of the comparator circuit is shown in Fig. 7.1.

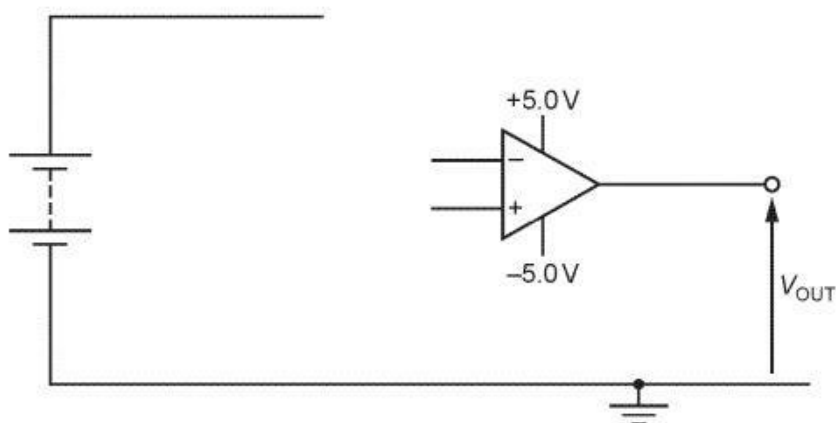


Fig. 7.1

Three resistors, each of resistance 1000Ω , and a negative temperature coefficient thermistor are available to complete the circuit.

The circuit is to be designed so that, at low temperatures, the output V_{OUT} is -5.0V and at higher temperatures, the output V_{OUT} is to be $+5.0\text{V}$.

- (a) On Fig. 7.1, draw the input circuit to the inverting and non-inverting inputs of the op-amp. [4]
- (b) State a suitable value for the thermistor resistance when the thermistor is at:

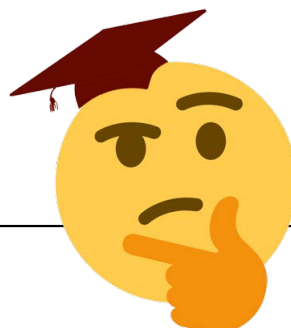
- (i) low temperature where V_{OUT} is -5.0V

..... [1]

- (ii) a higher temperature where V_{OUT} is $+5.0\text{V}$.

..... [1]

[Total: 6]



17 - (9702/42_Winter_2020_Q8) - Electronics

- (a) An ideal operational amplifier (op-amp) is said to have infinite bandwidth and infinite slew rate.

State what is meant by:

- (i) *infinite bandwidth*

.....
..... [1]

- (ii) *infinite slew rate.*

.....
..... [1]

- (b) An amplifier circuit incorporating an op-amp is shown in Fig. 8.1.

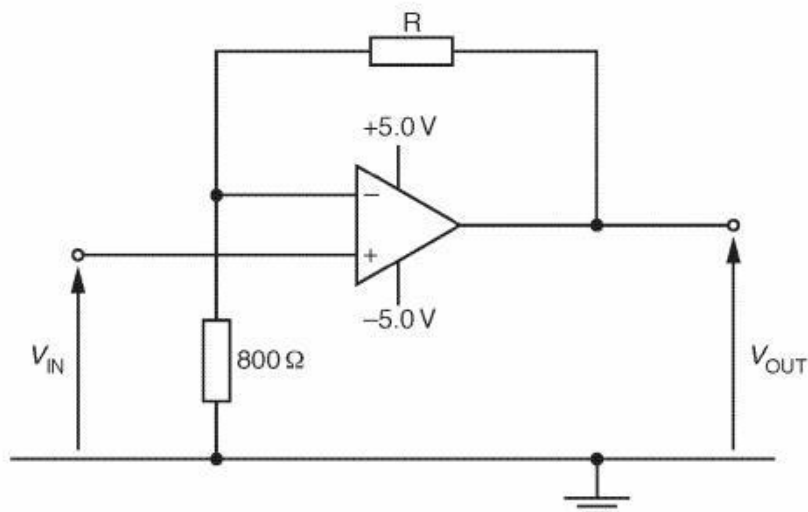


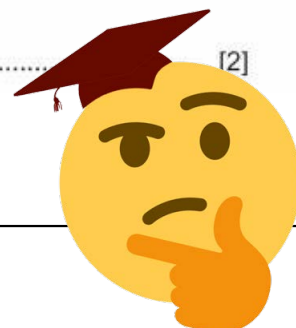
Fig. 8.1

The resistance of resistor R is to be fixed so that, for an input potential difference V_{IN} of 0.40 V , the amplifier is on the point of saturation.

Determine:

- (i) the gain of the amplifier circuit

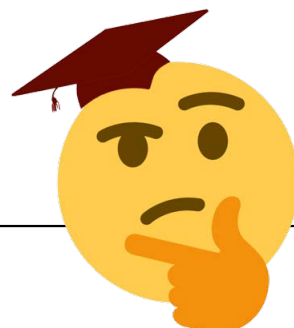
gain = [2]



(ii) the resistance of resistor R.

resistance = Ω [2]

[Total: 6]



18 - (9702/42_Summer_2021_Q7) - Electronics

- (a) Two properties of an ideal operational amplifier (op-amp) are infinite input impedance and infinite bandwidth.

State what is meant by:

- (i) *infinite input impedance*

.....
..... [1]

- (ii) *infinite bandwidth.*

.....
..... [1]

- (b) A student uses a negative temperature coefficient thermistor in the circuit of Fig. 7.1 to indicate changes in temperature.

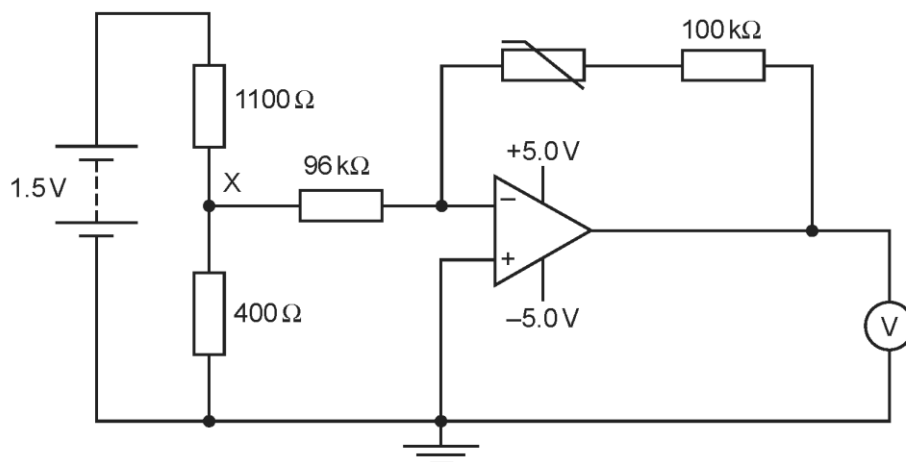
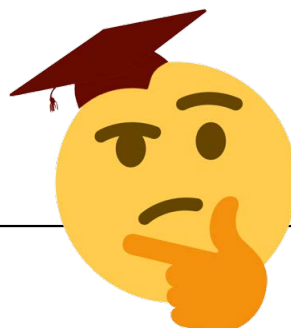


Fig. 7.1

- (i) Show that the potential at point X is 0.40 V.

[1]



- (ii) The thermistor has a resistance of $360\text{ k}\Omega$ at a particular temperature.

For this temperature of the thermistor, calculate the magnitude of the reading on the voltmeter.

voltmeter reading = V [3]

- (iii) The temperature of the thermistor increases.

State and explain the effect of this change on the magnitude of the reading on the voltmeter.

.....
.....
..... [2]

- (iv) Explain why the amplifier circuit will no longer indicate temperature changes when the magnitude of the gain of the circuit is greater than 12.5.

.....
..... [1]



19 - (9702/41_Winter_2021_Q7) - Electronics

(a) State **two** properties of an ideal operational amplifier (op-amp).

1.
2.

[2]

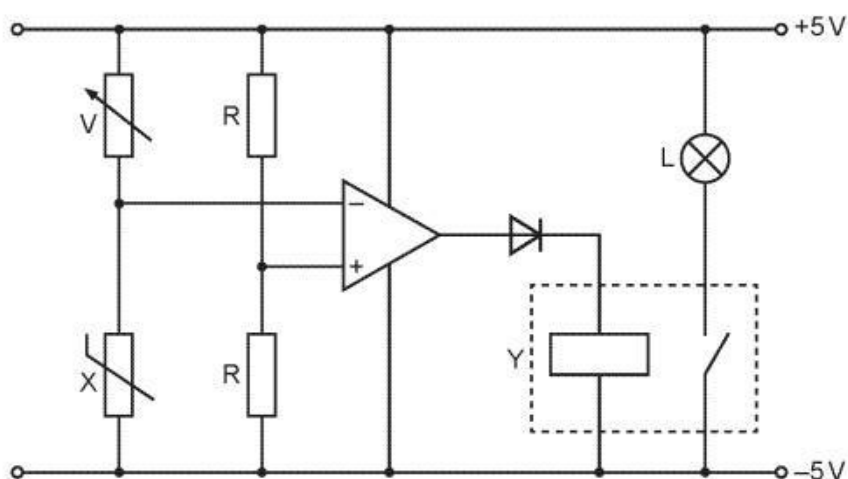
(b) Fig. 7.1 shows a circuit that includes an ideal op-amp and two identical resistors R .

Fig. 7.1

State the names of components X and Y.

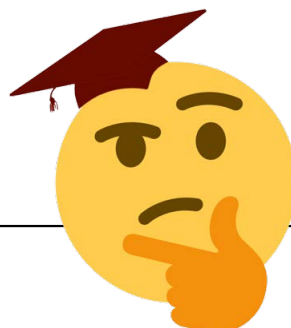
X: Y: [1]

(c) (i) Explain why the op-amp in Fig. 7.1 has only two possible output states.

-
-
-
- [2]

(ii) State the name of the type of op-amp circuit in which the op-amp behaves as in (c)(i).

..... [1]

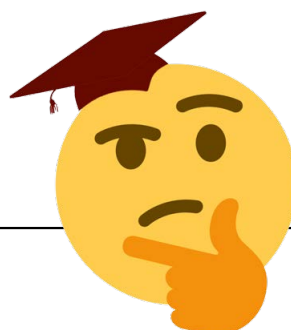


(iii) Describe the environmental condition under which the lamp L in Fig. 7.1 will light.

.....
.....
..... [2]

(iv) Suggest the purpose of the variable resistor V in the circuit.

.....
..... [1]



20 – (9702/42_Winter_2021_Q7) – Electronics

- (a) An operational amplifier (op-amp) has two input terminals and one output terminal.

State what is meant by the *gain* of an op-amp.

.....
.....
..... [2]

- (b) State **two** effects of negative feedback on the gain of an amplifier circuit that uses an op-amp.

1.
.....
2.
..... [2]

- (c) Fig. 7.1 shows an op-amp circuit that uses negative feedback.

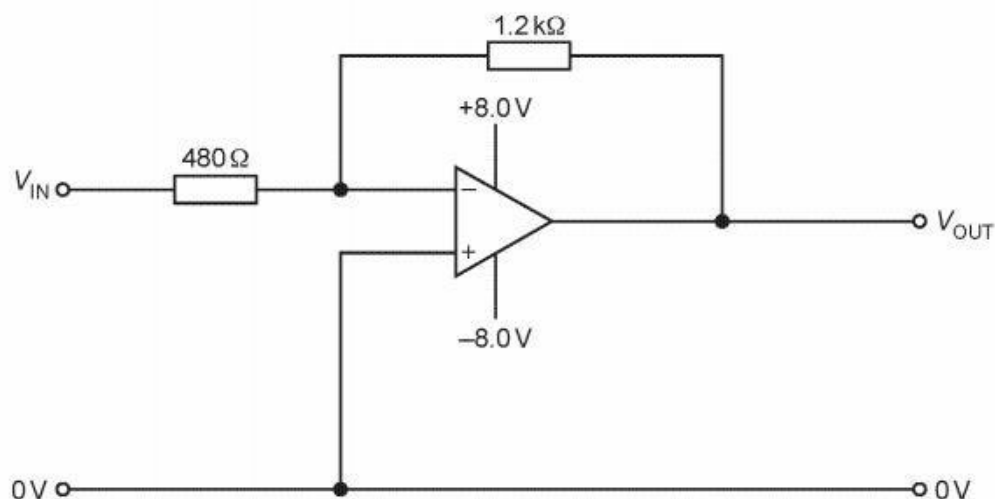
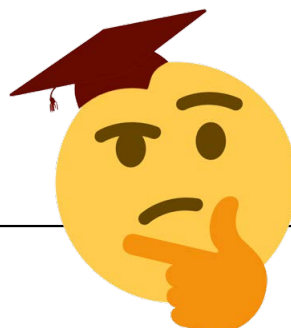


Fig. 7.1

- (i) State the name of the type of circuit shown in Fig. 7.1.

..... [1]

- (ii) On Fig. 7.1, label with the letter X a point in the circuit that is considered to be a virtual earth. [1]



(iii) Calculate the gain of the circuit in Fig. 7.1.

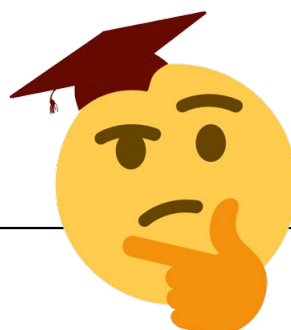
gain = [2]

(iv) Determine the value of V_{IN} when V_{OUT} is +6.5 V.

V_{IN} = V [1]

(v) Determine the value of V_{OUT} when V_{IN} is –5.4 V.

V_{OUT} = V [1]



21 - (9702/41_Summer_2023_Q7) - Electronics

- (a) State what is meant by the de Broglie wavelength.

.....
..... [1]

- (b) Fig. 7.1 shows a glass tube in which electrons are accelerated through a high p.d. to form a beam that is incident on a thin graphite crystal.

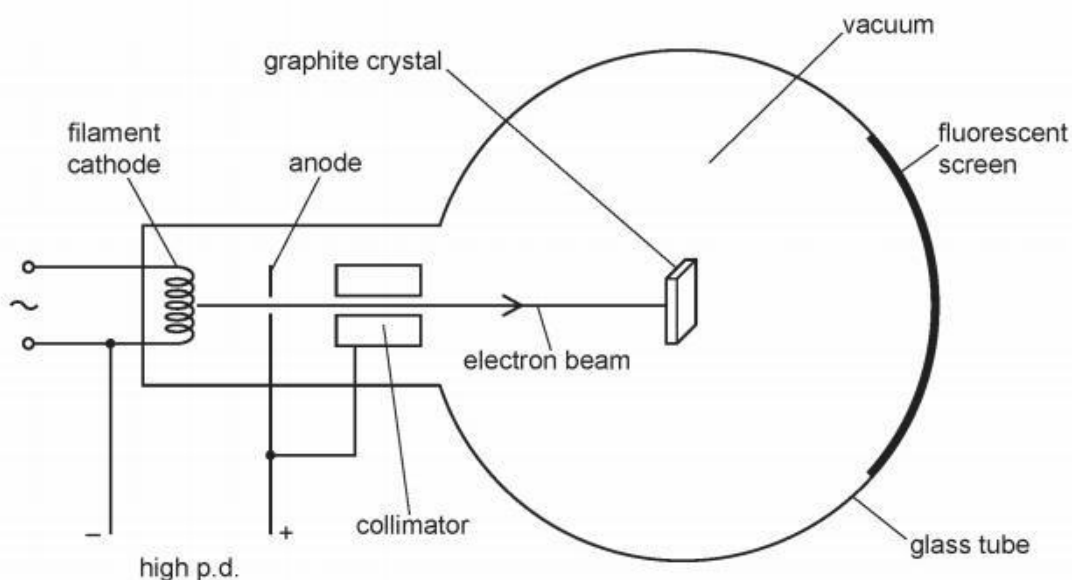


Fig. 7.1 (not to scale)

After passing through the graphite crystal, the electrons reach the fluorescent screen. The screen glows where the electrons strike it.

Fig. 7.2 shows the fluorescent screen viewed end-on, from the right-hand side of Fig. 7.1.

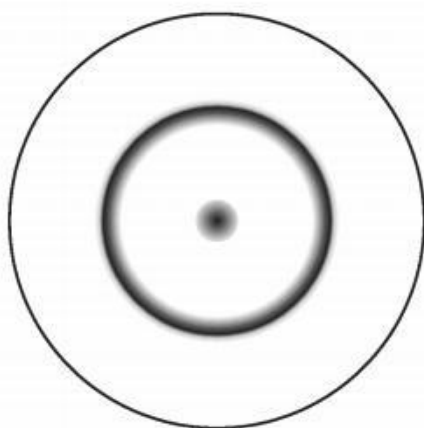
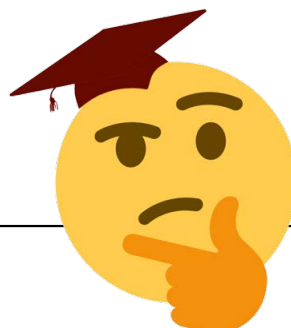


Fig. 7.2



- (i) State the name of the phenomenon demonstrated by the pattern shown in Fig. 7.2.

..... [1]

- (ii) Explain what can be concluded from the pattern in Fig. 7.2 about the nature of electrons.

.....

.....

..... [2]

- (c) The electrons in (b) are now accelerated through a greater potential difference between the cathode and the anode.

- (i) On Fig. 7.3, sketch the pattern that is now seen on the fluorescent screen in Fig. 7.1.

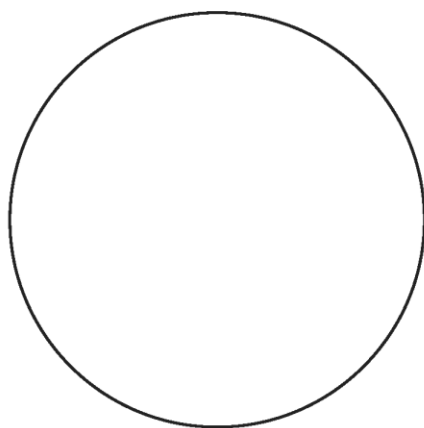


Fig. 7.3

[2]

- (ii) Explain, with reference to de Broglie wavelength, the change in the pattern on the fluorescent screen.

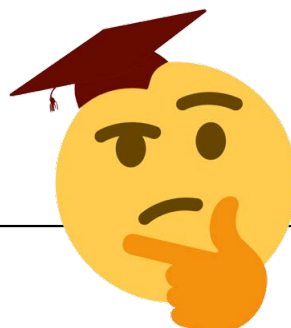
.....

.....

.....

.....

..... [3]



1 - (9702/41_Summer_2017_Q7) - *Magnetic Fields*

An electron having charge $-q$ and mass m is accelerated from rest in a vacuum through a potential difference V .

The electron then enters a region of uniform magnetic field of magnetic flux density B , as shown in Fig. 7.1.

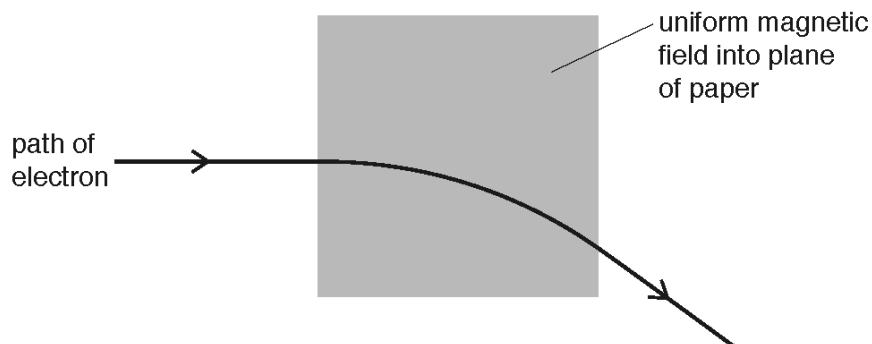


Fig. 7.1

The direction of the uniform magnetic field is into the plane of the paper.

The velocity of the electron as it enters the magnetic field is normal to the magnetic field.

The radius of the circular path of the electron in the magnetic field is r .

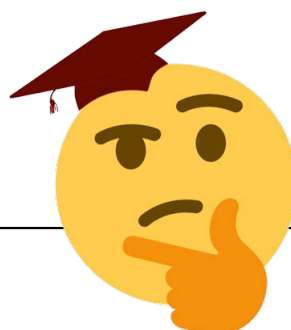
(a) Explain why the path of the electron in the magnetic field is the arc of a circle.

.....
.....
.....
.....[3]

(b) Show that the magnitude p of the momentum of the electron as it enters the magnetic field is given by

$$p = \sqrt{(2mqV)}.$$

[2]



- (c) The potential difference V is 120 V. The radius r of the circular arc is 7.4 cm.

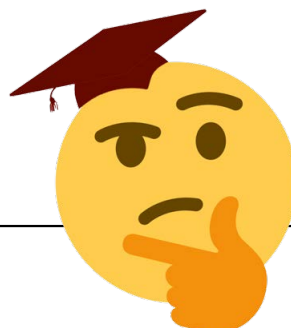
Determine the magnitude B of the magnetic flux density.

$$B = \dots\dots\dots \text{ T [3]}$$

- (d) The potential difference V in (c) is increased. The magnetic flux density B remains unchanged.

By reference to the momentum of the electron, explain the effect of this increase on the radius r of the path of the electron in the magnetic field.

.....
.....
..... [2]



Explain the main principles behind the use of nuclear magnetic resonance imaging (NMRI) to obtain information about internal body structures.

[8]



3 - (9702/42_Summer_2017_Q9) - *Magnetic Fields*

A Hall probe is placed near to one end of a current-carrying solenoid, as shown in Fig. 9.1.

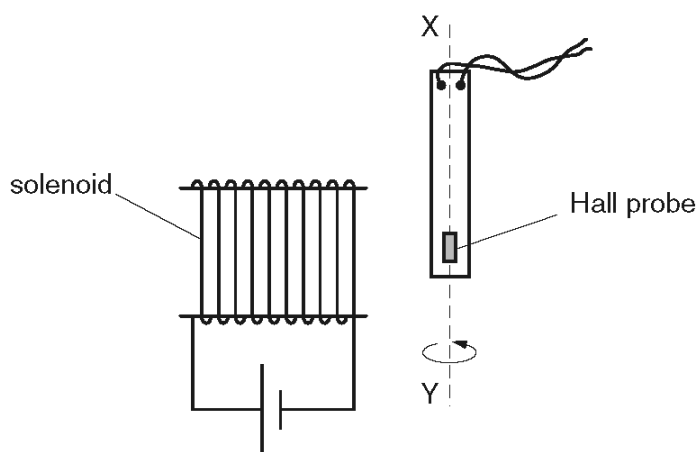


Fig. 9.1

The probe is rotated about the axis XY and is then held in a position so that the Hall voltage is maximum.

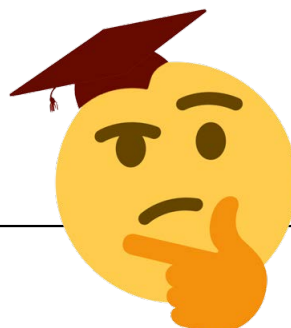
(a) Explain why

- (i) a Hall probe is made from a *thin slice* of material,

.....
.....
.....[2]

- (ii) in order for consistent measurements of magnetic flux density to be made, the current in the probe must be constant.

.....
.....[1]



- (b) The probe is now rotated through an angle of 360° about the axis XY.
At angle $\theta = 0$, the Hall voltage V_H has maximum value V_{MAX} .

On Fig. 9.2, sketch the variation with angle θ of the Hall voltage V_H for one complete revolution of the probe about axis XY.

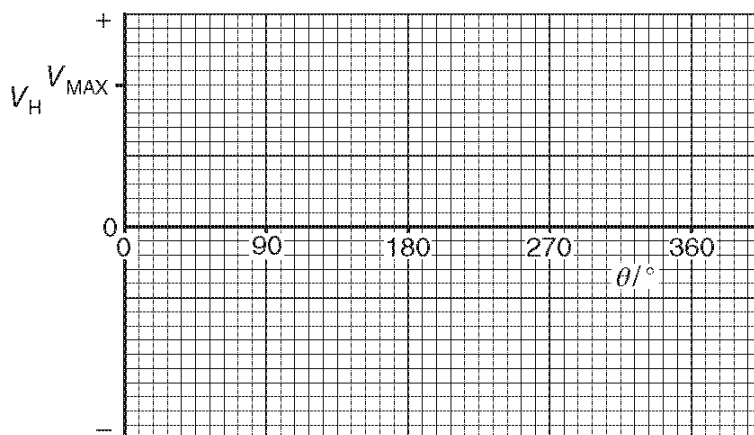
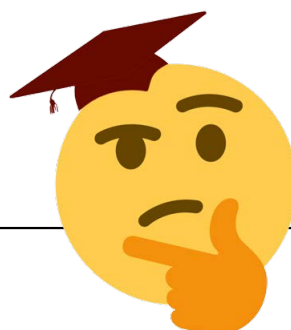


Fig. 9.2

[3]



4 - (9702/41_Winter_2017_Q8) - *Magnetic Fields, Electromagnetic Induction*

A thin slice of conducting material is placed normal to a uniform magnetic field of flux density B , as shown in Fig. 8.1.

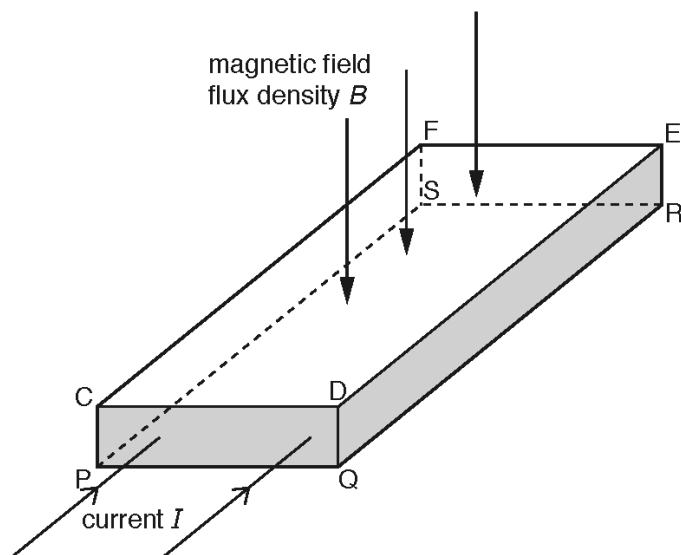


Fig. 8.1

The magnetic field is normal to face CDEF and to face PQRS.

A current I passes through the slice and is normal to the faces CDQP and FERS.

A potential difference, the Hall voltage V_H , is developed across the slice.

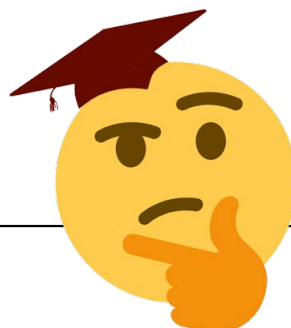
(a) State the faces between which the Hall voltage V_H is developed.

..... and [1]

(b) The current I is produced by charge carriers, each of charge $+q$ moving at speed v in the direction of the current. The number density of the charge carriers is n .

(i) Derive an expression relating the Hall voltage V_H to v , B and d , where d is one of the dimensions of the slice.

[3]



- (ii) Use your answer in (b)(i) and an expression for the current I in the slice to derive the expression

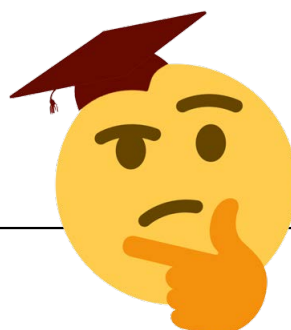
$$V_H = \frac{BI}{ntq}.$$

Explain your working.

[2]

- (c) Suggest why the Hall voltage is difficult to detect in a thin slice of copper.

.....
.....
..... [2]



5 - (9702/42_Winter_2017_Q9) - *Magnetic Fields*

(a) State what is meant by a *field of force*.

.....

.....

.....[2]

(b) Explain the use of a uniform magnetic field and a uniform electric field for the selection of the velocity of charged particles. You may draw a diagram if you wish.

.....

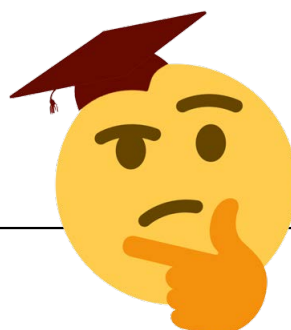
.....

.....

.....

.....

.....[4]



- (c) A beam of charged particles enters a region of uniform magnetic and electric fields, as illustrated in Fig. 9.1.



Fig. 9.1

The direction of the magnetic field is into the plane of the paper. The velocity of the charged particles is normal to the magnetic field as the particles enter the field.

A particle in the beam has mass m , charge $+q$ and velocity v . The particle passes undeviated through the region of the two fields.

On Fig. 9.1, sketch the path of a particle that has

- (i) mass m , charge $+2q$ and velocity v (label this path Q), [1]
- (ii) mass m , charge $+q$ and velocity slightly larger than v (label this path V). [2]



6 - (9702/42_Summer_2018_Q8) - *Magnetic Fields*

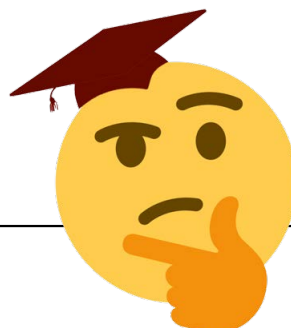
- (a) Explain how a uniform magnetic field and a uniform electric field may be used as a velocity selector for charged particles.

.....

.....

.....

.....[3]



- (b) Particles having mass m and charge $+1.6 \times 10^{-19}\text{C}$ pass through a velocity selector. They then enter a region of uniform magnetic field of magnetic flux density 94 mT with speed $3.4 \times 10^4\text{ ms}^{-1}$, as shown in Fig. 8.1.

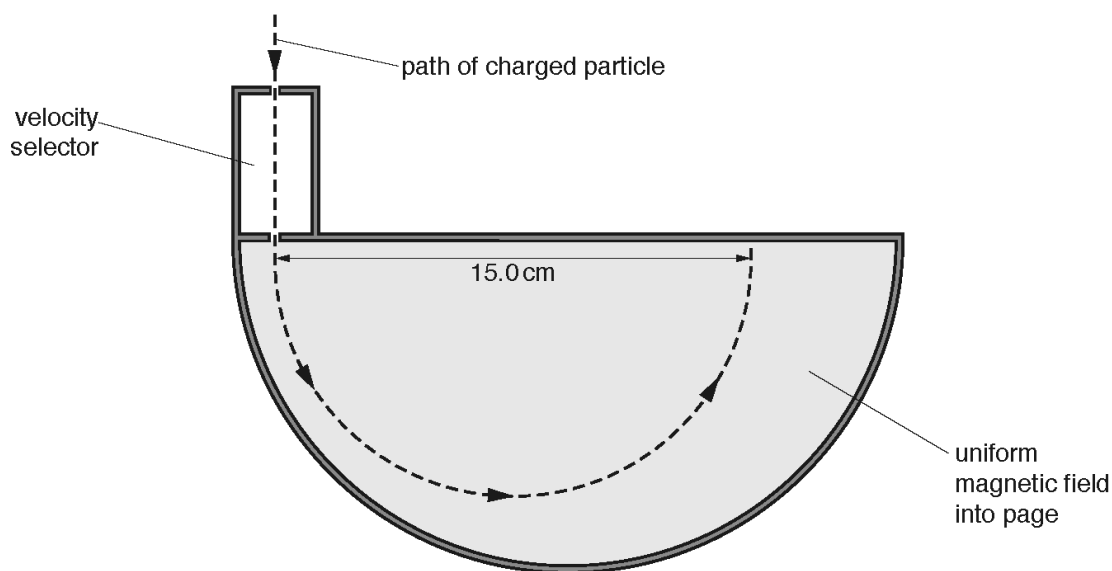


Fig. 8.1

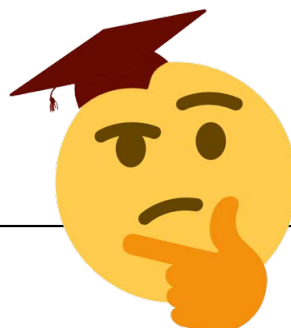
The direction of the uniform magnetic field is into the page and normal to the direction in which the particles are moving.

The particles are moving in a vacuum in a circular arc of diameter 15.0 cm .

Show that the mass of one of the particles is 20 u .

[4]

- (c) On Fig. 8.1, sketch the path in the uniform magnetic field of a particle of mass 22 u having the same charge and speed as the particle in (b). [2]



7 - (9702/41_Summer_2018_Q9) - *Magnetic Fields, Alternating Currents*

A rigid copper wire is held horizontally between the pole pieces of two magnets, as shown in Fig. 9.1.

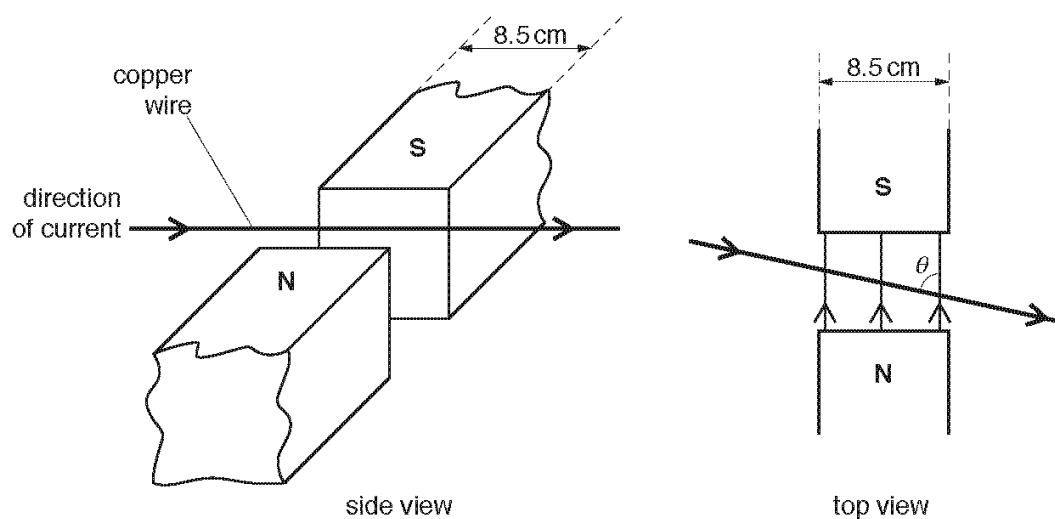


Fig. 9.1

The width of each pole piece is 8.5 cm.

The uniform magnetic flux density B in the region between the poles of the magnets is 3.7 mT and is zero outside this region.

The angle between the wire and the direction of the magnetic field is θ .

The current in the wire is in the direction shown on Fig. 9.1.

- (a) By reference to the **side** view of Fig. 9.1, state and explain the direction of the force on the **magnets**.

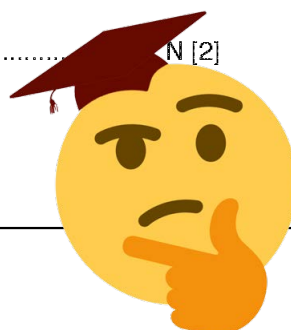
.....

 [2]

- (b) The constant current in the wire is 5.1 A.

- (i) For angle θ equal to 90° , calculate the force on the wire.

force = N [2]



- (ii) The angle θ is changed to 60° .

The length of wire in the magnetic field is $\left(\frac{8.5}{\sin 60^\circ}\right)$ cm.

Calculate the force on the wire.

force = N [1]

- (c) The constant current in the wire is now changed to an alternating current of frequency 20 Hz and root-mean-square (r.m.s.) value 5.1 A.

The angle between the wire and the direction of the magnetic field is 90° .

On Fig. 9.2, sketch a graph to show the variation with time t of the force F on the wire for two cycles of the alternating current.

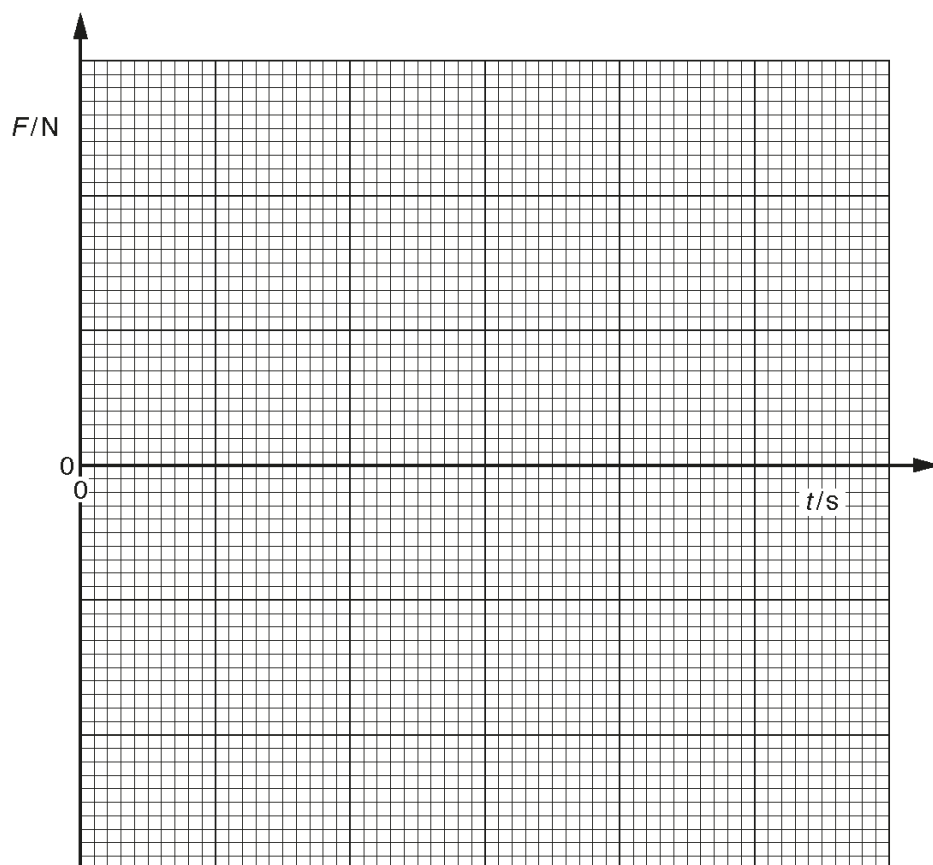
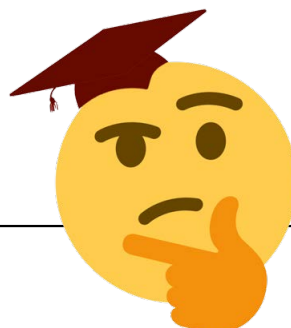


Fig. 9.2

[3]



8 - (9702/42_Summer_2018_Q11) - *Magnetic Fields*

(a) Describe the basic principles of CT scanning (computed tomography).

[5]

(b) By reference to your answer in (a), suggest why

(i) CT scanning was not possible before fast computers with large memories were available,

[1]

(ii) the radiation dose for a CT scan is much larger than for an X-ray image of a leg bone.

..... [1]



9 - (9702/41_Winter_2018_Q8) - Magnetic Fields

(a) Explain what is meant by a *magnetic field*.

.....

.....

.....[2]

(b) A particle has mass m , charge $+q$ and speed v .

The particle enters a uniform magnetic field of flux density B such that, on entry, it is moving normal to the magnetic field, as shown in Fig. 8.1.

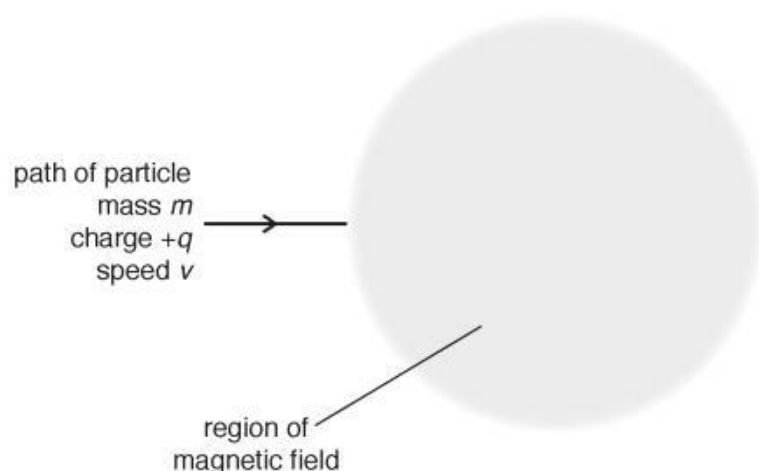


Fig. 8.1

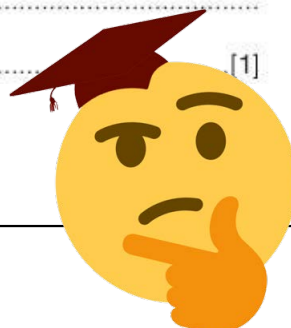
The direction of the magnetic field is perpendicular to, and into, the plane of the paper.

- (i) On Fig. 8.1, draw the path of the particle through, and beyond, the region of the magnetic field. [3]
- (ii) There is a force acting on the particle, causing it to accelerate.
Explain why the speed of the particle on leaving the magnetic field is v .

.....

.....

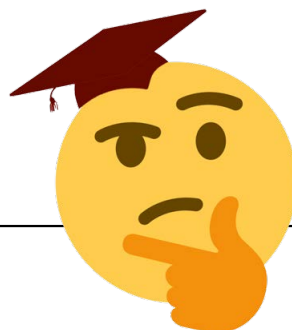
.....[1]



- (c) The particle in (b) loses an electron so that its charge becomes $+2q$. Its change in mass is negligible.

Determine, in terms of v , the initial speed of the particle such that its path through the magnetic field is unchanged. Explain your working.

speed = [3]



10 - (9702/42_Winter_2018_Q8) - Magnetic Fields

(a) Define *magnetic flux density*.

.....

.....

.....

.....[3]

(b) A stiff copper wire is balanced horizontally on a pivot, as shown in Fig. 8.1.

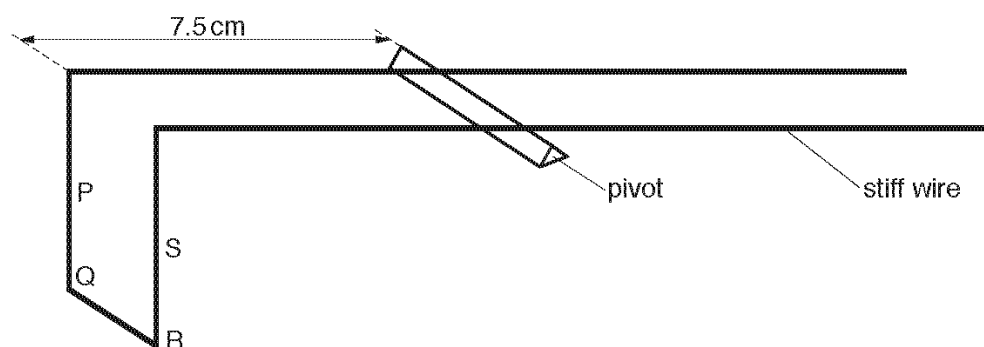


Fig. 8.1

Sections PQ, QR and RS of the wire are situated in a uniform magnetic field of flux density B produced between the poles of a permanent magnet. The perpendicular distance of PQRS from the pivot is 7.5 cm.

When a current of 2.7 A is passed through the wire, a small mass of 45 mg is placed a distance 8.8 cm from the pivot in order to restore the balance of the wire, as shown in Fig. 8.2.

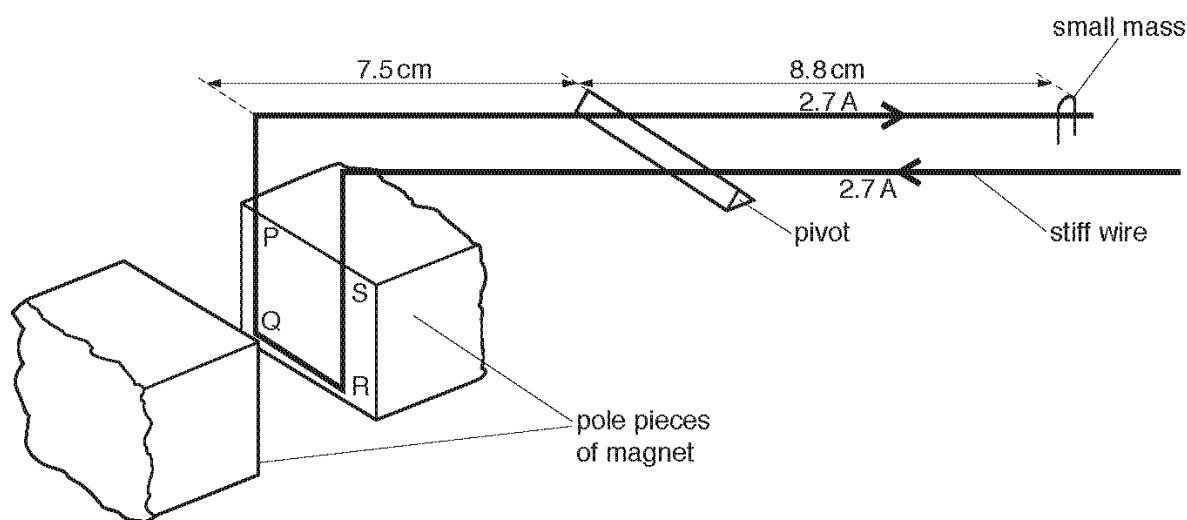
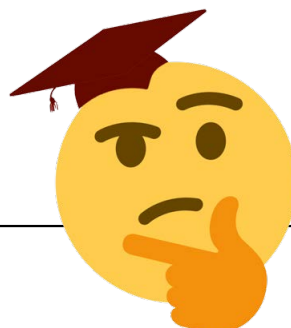


Fig. 8.2

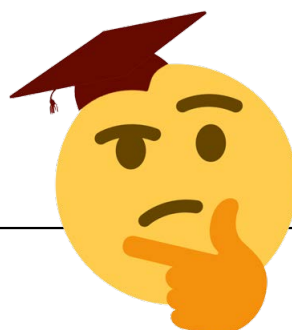


- (i) Explain why, when the current is switched on, the current in the sections PQ and RS of the wire does not affect the balance of the wire.

.....
.....
.....[2]

- (ii) The length of section QR of the wire is 1.2 cm.
Calculate the magnetic flux density B .

$B =$ T [3]



11 - (9702/41_Summer_2019_Q8) - *Magnetic Fields, Electromagnetic Induction*

A solenoid is connected in series with a battery and a switch, as illustrated in Fig. 8.1.

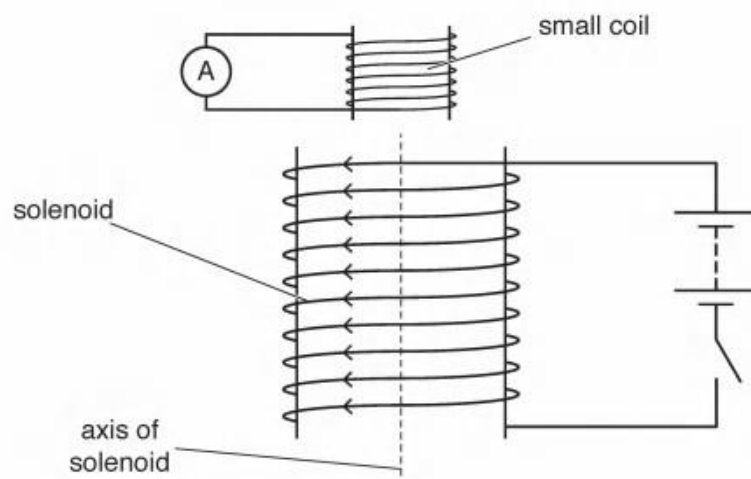


Fig. 8.1

A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid.

As the current in the solenoid is switched on, there is a changing magnetic field inside the solenoid.

(a) (i) State what is meant by a *magnetic field*.

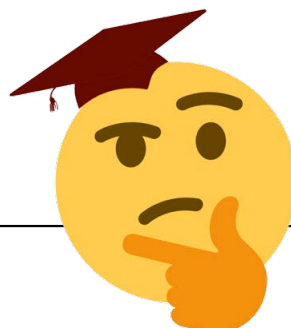
.....
..... [1]

(ii) On Fig. 8.1, draw an arrow on the axis of the solenoid to show the direction of the magnetic field inside the solenoid. Label this arrow P. [1]

(b) As the current in the solenoid is switched on, there is a current induced in the small coil. This induced current gives rise to a magnetic field in the small coil.

(i) State Lenz's law.

.....
.....
..... [2]



- (ii) Use Lenz's law to state and explain the direction of the magnetic field due to the induced current in the small coil. On Fig. 8.1, mark this direction with an arrow inside the small coil.

.....

.....

.....

..... [3]

- (c) The small coil has an area of cross-section $7.0 \times 10^{-4} \text{ m}^2$ and contains 75 turns of wire.

A constant current in the solenoid produces a uniform magnetic flux of flux density 1.4 mT throughout the small coil.

The direction of the current in the solenoid is reversed in a time of 0.12 s.

Calculate the average e.m.f. induced in the small coil.

e.m.f. = V [3]



12 - (9702/42_Summer_2019_Q8) - Magnetic Fields

An electron is travelling in a vacuum at a speed of $3.4 \times 10^7 \text{ m s}^{-1}$. The electron enters a region of uniform magnetic field of flux density 3.2 mT , as illustrated in Fig. 8.1.

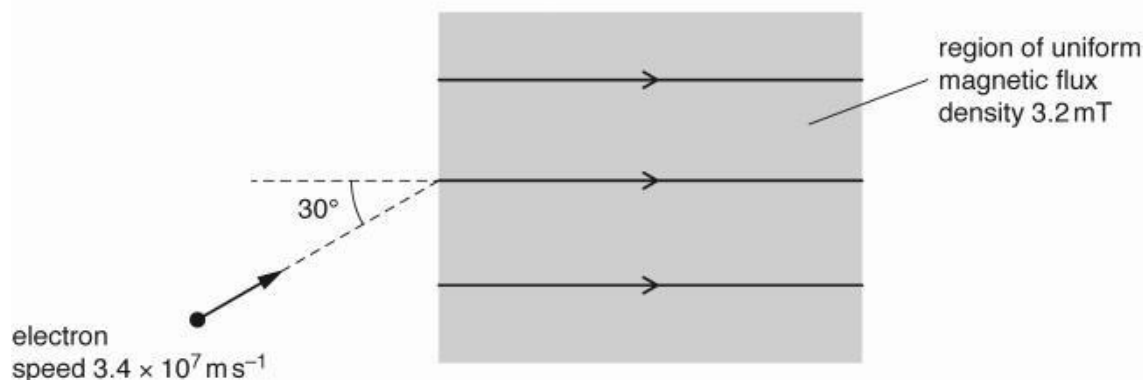


Fig. 8.1

The initial direction of the electron is at an angle of 30° to the direction of the magnetic field.

- (a) When the electron enters the magnetic field, the component of its velocity v_N normal to the direction of the magnetic field causes the electron to begin to follow a circular path.

Calculate:

- (i) v_N

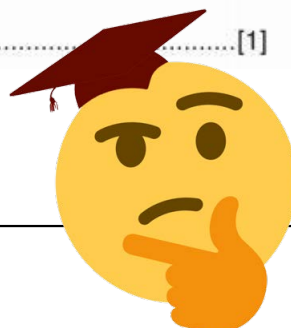
$$v_N = \dots\dots\dots \text{ m s}^{-1} \quad [1]$$

- (ii) the radius of this circular path.

$$\text{radius} = \dots\dots\dots \text{ m} \quad [3]$$

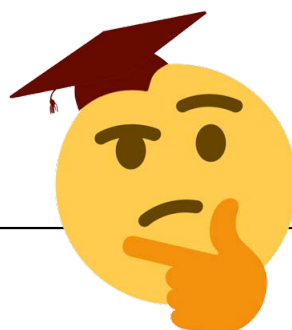
- (b) State the magnitude of the force, if any, on the electron in the magnetic field due to the component of its velocity along the direction of the field.

.....[1]



- (c) Use information from (a) and (b) to describe the resultant path of the electron in the magnetic field.

.....
.....[1]



13 - (9702/41_Summer_2019_Q9) - *Magnetic Fields*

Nuclear magnetic resonance imaging (NMRI) is used to obtain diagnostic information about internal body structures.

State, during the use of NMRI, the function of:

(a) the large constant magnetic field

.....

.....

.....

.....

..... [3]

(b) the non-uniform magnetic field.

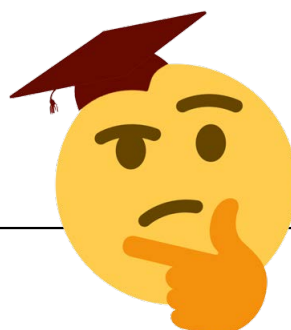
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..... [2]



14 - (9702/42_Winter_2019_Q7) - *Magnetic Fields*

Describe the principles of computed tomography (CT) scanning.

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.....

.....

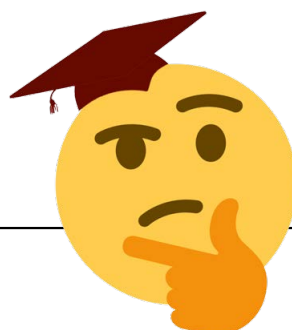
.....

.....

.....

.....

..... [5]



15 - (9702/41_Winter_2019_Q8) - *Magnetic Fields*

- (a) A long straight vertical wire carries a current I . The wire passes through a horizontal card EFGH, as shown in Fig. 8.1 and Fig. 8.2.

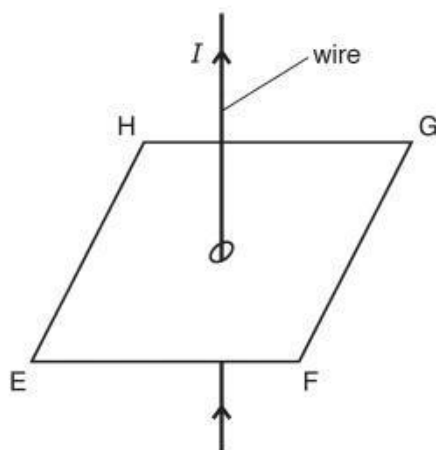


Fig. 8.1

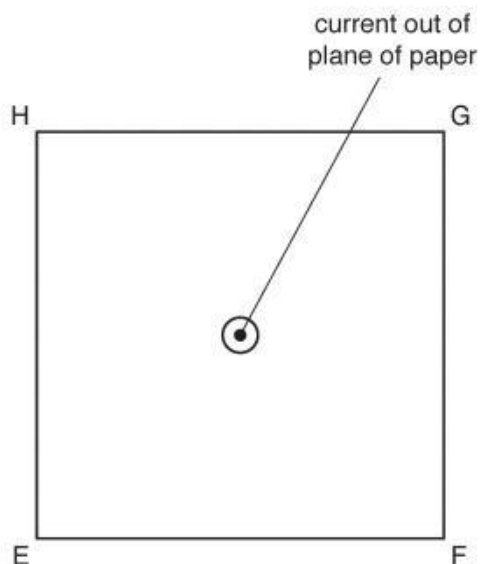


Fig. 8.2 (view from above)

On Fig. 8.2, draw the pattern of the magnetic field produced by the current-carrying wire on the plane EFGH. [3]

- (b) Two long straight parallel wires P and Q are situated a distance 3.1 cm apart, as illustrated in Fig. 8.3.

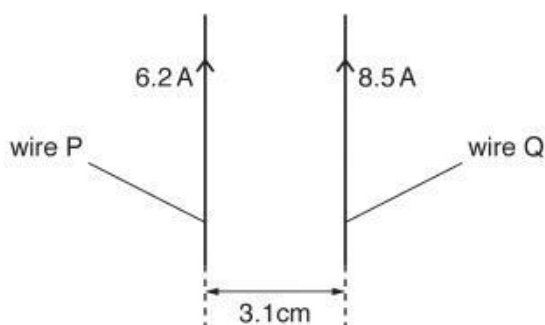


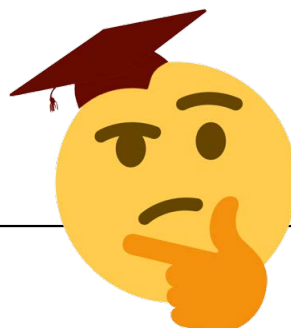
Fig. 8.3

The current in wire P is 6.2 A. The current in wire Q is 8.5 A.

The magnetic flux density B at a distance x from a long straight wire carrying current I is given by the expression

$$B = \frac{\mu_0 I}{2\pi x}$$

where μ_0 is the permeability of free space.



Calculate:

- (i) the magnetic flux density at wire Q due to the current in wire P

flux density = T [2]

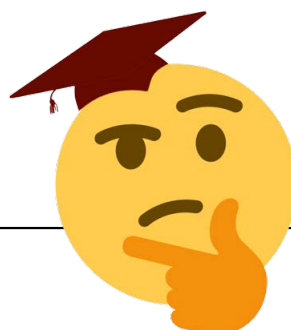
- (ii) the force per unit length, in N m^{-1} , acting on wire Q due to the current in wire P.

force per unit length = N m^{-1} [2]

- (c) The currents in wires P and Q are different in magnitude.

State and explain whether the forces per unit length on the two wires will be different.

.....
.....
..... [2]



16 - (9702/42_Winter_2019_Q8) - *Magnetic Fields, Electromagnetic Induction*

Electrons enter a rectangular slice PQRSEFGH of a semiconductor material at right-angles to face PQFE, as shown in Fig. 8.1.

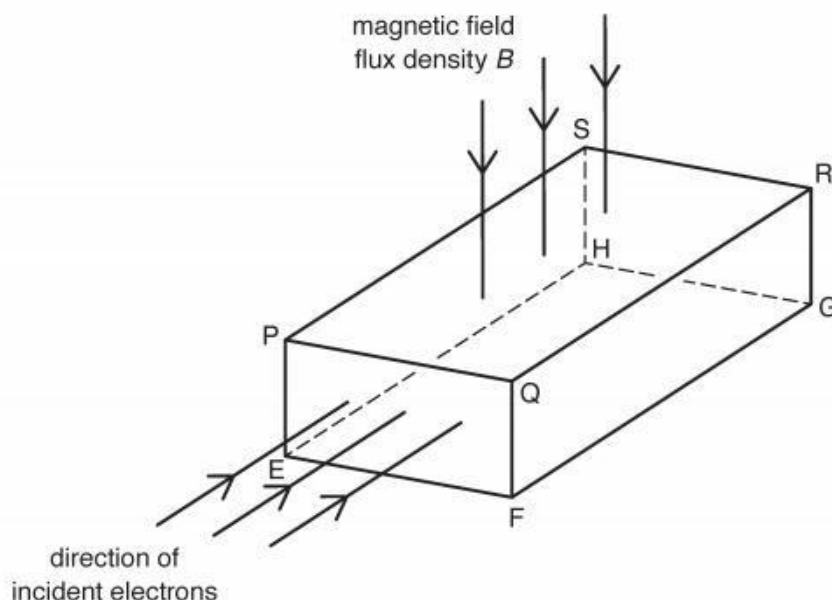


Fig. 8.1

A uniform magnetic field of flux density B is directed into the slice, at right-angles to face PQRS.

- (a) The electrons each have charge $-q$ and drift speed v in the slice.

State the magnitude and the direction of the force due to the magnetic field on each electron as it enters the slice.

.....

 [2]

- (b) The force on the electrons causes a voltage V_H to be established across the semiconductor slice given by the expression

$$V_H = \frac{BI}{ntq}$$

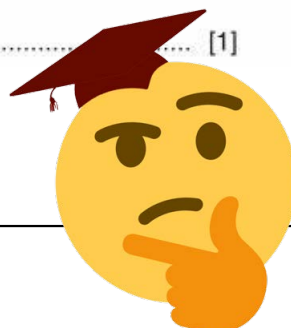
where I is the current in the slice.

- (i) State the two faces between which the voltage V_H is established.

face and face [1]

- (ii) Use letters from Fig. 8.1 to identify the distance t .

..... [1]



(c) Aluminium (${}^{27}_{13}\text{Al}$) has a density of 2.7 g cm^{-3} . Assume that there is one free electron available to carry charge per atom of aluminium.

(i) Show that the number of charge carriers per unit volume in aluminium is $6.0 \times 10^{28} \text{ m}^{-3}$.

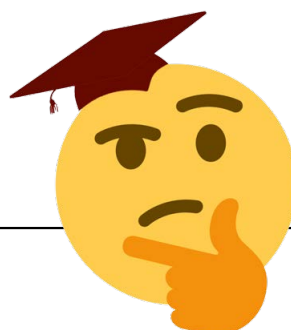
[2]

(ii) A sample of aluminium foil has a thickness of 0.090 mm . The current in the foil is 4.6 A .

A uniform magnetic field of flux density 0.15 T acts at right-angles to the foil.

Use the value in (i) to calculate the voltage V_H that is generated.

$V_H = \dots\dots\dots \text{ V}$ [2]



17 - (9702/41_Winter_2019_Q9) - *Magnetic Fields*

Diagnosis using nuclear magnetic resonance imaging (NMRI) requires the use of a non-uniform magnetic field superimposed on a constant magnetic field of large magnitude.

Explain the purpose of:

(a) the large constant magnetic field

.....

.....

.....

.....

..... [2]

(b) the non-uniform magnetic field.

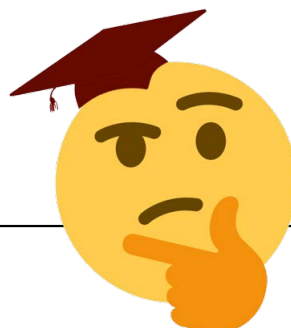
.....

.....

.....

.....

..... [2]



18 - (9702/41_Summer_2020_Q8) - *Magnetic Fields, Electromagnetic Induction*

(a) Define the *tesla*.

.....

.....

.....

..... [3]

(b) A magnet produces a uniform magnetic field of flux density B in the space between its poles.

A rigid copper wire carrying a current is balanced on a pivot. Part PQLM of the wire is between the poles of the magnet, as illustrated in Fig. 8.1.

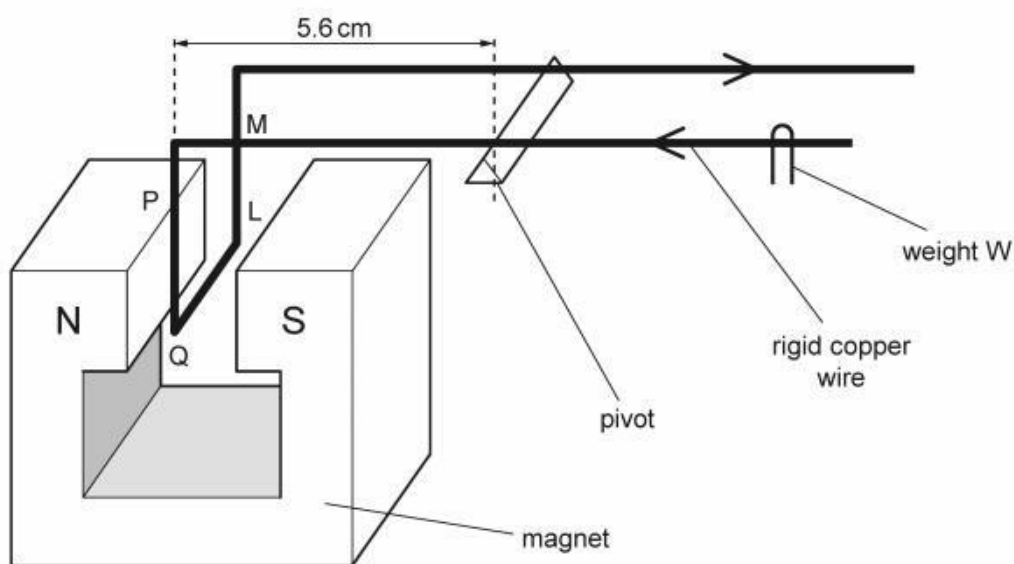


Fig. 8.1 (not to scale)

The wire is balanced horizontally by means of a small weight W .



The section of the wire between the poles of the magnet is shown in Fig. 8.2.

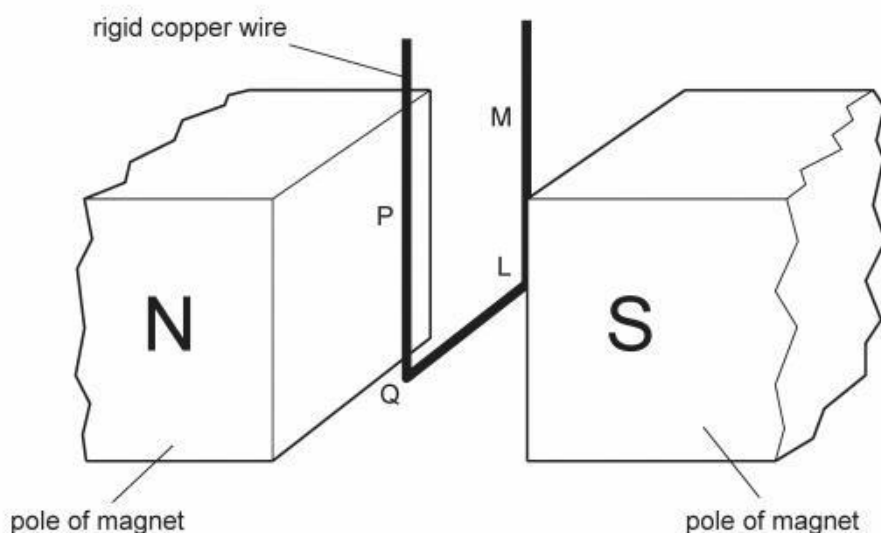


Fig. 8.2 (not to scale)

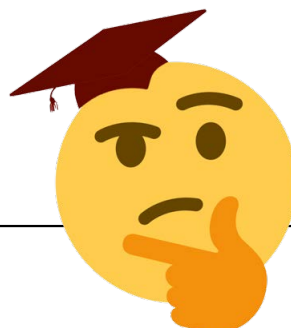
Explain why:

- (i) section QL of the wire gives rise to a moment about the pivot

.....
.....
.....
..... [3]

- (ii) sections PQ and LM of the wire do not affect the equilibrium of the wire.

.....
.....
.....
..... [2]



- (c) Section QL of the wire has length 0.85 cm.

The perpendicular distance of QL from the pivot is 5.6 cm.

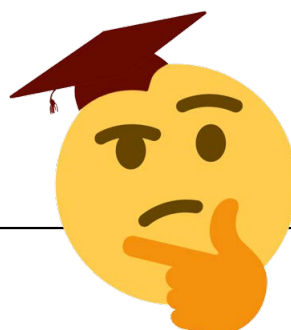
When the current in the wire is changed by 1.2 A, W is moved a distance of 2.6 cm along the wire in order to restore equilibrium. The mass of W is 1.3×10^{-4} kg.

- (i) Show that the change in moment of W about the pivot is 3.3×10^{-5} N m.

[2]

- (ii) Use the information in (i) to determine the magnetic flux density B between the poles of the magnet.

$B = \dots\dots\dots$ T [3]



19 - (9702/42_Summer_2020_Q9) - *Magnetic Fields*

- (a) An electron is travelling at speed v in a straight line in a vacuum. It enters a uniform magnetic field of flux density $8.0 \times 10^{-4} \text{ T}$. Initially, the electron is travelling at right angles to the magnetic field, as illustrated in Fig. 9.1.

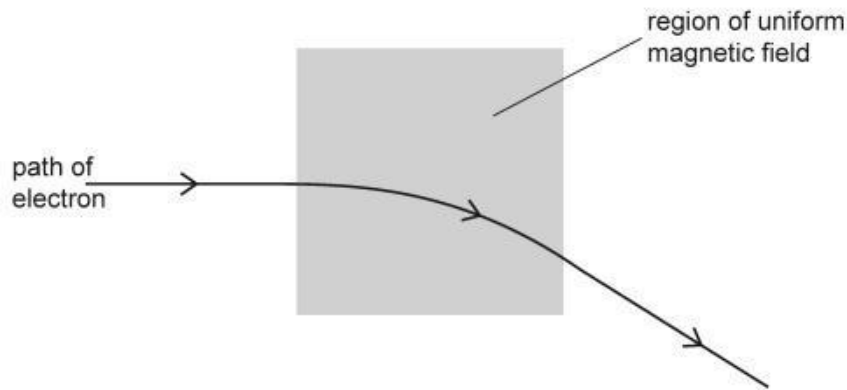


Fig. 9.1

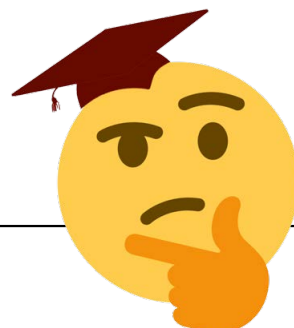
The path of the electron in the magnetic field is an arc of a circle of radius 6.4 cm.

- (i) State and explain the direction of the magnetic field.

.....
.....
..... [2]

- (ii) Show that the speed v of the electron is $9.0 \times 10^6 \text{ ms}^{-1}$.

[3]



- (b) A uniform electric field is now applied in the same region as the magnetic field.

The electron passes undeviated through the region of the two fields, as illustrated in Fig. 9.2.

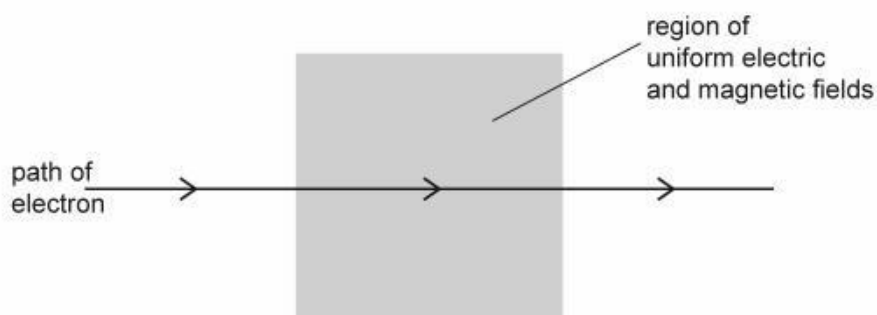


Fig. 9.2

- (i) On Fig. 9.2, mark with an arrow the direction of the uniform electric field. [1]
- (ii) Use data from (a) to calculate the magnitude of the electric field strength.

field strength = NC^{-1} [2]

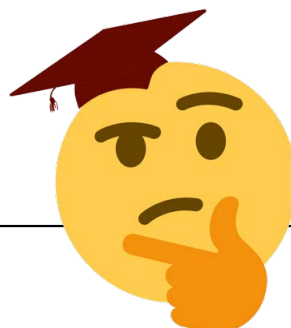
- (c) The electron in (b) is now replaced by an α -particle travelling at the same speed v along the same initial path as the electron.

Describe and explain the shape of the path in the region of the magnetic and electric fields.

.....

.....

..... [2]



20 - (9702/41_Winter_2020_Q8) - *Magnetic Fields*

A slice of a conducting material has its face QRLK normal to a uniform magnetic field of flux density B , as illustrated in Fig. 8.1.

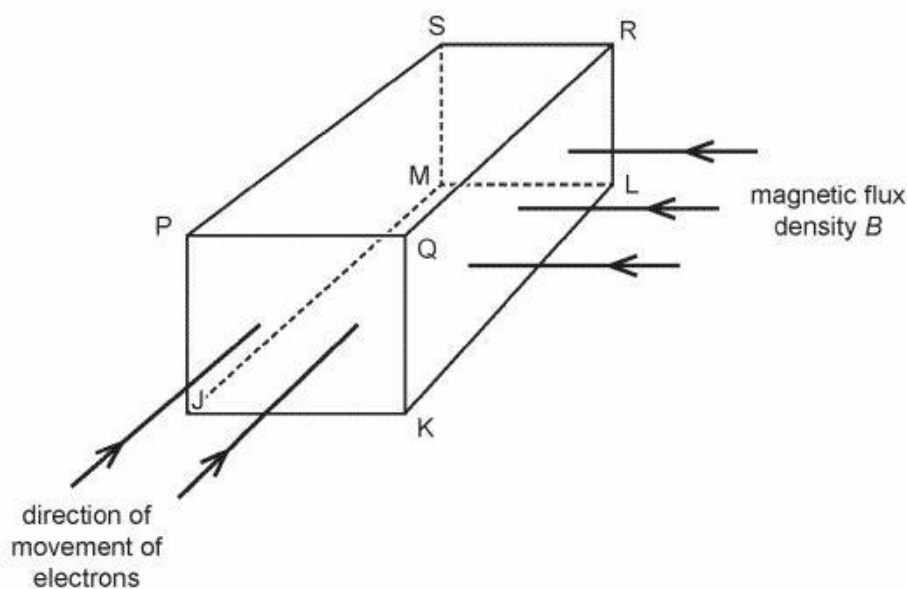


Fig. 8.1

Electrons enter the slice travelling perpendicular to face PQKJ.

(a) For the free electrons moving in the slice:

- (i) state the direction of the force on an electron due to movement of the electron in the magnetic field

.....
 [1]

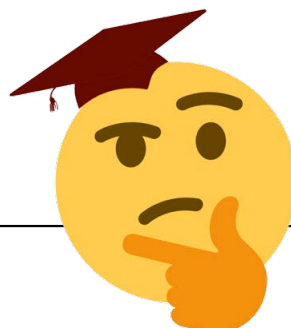
- (ii) identify the faces, using the letters on Fig. 8.1, between which a potential difference is developed.

face and face [1]

(b) Explain why the potential difference in (a)(ii) reaches a maximum value.

.....

 [2]



- (c) The number of free electrons per unit volume in the slice of material is $1.3 \times 10^{29} \text{ m}^{-3}$.
The thickness PQ of the slice is 0.10 mm.
The magnetic flux density B is $4.6 \times 10^{-3} \text{ T}$.

Calculate the potential difference across the slice for a current of $6.3 \times 10^{-4} \text{ A}$.

potential difference = V [2]

- (d) The slice in (c) is a metal.

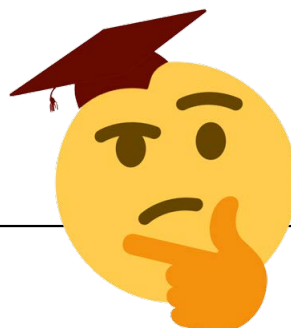
By reference to your answer in (c), suggest why Hall probes are usually made using semiconductors rather than metals.

.....

.....

..... [2]

[Total: 8]



21 - (9702/42_Winter_2020_Q10) - *Magnetic Fields*

- (a) A long straight vertical wire A carries a current in an upward direction. The wire passes through the centre of a horizontal card, as illustrated in Fig. 10.1.

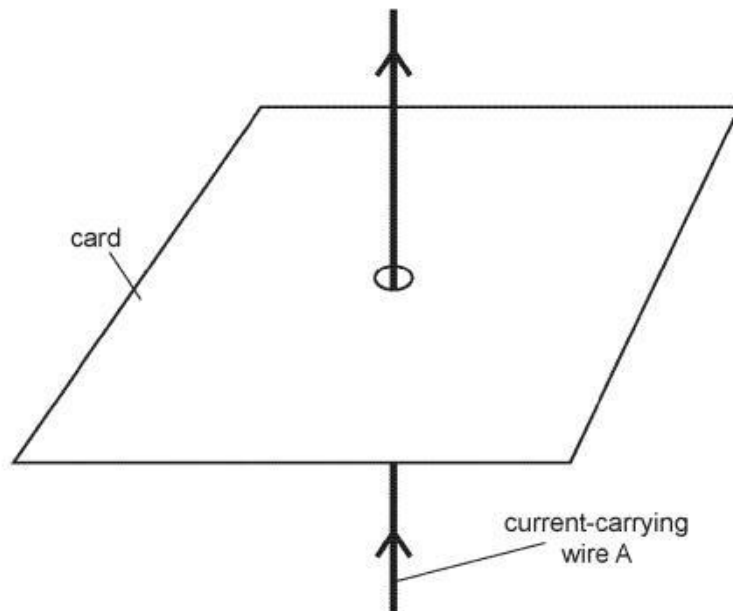


Fig. 10.1

The card is viewed from above. The card is shown from above in Fig. 10.2.

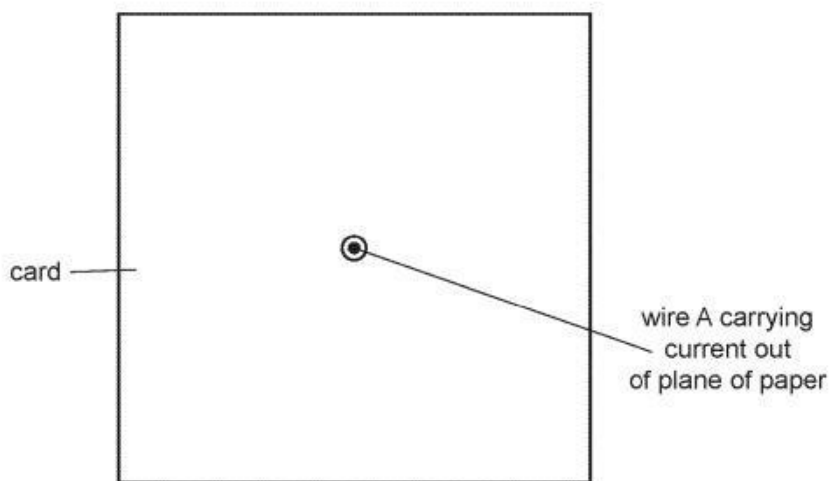
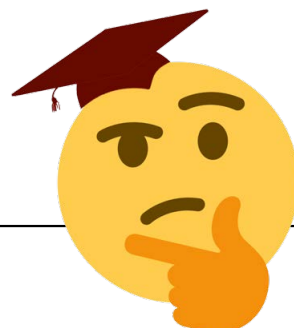


Fig. 10.2

On Fig. 10.2, draw four lines to represent the magnetic field produced by the current-carrying wire. [3]



- (b) Two wires A and B are now placed through a card. The two wires are parallel and carrying currents in the same direction, as illustrated in Fig. 10.3.

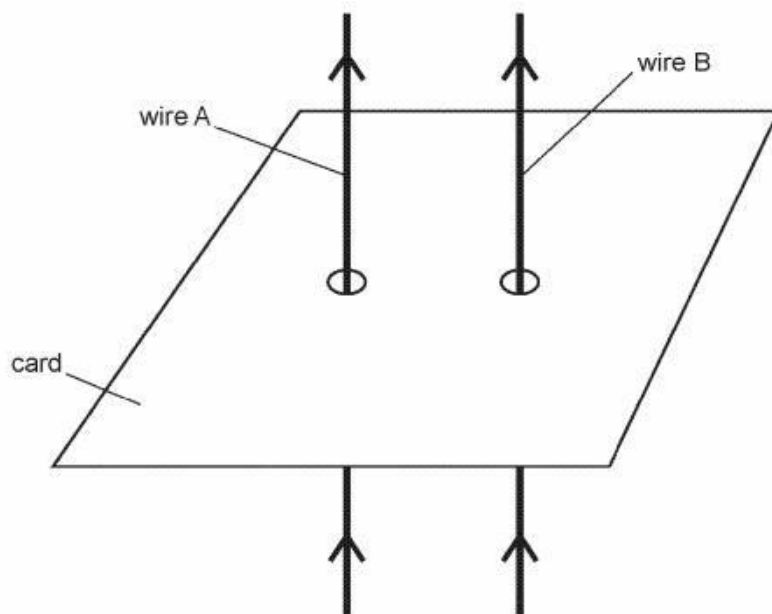


Fig. 10.3

- (i) Explain why a magnetic force is exerted on each wire.

.....
.....
.....
..... [2]

- (ii) State the directions of the forces.

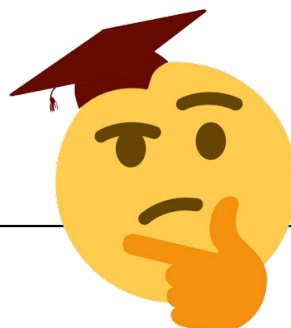
.....
..... [1]

- (c) The currents in the two wires are not equal.

Explain whether the magnetic forces on the two wires are equal in magnitude.

.....
.....
..... [1]

[Total: 7]



22 - (9702/42_Summer_2021_Q8) - *Magnetic Fields*

(a) Define *magnetic flux density*.

.....

.....

..... [2]

(b) Electrons, each of mass m and charge q , are accelerated from rest in a vacuum through a potential difference V .

Derive an expression, in terms of m , q and V , for the final speed v of the electrons. Explain your working.

[2]

(c) The accelerated electrons in (b) are injected at point S into a region of uniform magnetic field of flux density B , as illustrated in Fig. 8.1.

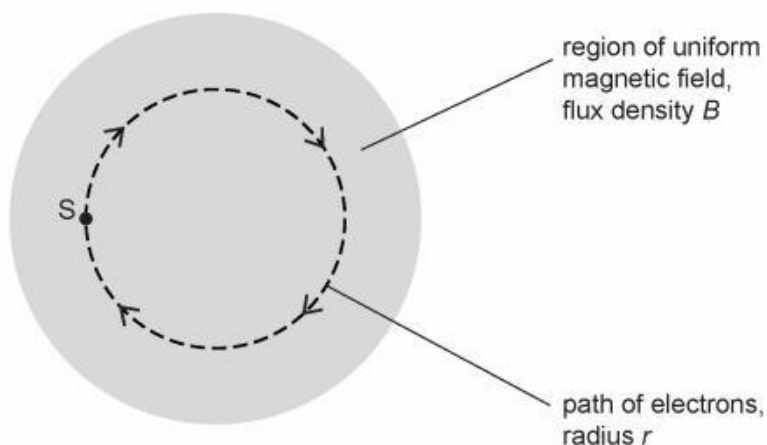
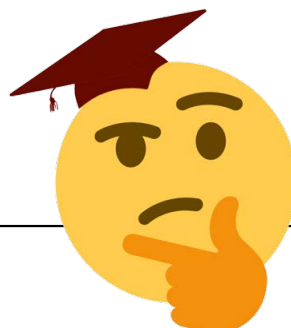


Fig. 8.1

The electrons move at right angles to the direction of the magnetic field. The path of the electrons is a circle of radius r .



- (i) Show that the specific charge $\frac{q}{m}$ of the electrons is given by the expression

$$\frac{q}{m} = \frac{2V}{B^2 r^2}.$$

Explain your working.

[2]

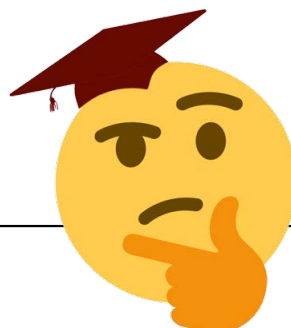
- (ii) Electrons are accelerated through a potential difference V of 230 V. The electrons are injected normally into the magnetic field of flux density 0.38 mT. The radius r of the circular orbit of the electrons is 14 cm.

Use this information to calculate a value for the specific charge of an electron.

specific charge = C kg⁻¹ [2]

- (iii) Suggest why the arrangement outlined in (ii), using the same values of B and V , is not practical for the determination of the specific charge of α -particles.

.....
.....
..... [2]



23 - (9702/41_Summer_2021_Q9) - *Magnetic Fields*

(a) State what is meant by a *magnetic field*.

.....
.....
..... [2]

(b) A rectangular piece of aluminium foil is situated in a uniform magnetic field of flux density B , as shown in Fig. 9.1.

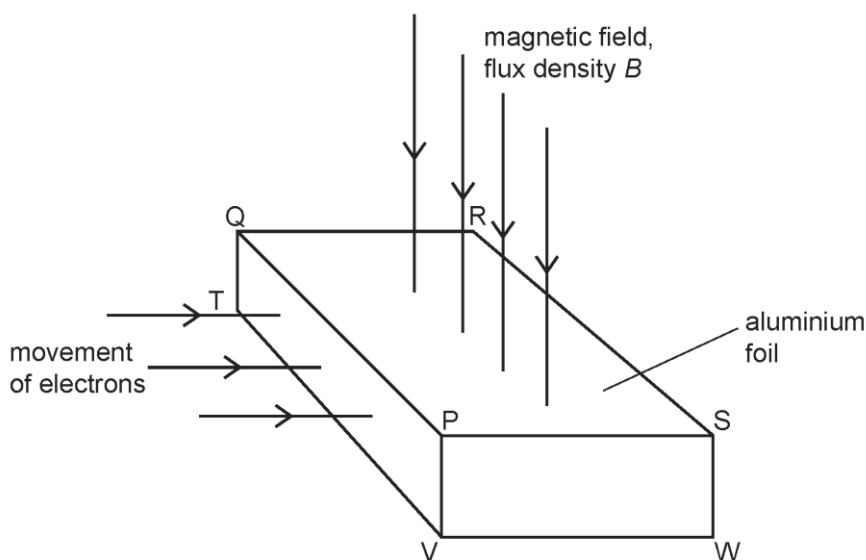


Fig. 9.1

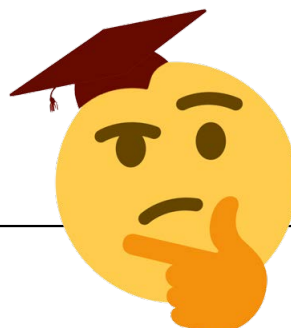
The magnetic field is normal to the face PQRS of the foil.

Electrons, each of charge $-q$, enter the foil at right angles to the face PQTV.

(i) On Fig. 9.1, shade the face of the foil on which electrons initially accumulate. [1]

(ii) Explain why electrons do not continuously accumulate on the face you have shaded.

.....
.....
.....
..... [3]



(c) The Hall voltage V_H developed across the foil in (b) is given by the expression

$$V_H = \frac{BI}{ntq}$$

where I is the current in the foil.

(i) State the meaning of the quantity n .

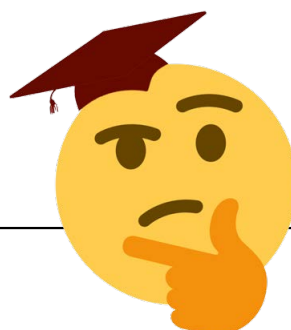
.....
..... [1]

(ii) Using the letters on Fig. 9.1, identify the distance t .

..... [1]

(d) Suggest why, in practice, Hall probes are usually made using a semiconductor material rather than a metal.

.....
..... [1]



24 - (9702/42_Summer_2021_Q9) - *Magnetic Fields, Electromagnetic Induction*

(a) State **two** situations in which a charged particle in a magnetic field does **not** experience a force.

1.

.....

2.

.....

[2]

(b) A loosely coiled metal spring is suspended from a fixed point, as shown in Fig. 9.1.

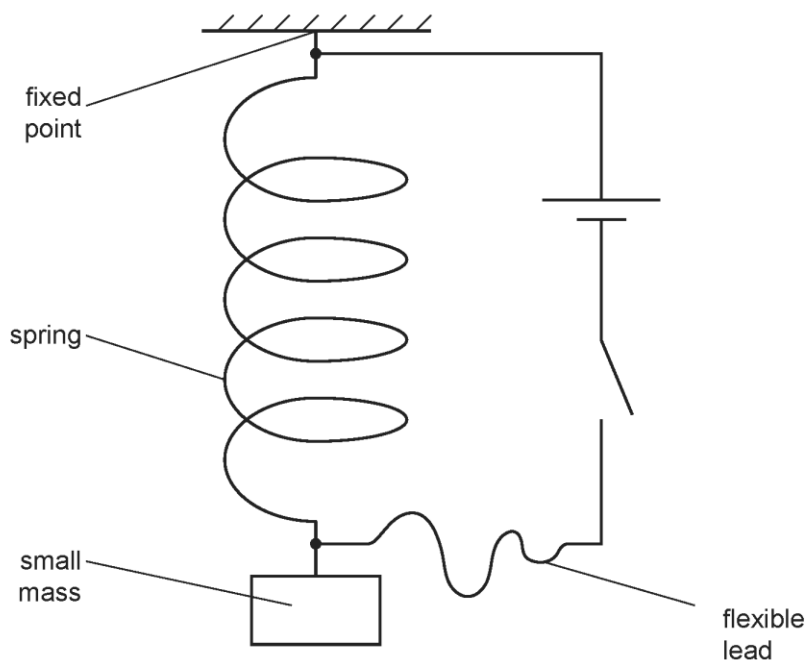
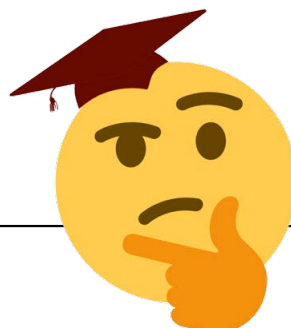


Fig. 9.1

Electrical connections are made to the ends of the spring by means of a flexible lead.

The length of the spring is measured before the switch is closed and then again after the switch is closed.



When the switch is closed, a magnetic field is set up around each coil of the spring.

By reference to these magnetic fields, explain why there is a change in length of the spring. State whether the spring extends or contracts.

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..... [4]

- (c) With the switch in (b) closed, the small mass on the free end of the spring is now made to oscillate vertically.

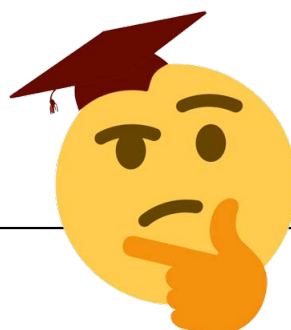
Use the principles of electromagnetic induction to explain why small fluctuations in the current in the spring are found to occur.

.....

.....

.....

..... [3]



25 – (9702/41_Winter_2021_Q8) – *Magnetic Fields*

(a) Define the *tesla*.

.....
.....
..... [2]

(b) A stiff metal wire is used to form a rectangular frame measuring $8.0\text{ cm} \times 6.0\text{ cm}$. The frame is open at the top, and is suspended from a sensitive newton meter, as shown in Fig. 8.1.

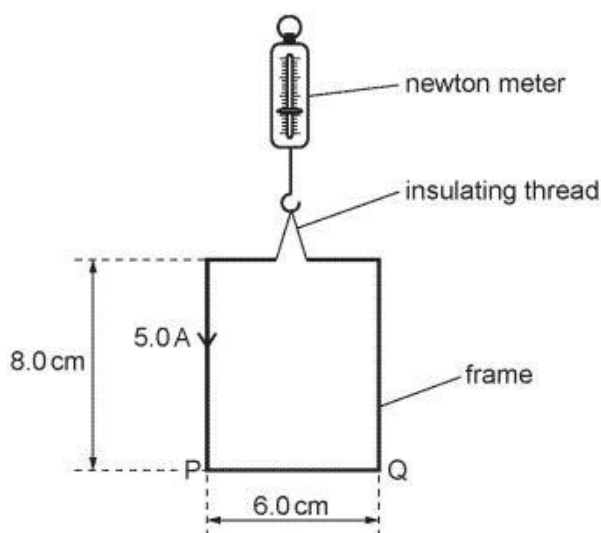


Fig. 8.1

The open ends of the frame are connected to a power supply so that there is a current of 5.0 A in the frame in the direction indicated in Fig. 8.1.

The frame is slowly lowered into a uniform magnetic field of flux density B so that all of side PQ is in the field. The magnetic field lines are horizontal and at an angle of 50° to PQ, as shown in Fig. 8.2.

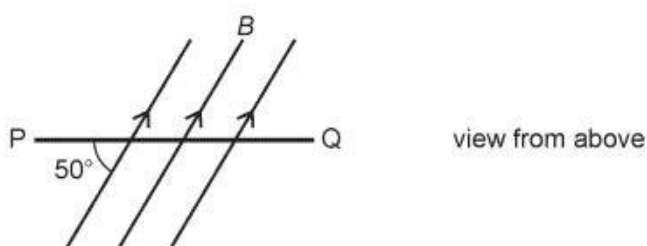
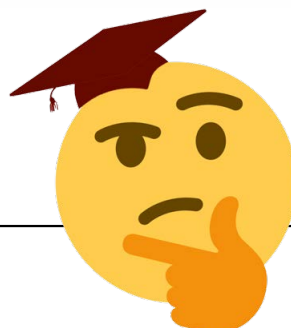


Fig. 8.2

When side PQ of the frame first enters the magnetic field, the reading on the newton meter changes by 1.0 mN .



- (i) Determine the magnetic flux density B , in mT.

$B = \dots\dots\dots$ mT [2]

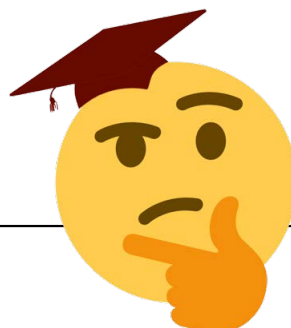
- (ii) State, with a reason, whether the change in the reading on the newton meter is an increase or a decrease.

.....
.....
..... [1]

- (iii) The frame is lowered further so that the vertical sides start to enter the magnetic field.

Suggest what effect this will have on the frame.

.....
.....
..... [1]



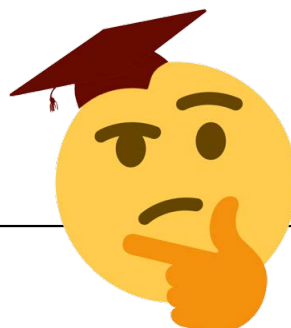
26 - (9702/42_Winter_2021_Q8) - *Magnetic Fields*

Two long straight parallel wires P and Q carry currents into the plane of the paper, as shown in Fig. 8.1.

**Fig. 8.1**

The current in P is I and the current in Q is $2I$.

- (a) (i) On Fig. 8.1, draw an arrow to show the direction of the magnetic field at wire Q due to the current in wire P. Label this arrow B. [1]
- (ii) On Fig. 8.1, draw another arrow to show the direction of the force acting on wire Q due to the current in wire P. Label this arrow F. [1]
- (b) (i) State, with a reason, how the magnitude of the force acting on wire P compares with the magnitude of the force acting on wire Q.
-
-
- [2]
- (ii) State how the direction of the force on wire P compares with the direction of the force on wire Q.
-
- [1]



27 - (9702/42_Winter_2021_Q9) - *Magnetic Fields*

(a) State what is meant by:

(i) the *photoelectric effect*

.....
.....
..... [2]

(ii) *work function energy*.

.....
..... [1]

(b) A polished calcium plate in a vacuum is investigated by illuminating the surface with light.

It is found that no photoelectric current is produced when the frequency of the light is less than 6.93×10^{14} Hz.

(i) State the name of the frequency below which no photoelectric current is produced.

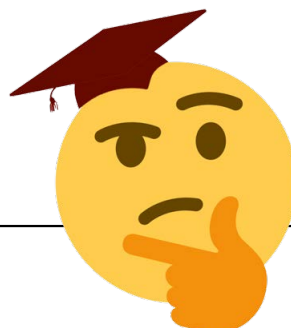
..... [1]

(ii) Explain how the photon model of electromagnetic radiation accounts for this phenomenon.

.....
.....
.....
..... [3]

(iii) Calculate the work function energy, in eV, of calcium.

work function energy = eV [2]



28 – (9702/43_Winter_2021_Q9) – *Magnetic Fields*

- (a) State, by reference to the power dissipated in a resistor, what is meant by the *root-mean-square (r.m.s.)* value of an alternating voltage.

.....

.....

.....

..... [2]

- (b) A coil is rotating freely, on frictionless bearings, at constant speed in a uniform magnetic field. This rotation causes an induced alternating electromotive force (e.m.f.) across the open terminals of the coil. The induced e.m.f. has r.m.s. value 12 V and frequency 50 Hz.

The speed of rotation of the coil is now doubled.

- (i) State and explain, with reference to the principles of electromagnetic induction, the effect of the increased speed of rotation on the r.m.s. value of the induced e.m.f.

.....

.....

.....

..... [2]

- (ii) On Fig. 9.1, sketch the variation with time t of the induced e.m.f. E across the terminals of the coil at the **increased** speed of rotation. Your line should extend from time $t = 0$ to time $t = 20$ ms. Assume that $E = 0$ when $t = 0$.

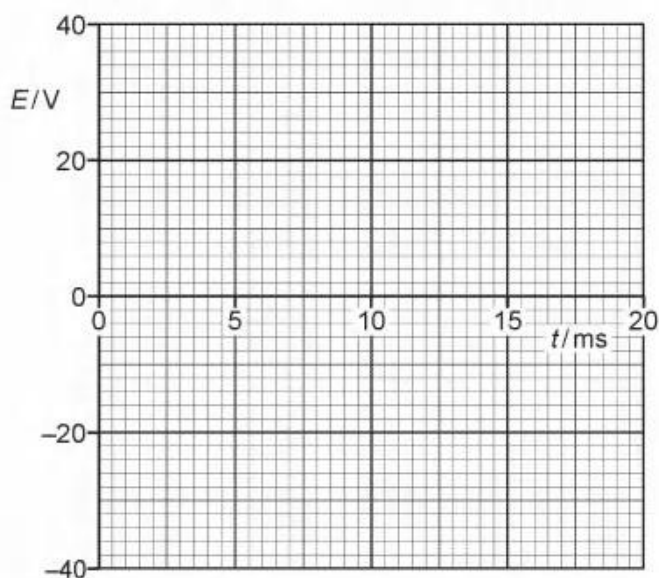
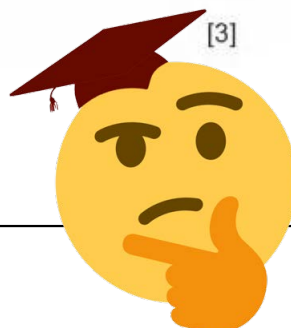


Fig. 9.1

[3]



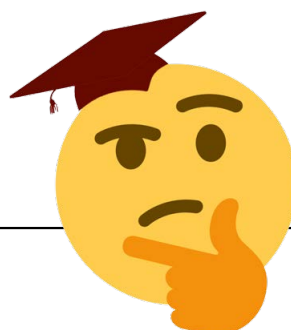
- (c) State and explain the effect on the motion of the coil in (b) of connecting a load resistor across its terminals.

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.....

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..... [2]



29 - (9702/41_Summer_2022_Q6) - *Magnetic Fields*

(a) Define magnetic flux.

.....
.....
..... [2]

(b) A square coil of wire of side length 12 cm consists of 8 insulated turns. The coil is stationary in a uniform magnetic field. The plane of the coil is perpendicular to the magnetic field, as shown in Fig. 6.1.

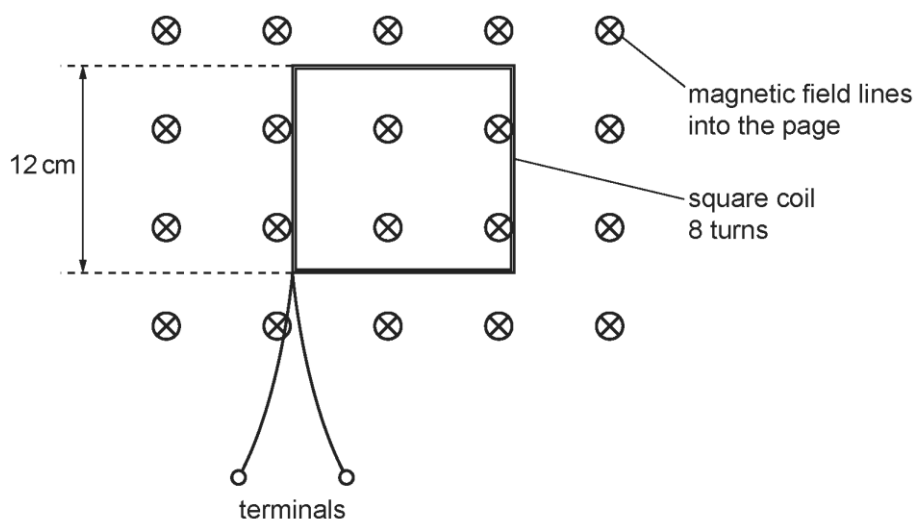


Fig. 6.1

The flux density B of the magnetic field varies with time t as shown in Fig. 6.2.

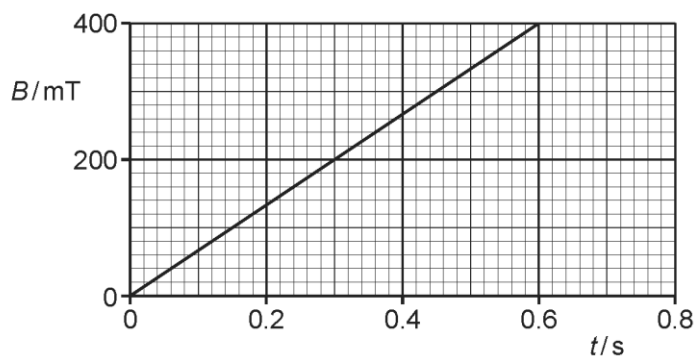
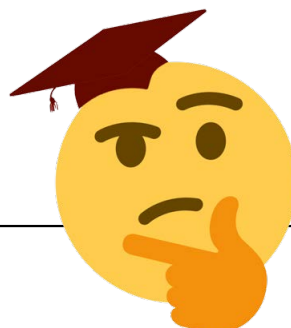


Fig. 6.2



- (i) Determine the magnetic flux linkage inside the coil at time $t = 0.60$ s. Give a unit with your answer.

magnetic flux linkage = unit [3]

- (ii) State how Fig. 6.2 shows that the electromotive force (e.m.f.) E induced across the terminals between $t = 0$ and $t = 0.60$ s is constant.

..... [1]

- (iii) Calculate the magnitude of E .

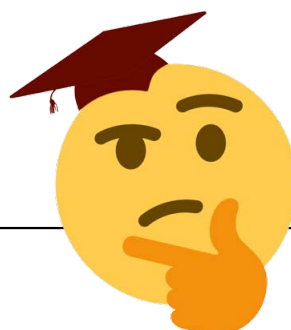
$E =$ V [2]

- (c) The procedure in (b) is repeated, but this time the terminals of the coil are connected together.

State and explain the effect on the coil of connecting the terminals together during the change of magnetic flux density shown in Fig. 6.2.

.....
.....
.....
..... [3]

[Total: 11]



30 - (9702/42_Summer_2022_Q6) - *Magnetic Fields*

- (a) State the **two** conditions that must be satisfied for a copper wire, placed in a magnetic field, to experience a magnetic force.

1

.....

2

.....

[2]

- (b) A long air-cored solenoid is connected to a power supply, so that the solenoid creates a magnetic field. Fig. 6.1 shows a cross-section through the middle of the solenoid.

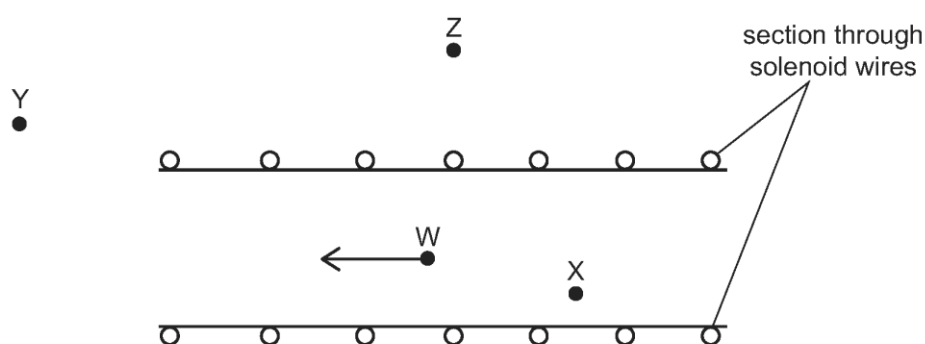


Fig. 6.1

The direction of the magnetic field at point W is indicated by the arrow. Three other points are labelled X, Y and Z.

- (i) On Fig. 6.1, draw arrows to indicate the direction of the magnetic field at each of the points X, Y and Z. [3]

- (ii) Compare the magnitude of the flux density of the magnetic field:

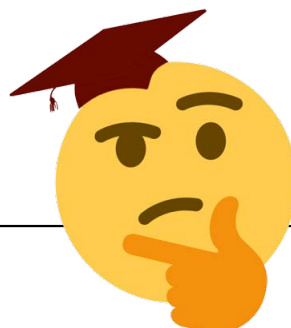
• at X and at W

.....

• at Y and at Z.

.....

[2]



(c) Two long parallel current-carrying wires are placed near to each other in a vacuum.

Explain why these wires exert a magnetic force on each other. You may draw a labelled diagram if you wish.

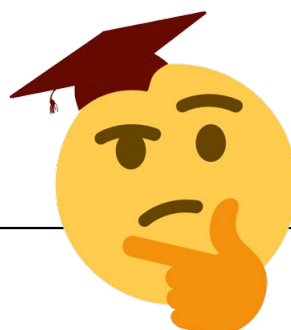
.....

.....

.....

..... [3]

[Total: 10]



31 - (9702/42_Summer_2022_Q7) - *Magnetic Fields*

(a) State Faraday's law of electromagnetic induction.

.....

.....

..... [2]

(b) Two coils are wound on an iron bar, as shown in Fig. 7.1.

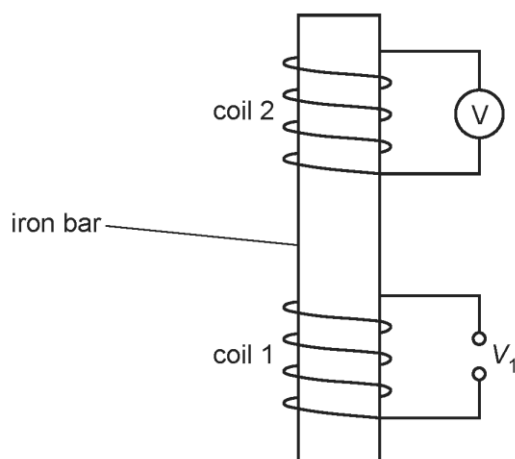


Fig. 7.1

Coil 1 is connected to a potential difference (p.d.) V_1 that gives rise to a magnetic field in the iron bar.

Fig. 7.2 shows the variation with time t of the magnetic flux density B in the iron bar.

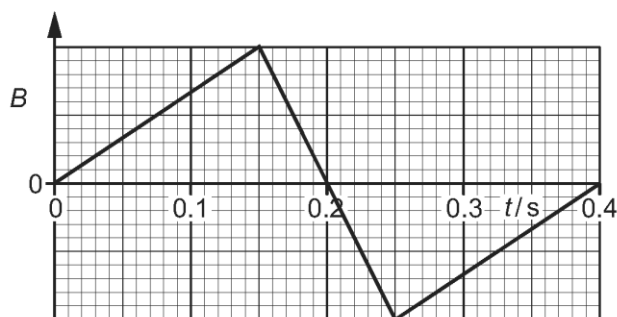
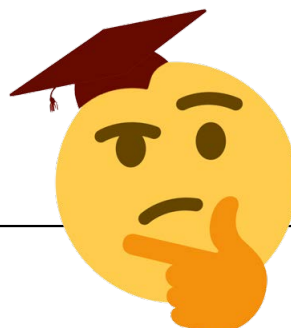


Fig. 7.2

A voltmeter measures the electromotive force (e.m.f.) V_2 that is induced across coil 2.



On Fig. 7.3, sketch the variation with t of V_2 between $t = 0$ and $t = 0.40$ s.

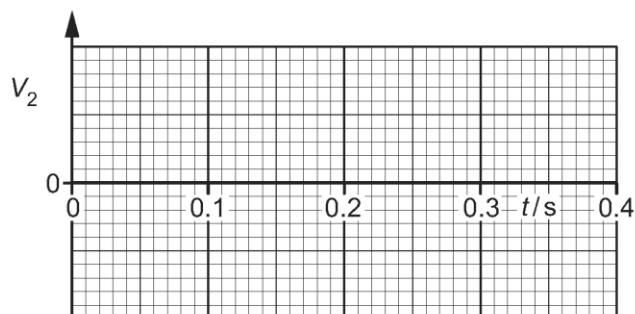


Fig. 7.3

[4]

- (c) Coil 2 in (b) is now replaced with a copper ring that rests loosely on top of coil 1. The supply to coil 1 is replaced with a cell and a switch that is initially open, as shown in Fig. 7.4.

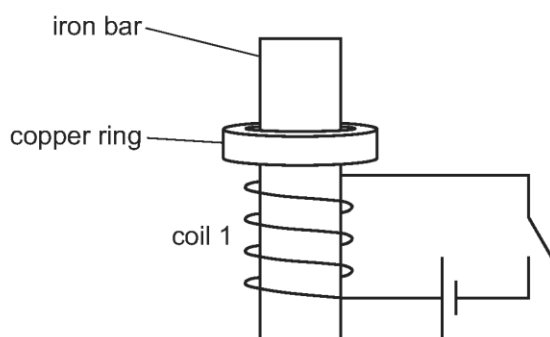


Fig. 7.4

- (i) The switch is now closed. As it is closed, the copper ring is observed to jump upwards.

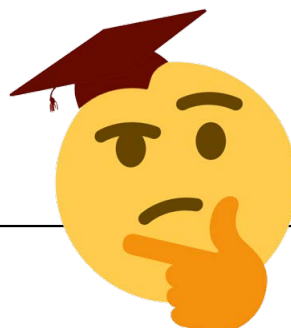
Explain why this happens.

.....
.....
.....
..... [3]

- (ii) Suggest, with a reason, what would be the effect of repeating the procedure in (c)(i) with the terminals of the cell reversed.

.....
..... [1]

[Total: 10]



32 - (9702/41_Winter_2022_Q6) - *Magnetic Fields*

Fig. 6.1 shows a thin slice of semiconducting material used in a Hall probe.

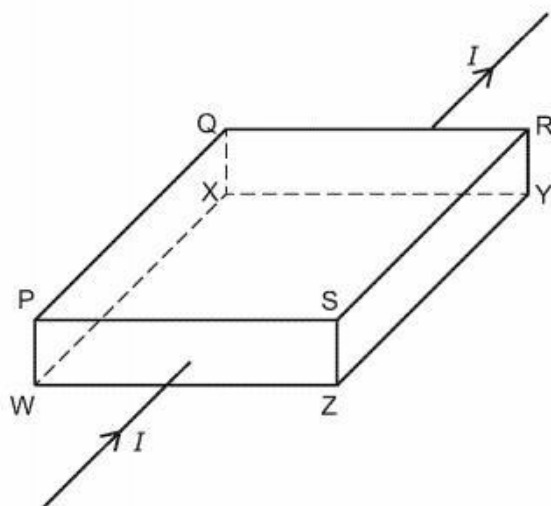


Fig. 6.1 (not to scale)

Current I passes through the slice in the direction shown.

The slice is placed in a uniform magnetic field of flux density B , so that two of its faces are perpendicular to the magnetic field.

A steady Hall voltage V_H is developed between face PQXW and face SRYZ.

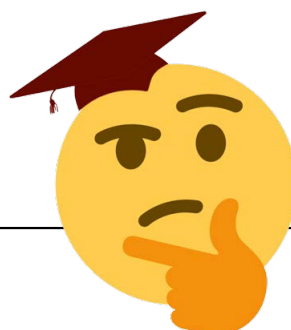
- (a) (i) Use the letters in Fig. 6.1 to identify the faces that are perpendicular to the magnetic field.

..... and [1]

- (ii) Explain how the steady Hall voltage V_H is developed between faces PQXW and SRYZ.

.....

 [3]



(b) The magnitude of V_H is given by the equation

$$V_H = \frac{BI}{ntq}.$$

(i) State the meaning of the symbols n , t and q . You may refer to the letters in Fig. 6.1.

n :

t :

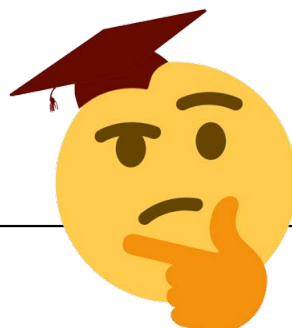
q : [3]

(ii) Suggest, with reference to the equation, why the slice of the material used in a Hall probe is thin.

.....

.....

..... [2]



33 - (9702/42_Winter_2022_Q7) - *Magnetic Fields*

(a) Define magnetic flux density.

.....

.....

.....

..... [3]

(b) An insulated rectangular coil of wire, consisting of 40 turns, is suspended in a cradle from a newton meter, as shown in Fig. 7.1.

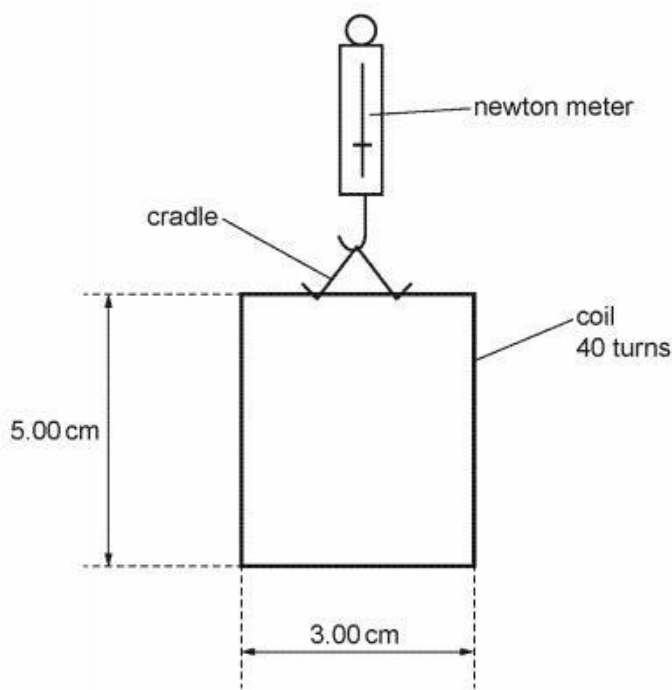
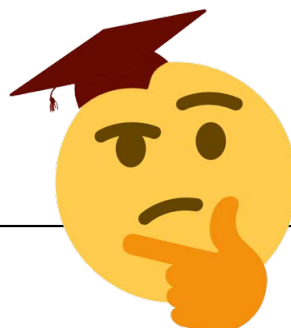


Fig. 7.1

The vertical sides of the coil have a length of 5.00 cm and the horizontal sides have a length of 3.00 cm. The initial reading on the newton meter is 0.563 N.

A U-shaped magnet rests on a top-pan balance that is set to a reading of 0.00 g. The lower edge of the coil is lowered into the region between the poles of the U-shaped magnet, as shown in the side view in Fig. 7.2.



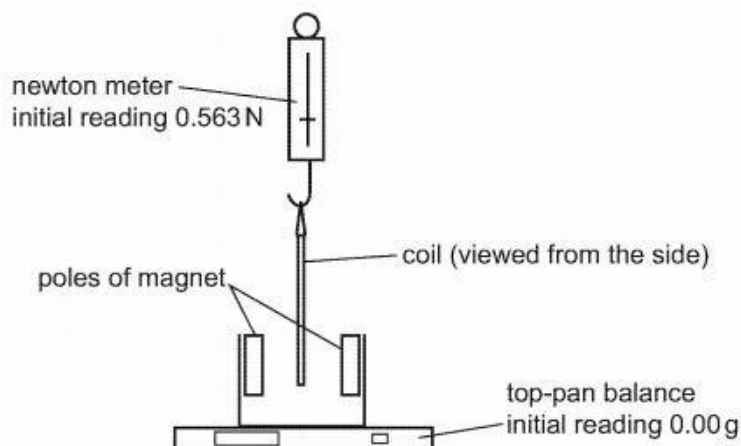


Fig. 7.2

The magnetic field in the region between the poles is uniform.
The lower edge of the coil is entirely within the uniform magnetic field.

A current of 3.94 A is now passed through the coil. This causes the reading on the top-pan balance to change to 2.16 g .

- (i) Explain why the current causes a vertical force to act on the coil.

.....

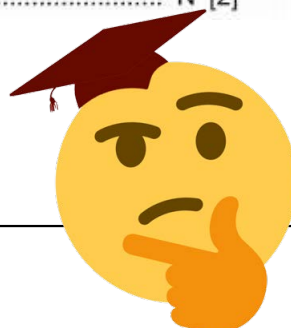
 [2]

- (ii) Determine, to three significant figures, the flux density B of the uniform magnetic field.

$B = \dots\dots\dots \text{ T}$ [3]

- (iii) Determine what is now the reading on the newton meter. Explain your reasoning.

reading = $\dots\dots\dots \text{ N}$ [2]



34 - (9702/41_Summer_2023_Q6) - *Magnetic Fields, Electromagnetic Induction*

- (a) State what is meant by a magnetic field.

.....

.....

..... [2]

- (b) A long, straight wire P carries a current into the page, as shown in Fig. 6.1.

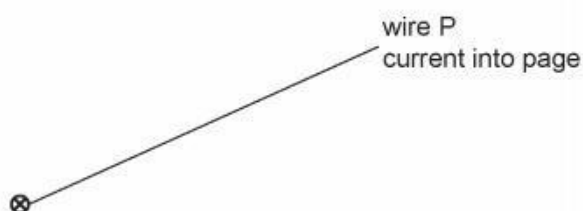


Fig. 6.1

On Fig. 6.1, draw four field lines to represent the magnetic field around wire P due to the current in the wire. [3]

- (c) A second long, straight wire Q, carrying a current of 5.0 A out of the page, is placed parallel to wire P, as shown in Fig. 6.2.

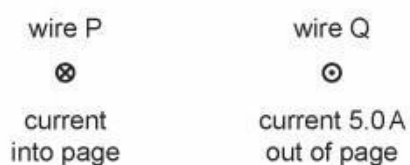
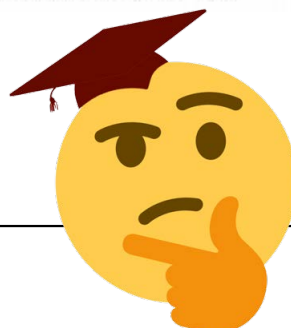


Fig. 6.2

The flux density of the magnetic field at wire Q due to the current in wire P is 2.6 mT.

- (i) Calculate the magnetic force per unit length exerted on wire Q by wire P.

force per unit length = N m^{-1} [2]



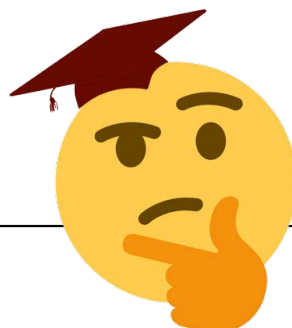
- (ii) State the direction of the force exerted on wire Q by wire P.

..... [1]

- (iii) The flux density of the magnetic field at wire P due to the current in wire Q is 1.5 mT.

Determine the magnitude of the current in wire P. Explain your reasoning.

current = A [2]



1 - (9702/42_Summer_2017_Q3) - Oscillations, Electromagnetic Induction

A bar magnet of mass 250g is suspended from the free end of a spring, as illustrated in Fig. 3.1.

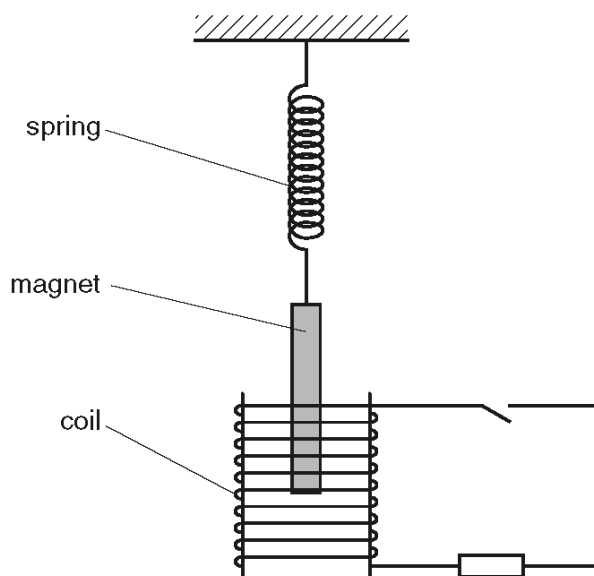


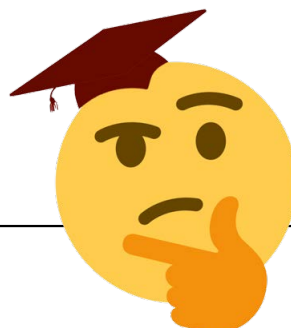
Fig. 3.1

The magnet hangs so that one pole is near the centre of a coil of wire.

The coil is connected in series with a resistor and a switch. The switch is open.

The magnet is displaced vertically and then allowed to oscillate with one pole remaining inside the coil. The other pole remains outside the coil.

At time $t = 0$, the magnet is oscillating freely as it passes through its equilibrium position. At time $t = 6.0\text{ s}$, the switch in the circuit is closed.



The variation with time t of the vertical displacement y of the magnet is shown in Fig. 3.2.

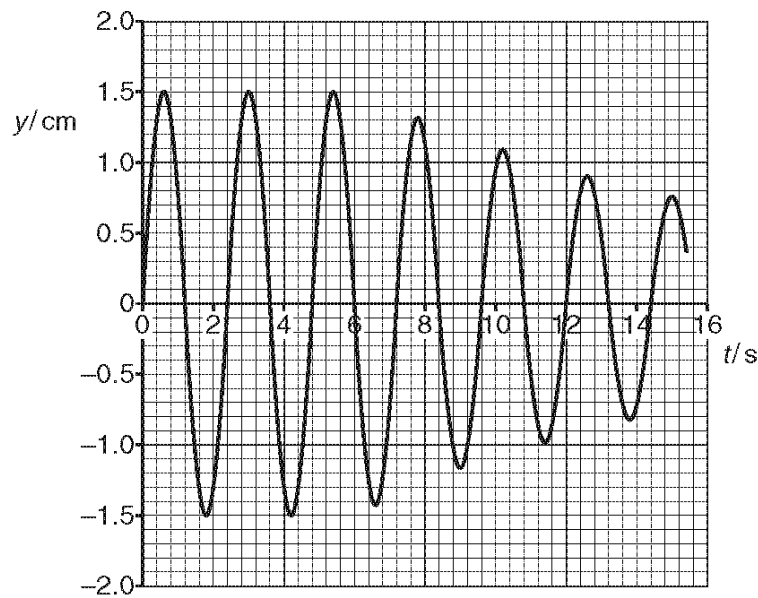


Fig. 3.2

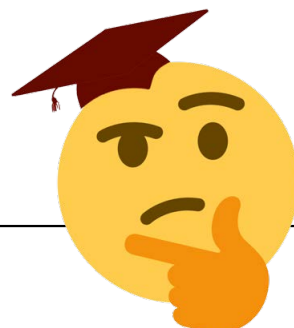
(a) For the oscillating magnet, use data from Fig. 3.2 to calculate, to two significant figures,

(i) the frequency f ,

$f = \dots\dots\dots$ Hz [2]

(ii) the energy of the oscillations during the time $t = 0$ to time $t = 6.0$ s.

energy = $\dots\dots\dots$ J [3]

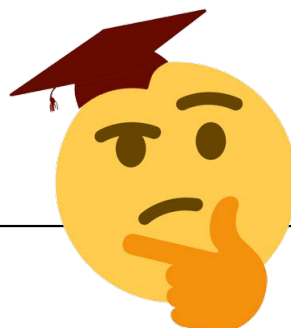


(b) (i) State Faraday's law of electromagnetic induction.

.....
.....
.....
.....[2]

(ii) Use Faraday's law and energy conservation to explain why the amplitude of the oscillations of the magnet reduces after time $t = 6.0\text{ s}$.

.....
.....
.....
.....
.....
.....
.....[3]



2 - (9702/41_Summer_2017_Q9) - *Electromagnetic Induction*

A simple transformer is illustrated in Fig. 9.1.

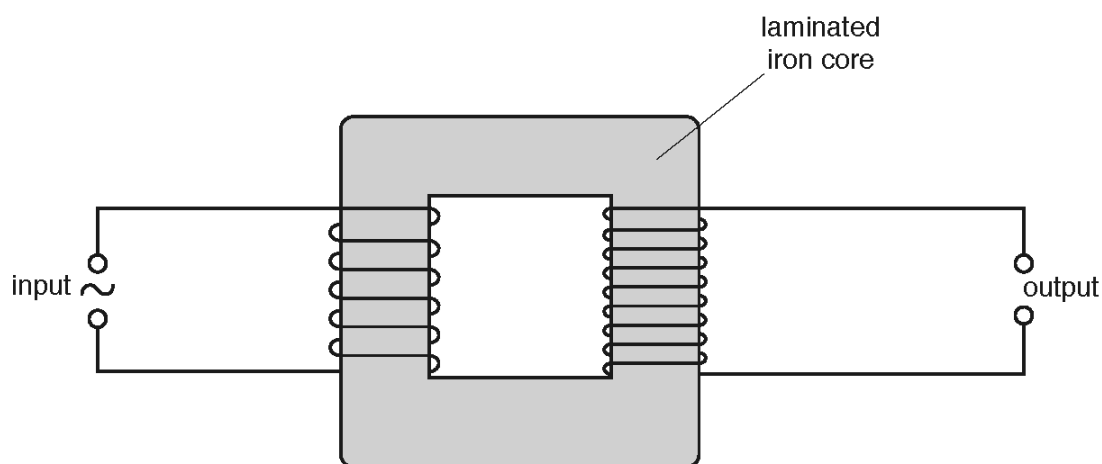


Fig. 9.1

(a) (i) State why the transformer has an iron core, rather than having no core.

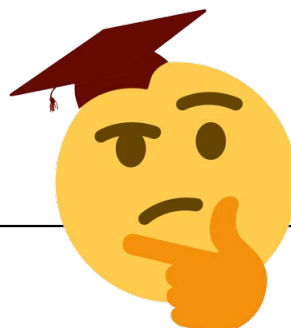
.....
.....[1]

(ii) Explain why the core is laminated.

.....
.....
.....[2]

(b) By reference to the action of a transformer, explain why the input to the transformer is an alternating voltage, rather than a constant voltage.

.....
.....
.....
.....
.....[3]



3 - (9702/41_Winter_2017_Q5) - *Electric Fields, Electromagnetic Induction*

- (a) (i) State Coulomb's law for the force between two point charges.

.....
..... [1]

- (ii) Two point charges are situated in a vacuum and separated by a distance R . The force between the charges is F_C .

On Fig. 5.1, sketch a graph to show the variation of the force F between the charges with separation x for values of x from $x = R$ to $x = 4R$.

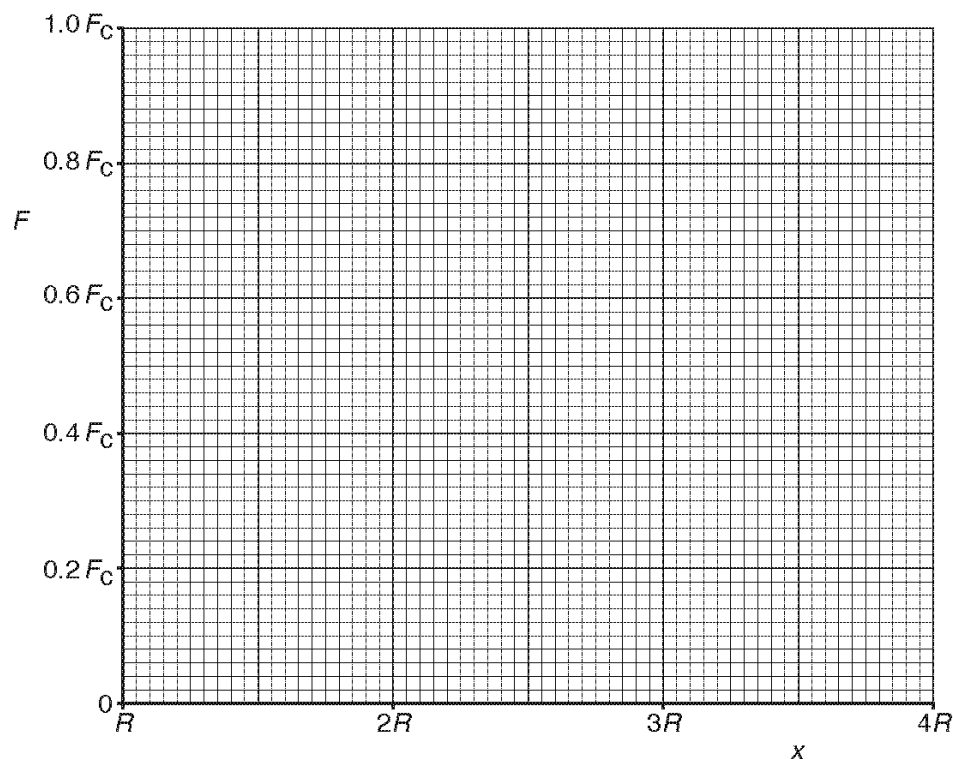


Fig. 5.1

[3]

- (b) Two coils C and D are placed close to one another, as shown in Fig. 5.2.

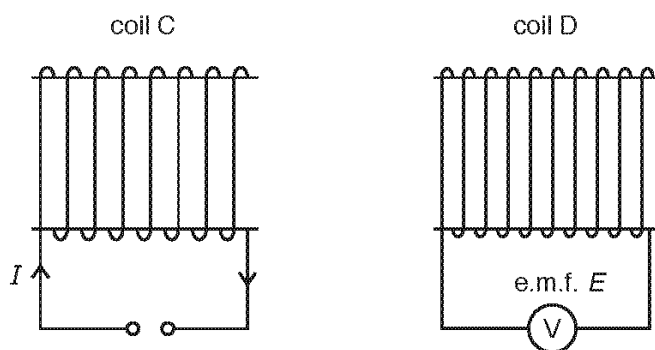


Fig. 5.2



The variation with time t of the current I in coil C is shown in Fig. 5.3.

On Fig. 5.4, show the variation with time t of the e.m.f. E induced in coil D for time $t = 0$ to time $t = t_5$.

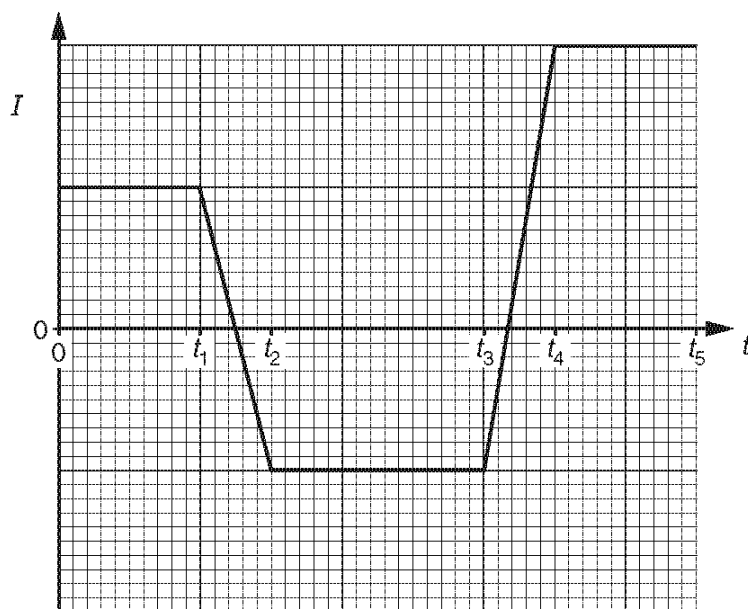


Fig. 5.3

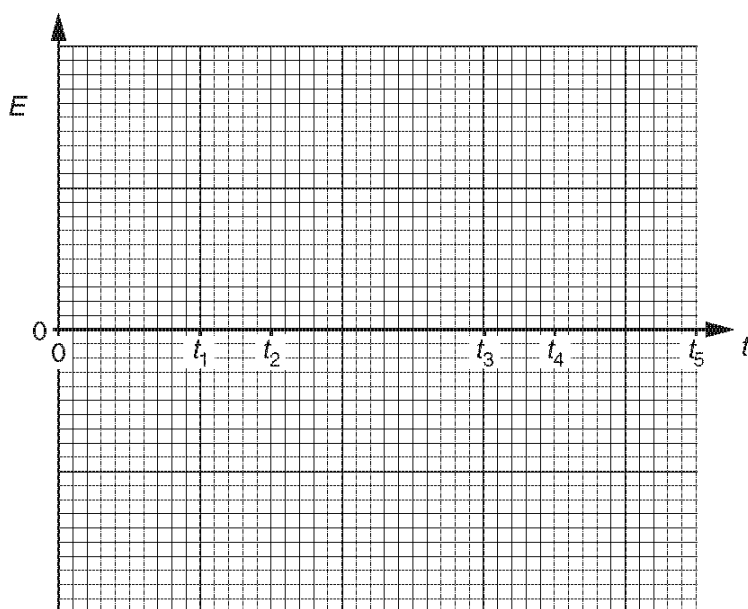
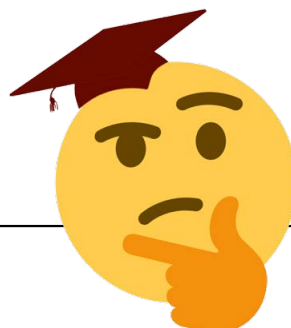


Fig. 5.4

[4]



4 - (9702/41_Winter_2017_Q8) - *Magnetic Fields, Electromagnetic Induction*

A thin slice of conducting material is placed normal to a uniform magnetic field of flux density B , as shown in Fig. 8.1.

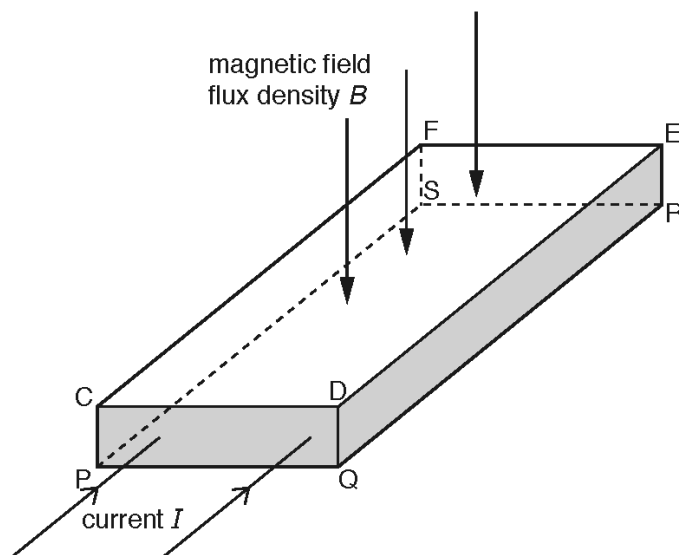


Fig. 8.1

The magnetic field is normal to face CDEF and to face PQRS.

A current I passes through the slice and is normal to the faces CDQP and FERS.

A potential difference, the Hall voltage V_H , is developed across the slice.

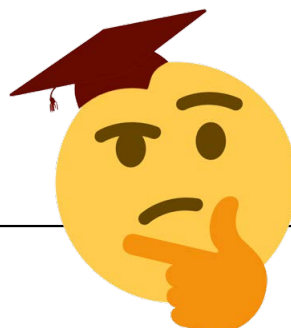
(a) State the faces between which the Hall voltage V_H is developed.

..... and [1]

(b) The current I is produced by charge carriers, each of charge $+q$ moving at speed v in the direction of the current. The number density of the charge carriers is n .

(i) Derive an expression relating the Hall voltage V_H to v , B and d , where d is one of the dimensions of the slice.

[3]



- (ii) Use your answer in (b)(i) and an expression for the current I in the slice to derive the expression

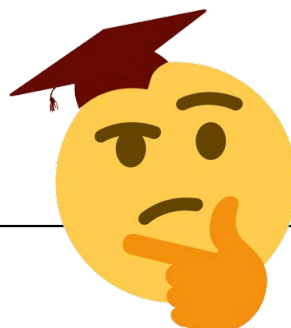
$$V_H = \frac{BI}{ntq}.$$

Explain your working.

[2]

- (c) Suggest why the Hall voltage is difficult to detect in a thin slice of copper.

.....
.....
..... [2]



5 - (9702/42_Winter_2017_Q8) - *Electromagnetic Induction*

A thin slice of conducting material is placed normal to a uniform magnetic field, as shown in Fig. 8.1.

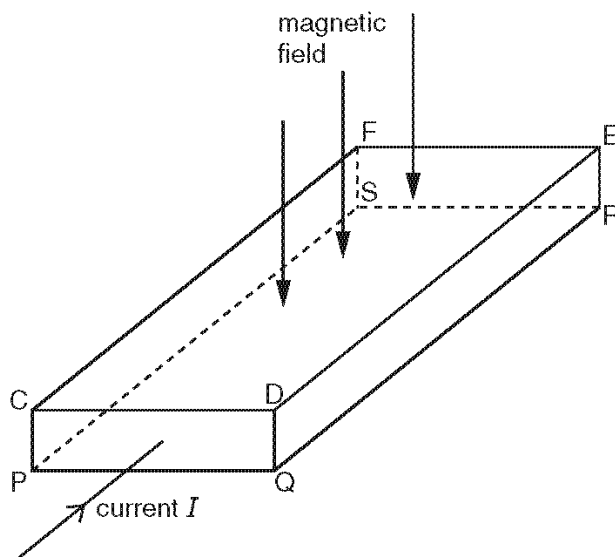


Fig. 8.1

The magnetic field is normal to face CDEF and to face PQRS.

The current I in the slice is normal to the faces CDQP and FERS.

A potential difference, the Hall voltage V_H , is developed across the slice.

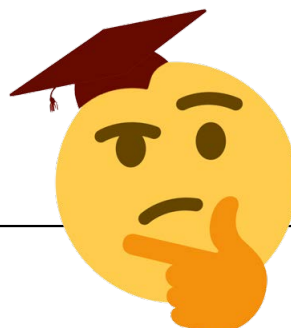
(a) (i) State the faces between which the Hall voltage V_H is developed.

..... and [1]

(ii) Explain why a constant voltage V_H is developed between the faces you have named in (i).

.....

 [4]



- (b) Two slices have similar dimensions. One slice is made of a metal and the other slice is made of a semiconductor material.

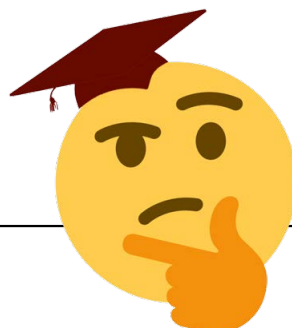
For the same values of magnetic flux density and current, state which slice, if either, will give rise to the larger Hall voltage. Explain your reasoning.

.....

.....

.....

.....[2]



6 - (9702/42_Summer_2018_Q9) - Electromagnetic Induction

- (a) State what is meant by the *magnetic flux linkage* of a coil.

.....

.....

.....

.....[3]

- (b) A coil of wire has 160 turns and diameter 2.4 cm. The coil is situated in a uniform magnetic field of flux density 7.5 mT, as shown in Fig. 9.1.

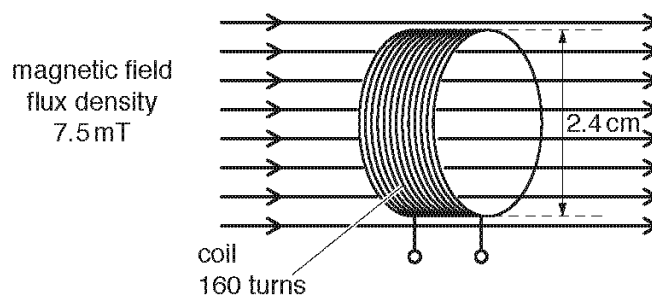


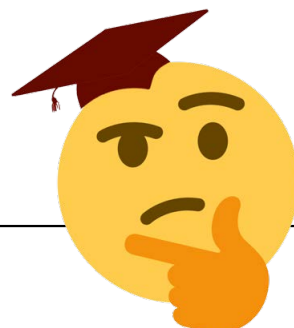
Fig. 9.1

The direction of the magnetic field is along the axis of the coil.

The magnetic flux density is reduced to zero in a time of 0.15 s.

Show that the average e.m.f. induced in the coil is 3.6 mV.

[2]



(c) The magnetic flux density B in the coil in (b) is now varied with time t as shown in Fig. 9.2.

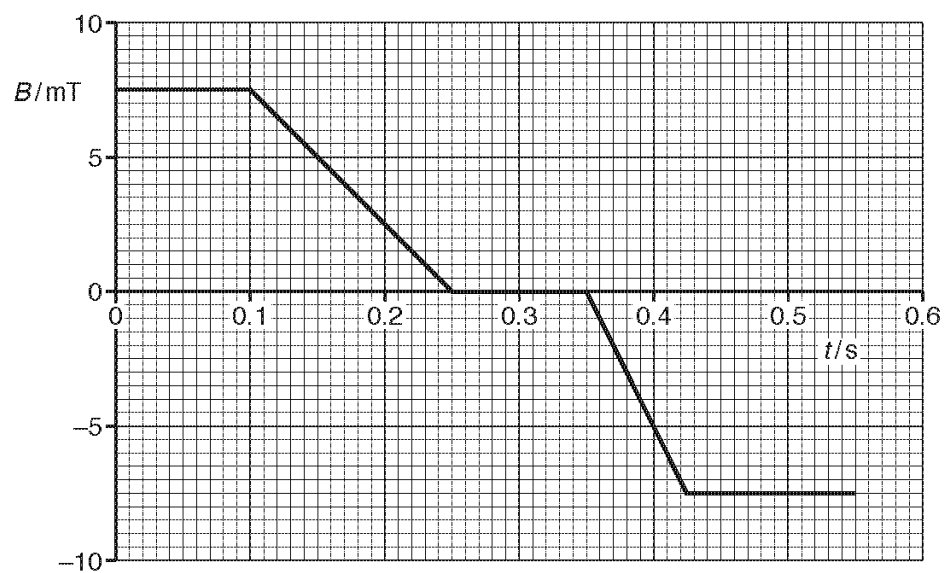


Fig. 9.2

Use data in (b) to show, on Fig. 9.3, the variation with time t of the e.m.f. E induced in the coil.

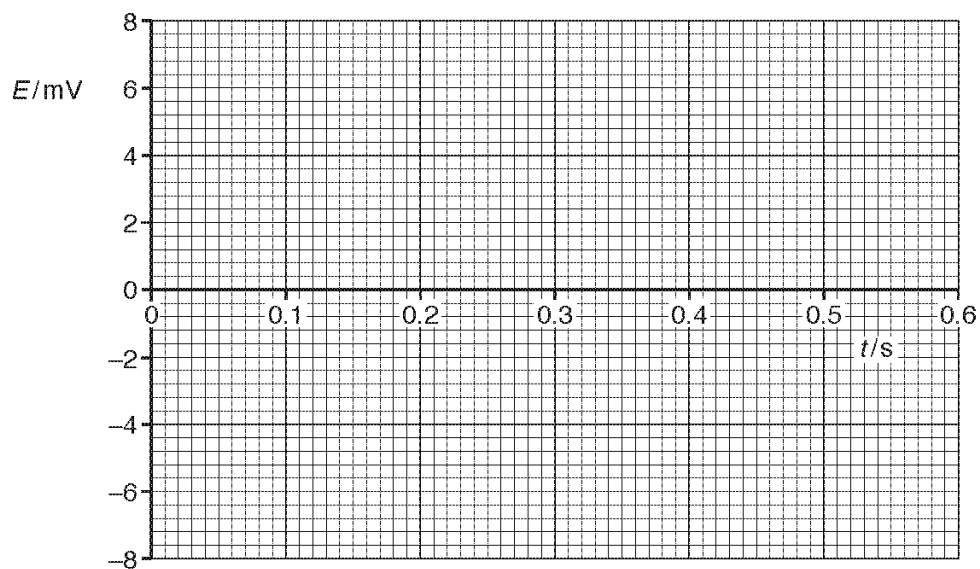
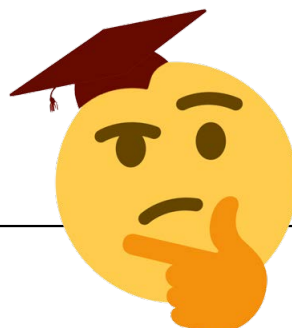


Fig. 9.3

[4]



7 - (9702/41_Summer_2018_Q10) - *Electromagnetic Induction*

(a) State Faraday's law of electromagnetic induction.

.....

.....

.....

.....[2]

(b) A coil of insulated wire is wound on to one end of a ferrous core and connected to a battery, as shown in Fig. 10.1.

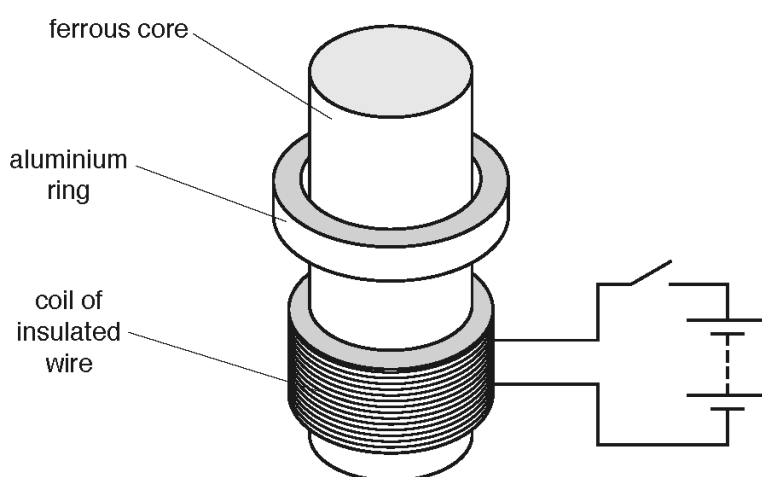


Fig. 10.1

An aluminium ring is placed on the core. The ring can move freely along the length of the core.

The switch is initially open.

Use Faraday's law and Lenz's law to explain why the aluminium ring jumps upwards when the switch is closed.

.....

.....

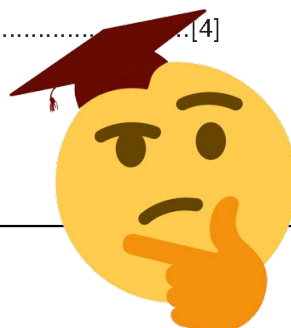
.....

.....

.....

.....

.....[4]



8 - (9702/41_Winter_2018_Q9) - *Electromagnetic Induction*

(a) State Faraday's law of electromagnetic induction.

.....

.....

.....[2]

(b) A solenoid S is wound on a soft-iron core, as shown in Fig. 9.1.

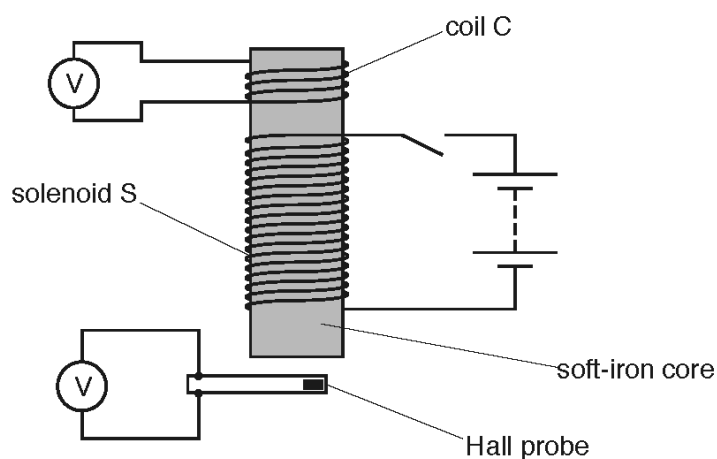


Fig. 9.1

A coil C having 120 turns of wire is wound on to one end of the core. The area of cross-section of coil C is 1.5 cm^2 .

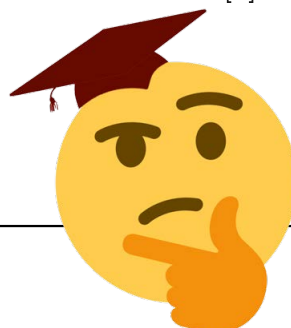
A Hall probe is close to the other end of the core.

When there is a constant current in solenoid S, the flux density in the core is 0.19 T . The reading on the voltmeter connected to the Hall probe is 0.20 V .

The current in solenoid S is now reversed in a time of 0.13 s at a constant rate.

- (i) Calculate the reading on the voltmeter connected to coil C during the time that the current is changing.

reading = V [2]

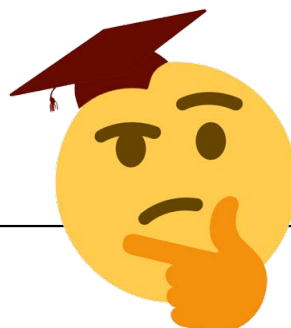


- (ii) Complete Fig. 9.2 for the voltmeter readings for the times before, during and after the direction of the current is reversed.

	before current changes	during current change when current is zero	after current changes
reading on voltmeter connected to coil C/V	.....	.....	.....
reading on voltmeter connected to Hall probe/V	0.20	.....	.....

Fig. 9.2

[4]



9 - (9702/42_Winter_2018_Q9) - Electromagnetic Induction

- (a) A Hall probe is placed near one end of a solenoid that has been wound on a soft-iron core, as shown in Fig. 9.1.

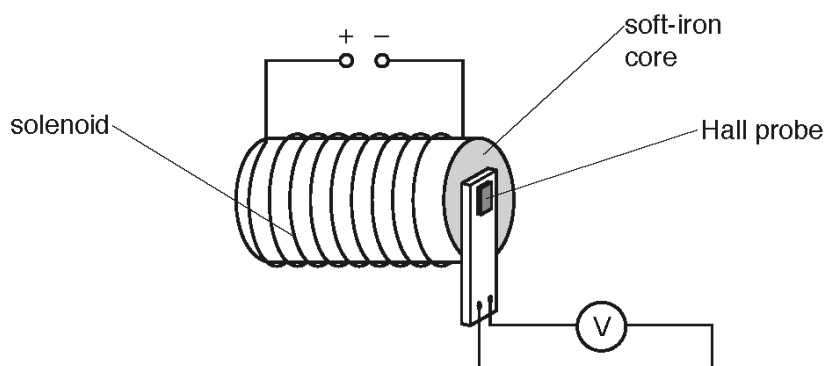


Fig. 9.1

The current in the solenoid is switched on.

The Hall probe is rotated until the reading V_H on the voltmeter is maximum.

The current in the solenoid is then varied, causing the magnetic flux density to change.

The variation with time t of the magnetic flux density B at the Hall probe is shown in Fig. 9.2.

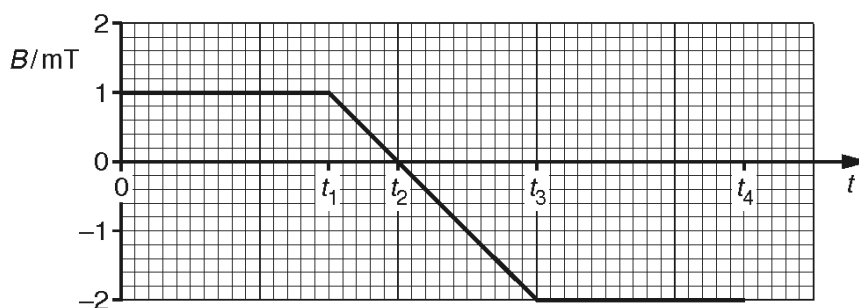


Fig. 9.2

At time $t = 0$, the Hall voltage is V_0 .

On Fig. 9.3, draw a line to show the variation with time t of the Hall voltage V_H for time $t = 0$ to time $t = t_4$.

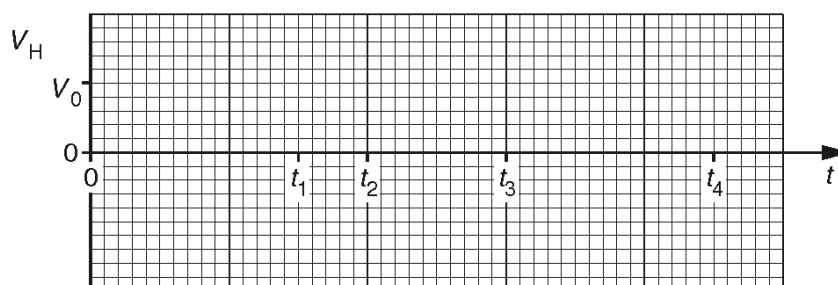
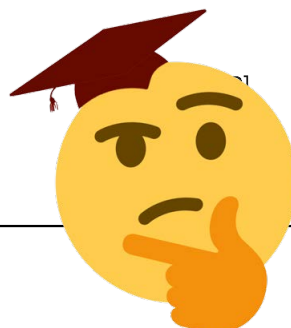


Fig. 9.3



- (b) The Hall probe in (a) is now replaced by a small coil of wire connected to a sensitive voltmeter, as shown in Fig. 9.4.

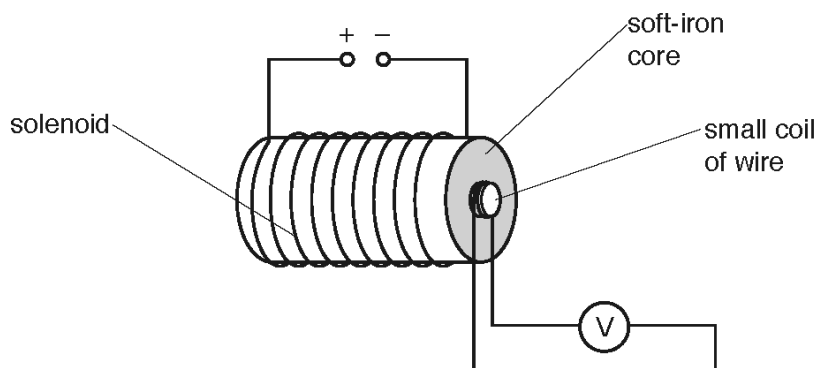


Fig. 9.4

The magnetic flux density, normal to the plane of the small coil, is again varied as shown in Fig. 9.2.

On Fig. 9.5, draw a line to show the variation with time t of the e.m.f. E induced in the small coil for time $t = 0$ to time $t = t_4$.

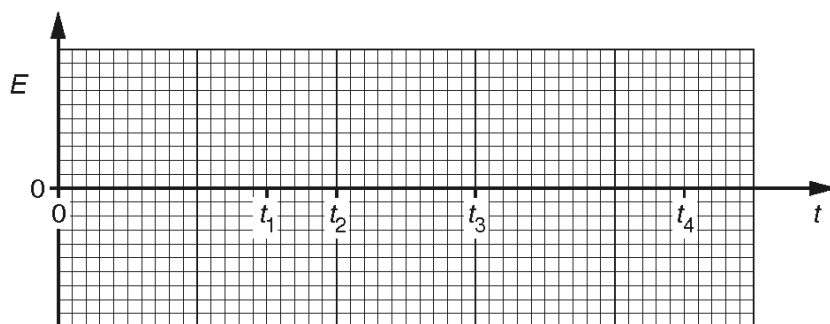
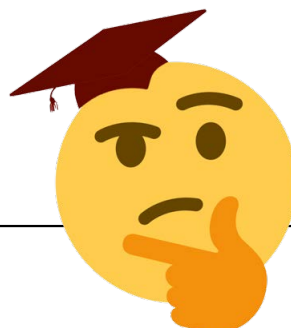


Fig. 9.5

[3]



10 - (9702/41_Summer_2019_Q8) - *Magnetic Fields, Electromagnetic Induction*

A solenoid is connected in series with a battery and a switch, as illustrated in Fig. 8.1.

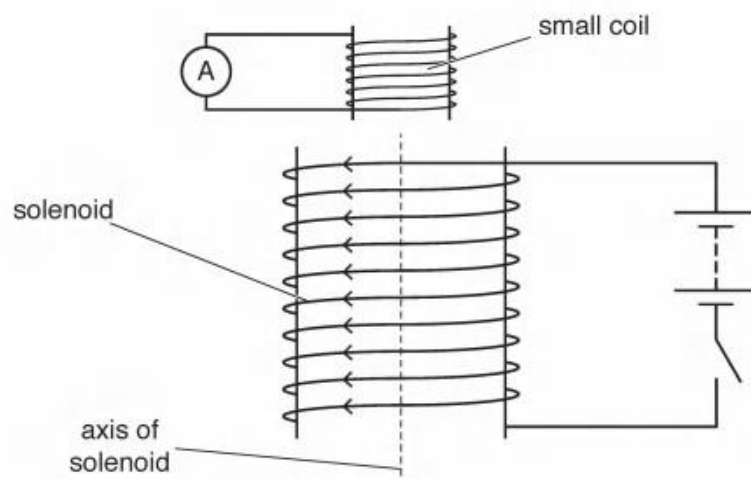


Fig. 8.1

A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid.

As the current in the solenoid is switched on, there is a changing magnetic field inside the solenoid.

(a) (i) State what is meant by a *magnetic field*.

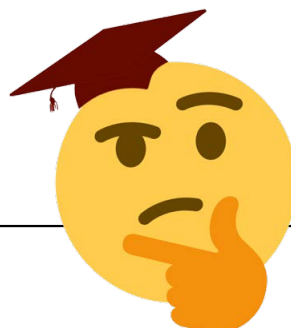
.....
..... [1]

(ii) On Fig. 8.1, draw an arrow on the axis of the solenoid to show the direction of the magnetic field inside the solenoid. Label this arrow P. [1]

(b) As the current in the solenoid is switched on, there is a current induced in the small coil. This induced current gives rise to a magnetic field in the small coil.

(i) State Lenz's law.

.....
.....
..... [2]



- (ii) Use Lenz's law to state and explain the direction of the magnetic field due to the induced current in the small coil. On Fig. 8.1, mark this direction with an arrow inside the small coil.

.....

.....

.....

..... [3]

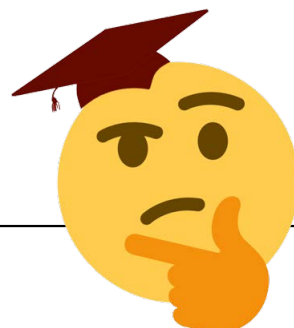
- (c) The small coil has an area of cross-section $7.0 \times 10^{-4} \text{ m}^2$ and contains 75 turns of wire.

A constant current in the solenoid produces a uniform magnetic flux of flux density 1.4 mT throughout the small coil.

The direction of the current in the solenoid is reversed in a time of 0.12 s.

Calculate the average e.m.f. induced in the small coil.

e.m.f. = V [3]



11 - (9702/42_Summer_2019_Q10) - *Electromagnetic Induction*

(a) State Faraday's law of electromagnetic induction.

.....
.....
.....[2]

(b) An ideal transformer is illustrated in Fig. 10.1.

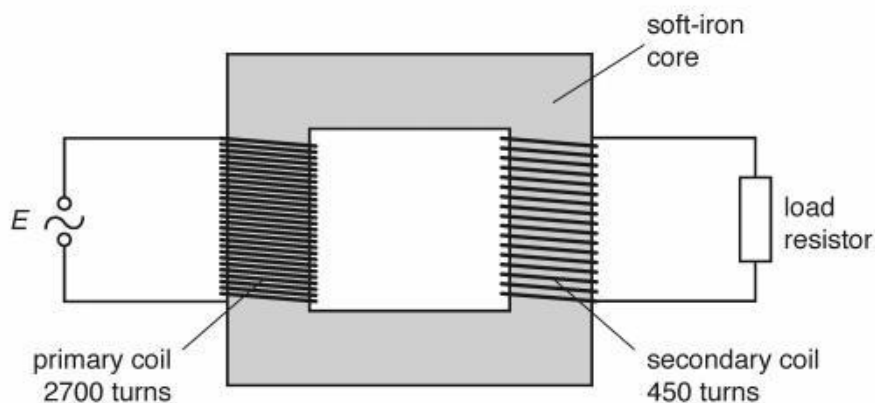
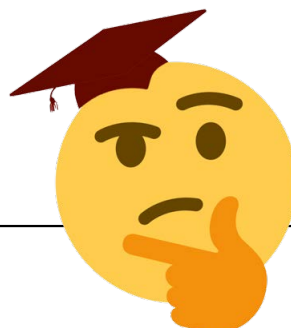


Fig. 10.1

Explain why, when there is an alternating current in the primary coil, there is a current in the load resistor.

.....
.....
.....
.....
.....[3]



(c) The primary coil in (b) has 2700 turns. The secondary coil has 450 turns.

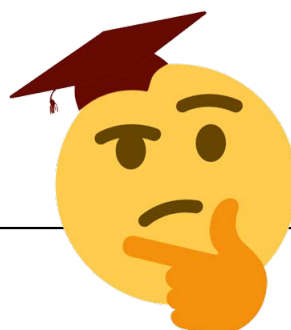
The e.m.f. E applied across the primary coil is given by the expression

$$E = 220 \sin(100\pi t)$$

where E is measured in volts and t is the time in seconds.

Calculate the root-mean-square (r.m.s.) e.m.f. induced in the secondary coil.

r.m.s. e.m.f. = V [3]



12 - (9702/42_Winter_2019_Q8) - Magnetic Fields, Electromagnetic Induction

Electrons enter a rectangular slice PQRSEFGH of a semiconductor material at right-angles to face PQFE, as shown in Fig. 8.1.

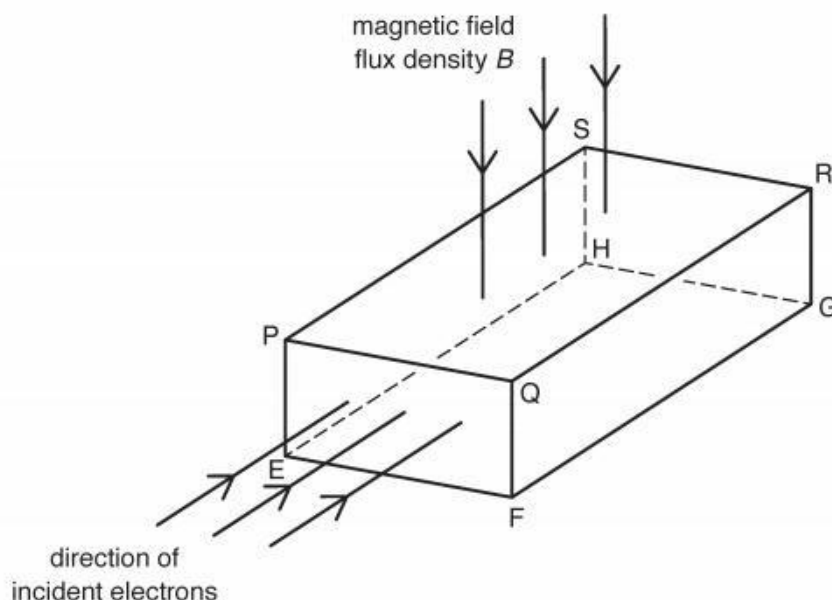


Fig. 8.1

A uniform magnetic field of flux density B is directed into the slice, at right-angles to face PQRS.

- (a) The electrons each have charge $-q$ and drift speed v in the slice.

State the magnitude and the direction of the force due to the magnetic field on each electron as it enters the slice.

.....

 [2]

- (b) The force on the electrons causes a voltage V_H to be established across the semiconductor slice given by the expression

$$V_H = \frac{BI}{ntq}$$

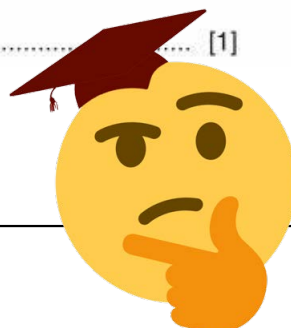
where I is the current in the slice.

- (i) State the two faces between which the voltage V_H is established.

face and face [1]

- (ii) Use letters from Fig. 8.1 to identify the distance t .

..... [1]



(c) Aluminium (${}^{27}_{13}\text{Al}$) has a density of 2.7 g cm^{-3} . Assume that there is one free electron available to carry charge per atom of aluminium.

(i) Show that the number of charge carriers per unit volume in aluminium is $6.0 \times 10^{28}\text{ m}^{-3}$.

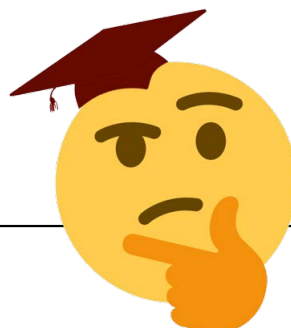
[2]

(ii) A sample of aluminium foil has a thickness of 0.090 mm . The current in the foil is 4.6 A .

A uniform magnetic field of flux density 0.15 T acts at right-angles to the foil.

Use the value in (i) to calculate the voltage V_H that is generated.

$V_H = \dots\dots\dots\text{ V}$ [2]



13 - (9702/42_Winter_2019_Q11) - *Electromagnetic Induction, Alternating Currents*

(a) State Faraday's law of electromagnetic induction.

.....

.....

..... [2]

(b) A solenoid S has a small coil C placed near to one of its ends, as shown in Fig. 11.1.

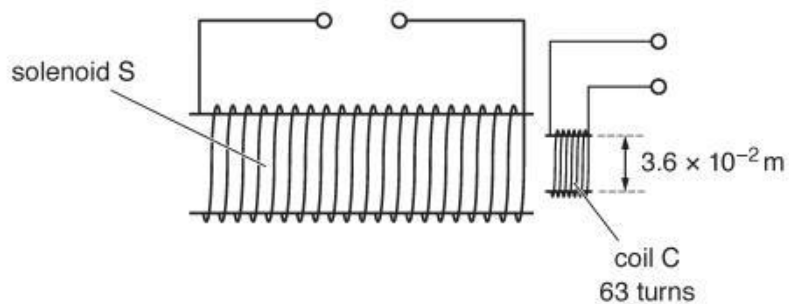
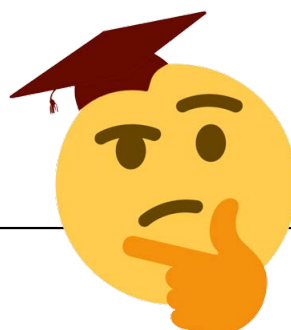


Fig. 11.1



The coil C has a circular cross-section of diameter $3.6 \times 10^{-2} \text{ m}$ and contains 63 turns of wire.

The solenoid S produces a uniform magnetic field of flux density B , in tesla, in the region of coil C given by the expression

$$B = 9.4 \times 10^{-4} I$$

where I is the current, in ampere, in the solenoid S.

The variation with time t of the current I in solenoid S is shown in Fig. 11.2.

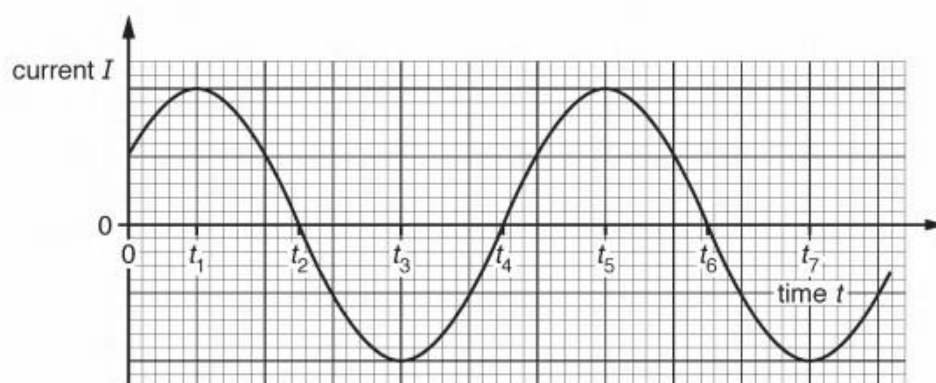


Fig. 11.2

State two times at which:

- (i) there is no electromotive force (e.m.f.) induced in coil C

time and time [1]

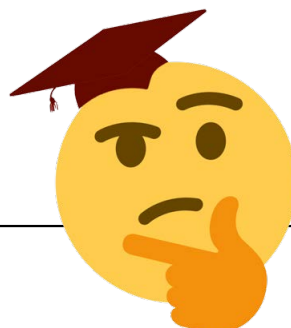
- (ii) the induced e.m.f. in coil C is a maximum but with opposite polarities.

time and time [1]

- (c) The alternating current in the solenoid S in (b) is replaced by a constant current of 5.0 A.

Calculate the average e.m.f. induced in coil C when the current in solenoid S is reversed in a time of 6.0 ms.

e.m.f. induced = V [3]



14 - (9702/41_Summer_2020_Q8) - *Magnetic Fields, Electromagnetic Induction*

(a) Define the *tesla*.

.....

.....

.....

..... [3]

(b) A magnet produces a uniform magnetic field of flux density B in the space between its poles.

A rigid copper wire carrying a current is balanced on a pivot. Part PQLM of the wire is between the poles of the magnet, as illustrated in Fig. 8.1.

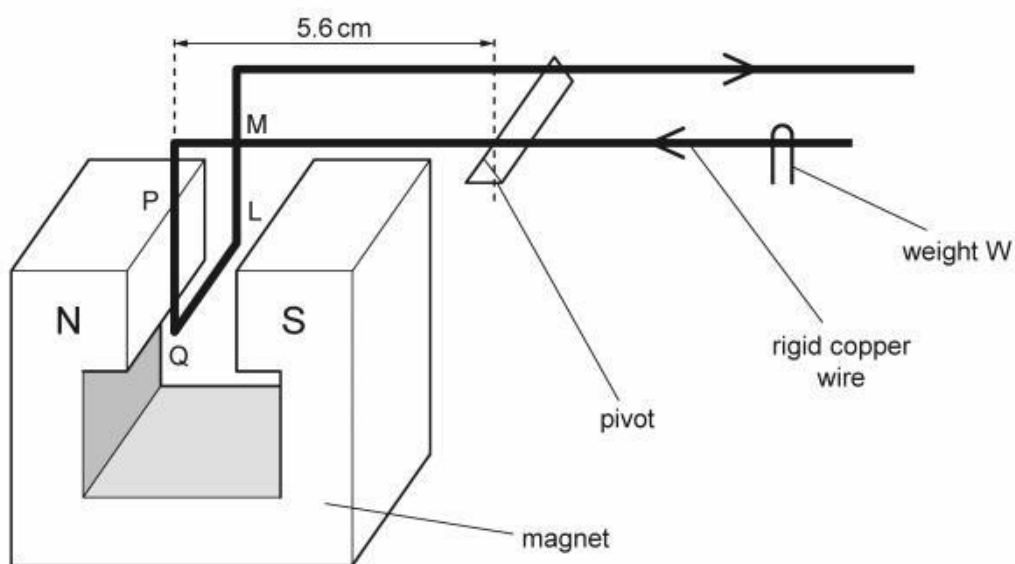
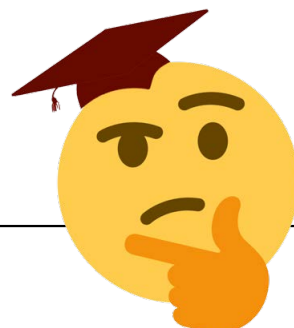


Fig. 8.1 (not to scale)

The wire is balanced horizontally by means of a small weight W .



The section of the wire between the poles of the magnet is shown in Fig. 8.2.

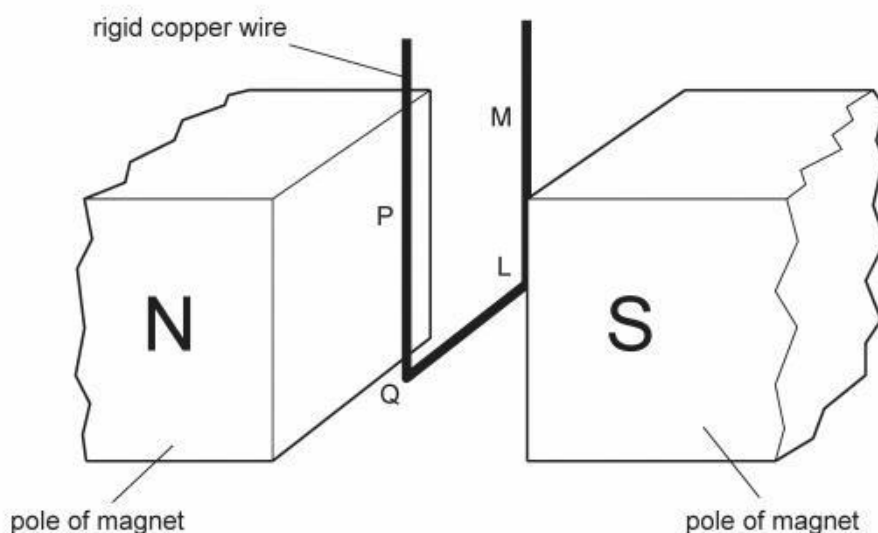


Fig. 8.2 (not to scale)

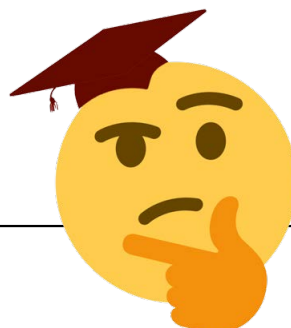
Explain why:

- (i) section QL of the wire gives rise to a moment about the pivot

.....
.....
.....
..... [3]

- (ii) sections PQ and LM of the wire do not affect the equilibrium of the wire.

.....
.....
.....
..... [2]



- (c) Section QL of the wire has length 0.85 cm.

The perpendicular distance of QL from the pivot is 5.6 cm.

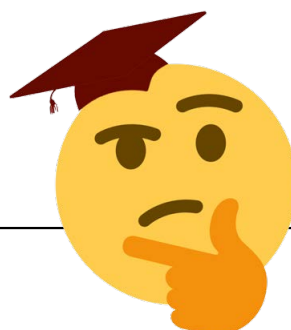
When the current in the wire is changed by 1.2 A, W is moved a distance of 2.6 cm along the wire in order to restore equilibrium. The mass of W is 1.3×10^{-4} kg.

- (i) Show that the change in moment of W about the pivot is 3.3×10^{-5} N m.

[2]

- (ii) Use the information in (i) to determine the magnetic flux density B between the poles of the magnet.

$B = \dots\dots\dots$ T [3]



15 - (9702/41_Summer_2020_Q9) - *Electromagnetic Induction*

- (a) A coil of wire is situated in a uniform magnetic field of flux density B . The coil has diameter 3.6 cm and consists of 350 turns of wire, as illustrated in Fig. 9.1.

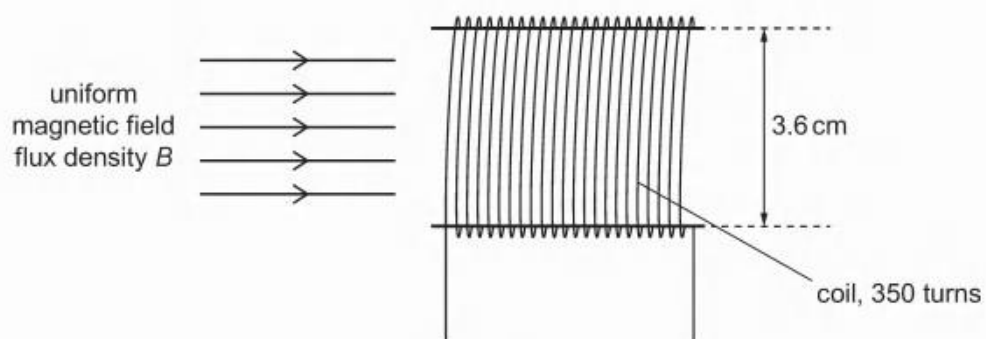
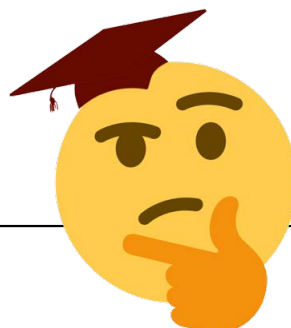


Fig. 9.1



The variation with time t of B is shown in Fig. 9.2.

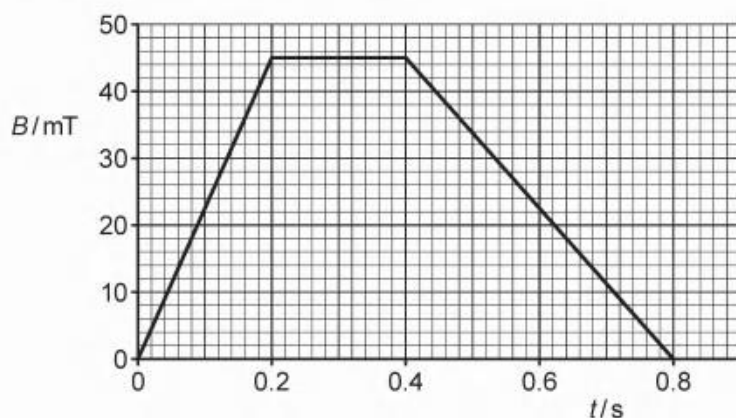


Fig. 9.2

- (i) Show that, for the time $t = 0$ to time $t = 0.20$ s, the electromotive force (e.m.f.) induced in the coil is 0.080 V.

[2]

- (ii) On the axes of Fig. 9.3, show the variation with time t of the induced e.m.f. E for time $t = 0$ to time $t = 0.80$ s.

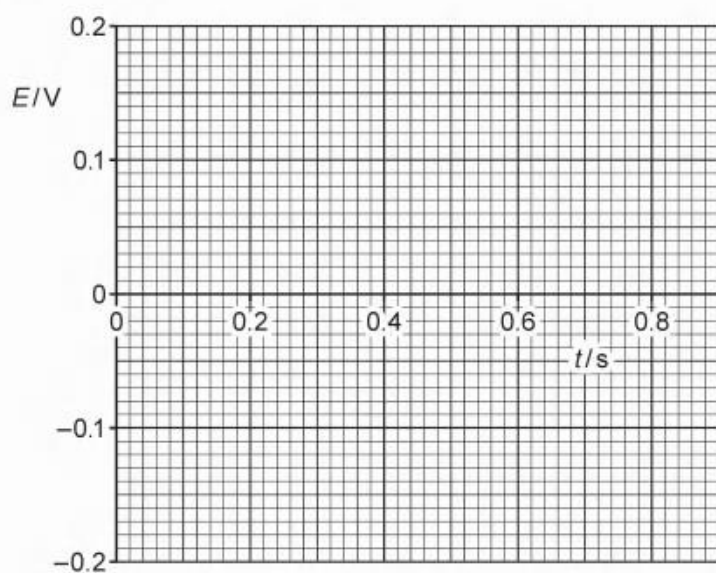
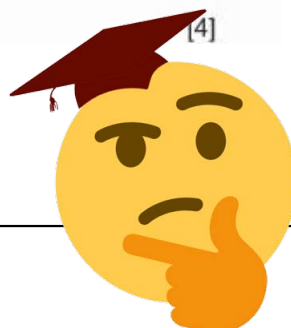


Fig. 9.3

[4]



- (b) A bar magnet is held a small distance above the surface of an aluminium disc by means of a rod, as illustrated in Fig. 9.4.

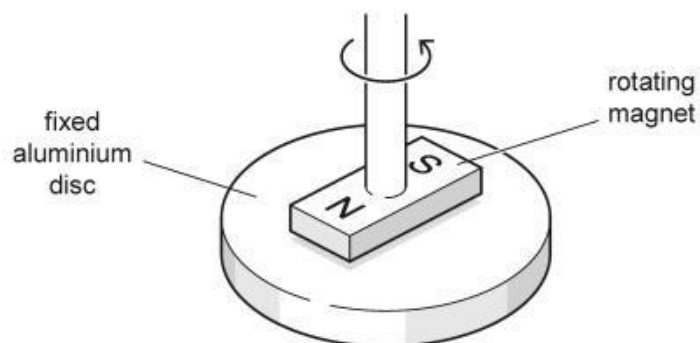


Fig. 9.4

The aluminium disc is supported horizontally and held stationary.

The magnet is rotated about a vertical axis at constant speed.

Use laws of electromagnetic induction to explain why there is a torque acting on the aluminium disc.

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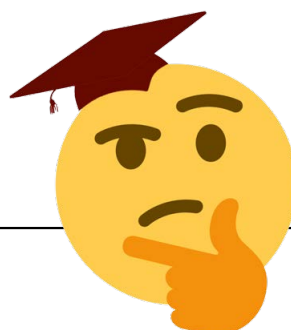
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.....

..... [4]



16 - (9702/42_Summer_2020_Q10) - *Electromagnetic Induction*

(a) State Faraday's law of electromagnetic induction.

.....

.....

..... [2]

(b) A simple iron-cored transformer is illustrated in Fig. 10.1.

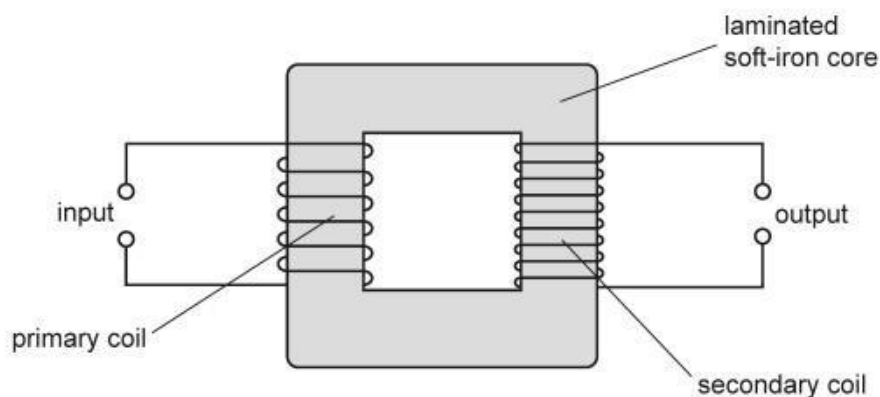


Fig. 10.1

(i) State **one** function of a transformer.

.....

..... [1]

(ii) A sinusoidal alternating current in the primary coil gives rise to a varying magnetic flux linking the secondary coil.

Use Faraday's law to explain why the output from the transformer is an electromotive force (e.m.f.) that is alternating.

.....

.....

.....

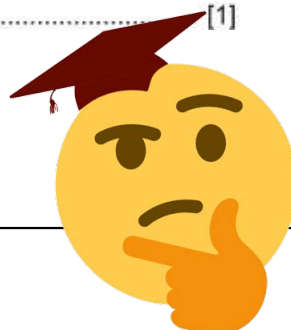
.....

..... [3]

(iii) State why the soft-iron core of the transformer is laminated.

.....

..... [1]



17 - (9702/41_Winter_2020_Q9) - Electromagnetic Induction

(a) Define *magnetic flux*.

.....

.....

..... [2]

(b) A simple transformer consists of two coils of wire wound on a soft-iron core, as illustrated in Fig. 9.1.

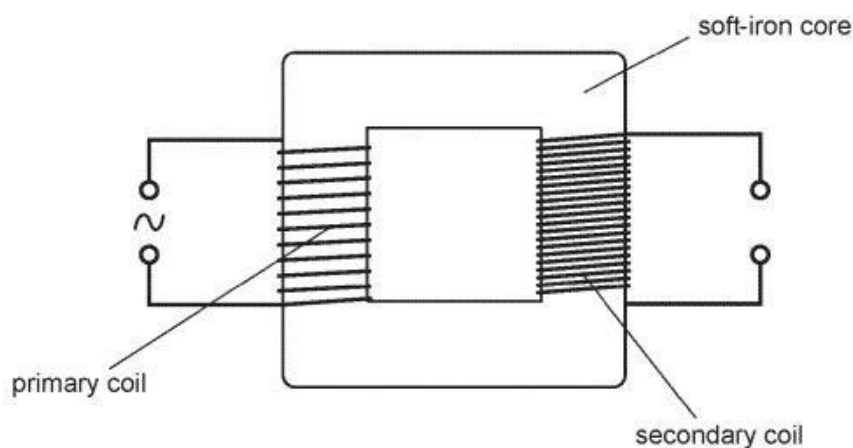


Fig. 9.1

There is a sinusoidal current in the primary coil.

Explain:

(i) how this current gives rise to an induced electromotive force (e.m.f.) in the secondary coil

.....

.....

.....

..... [3]

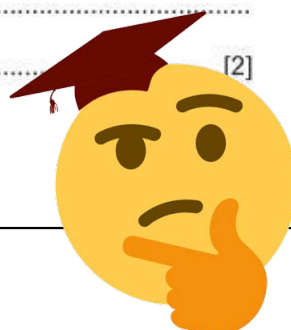
(ii) why the e.m.f. induced in the secondary coil is not constant.

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.....

.....

..... [2]



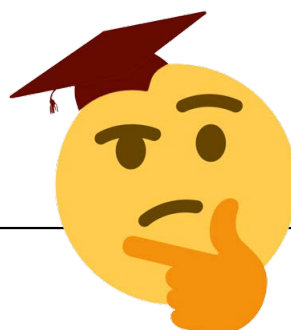
(c) Explain why the soft-iron core in (b) is laminated.

.....

.....

..... [2]

[Total: 9]



18 - (9702/42_Winter_2020_Q9) - *Electromagnetic Induction, Alternating Currents*

- (a) A small coil is placed close to one end of a solenoid connected to a power supply. The plane of the small coil is normal to the axis of the solenoid, as illustrated in Fig. 9.1.

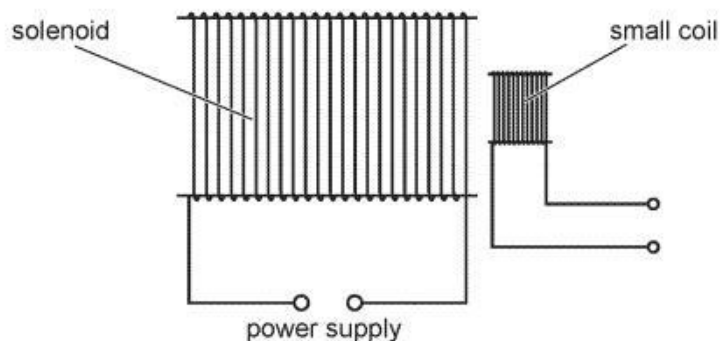
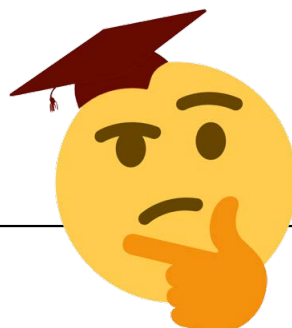


Fig. 9.1



The power supply causes the current I in the solenoid to vary with time t as shown in Fig. 9.2.

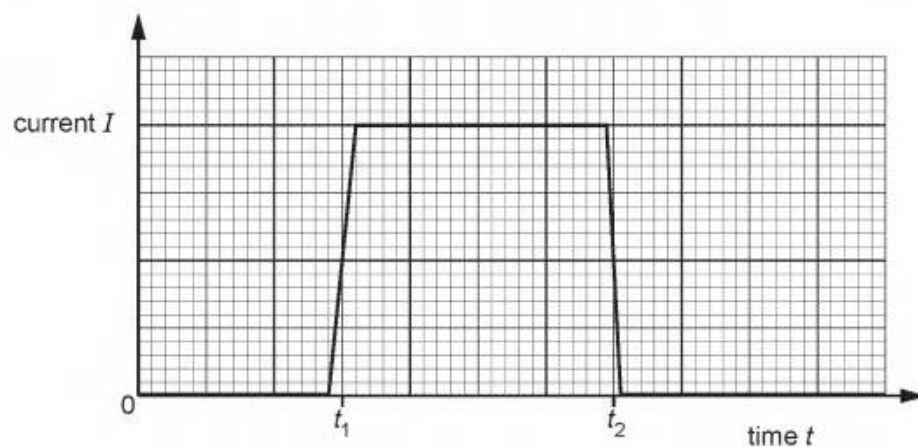


Fig. 9.2

- (i) State Faraday's law of electromagnetic induction.

.....
.....
..... [2]

- (ii) On the axes of Fig. 9.3, sketch a graph to show the variation with time t of the electromotive force (e.m.f.) induced in the small coil.

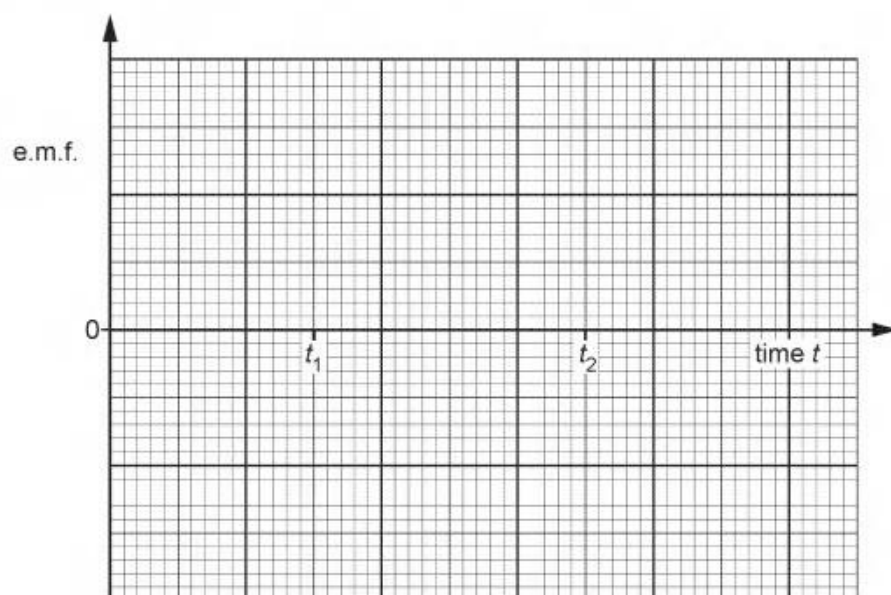
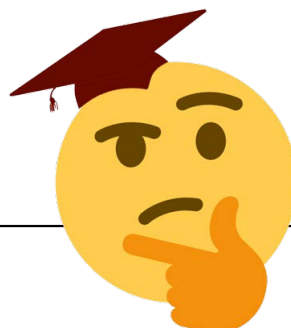


Fig. 9.3

[4]



(b) The small coil in (a) is now replaced by a Hall probe.

The Hall probe is positioned so that the reading for the probe is a maximum.

The current I in the solenoid varies again as shown in Fig. 9.2.

On the axes of Fig. 9.4, sketch a graph to show the variation with time t of the reading V_H of the probe.

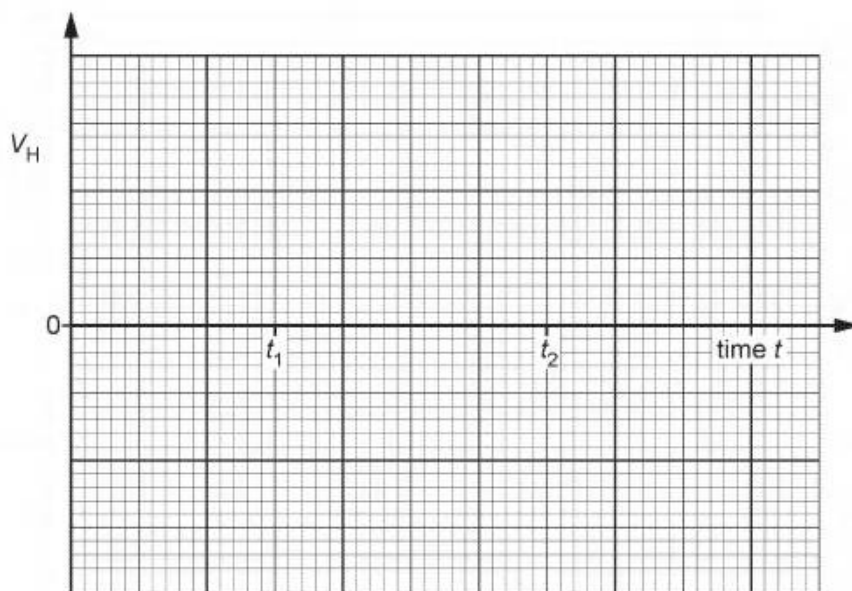
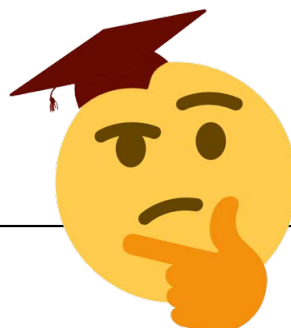


Fig. 9.4

[2]

[Total: 8]



19 - (9702/42_Summer_2021_Q9) - *Magnetic Fields, Electromagnetic Induction*

(a) State **two** situations in which a charged particle in a magnetic field does **not** experience a force.

1.

.....

2.

.....

[2]

(b) A loosely coiled metal spring is suspended from a fixed point, as shown in Fig. 9.1.

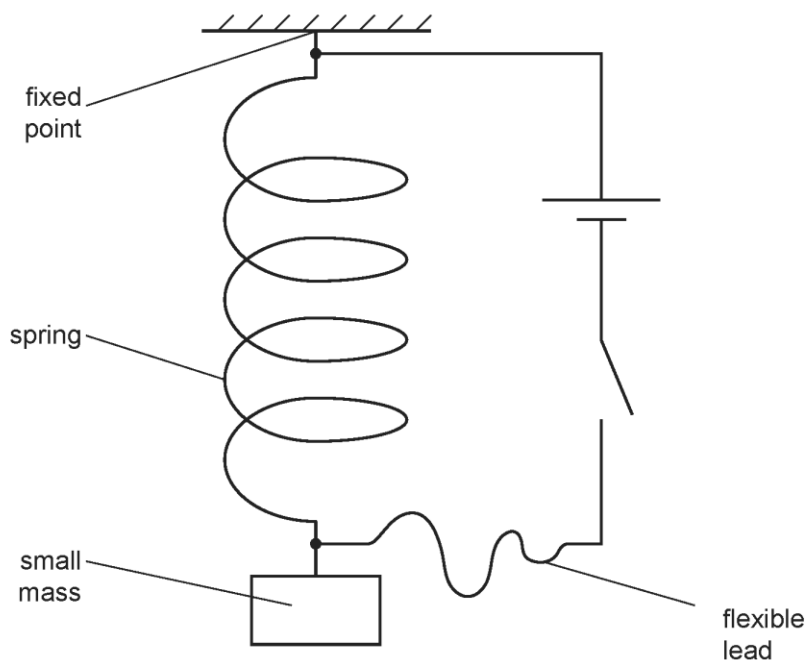
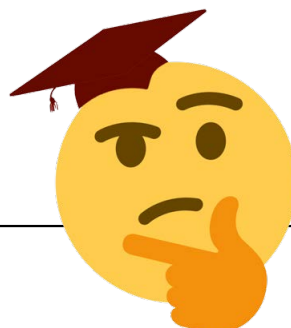


Fig. 9.1

Electrical connections are made to the ends of the spring by means of a flexible lead.

The length of the spring is measured before the switch is closed and then again after the switch is closed.



When the switch is closed, a magnetic field is set up around each coil of the spring.

By reference to these magnetic fields, explain why there is a change in length of the spring. State whether the spring extends or contracts.

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..... [4]

- (c) With the switch in (b) closed, the small mass on the free end of the spring is now made to oscillate vertically.

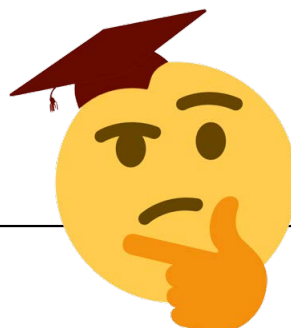
Use the principles of electromagnetic induction to explain why small fluctuations in the current in the spring are found to occur.

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..... [3]



20 - (9702/41_Summer_2021_Q10) - *Electromagnetic Induction*

) (a) State Lenz's law.

.....

.....

..... [2]

(b) A metal ring is suspended from a fixed point P by means of a thread, as shown in Fig. 10.1.

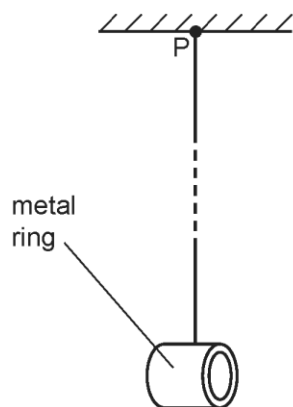


Fig. 10.1

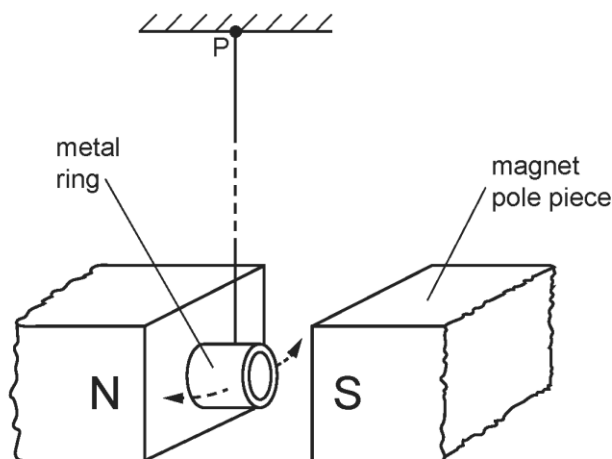


Fig. 10.2

The ring is displaced a distance d and then released. The ring completes many oscillations before coming to rest.

The poles of a magnet are now placed near to the ring so that the ring hangs midway between the poles of the magnet, as shown in Fig. 10.2.

The ring is again displaced a distance d and then released.
Explain why the ring completes fewer oscillations before coming to rest.

.....

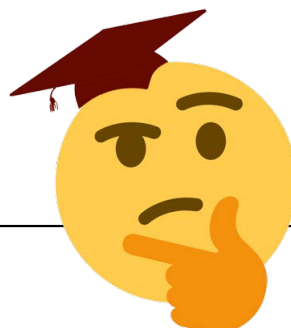
.....

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.....

..... [4]



(c) The ring in (b) is now cut so that it has the shape shown in Fig. 10.3.



Fig. 10.3

Explain why, when the procedure in (b) is repeated, the cut ring completes more oscillations than the complete ring when oscillating between the poles of the magnet.

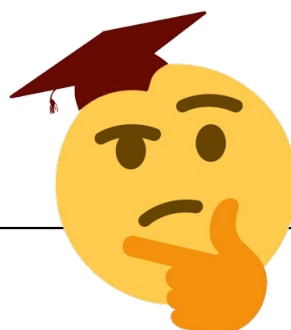
.....

.....

.....

.....

..... [3]



21 - (9702/41_Winter_2021_Q9) - Electromagnetic Induction

- (a) State, by reference to the power dissipated in a resistor, what is meant by the *root-mean-square (r.m.s.)* value of an alternating voltage.

.....

.....

.....

..... [2]

- (b) A coil is rotating freely, on frictionless bearings, at constant speed in a uniform magnetic field. This rotation causes an induced alternating electromotive force (e.m.f.) across the open terminals of the coil. The induced e.m.f. has r.m.s. value 12 V and frequency 50 Hz.

The speed of rotation of the coil is now doubled.

- (i) State and explain, with reference to the principles of electromagnetic induction, the effect of the increased speed of rotation on the r.m.s. value of the induced e.m.f.

.....

.....

.....

..... [2]

- (ii) On Fig. 9.1, sketch the variation with time t of the induced e.m.f. E across the terminals of the coil at the **increased** speed of rotation. Your line should extend from time $t = 0$ to time $t = 20$ ms. Assume that $E = 0$ when $t = 0$.

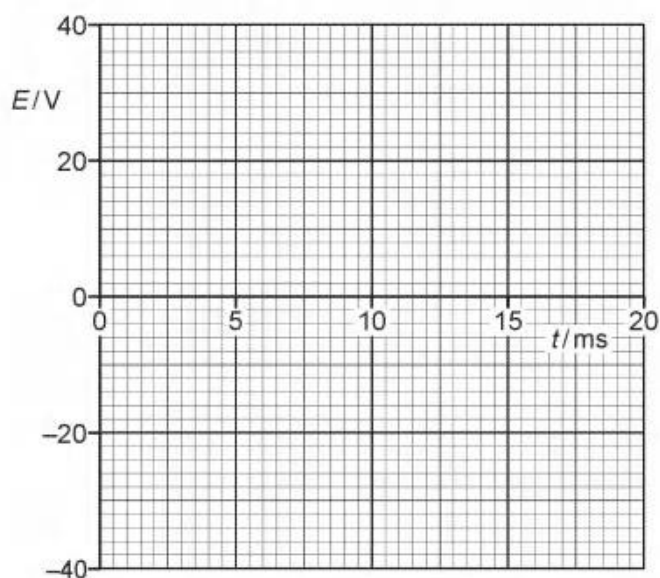
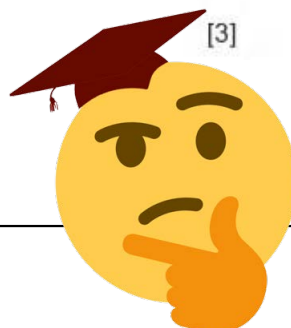


Fig. 9.1

[3]



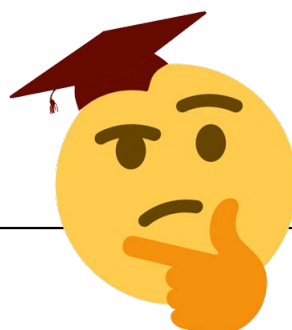
- (c) State and explain the effect on the motion of the coil in (b) of connecting a load resistor across its terminals.

.....

.....

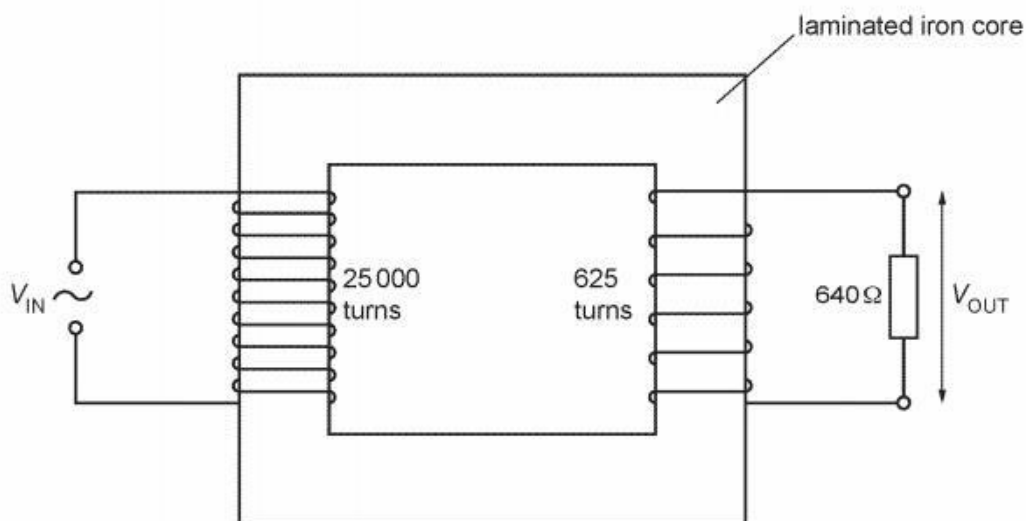
.....

..... [2]



22 - (9702/42_Winter_2021_Q10) - Electromagnetic Induction

Fig. 10.1 shows a simple laminated iron-cored transformer consisting of a primary coil of 25 000 turns and a secondary coil of 625 turns.

**Fig. 10.1**

The output potential difference (p.d.) V_{OUT} is applied to a load resistor of resistance $640\ \Omega$.

(a) (i) State the function of the iron core.

.....
..... [1]

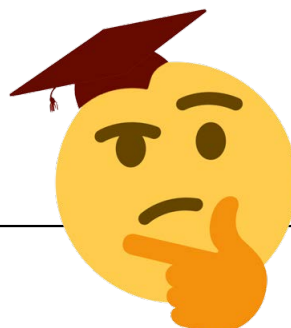
(ii) Explain why the iron core is laminated.

.....
.....
..... [2]

(b) The input p.d. V_{IN} is a sinusoidal alternating voltage of peak value 12 kV and period 40 ms.

(i) Calculate the maximum value of V_{OUT} .

maximum $V_{OUT} = \dots\dots\dots$ V [1]



- (ii) Calculate the root-mean-square (r.m.s.) current in the load resistor.

r.m.s. current = A [1]

- (iii) On Fig. 10.2, sketch the variation with time t of the power P dissipated in the load resistor for time $t = 0$ to $t = 40$ ms. Assume that $P = 0$ when $t = 0$.

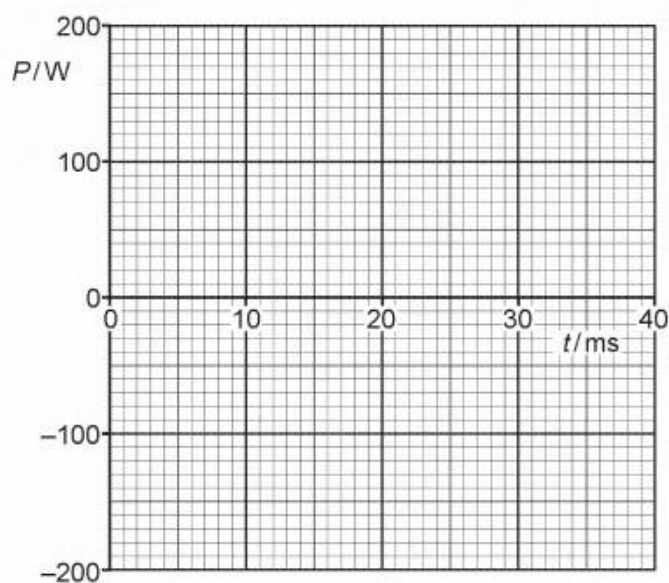
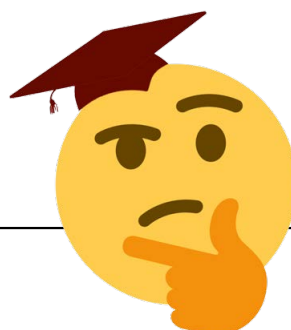


Fig. 10.2

[3]

- (c) Explain, with reference to Fig. 10.2, why the mean power in the load resistor is 70 W.

.....
.....
.....
..... [2]



23 - (9702/43_Winter_2021_Q10) - *Electromagnetic Induction*

(a) State an experimental phenomenon that provides evidence for:

(i) the particulate nature of electromagnetic radiation

..... [1]

(ii) the wave nature of matter.

..... [1]

(b) A particle of matter moves with momentum p .

(i) State the equation that gives the effective wavelength λ of the particle. State the name of any other symbols used.

[2]

(ii) State the name given to the wavelength of the moving particle.

..... [1]

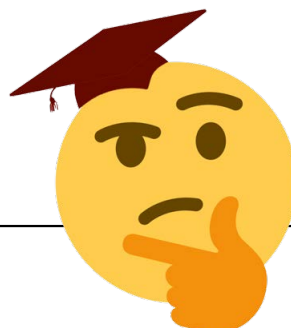
(c) Electrons are accelerated from rest through a potential difference (p.d.) of 4.8 kV.

(i) Show that the final speed of the electrons is $4.1 \times 10^7 \text{ m s}^{-1}$.

[2]

(ii) Calculate the effective wavelength of a beam of electrons moving at the speed in (c)(i).

wavelength = m [2]



24 - (9702/42_Winter_2022_Q8) - Electromagnetic Induction

(a) State Lenz's law of electromagnetic induction.

.....
.....
..... [2]

(b) Two coils of insulated wire are wound on an iron bar, as shown in Fig. 8.1.

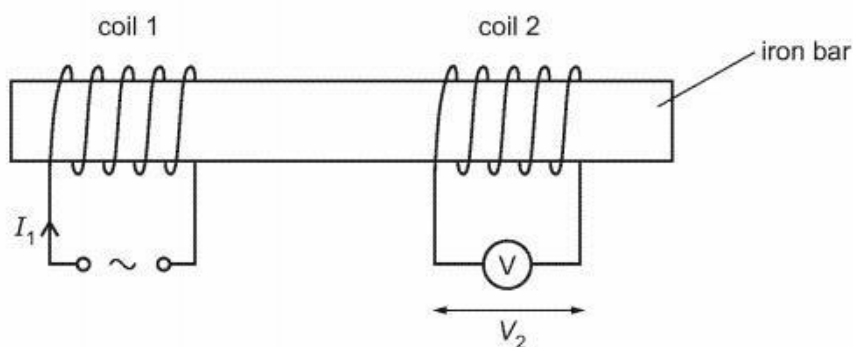


Fig. 8.1

There is a current I_1 in coil 1 that varies with time t as shown in Fig. 8.2.

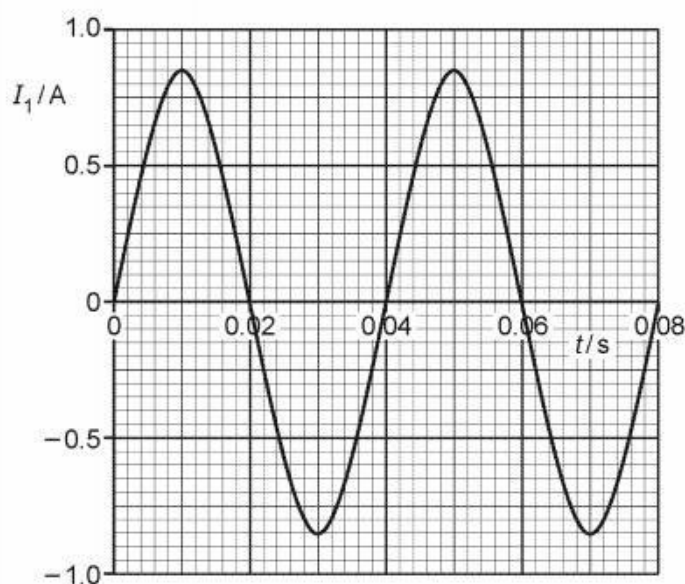
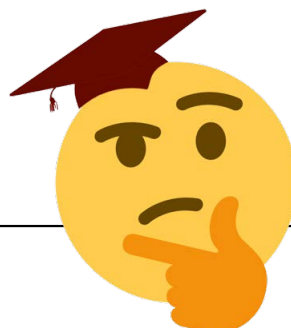


Fig. 8.2



- (i) The variation with t of I_1 can be represented by the equation

$$I_1 = X \sin Yt$$

where X and Y are constants.

Use Fig. 8.2 to determine the values of X and Y . Give units with your answers.

$X = \dots\dots\dots$ unit $\dots\dots\dots$

$Y = \dots\dots\dots$ unit $\dots\dots\dots$
[3]

- (ii) The current in coil 1 gives rise to a magnetic field in the iron bar.
Assume that the flux density of this magnetic field is proportional to I_1 .

An alternating electromotive force (e.m.f.) is induced across coil 2. The p.d. across coil 2 is measured using the voltmeter and has a root-mean-square (r.m.s.) value of 4.6 V.

On Fig. 8.3, sketch a line to show the variation with t of V_2 between $t = 0$ and $t = 0.08$ s.

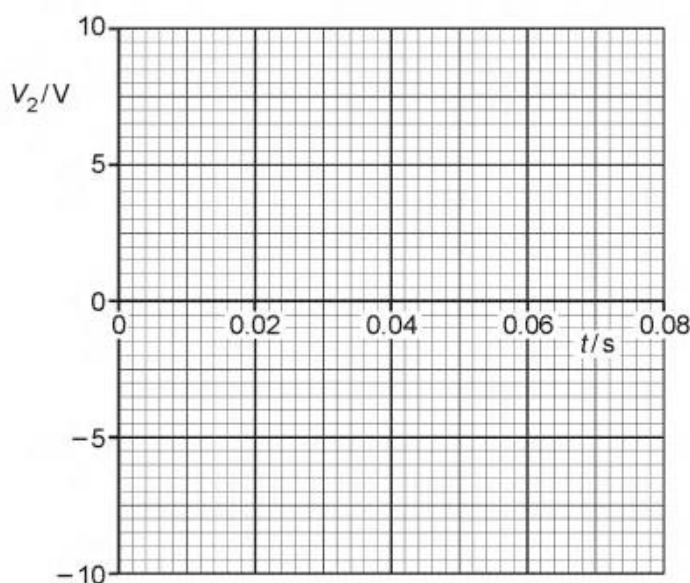
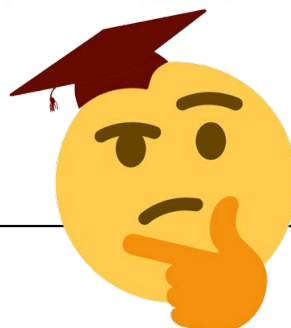


Fig. 8.3

[3]

- (iii) Use the laws of electromagnetic induction to explain the shape of your line in (b)(ii).

.....
.....
.....
..... [3]



25 - (9702/41_Summer_2023_Q6) - *Magnetic Fields, Electromagnetic Induction*

- (a) State what is meant by a magnetic field.

.....

.....

..... [2]

- (b) A long, straight wire P carries a current into the page, as shown in Fig. 6.1.

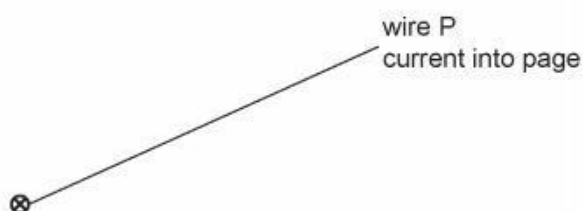


Fig. 6.1

On Fig. 6.1, draw four field lines to represent the magnetic field around wire P due to the current in the wire. [3]

- (c) A second long, straight wire Q, carrying a current of 5.0 A out of the page, is placed parallel to wire P, as shown in Fig. 6.2.

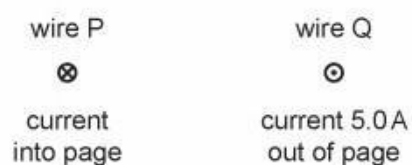
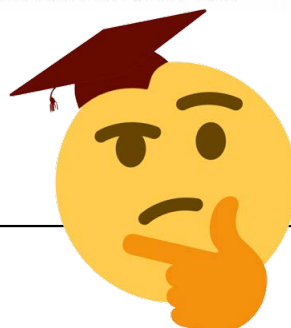


Fig. 6.2

The flux density of the magnetic field at wire Q due to the current in wire P is 2.6 mT.

- (i) Calculate the magnetic force per unit length exerted on wire Q by wire P.

force per unit length = N m^{-1} [2]



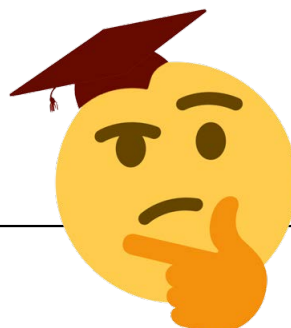
- (ii) State the direction of the force exerted on wire Q by wire P.

..... [1]

- (iii) The flux density of the magnetic field at wire P due to the current in wire Q is 1.5 mT .

Determine the magnitude of the current in wire P. Explain your reasoning.

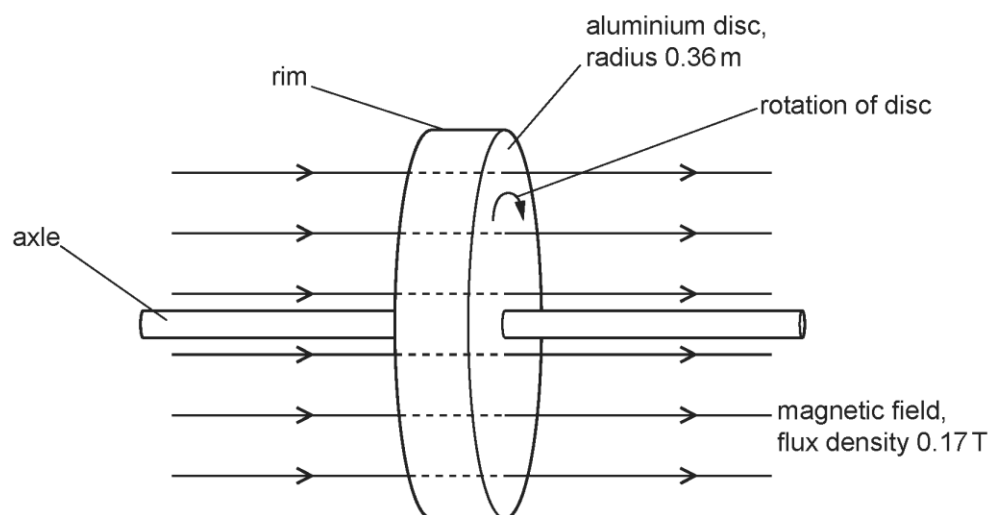
current = A [2]



26 - (9702/42_Summer_2023_Q6) - *Electromagnetic Induction*

A heavy aluminium disc has a radius of 0.36 m. The disc rotates with the wheels of a vehicle and forms part of an electromagnetic braking system on the vehicle.

In order to activate the braking system, a uniform magnetic field of flux density 0.17 T is switched on. This magnetic field is perpendicular to the plane of rotation of the disc, as shown in Fig. 6.1.

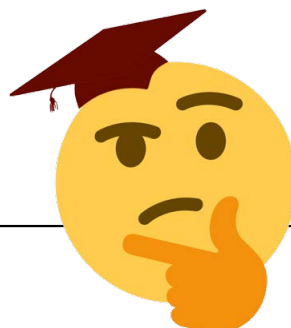
**Fig. 6.1**

- (a) (i) Define magnetic flux.

.....
.....
..... [2]

- (ii) Calculate the magnetic flux through the disc. Give a unit with your answer.

magnetic flux = unit [2]



- (b) The disc is rotating at a rate of 25 revolutions per second.

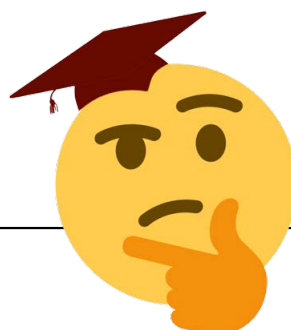
Calculate the magnitude of the electromotive force (e.m.f.) induced between the axle and the rim of the disc.

e.m.f. = V [3]

- (c) The axle and the rim are connected into an external circuit that enables the energy of the rotation of the disc to be stored for future use. The direction of rotation is shown in Fig. 6.1.

Use Lenz's law of electromagnetic induction to determine whether the current in the disc is from the rim to the axle or from the axle to the rim. Explain your reasoning.

.....
.....
.....
.....
..... [3]



27 - (9702/41_Winter_2023_Q6) - *Electromagnetic Induction*

(a) Define magnetic flux density.

.....
.....
.....
..... [2]

(b) Electrons are moving in a vacuum with speed $1.7 \times 10^7 \text{ m s}^{-1}$. The electrons enter a uniform magnetic field of flux density 4.8 mT . Fig. 6.1 shows the path of the electrons.

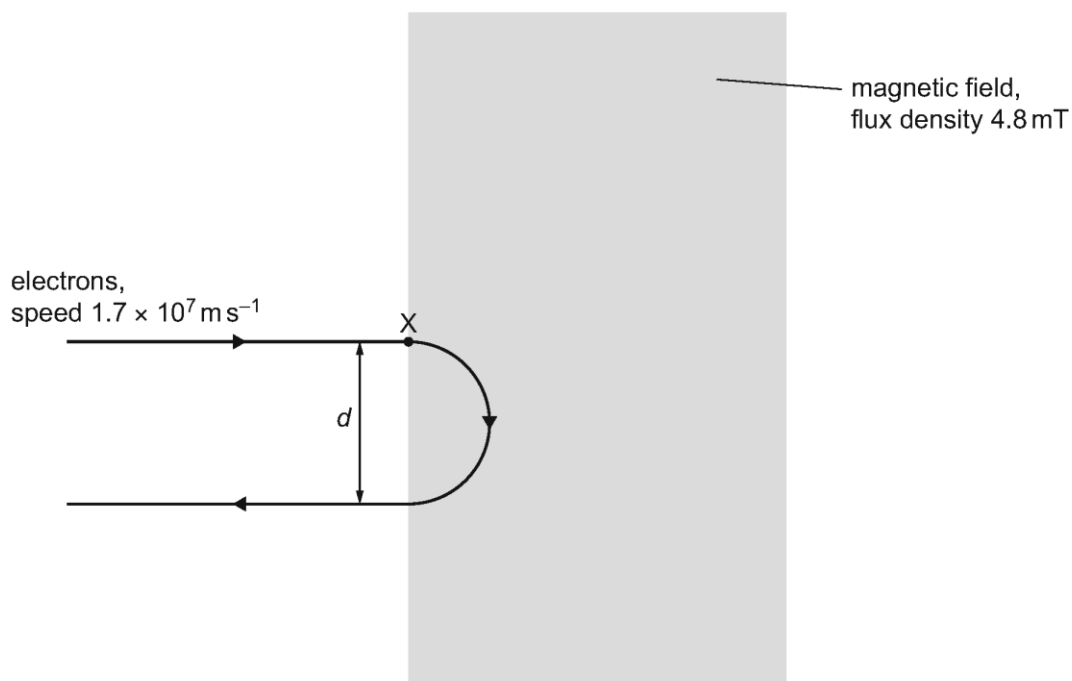
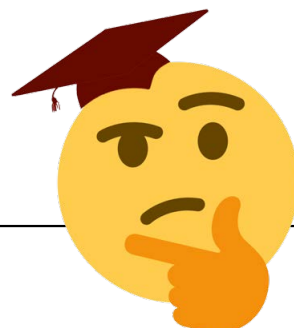


Fig. 6.1

The path of the electrons remains in the plane of the page.

(i) State the direction of the magnetic field.

.....
..... [1]



- (ii) Show that the magnitude of the force exerted on each electron by the magnetic field is $1.3 \times 10^{-14} \text{ N}$.

[2]

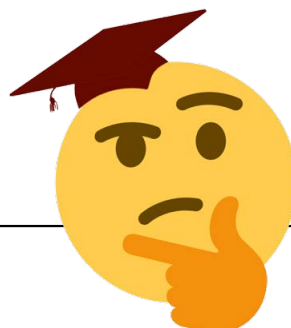
- (iii) On Fig. 6.1, draw an arrow to indicate the direction of the centripetal acceleration of the electron where it enters the magnetic field at point X. [1]

- (iv) Use the information in (b)(ii) to calculate the distance d between the path of the electrons entering the magnetic field and the path of the electrons leaving it.

 $d = \dots\dots\dots \text{ m}$ [3]

- (c) The electrons in (b) are replaced with positrons that are moving with speed $3.4 \times 10^7 \text{ ms}^{-1}$ along the same initial path as the electrons.
The positrons enter the magnetic field at point X on Fig. 6.1.

On Fig. 6.1, draw a line to show the path of the positrons through the magnetic field. [3]



28 - (9702/42_Winter_2023_Q7) - Electromagnetic Induction

- (a) A Hall probe containing a thin slice of semiconducting material is placed in a uniform magnetic field of flux density B . The largest faces of the slice are perpendicular to the magnetic field, as shown in Fig. 7.1.

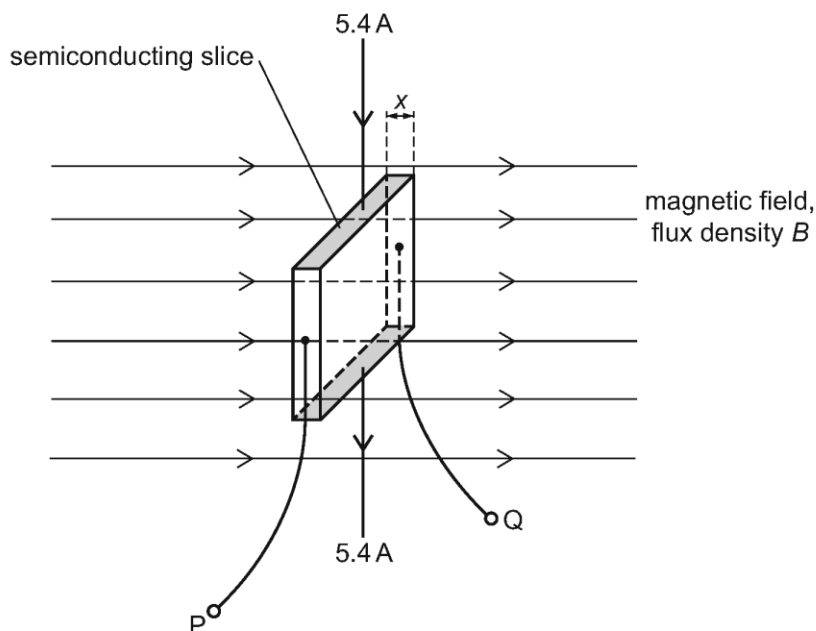


Fig. 7.1

The thickness x of the slice is 1.8 mm. The number density of charge carriers in the semiconducting material is $1.5 \times 10^{16} \text{ m}^{-3}$.

A constant current of 5.4 A is passed through the slice between the shaded faces.

The Hall voltage V_H that is developed between the terminals PQ is recorded.

Fig. 7.2 shows the variation with time t of B .

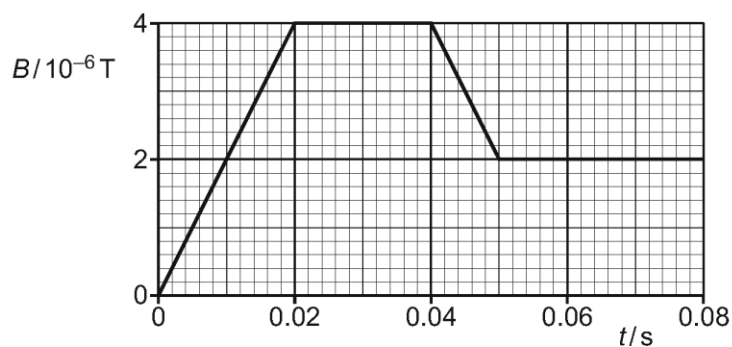
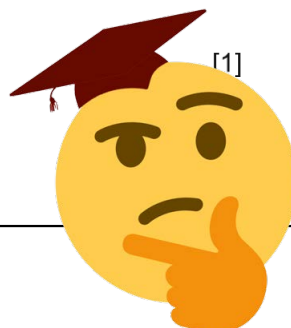


Fig. 7.2

- (i) Show that, when B is equal to $4.0 \times 10^{-6} \text{ T}$, the magnitude of V_H is 5.0 V.



- (ii) On Fig. 7.3, sketch the variation of V_H with t between $t = 0$ and $t = 0.080$ s.

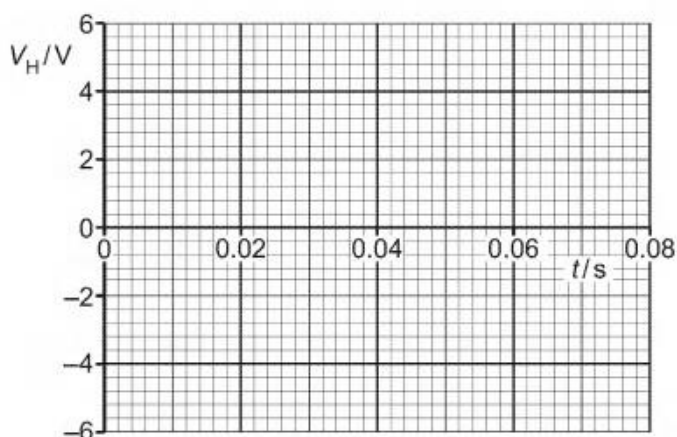


Fig. 7.3

[3]

- (b) The Hall probe in (a) is replaced with a small flat coil that has 3000 turns. The cross-sectional area of the coil is $3.4 \times 10^{-4} \text{ m}^2$. The plane of the coil is perpendicular to the magnetic field. The electromotive force (e.m.f.) E induced between the terminals of the coil is recorded as B varies as shown in Fig. 7.2.

- (i) Show that the magnitude of E at time $t = 0.010$ s is 2.0×10^{-4} V.

[3]

- (ii) On Fig. 7.4, sketch the variation of E with t between $t = 0$ and $t = 0.080$ s.

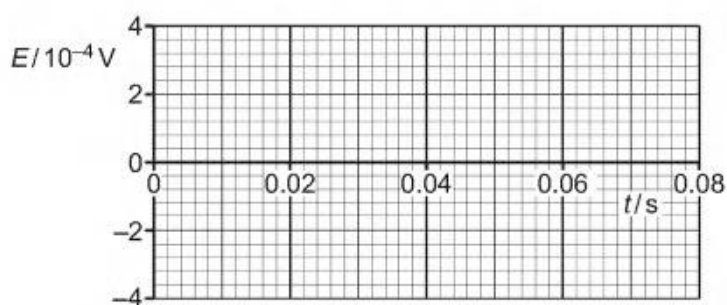
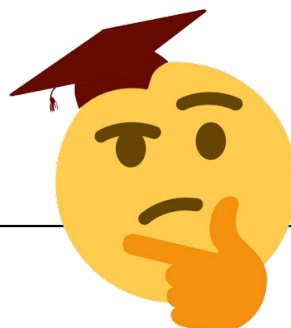


Fig. 7.4

[4]



1 - (9702/41_Winter_2017_Q10) - *Alternating Currents*

- (a) The mean value of an alternating current is zero.
Explain why heating occurs when there is an alternating current in a resistor.

.....

.....

.....

..... [2]

- (b) Transmission of electrical energy is frequently achieved using alternating high voltages.
Suggest why

- (i) high voltages are used,

.....

.....

.....

..... [2]

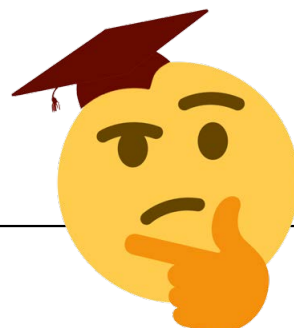
- (ii) the voltage is alternating.

.....

.....

.....

..... [2]



2 - (9702/42_Winter_2017_Q11) - *Alternating Currents*

The circuit for a full-wave rectifier using four ideal diodes is shown in Fig. 11.1.

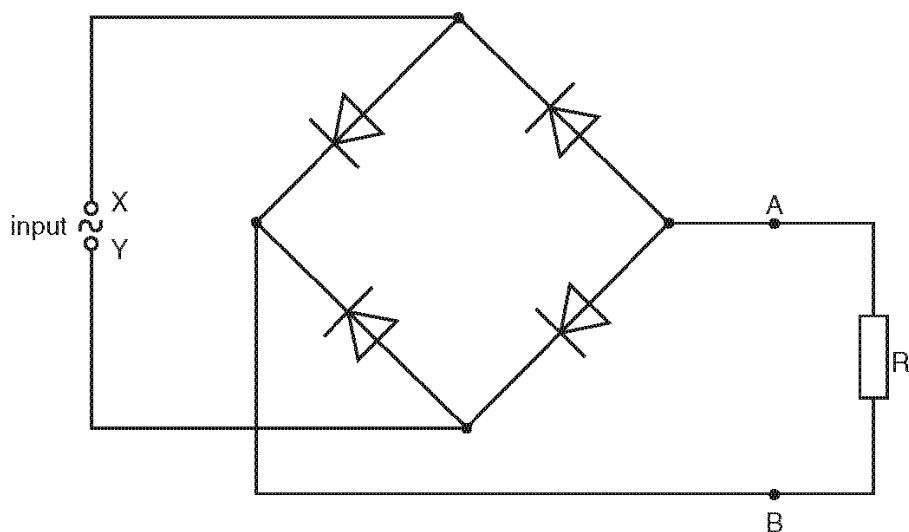
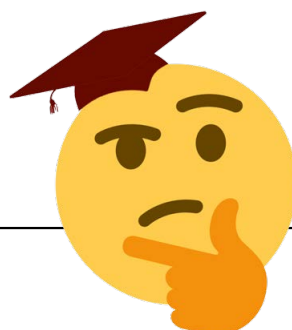


Fig. 11.1

A resistor R is connected across the output AB of the rectifier.

(a) On Fig. 11.1,

- (i) draw a circle around any diodes that conduct when the terminal X of the input is positive with respect to terminal Y , [1]
- (ii) label the positive (+) and the negative (–) terminals of the output AB . [1]



- (b) The variation with time t of the potential difference V across the input XY is given by the expression

$$V = 5.6 \sin 380t$$

where V is measured in volts and t is measured in seconds.

The variation with time t of the rectified potential difference across the resistor R is shown in Fig. 11.2.

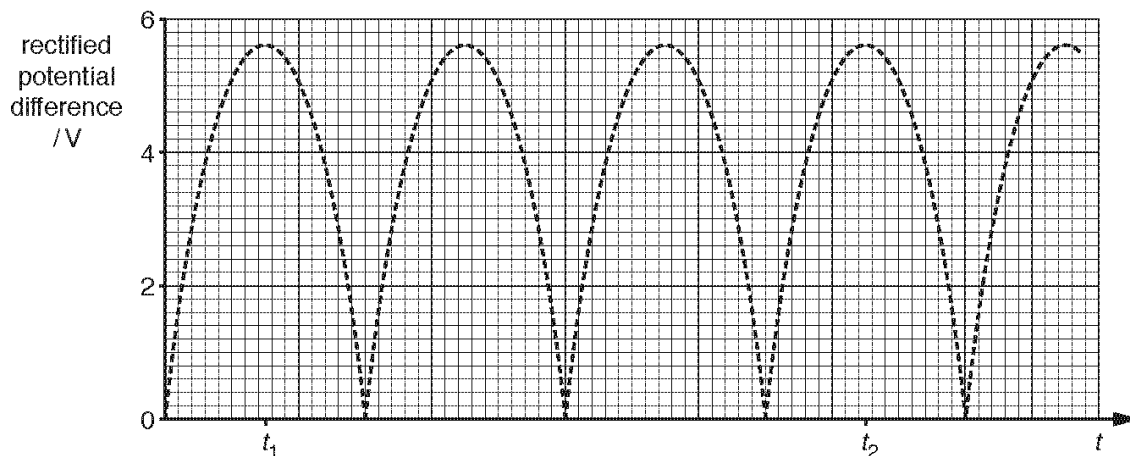


Fig. 11.2

Use the expression for the input potential difference V , or otherwise, to determine

- (i) the root-mean-square (r.m.s.) potential difference $V_{\text{r.m.s.}}$ of the input,

$$V_{\text{r.m.s.}} = \dots\dots\dots \text{ V [1]}$$



- (ii) the number of times per second that the rectified potential difference at the output reaches a peak value.

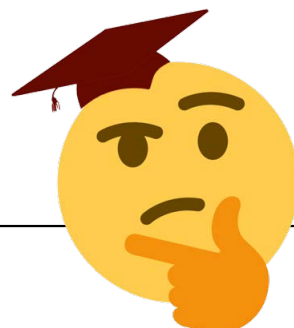
number = [2]

- (c) A capacitor is now connected between the terminals AB of the output.
The capacitor reduces the variation (the ripple) in the output to 1.6 V.

- (i) On Fig. 11.2, sketch the variation with time t of the smoothed output voltage for time $t = t_1$ to time $t = t_2$. [4]

- (ii) Suggest and explain the effect, if any, on the mean power dissipation in resistor R when the capacitor is connected between terminals AB.

.....
.....
.....[2]



3 - (9702/41_Summer_2018_Q9) - Magnetic Fields, Alternating Currents

A rigid copper wire is held horizontally between the pole pieces of two magnets, as shown in Fig. 9.1.

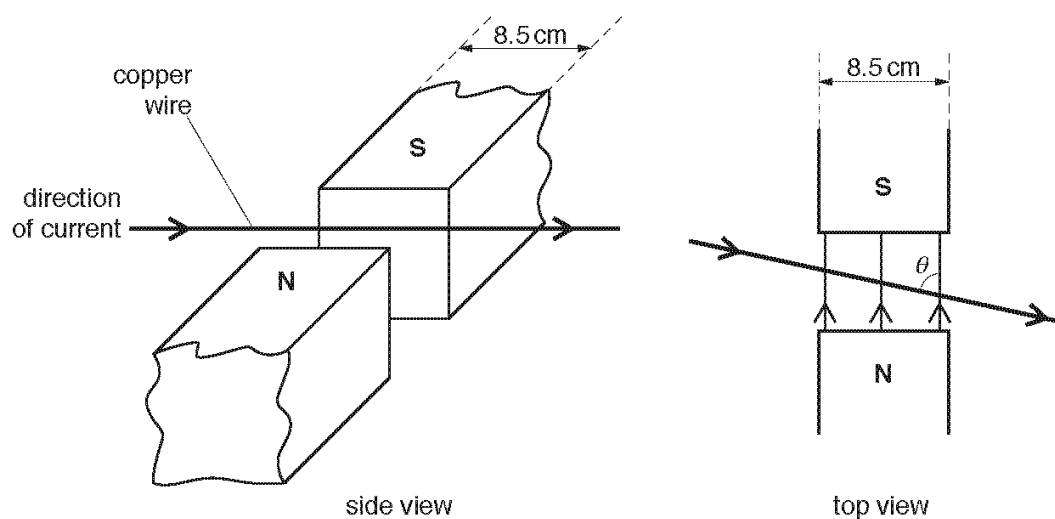


Fig. 9.1

The width of each pole piece is 8.5 cm.

The uniform magnetic flux density B in the region between the poles of the magnets is 3.7 mT and is zero outside this region.

The angle between the wire and the direction of the magnetic field is θ .

The current in the wire is in the direction shown on Fig. 9.1.

- (a) By reference to the **side** view of Fig. 9.1, state and explain the direction of the force on the magnets.

.....

.....

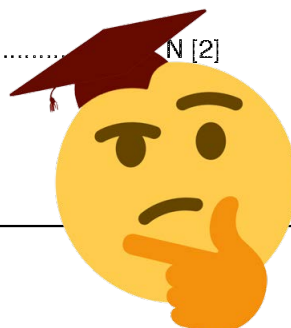
.....

..... [2]

- (b) The constant current in the wire is 5.1 A.

- (i) For angle θ equal to 90° , calculate the force on the wire.

force = N [2]



- (ii) The angle θ is changed to 60° .

The length of wire in the magnetic field is $\left(\frac{8.5}{\sin 60^\circ}\right)$ cm.

Calculate the force on the wire.

force = N [1]

- (c) The constant current in the wire is now changed to an alternating current of frequency 20 Hz and root-mean-square (r.m.s.) value 5.1 A.

The angle between the wire and the direction of the magnetic field is 90° .

On Fig. 9.2, sketch a graph to show the variation with time t of the force F on the wire for two cycles of the alternating current.

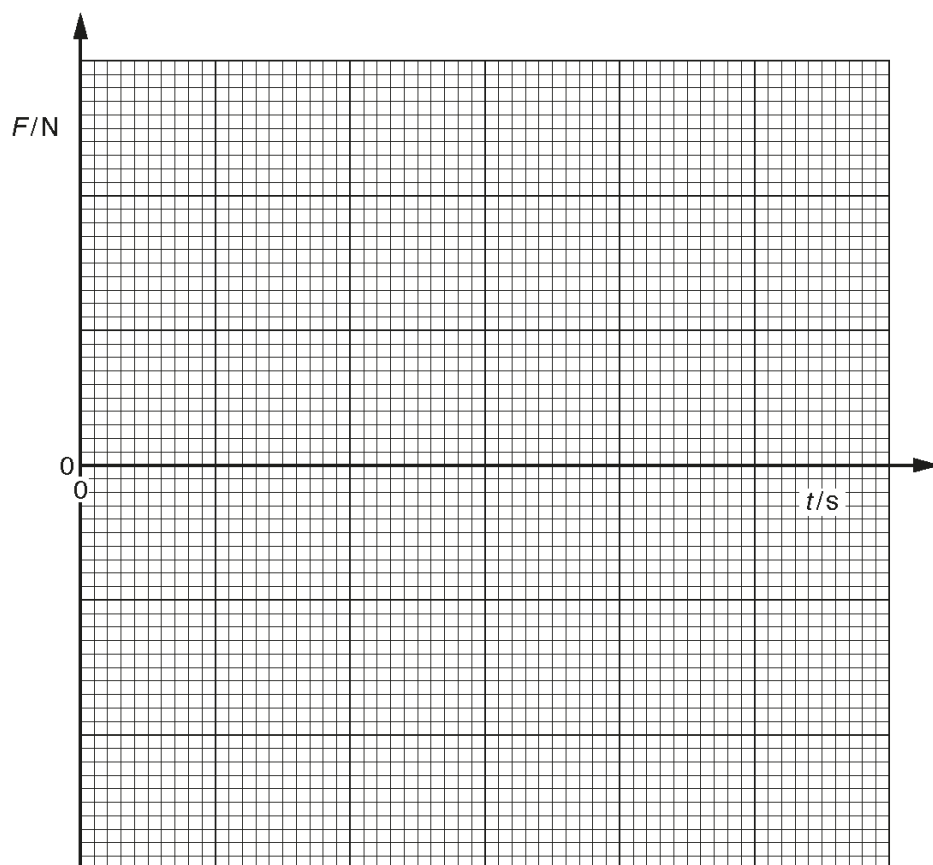
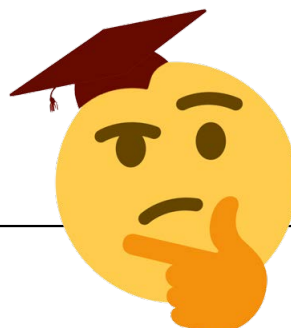


Fig. 9.2

[3]



4 - (9702/42_Winter_2018_Q10) - *Alternating Currents*

- (a) The root-mean-square (r.m.s.) value of the voltage of a sinusoidal alternating supply is 9.9 V. The frequency of the supply is 50 Hz.

Derive an expression for the variation with time t (in second) of the potential difference V (in volt) of the supply.

$V = \dots\dots\dots$ [2]

- (b) Explain the function of the non-uniform magnetic field superposed on the large constant magnetic field in diagnosis using magnetic resonance imaging (NMRI).

.....
.....
.....
.....
.....
.....
.....
.....[3]



- (c) A parallel beam of X-rays of intensity I_0 is incident normally on some soft tissue and bone, as illustrated in Fig. 10.1.

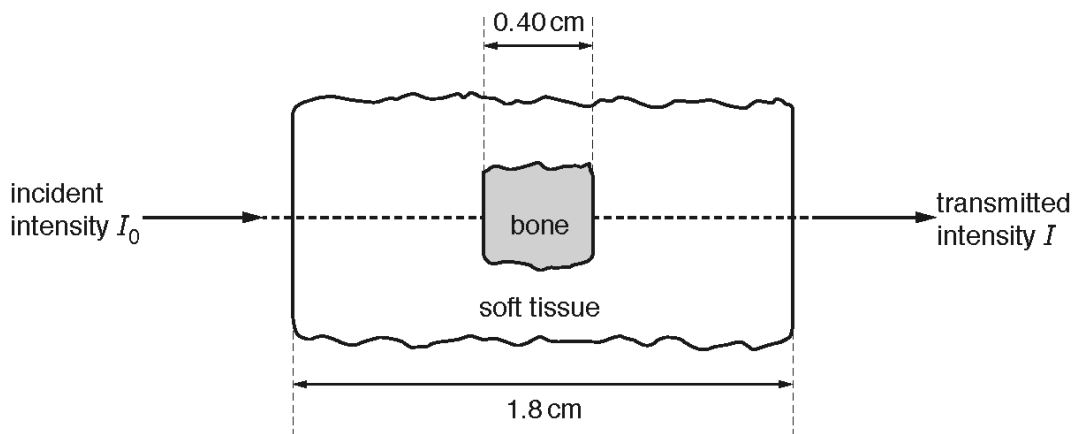


Fig. 10.1

The bone is 0.40 cm thick and the total thickness of the bone and the soft tissue is 1.8 cm. The intensity of the transmitted beam is I .

Data for the linear attenuation (absorption) coefficient μ of bone and of soft tissue are given in Fig. 10.2.

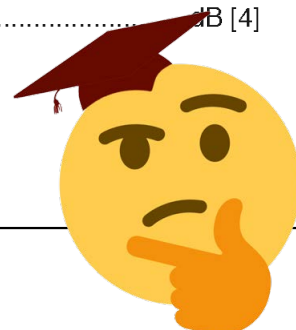
	μ/cm^{-1}
bone	2.9
soft tissue	0.92

Fig. 10.2

Calculate, in dB, the ratio

$$\frac{\text{transmitted intensity } I}{\text{incident intensity } I_0}.$$

ratio = dB [4]



5 - (9702/41_Summer_2019_Q10) - Alternating Currents

A bridge rectifier contains four diodes. The output of the rectifier is connected to a resistor R , as shown in Fig. 10.1.

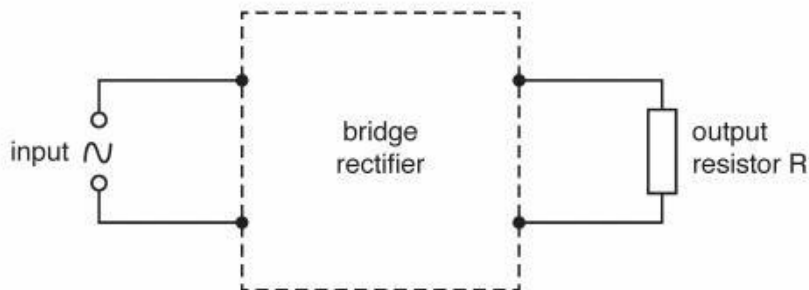


Fig. 10.1

The variation with time t of the input e.m.f. E to the rectifier is given by the expression

$$E = 15 \cos(210t)$$

where t is measured in seconds and E in volts.

The variation with time t of the potential difference V across resistor R is shown in Fig. 10.2.

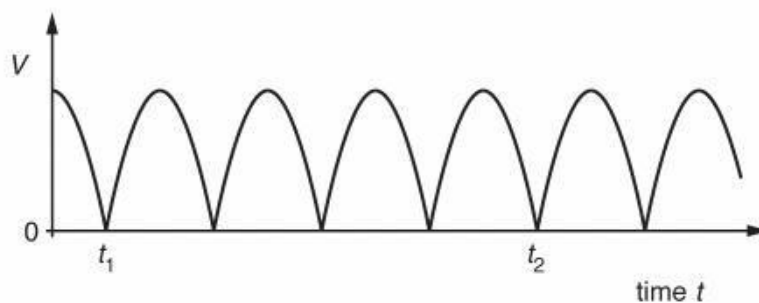


Fig. 10.2

Determine:

- (a) the maximum potential difference V_{MAX} across resistor R

$$V_{\text{MAX}} = \dots\dots\dots \text{V [1]}$$



(b) the time interval, to two significant figures, between time t_1 and time t_2 .

time = s [3]



6 - (9702/41_Winter_2019_Q10) - *Alternating Currents*

A bridge rectifier using four ideal diodes is shown in Fig. 10.1.

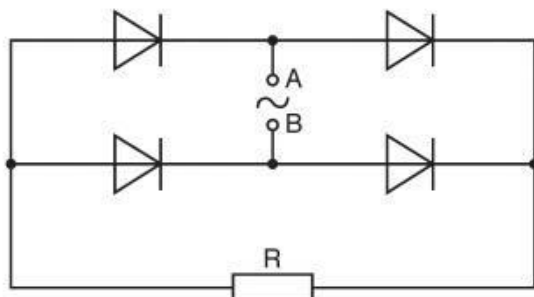
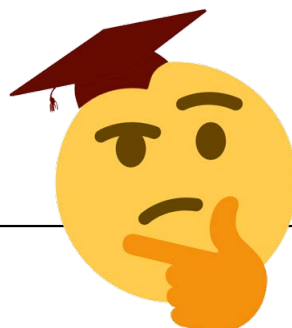


Fig. 10.1

The sinusoidal alternating electromotive force (e.m.f.) applied between points A and B has a root-mean-square (r.m.s.) value of 7.0 V.

- (a) (i) On Fig. 10.1, circle the diodes that conduct when point B is positive with respect to point A. [1]
- (ii) Calculate the maximum potential difference V_{MAX} across resistor R.

$V_{\text{MAX}} = \dots\dots\dots \text{ V [1]}$



- (b) A capacitor is connected into the circuit to produce smoothing of the potential difference across resistor R.

The variation with time t of the potential difference V across resistor R is shown in Fig. 10.2.

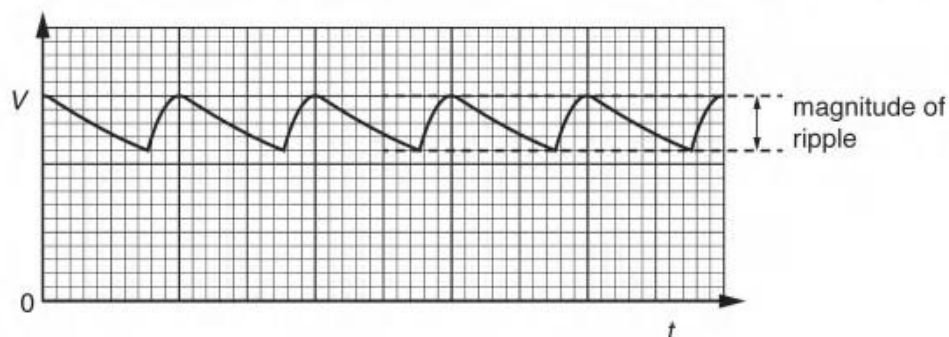


Fig. 10.2

- (i) On Fig. 10.1, draw the symbol for a capacitor, connected so as to produce smoothing. [1]

- (ii) State the effect, if any, on the magnitude of the ripple on V when, separately:

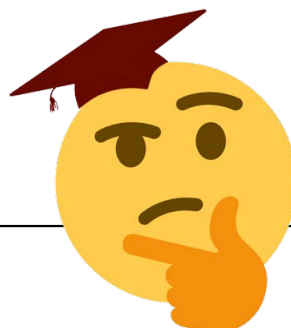
1. a capacitor of larger capacitance is used

.....

2. the resistor R has a smaller resistance.

.....

[2]



7 - (9702/42_Winter_2019_Q11) - *Electromagnetic Induction, Alternating Currents*

(a) State Faraday's law of electromagnetic induction.

.....
.....
..... [2]

(b) A solenoid S has a small coil C placed near to one of its ends, as shown in Fig. 11.1.

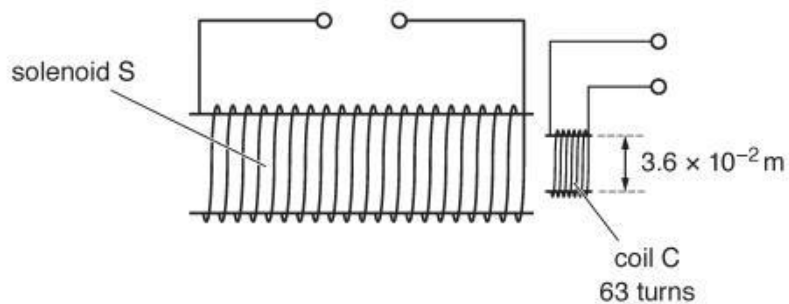
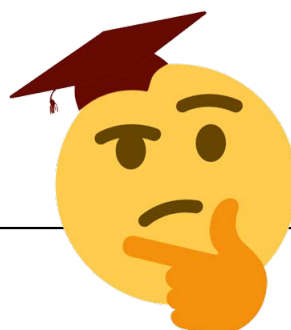


Fig. 11.1



The coil C has a circular cross-section of diameter $3.6 \times 10^{-2} \text{ m}$ and contains 63 turns of wire.

The solenoid S produces a uniform magnetic field of flux density B , in tesla, in the region of coil C given by the expression

$$B = 9.4 \times 10^{-4} I$$

where I is the current, in ampere, in the solenoid S.

The variation with time t of the current I in solenoid S is shown in Fig. 11.2.

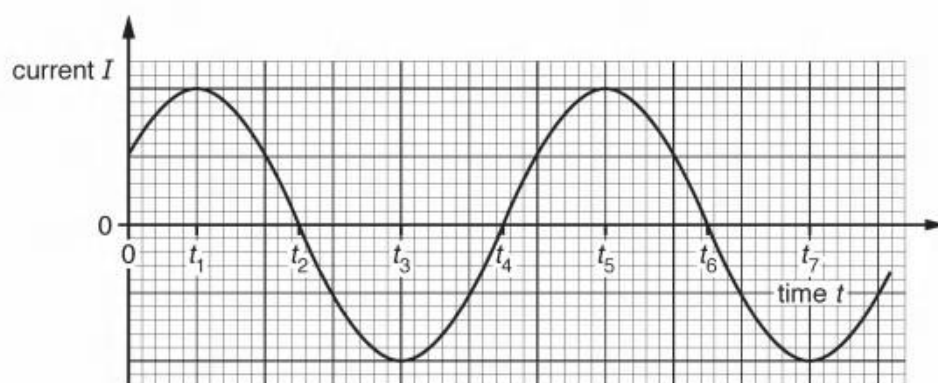


Fig. 11.2

State two times at which:

- (i) there is no electromotive force (e.m.f.) induced in coil C

time and time [1]

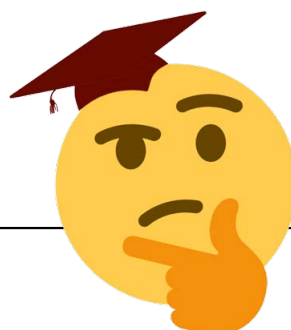
- (ii) the induced e.m.f. in coil C is a maximum but with opposite polarities.

time and time [1]

- (c) The alternating current in the solenoid S in (b) is replaced by a constant current of 5.0 A.

Calculate the average e.m.f. induced in coil C when the current in solenoid S is reversed in a time of 6.0 ms.

e.m.f. induced = V [3]



8 - (9702/42_Winter_2020_Q9) - *Electromagnetic Induction, Alternating Currents*

- (a) A small coil is placed close to one end of a solenoid connected to a power supply. The plane of the small coil is normal to the axis of the solenoid, as illustrated in Fig. 9.1.

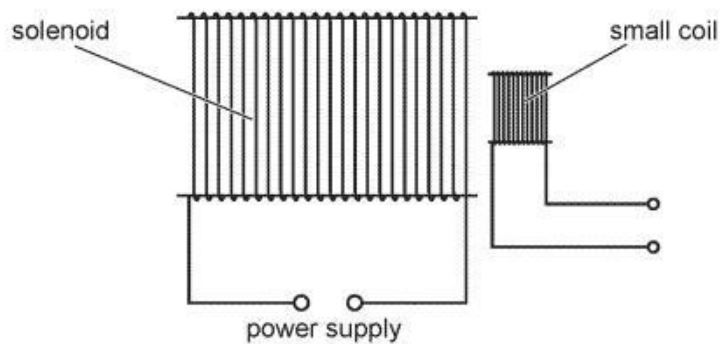
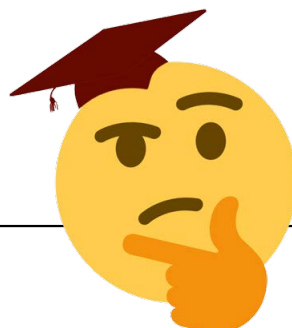


Fig. 9.1



The power supply causes the current I in the solenoid to vary with time t as shown in Fig. 9.2.

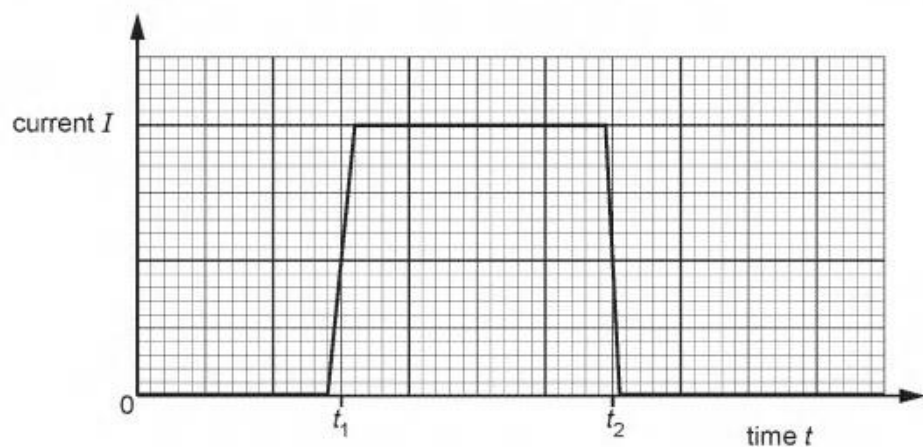


Fig. 9.2

- (i) State Faraday's law of electromagnetic induction.

.....
.....
..... [2]

- (ii) On the axes of Fig. 9.3, sketch a graph to show the variation with time t of the electromotive force (e.m.f.) induced in the small coil.

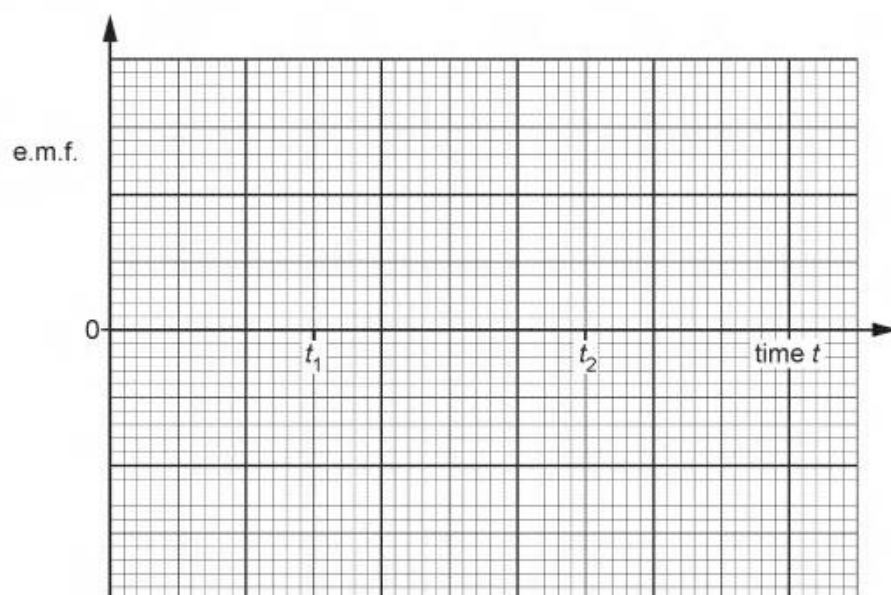
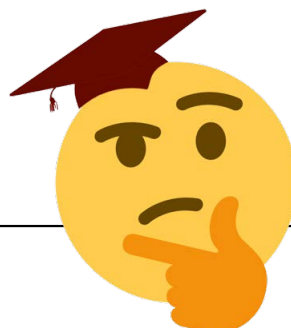


Fig. 9.3

[4]



(b) The small coil in (a) is now replaced by a Hall probe.

The Hall probe is positioned so that the reading for the probe is a maximum.

The current I in the solenoid varies again as shown in Fig. 9.2.

On the axes of Fig. 9.4, sketch a graph to show the variation with time t of the reading V_H of the probe.

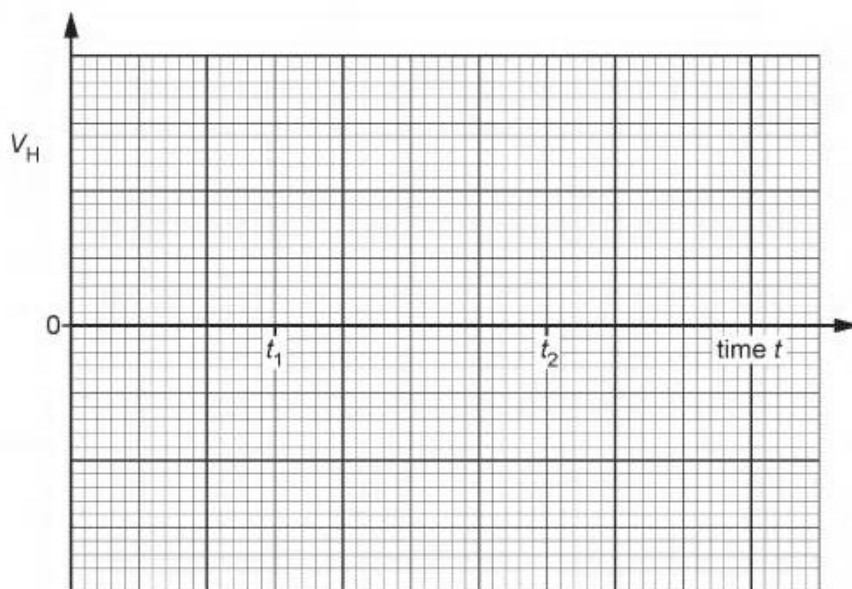
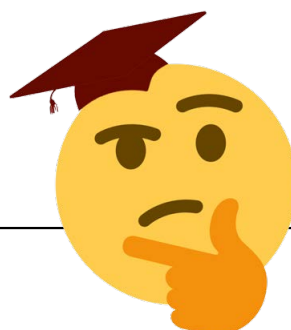


Fig. 9.4

[2]

[Total: 8]



9 - (9702/42_Summer_2021_Q10) - Alternating Currents

- (a) By reference to heating effect, explain what is meant by the *root-mean-square (r.m.s.)* value of an alternating current.

.....
.....
..... [2]

- (b) The variations with time t of two currents I_1 and I_2 are shown in Fig. 10.1 and Fig. 10.2.

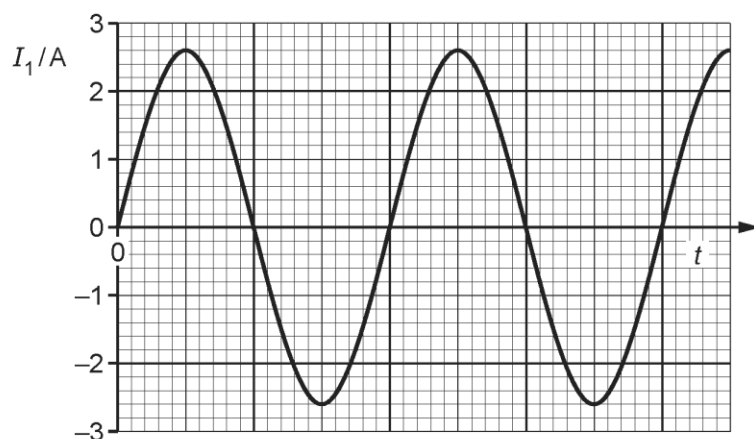


Fig. 10.1

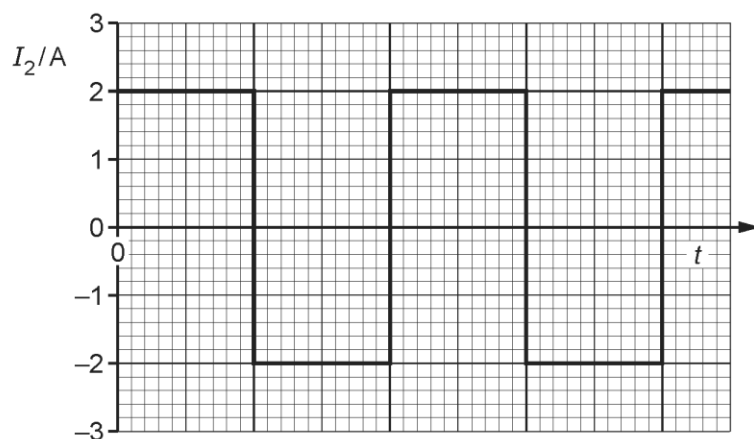
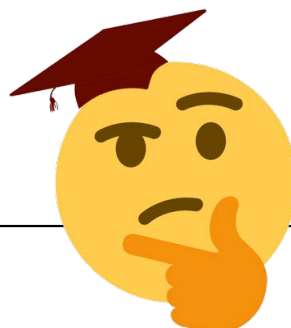


Fig. 10.2



- (i) Use Fig. 10.1 to determine the peak value and the r.m.s. value of the current I_1 .

peak value = A

r.m.s. value = A
[1]

- (ii) Use Fig. 10.2 to determine the peak value and the r.m.s. value of the current I_2 .

peak value = A

r.m.s. value = A
[1]

- (c) The variation with time t of the supply voltage V to a house is given by the expression

$$V = 240 \sin kt$$

where V is in volts, t is in seconds and k is a constant with unit rad s^{-1} .

- (i) The frequency of the supply voltage is 50 Hz.

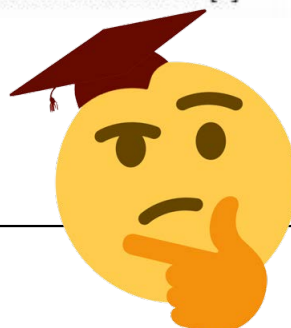
Determine k to two significant figures.

$k = \dots\dots\dots \text{rad s}^{-1}$ [2]

- (ii) The supply voltage is applied to a heater. The mean power of the heater is 3.2 kW.

Calculate the resistance of the heater.

resistance = Ω [2]



10 - (9702/41_Summer_2022_Q5) - *Alternating Currents*

Fig. 5.1 shows four diodes and a load resistor of resistance $1.2\text{ k}\Omega$, connected in a circuit that is used to produce rectification of an alternating voltage.

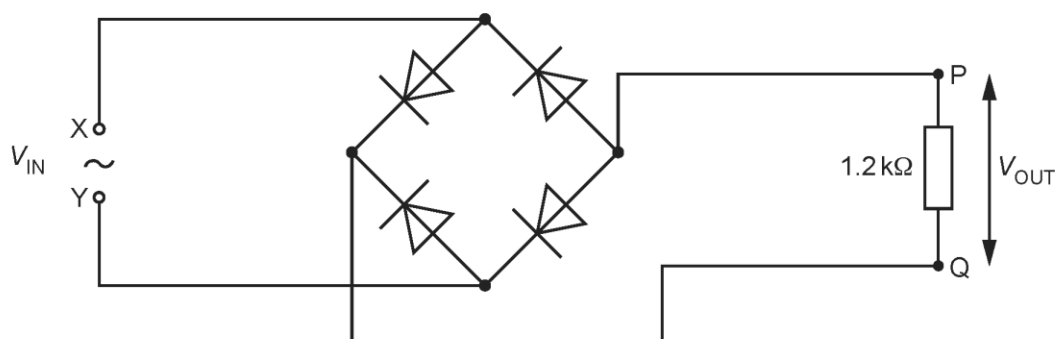


Fig. 5.1

- (a) (i) State what is meant by rectification.

.....
..... [1]

- (ii) State the type of rectification produced by the circuit in Fig. 5.1.

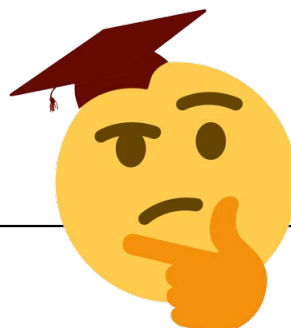
..... [1]

- (b) A sinusoidal alternating voltage V_{IN} is applied across the input terminals X and Y. The variation with time t of V_{IN} is given by the equation

$$V_{IN} = 6.0 \sin 25\pi t$$

where V_{IN} is in volts and t is in seconds.

- (i) On Fig. 5.1, label the output terminals P and Q with the appropriate symbols to indicate the polarity of the output voltage V_{OUT} . [1]



- (ii) The magnitude of the output voltage V_{OUT} varies with t as shown in Fig. 5.2.

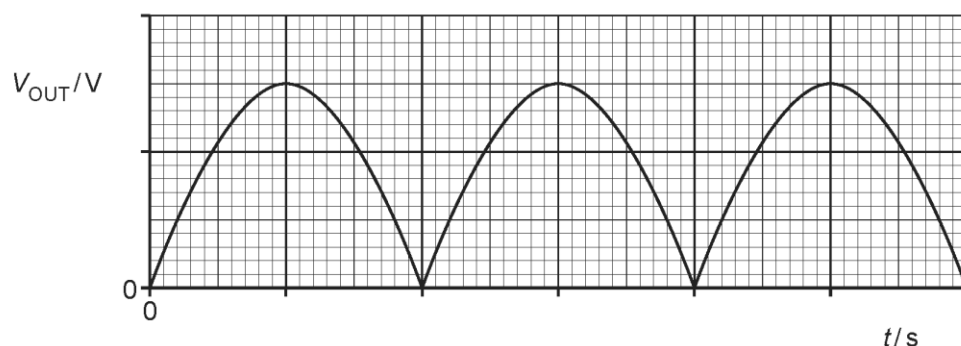


Fig. 5.2

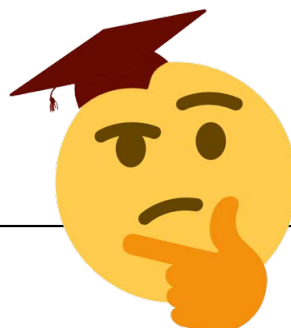
On Fig. 5.2, label both of the axes with the correct scales. Use the space below for any working that you need.

[3]

- (c) The output voltage in (b) is smoothed by adding a capacitor to the circuit in Fig. 5.1. The difference between the maximum and minimum values of the smoothed output voltage is 10% of the peak voltage.
- (i) On Fig. 5.1, draw the circuit symbol for a capacitor showing the capacitor correctly connected into the circuit. [1]
- (ii) On Fig. 5.2, sketch the variation with t of the smoothed output voltage. [2]
- (iii) Calculate the capacitance C of the capacitor.

$C = \dots\dots\dots$ F [3]

[Total: 12]



11 - (9702/41_Winter_2022_Q7) - Alternating Currents

- (a) A sinusoidal alternating voltage has a root-mean-square (r.m.s.) potential difference (p.d.) of 4.2 V and a frequency of 50 kHz.

- (i) The alternating voltage is applied across a resistor of resistance 760 Ω .

By considering the peak voltage, show that the maximum power dissipated by the resistor is 46 mW.

[2]

- (ii) On Fig. 7.1, draw a smooth curve to show how the power P dissipated in the resistor varies with time t between $t = 0$ and $t = 40 \mu\text{s}$. Assume that $P = 0$ when $t = 0$.

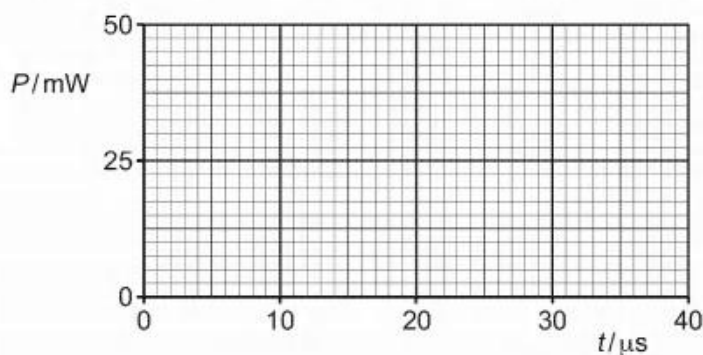
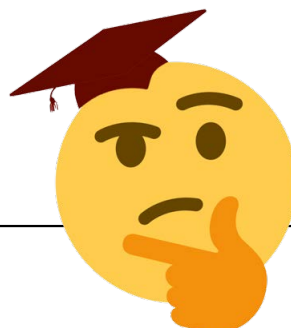


Fig. 7.1

[3]

- (iii) Use your line in (a)(ii) to explain why the mean power dissipated in the resistor is 23 mW.

.....
.....
..... [1]



(b) The alternating voltage in **(a)** is now applied to a piezoelectric crystal in air.

(i) Explain what happens to the air surrounding the crystal.

.....

.....

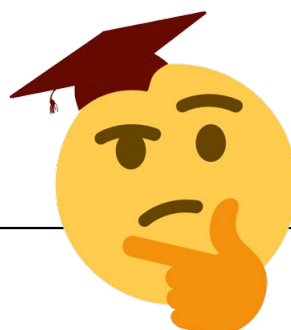
.....

..... [3]

(ii) A second piezoelectric crystal is placed in the air near to the first crystal.

Explain the effect of the surrounding air in **(b)(i)** on the second crystal.

..... [1]



12 - (9702/42_Summer_2023_Q7) - Alternating Currents

Four diodes are used in a bridge rectifier circuit to produce rectification of a sinusoidal a.c. input voltage V_{IN} .

Fig. 7.1 shows part of the circuit, but three of the diodes are missing.

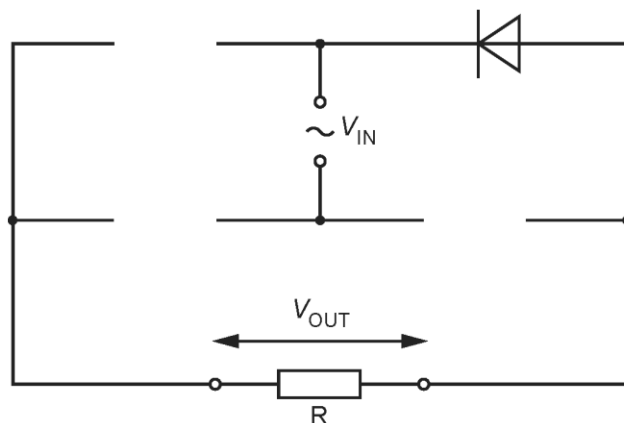


Fig. 7.1

The p.d. across the load resistor R is the output p.d. V_{OUT} of the bridge rectifier.

(a) (i) State the name of the type of rectification produced by a bridge rectifier.

..... [1]

(ii) Complete Fig. 7.1 by drawing the three missing diodes, correctly connected. [2]

(iii) On Fig. 7.1, draw an arrow to indicate the direction of the current in resistor R . [1]

(b) V_{IN} has amplitude V_0 and period T . Fig. 7.2 shows the variation with time t of V_{IN} .

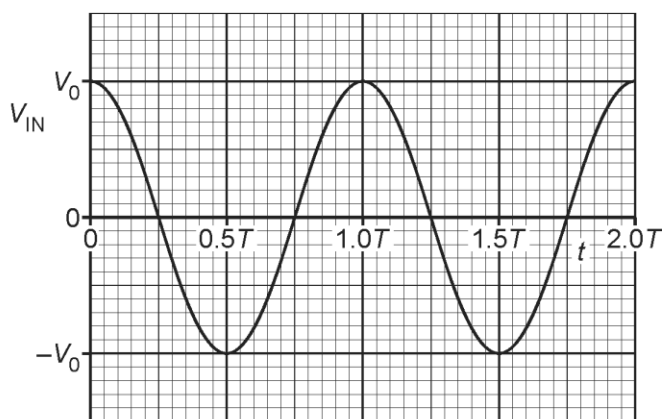
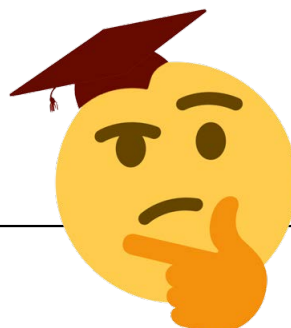


Fig. 7.2



- (i) On Fig. 7.3, sketch the variation of V_{OUT} with t between $t = 0$ and $t = 2.0T$.

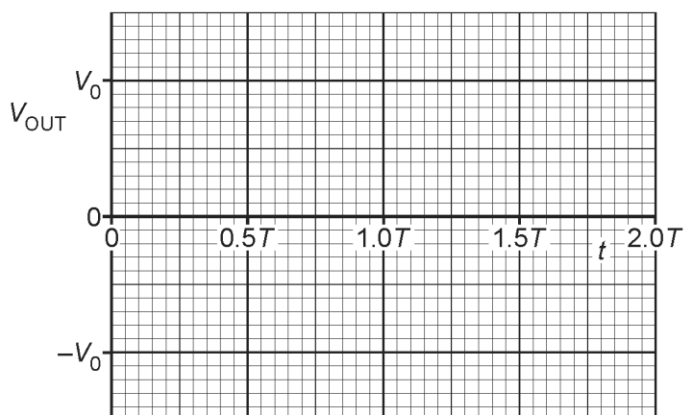


Fig. 7.3

[3]

- (ii) The power dissipated in the resistor is P .

On Fig. 7.4, sketch the variation of P with t between $t = 0$ and $t = 2.0T$.

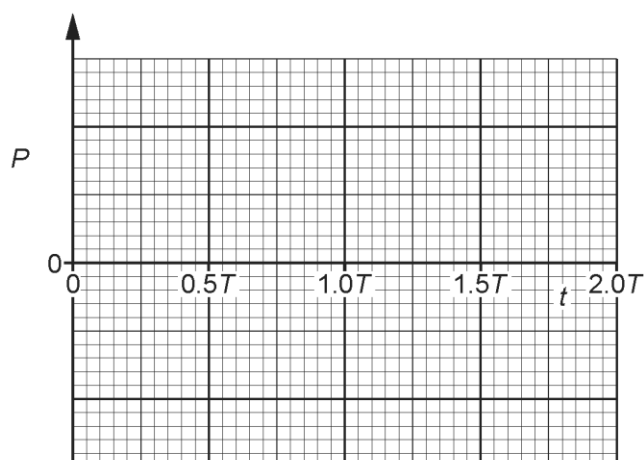


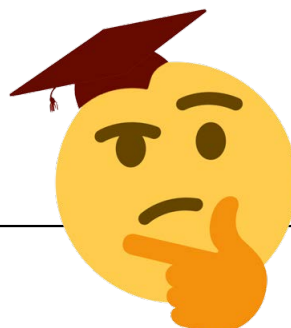
Fig. 7.4

[2]

- (iii) Suggest, with a reason, how the root-mean-square (r.m.s.) value of V_{OUT} compares with the r.m.s. value of V_{IN} .

.....

..... [1]



13 - (9702/41_Winter_2023_Q7) - Alternating Currents

A varying current I passes through a resistor of resistance R in the circuit shown in Fig. 7.1.

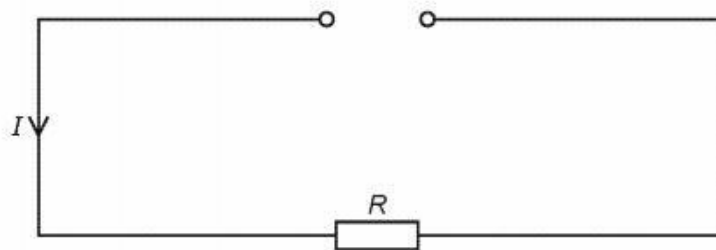


Fig. 7.1

Fig. 7.2 shows the variation with time t of I .

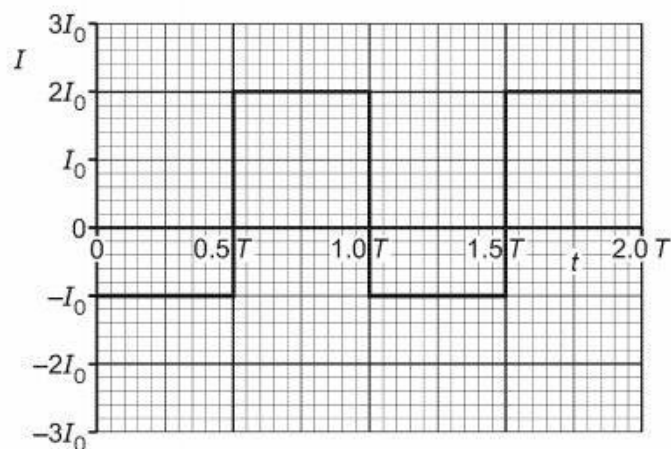


Fig. 7.2

The current has magnitude $2I_0$ when it is in the positive direction and I_0 when it is in the negative direction. The period of the variation of the current is T .

(a) Determine expressions, in terms of I_0 and R , for the power P dissipated in the resistor for the times when:

(i) the current is in the negative direction

$$P = \dots\dots\dots [1]$$

(ii) the current is in the positive direction.

$$P = \dots\dots\dots [1]$$



- (b) On Fig. 7.3, sketch the variation of P with t between $t = 0$ and $t = 2.0T$. Label the power axis with an appropriate scale.

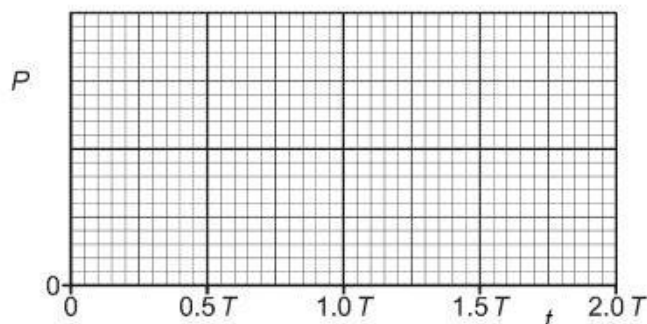


Fig. 7.3

[3]

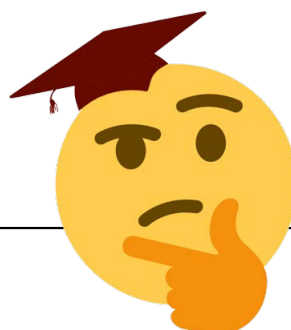
- (c) Use your answer in (b) to determine an expression, in terms of I_0 and R , for:

- (i) the mean power $\langle P \rangle$ in the resistor

$$\langle P \rangle = \dots\dots\dots [1]$$

- (ii) the root-mean-square (r.m.s.) current $I_{\text{r.m.s.}}$ in the resistor.

$$I_{\text{r.m.s.}} = \dots\dots\dots [2]$$



14 – (9702/42_Winter_2023_Q4) – Alternating Currents

An electron in a metal rod moves randomly about a mean position. When an alternating voltage is applied to the ends of the rod, the mean position can be considered to oscillate with simple harmonic motion along the axis of the rod. Fig. 4.1 shows the variation with time t of the displacement x of the mean position from a fixed point on the axis of the rod.

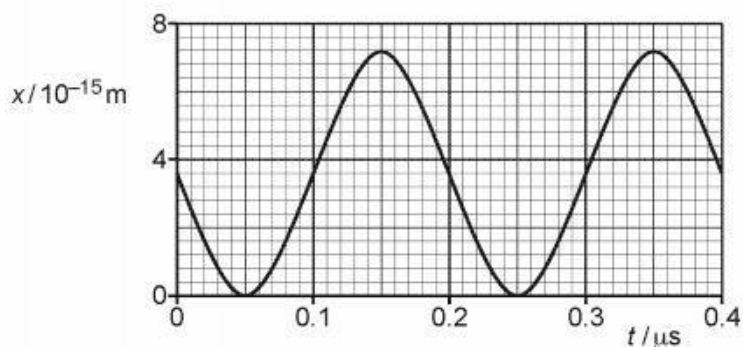


Fig. 4.1

- (a) (i) Determine the amplitude of the oscillations.

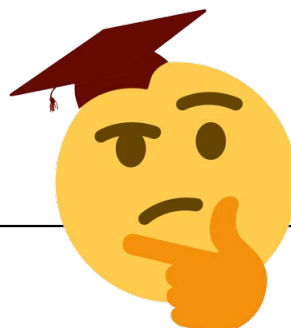
amplitude = m [1]

- (ii) Determine the angular frequency of the oscillations.

angular frequency = rad s^{-1} [1]

- (iii) Use your answers in (a)(i) and (a)(ii) to show that the maximum drift speed v_0 of the electron is $1.1 \times 10^{-7} \text{ m s}^{-1}$.

[2]



- (b) The rod has a cross-sectional area of 4.3 cm^2 and contains a number density of conduction electrons (charge carriers) of $8.5 \times 10^{28}\text{ m}^{-3}$.

All of the conduction electrons in the rod may be assumed to be oscillating in phase with, and with the same amplitude as, the oscillation shown in Fig. 4.1.

- (i) Use the information in (a)(iii) to calculate the magnitude I_0 of the maximum current in the rod.

$$I_0 = \dots\dots\dots\text{A} \quad [2]$$

- (ii) On Fig. 4.2, sketch the variation of the current I in the rod with time t between $t = 0$ and $t = 0.40\text{ }\mu\text{s}$.

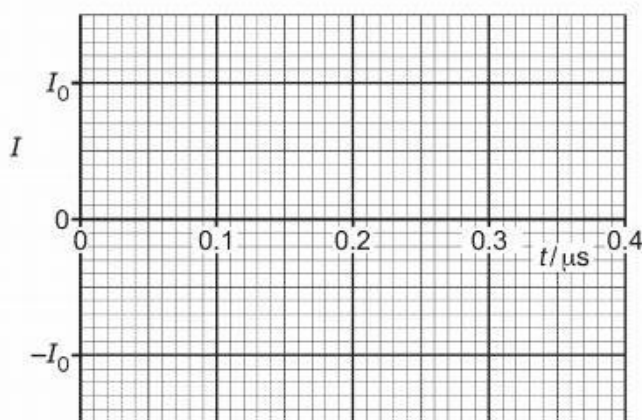


Fig. 4.2

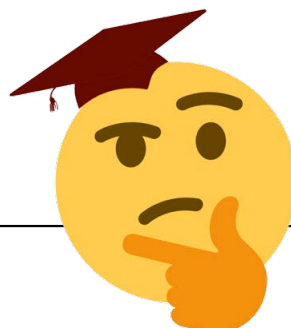
[2]

- (iii) Use your answers in (a)(ii) and (b)(i) to determine an expression for I in terms of t , where I is in A and t is in s.

$$I = \dots\dots\dots \quad [2]$$

- (iv) Determine the root-mean-square (r.m.s.) current in the rod.

$$\text{r.m.s. current} = \dots\dots\dots\text{A} \quad [1]$$



1 - (9702/41_Summer_2017_Q5) - Quantum Physics

An α -particle is travelling in a vacuum towards the centre of a gold nucleus, as illustrated in Fig. 5.1.



Fig. 5.1

The gold nucleus has charge $79e$.

The gold nucleus and the α -particle may be assumed to behave as point charges.

At a large distance from the gold nucleus, the α -particle has energy $7.7 \times 10^{-13} \text{ J}$.

- (a) The α -particle does not collide with the gold nucleus. Show that the radius of the gold nucleus must be less than $4.7 \times 10^{-14} \text{ m}$.

[3]

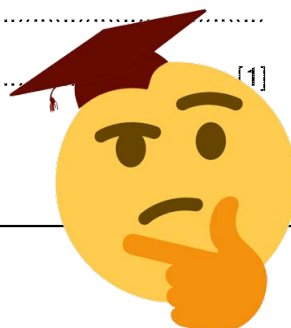
- (b) Determine the acceleration of the α -particle for a separation of $4.7 \times 10^{-14} \text{ m}$ between the centres of the gold nucleus and of the α -particle.

acceleration = ms^{-2} [3]

- (c) In an α -particle scattering experiment, the beam of α -particles is incident on a very thin gold foil.

Suggest why the gold foil must be very thin.

.....
..... [1]



2 - (9702/41_Summer_2017_Q10) - Quantum Physics

(a) State

(i) what is meant by the *hardness* of an X-ray beam,

.....
.....
.....[2]

(ii) how the hardness of an X-ray beam from an X-ray tube is increased.

.....
.....[1]

(b) The same parallel beam of X-ray radiation is incident, separately, on samples of bone and of muscle.

Data for the thickness x of the samples of bone and of muscle, together with the linear attenuation (absorption) coefficients μ of the radiation in bone and in muscle, are given in Fig. 10.1.

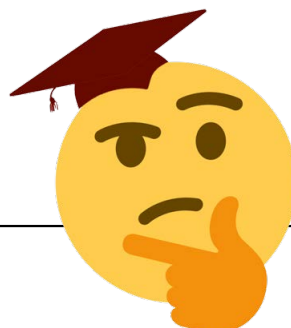
	x/cm	μ/cm^{-1}
bone	1.5	2.9
muscle	4.0	0.95

Fig. 10.1

Determine the ratio

$$\frac{\text{intensity transmitted through bone}}{\text{intensity transmitted through muscle}}.$$

ratio = [2]



3 - (9702/42_Summer_2017_Q10) - Quantum Physics

- (a) Briefly describe two phenomena associated with the photoelectric effect that cannot be explained using a wave theory of light.

1.

.....

2.

.....

[2]

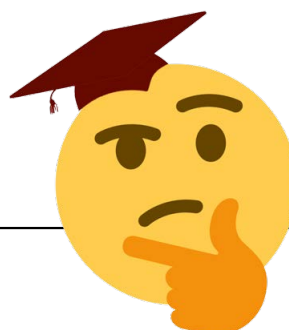
- (b) The maximum energy E_{MAX} of electrons emitted from a metal surface when illuminated by light of wavelength λ is given by the expression

$$E_{\text{MAX}} = hc \left(\frac{1}{\lambda} - \frac{1}{\lambda_0} \right)$$

where h is the Planck constant and c is the speed of light.

- (i) Identify the symbol λ_0 .

.....[1]



- (ii) The variation with $\frac{1}{\lambda}$ of E_{MAX} for the metal surface is shown in Fig. 10.1.

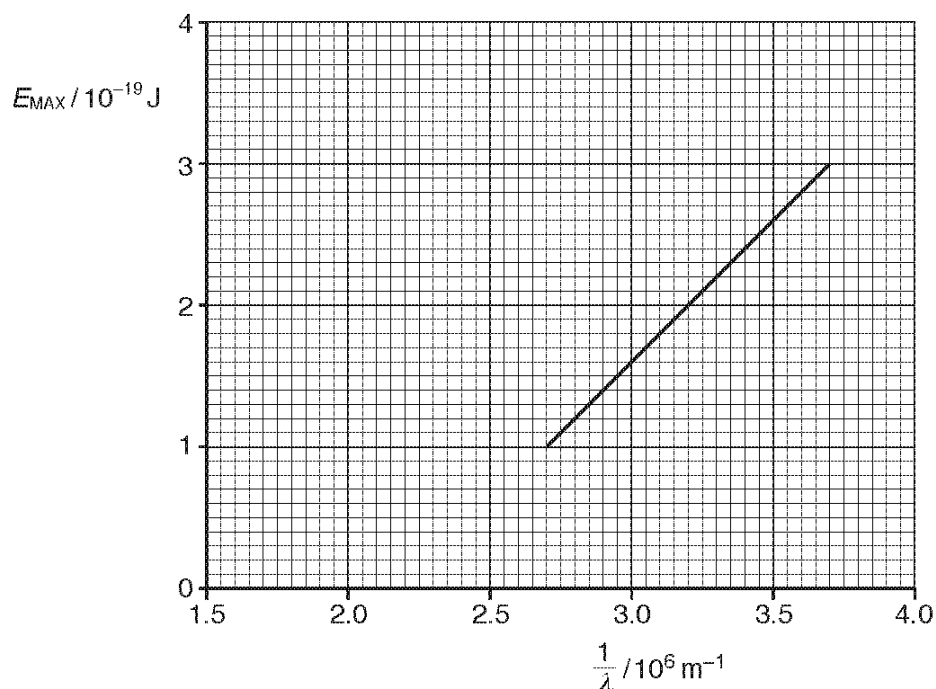


Fig. 10.1

1. Use Fig. 10.1 to determine the magnitude of λ_0 .

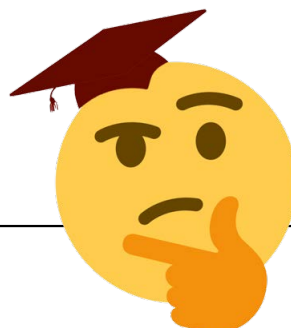
$$\lambda_0 = \dots\dots\dots \text{ m [1]}$$

2. Use the gradient of Fig. 10.1 to determine a value for the Planck constant h .

$$h = \dots\dots\dots \text{ Js [3]}$$

- (c) The metal surface in (b) becomes oxidised.
Photoelectric emission is still observed but the work function energy is increased.

On Fig. 10.1, draw a line to show the variation with $\frac{1}{\lambda}$ of E_{MAX} for the oxidised surface. [2]



4 - (9702/41_Summer_2017_Q11) - Quantum Physics

A beam of light consists of a continuous range of wavelengths from 420 nm to 740 nm. The light passes through a cloud of cool gas, as shown in Fig. 11.1.

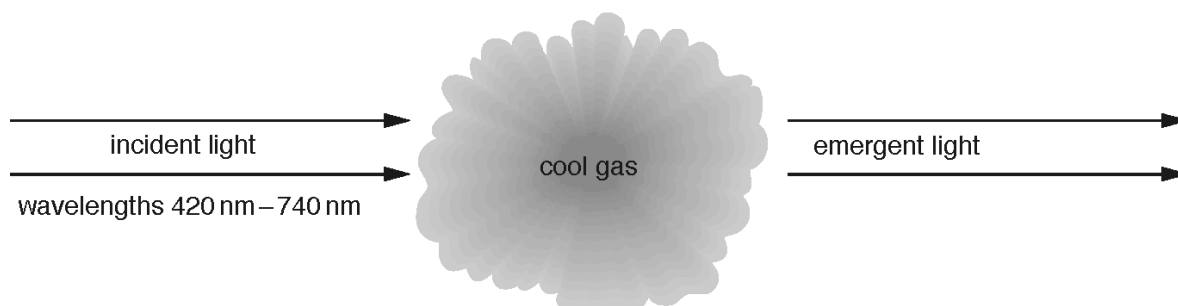


Fig. 11.1

- (a) The spectrum of the light emerging from the cloud of cool gas is viewed using a diffraction grating. Explain why this spectrum contains a number of dark lines.

.....
.....
.....
.....
.....
.....[4]

- (b) Some of the electron energy levels of the atoms in the cloud of gas are represented in Fig. 11.2.

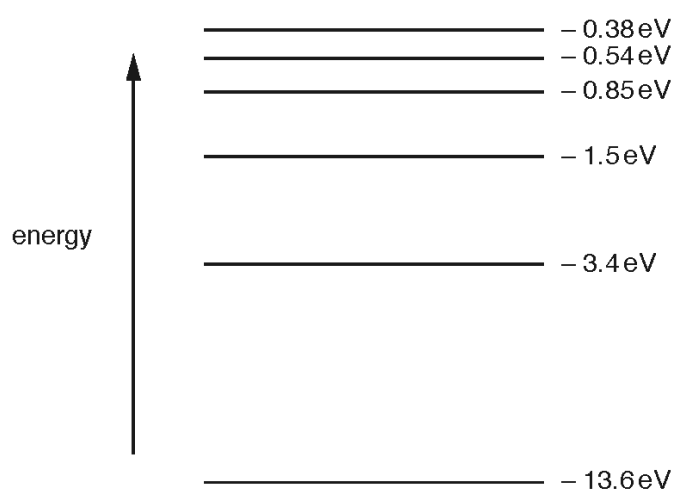
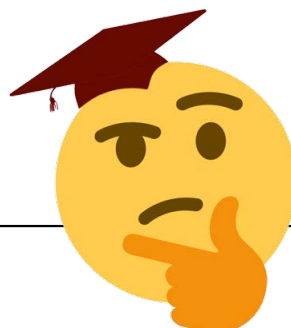


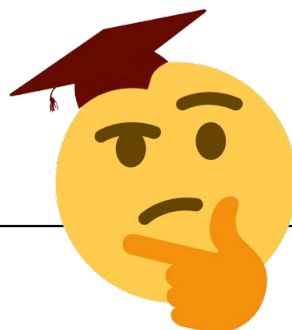
Fig. 11.2 (not to scale)



- (i) Light of wavelength 420 nm has a photon energy of 2.96 eV.
Calculate the photon energy, in eV, of light of wavelength 740 nm.

photon energy = eV [2]

- (ii) Use data from (i) and your answer in (i) to show, on Fig. 11.2, the changes in energy levels giving rise to the dark lines in (a). [2]



5 - (9702/42_Summer_2017_Q11) - Quantum Physics

An electron has charge $-q$ and mass m . It is accelerated from rest in a vacuum through a potential difference V .

(a) Show that the momentum p of the accelerated electron is given by

$$p = \sqrt{2mqV}.$$

[2]

(b) The potential difference V through which the electron is accelerated is 120 V.

(i) State what is meant by the *de Broglie wavelength*.

.....
.....
.....[2]

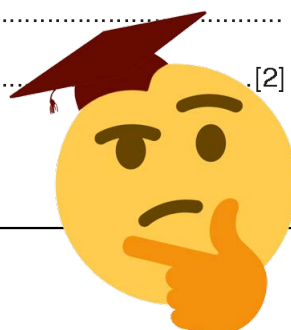
(ii) Calculate the de Broglie wavelength of the electron.

wavelength = m [3]

(c) The separation of copper atoms in a copper crystal is approximately 2×10^{-10} m.

By reference to your answer in (b)(ii), suggest whether electron diffraction could be observed using a beam of electrons that have been accelerated through a potential difference of 120 V and are then incident on a thin copper crystal.

.....
.....
.....[2]



6 - (9702/42_Winter_2017_Q10) - Quantum Physics

- (a) A metal surface is illuminated with light of a single wavelength λ .
On Fig. 10.1, sketch the variation with λ of the maximum kinetic energy E_{MAX} of the electrons emitted from the surface.
On your graph mark, with the symbol λ_0 , the threshold wavelength.

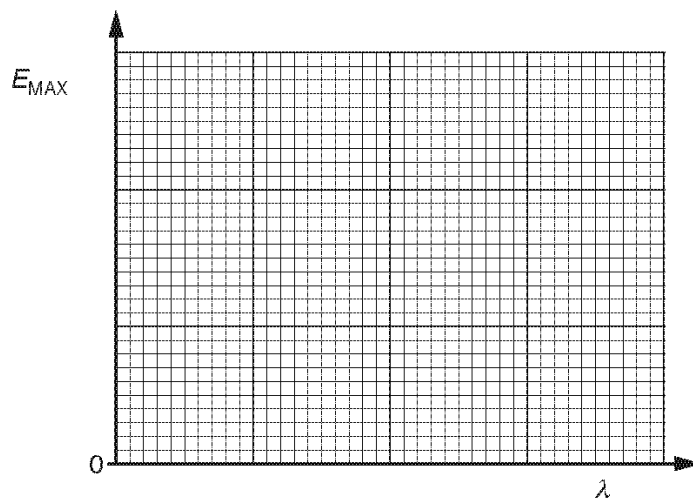


Fig. 10.1

[3]

- (b) A neutron is moving in a straight line with momentum p .
The de Broglie wavelength associated with this neutron is λ .
On Fig. 10.2, sketch the variation with momentum p of the de Broglie wavelength λ .

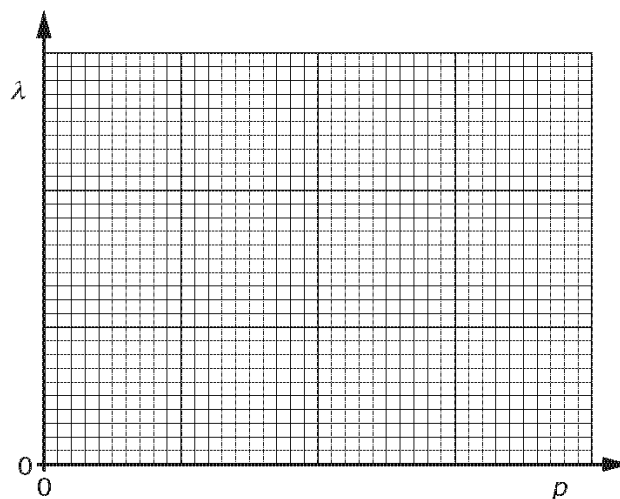


Fig. 10.2

[2]



7 - (9702/41_Winter_2017_Q11) - Quantum Physics

(a) State what is meant by a *photon*.

.....
..... [1]

(b) Indium-123 ($^{123}_{49}\text{In}$) is radioactive.

A nucleus of indium-123 emits a γ -ray photon of energy 1.1 MeV.

Determine, for this γ -radiation,

(i) the frequency,

frequency = Hz [2]

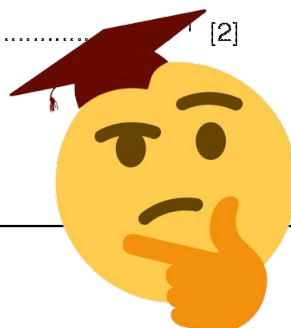
(ii) the momentum of a photon.

momentum = N s [2]

(c) The indium-123 nucleus is stationary before emission of the γ -ray photon.

Use your answer in (b)(ii) to estimate the recoil speed of the nucleus after emission of the photon.

speed = [2]



8 - (9702/42_Summer_2018_Q10) - Quantum Physics

(a) Describe the *photoelectric effect*.

.....
.....
.....[2]

(b) Data for the work function energy Φ of two metals are shown in Fig. 10.1.

	Φ/J
sodium	3.8×10^{-19}
zinc	5.8×10^{-19}

Fig. 10.1

Light of wavelength 420 nm is incident on the surface of each of the metals.

(i) State what is meant by a *photon*.

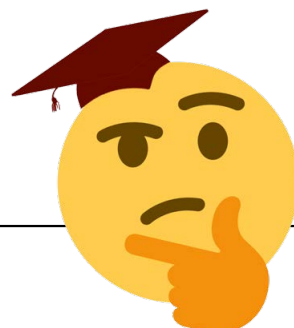
.....
.....
.....[2]

(ii) Calculate the energy of a photon of the incident light.

energy = J [2]

(iii) State whether photoelectric emission will occur from each of the metals.

sodium:
zinc:
[1]



9 - (9702/41_Summer_2018_Q11) - Quantum Physics

(a) (i) Explain what is meant by a *photon*.

.....
.....
.....[2]

(ii) By reference to intensity of light, state one piece of evidence provided by the photoelectric effect for a particulate nature of light.

.....
.....[1]

(b) Some electron energy levels in a solid are illustrated in Fig. 11.1.

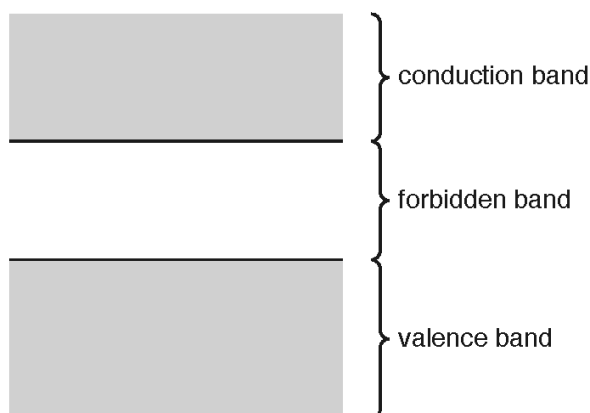
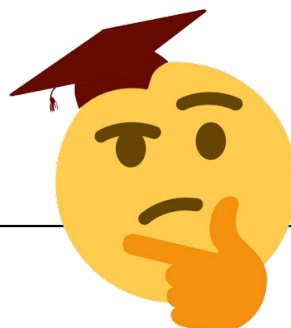


Fig. 11.1

A semiconductor material has a very high resistance in darkness.
Light incident on the semiconductor material causes its resistance to decrease.

Explain the resistance of the semiconductor material in different light conditions.

.....
.....
.....
.....
.....
.....[5]



10 - (9702/41_Winter_2018_Q10) - Quantum Physics

Some of the electron energy bands in a semiconductor material at the absolute zero of temperature are shown in Fig. 10.1.

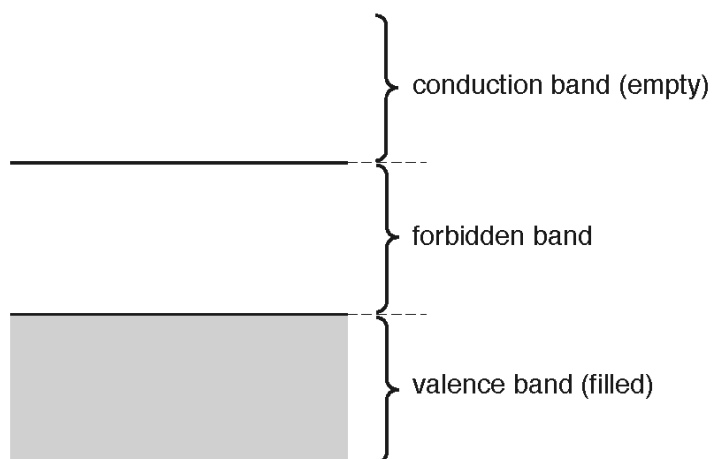


Fig. 10.1

Use band theory to explain why, as the temperature of the semiconductor material rises, the electrical resistance of the sample of material decreases.

.....

.....

.....

.....

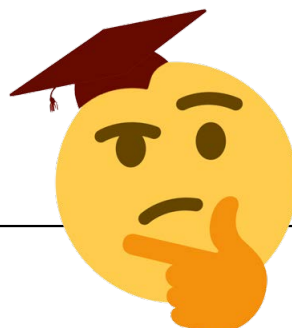
.....

.....

.....

.....

.....[5]



11 - (9702/41_Winter_2018_Q11) - Quantum Physics

A stationary isolated nucleus emits a γ -ray photon of energy 0.51 MeV .

(a) State what is meant by a *photon*.

.....
.....
..... [2]

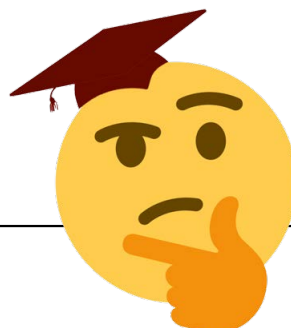
(b) For the γ -ray photon, calculate

(i) its wavelength,

wavelength = m [2]

(ii) its momentum.

momentum = N s [2]

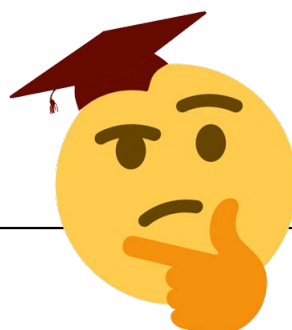


- (c) (i) For this nucleus, determine the change in mass Δm during the decay that gives rise to the energy of the γ -ray photon.

$$\Delta m = \dots\dots\dots \text{ kg [2]}$$

- (ii) Explain why, after the decay, the nucleus is no longer stationary.

.....
.....
.....[1]



12 - (9702/42_Winter_2018_Q11) - Quantum Physics

(a) State what is meant by a *photon*.

.....
.....
.....[2]

(b) Describe the appearance of a visible line emission spectrum, as seen using a diffraction grating.

.....
.....
.....
.....[2]

(c) The lowest electron energy levels in an isolated hydrogen atom are shown in Fig. 11.1.

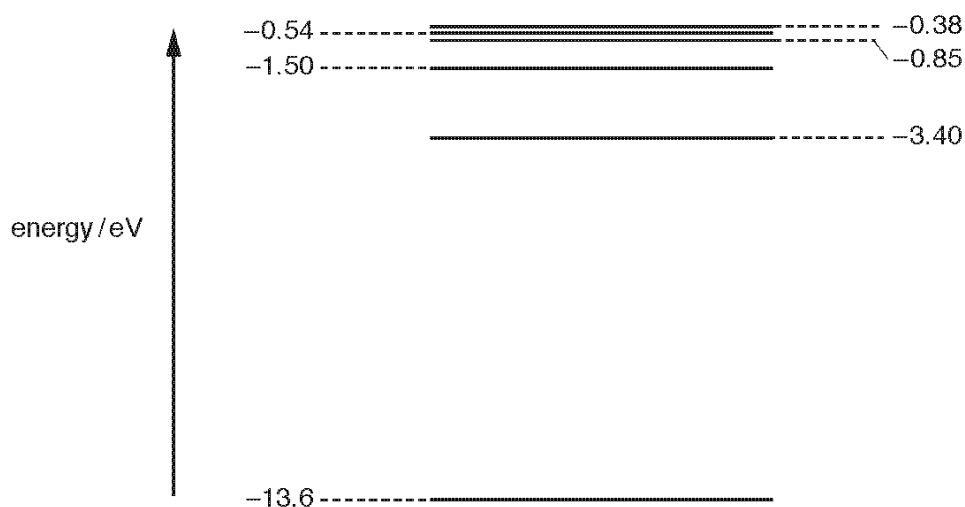
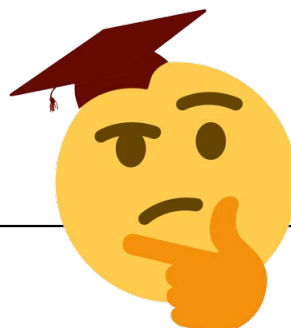


Fig. 11.1 (not to scale)

(i) An electron is initially at the energy level -0.85 eV . State the total number of different wavelengths that may be emitted as the electron de-excites (loses energy).

number = [1]



- (ii) Photons resulting from electron de-excitation from the -0.85 eV energy level are incident on the surface of a sample of platinum.

Platinum has a work function energy of 5.6 eV .

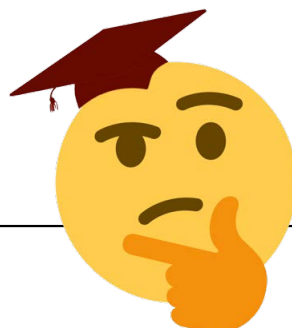
Determine

1. the maximum kinetic energy, in eV, of a photoelectron emitted from the surface of the platinum,

maximum energy = eV [2]

2. the wavelength of the photon producing the photoelectron in (ii) part 1.

wavelength = m [3]



13 - (9702/42_Summer_2019_Q7) - *Quantum Physics*

(a) Use band theory to explain why the resistance of an intrinsic semiconductor decreases as its temperature rises.

[5]

(b) The variation with temperature t of the resistance R of a thermistor is shown in Fig. 7.1.

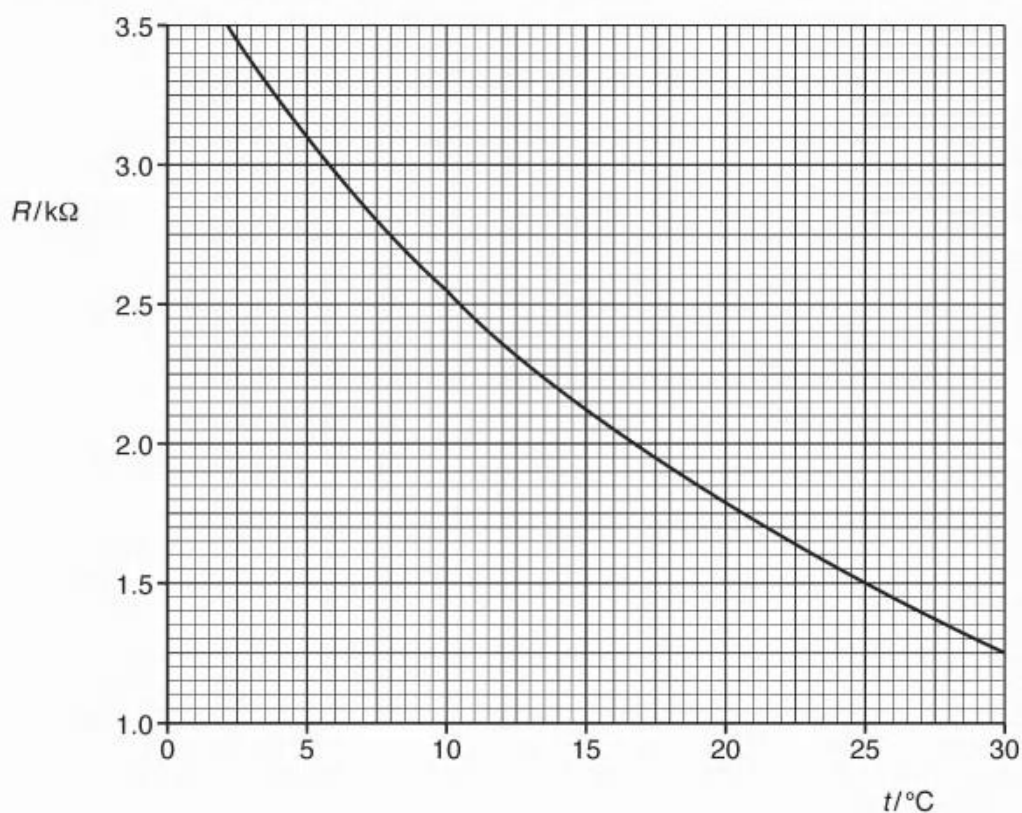
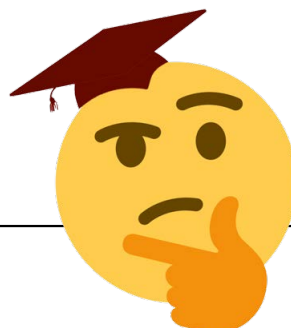


Fig. 7.1



The thermistor is connected into the circuit shown in Fig. 7.2.

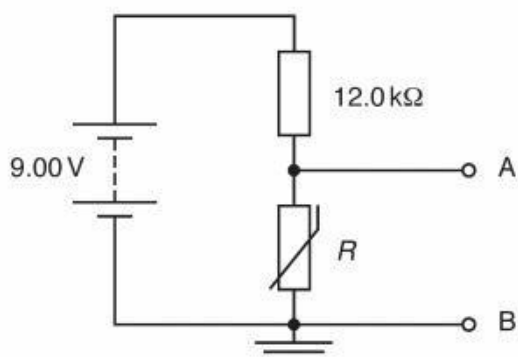


Fig. 7.2

The battery has electromotive force (e.m.f.) 9.00 V and negligible internal resistance.

When the temperature of the thermistor is 25 °C, the potential difference between the terminals A and B is 1.00 V.

The temperature of the thermistor changes from 25 °C to 10 °C.

Determine, to two significant figures, the change in potential difference between A and B.

change = V [3]

- (c) The temperature of the thermistor in (b) changes from 25 °C to 10 °C at a constant rate.

State **two** reasons why the potential difference between A and B does **not** change at a constant rate.

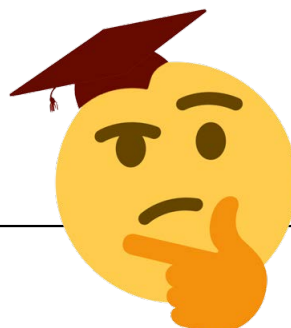
1.

.....

2.

.....

[2]



14 - (9702/41_Summer_2019_Q11) - Quantum Physics

- (a) State **three** pieces of evidence provided by the photoelectric effect for a particulate nature of electromagnetic radiation.

1.

.....

2.

.....

3.

.....

[3]

- (b) The work function energies of some metals are shown in Fig. 11.1.

	work function energy / eV
sodium	2.4
calcium	2.9
zinc	3.6
silver	4.3

Fig. 11.1

Each metal is irradiated with electromagnetic radiation of wavelength 380 nm.

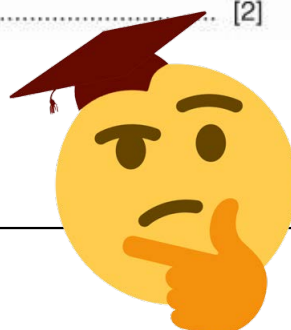
- (i) Calculate the energy, in eV, of a photon of electromagnetic radiation of wavelength 380 nm.

energy =eV [3]

- (ii) Determine which metals will give rise to the emission of photoelectrons. Explain your answer.

.....

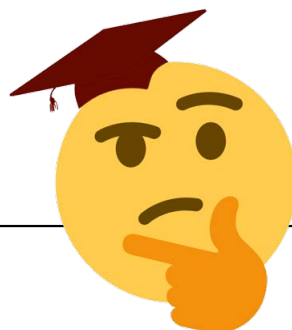
..... [2]



- (c) Photons of wavelength 380nm are incident normally on a metal surface at a rate of $7.6 \times 10^{14} \text{ s}^{-1}$.
All the photons are absorbed in the surface and no photoelectrons are emitted.

Calculate the force exerted on the metal surface by the incident photons.

force = N [3]



15 - (9702/42_Summer_2019_Q11) - Quantum Physics

(a) State what is meant by a *photon*.

.....
.....
..... [2]

(b) A stationary cobalt-60 (${}^{60}_{27}\text{Co}$) nucleus emits a γ -ray photon of energy 1.18 MeV.

(i) Calculate the wavelength of the photon.

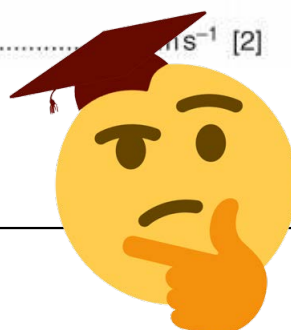
wavelength = m [2]

(ii) Show that the momentum of the photon is $6.3 \times 10^{-22} \text{ N s}$.

[2]

(c) Use information in (b)(ii) to determine the recoil speed of the cobalt-60 nucleus when the γ -ray photon is emitted.

speed = m s^{-1} [2]



16 - (9702/42_Winter_2019_Q10) - *Electronics, Quantum Physics*

- (a) The upper electron energy bands in an intrinsic semiconductor material are illustrated in Fig. 10.1.

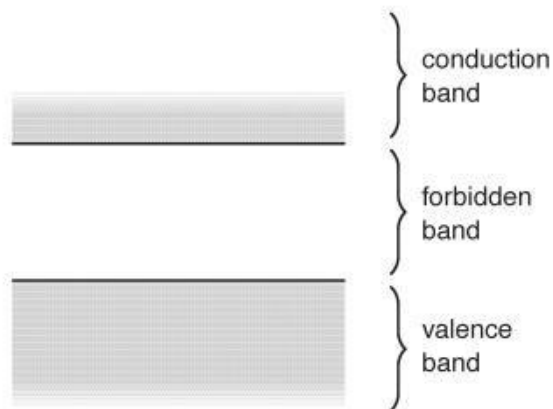


Fig. 10.1

Use band theory to explain why the resistance of an intrinsic semiconductor material decreases as its temperature increases.

.....

.....

.....

.....

.....

.....

.....

..... [4]



(b) A comparator circuit incorporating an ideal operational amplifier (op-amp) is shown in Fig. 10.2.

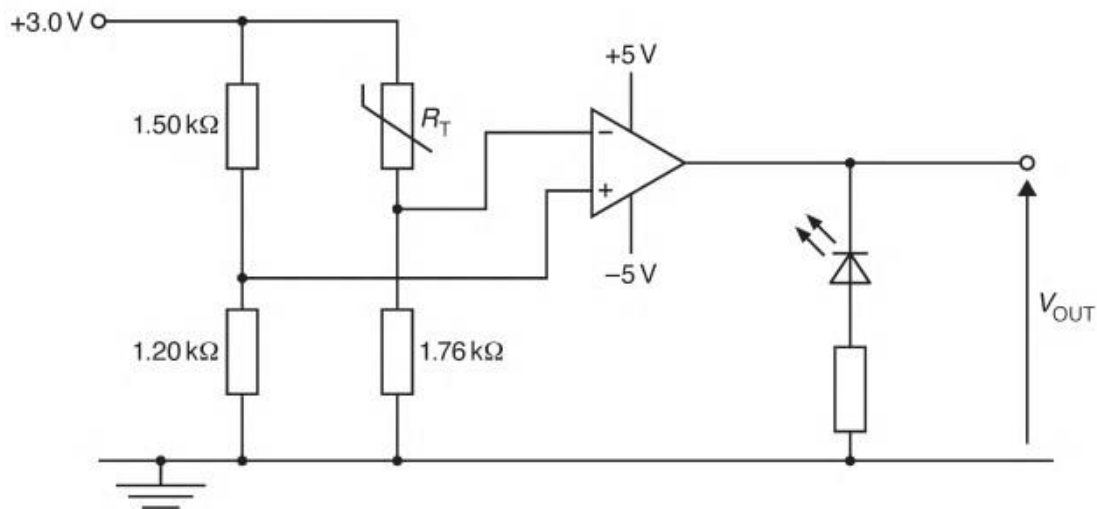


Fig. 10.2

The variation with temperature θ of the resistance R_T of the thermistor is shown in Fig. 10.3.

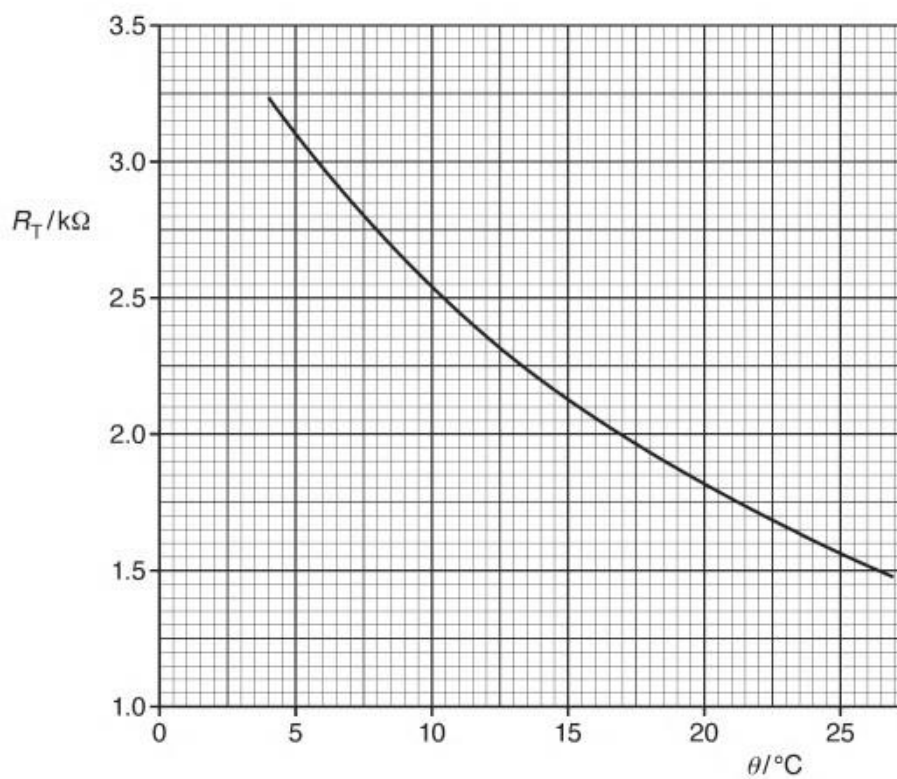


Fig. 10.3

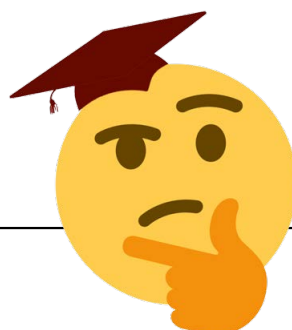


- (i) Determine the temperature at which the light-emitting diode (LED) in Fig. 10.2 switches on or off.

temperature = °C [4]

- (ii) State and explain whether the thermistor is above or below the temperature calculated in (i) for the LED to emit light.

.....
.....
.....
..... [3]



17 - (9702/41_Winter_2019_Q11) - Quantum Physics

- (a) With reference to the photoelectric effect, state what is meant by *work function energy*.

.....
.....
..... [2]

- (b) The work function energy of a clean metal surface is $5.5 \times 10^{-19} \text{ J}$.

Electromagnetic radiation of wavelength 280 nm is incident on the metal surface. The metal is in a vacuum.

- (i) Calculate:

1. the photon energy

photon energy = J [2]

2. the maximum speed v_{MAX} of the electrons emitted from the surface.

$v_{\text{MAX}} = \dots \text{ ms}^{-1}$ [3]

- (ii) Explain why most of the emitted electrons will have a speed lower than v_{MAX} .

.....
..... [1]



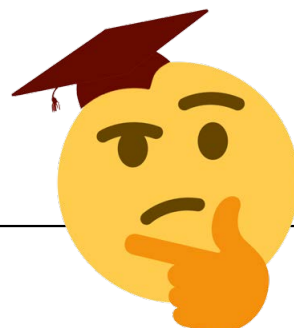
- (c) The electromagnetic radiation incident on the metal surface may change in intensity or in frequency.

Complete Fig. 11.1 by inserting either '*increases*' or '*decreases*' or '*no change*' to describe the effects of the changes shown on the maximum speed and on the rate of emission of electrons.

change	maximum speed of electrons	rate of emission of electrons
reduced intensity at constant frequency		
increased frequency at constant intensity		

Fig. 11.1

[4]



18 - (9702/41_Summer_2020_Q10) - Quantum Physics

(a) White light passes through a cloud of cool low-pressure gas, as illustrated in Fig. 10.1.

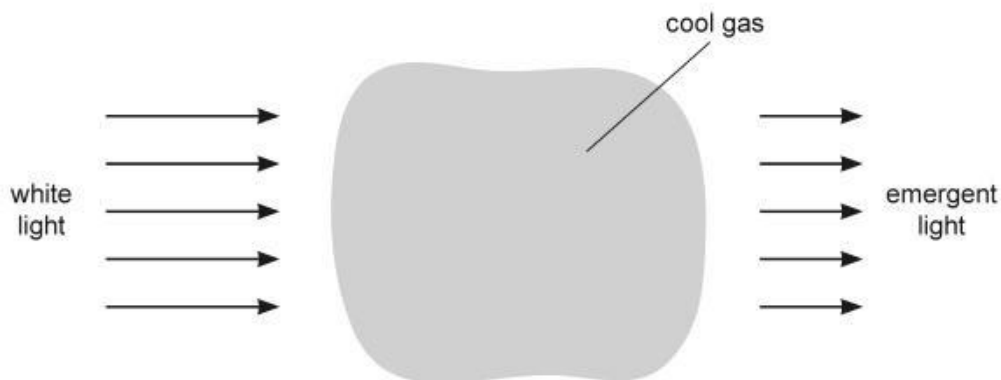


Fig. 10.1

For light that has passed through the gas, its continuous spectrum is seen to contain a number of darker lines.

Use the concept of discrete electron energy levels to explain the existence of these darker lines.

.....

.....

.....

.....

.....

..... [4]



(b) The uppermost electron energy bands in a solid are illustrated in Fig. 10.2.

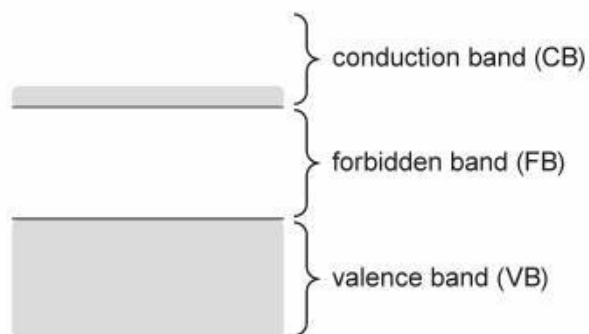


Fig. 10.2

Use band theory to explain the dependence on light intensity of the resistance of a light-dependent resistor (LDR).

.....

.....

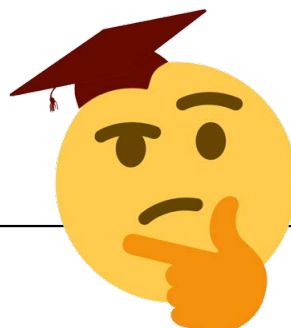
.....

.....

.....

.....

..... [5]



19 – (9702/41_Summer_2020_Q11) – Quantum Physics

An electron, at rest, has mass m_e and charge $-q$.

A positron is a particle that, at rest, has mass m_e and charge $+q$.

A positron interacts with an electron. The electron and the positron may be considered to be at rest.

The outcome of this interaction is that the electron and the positron become two gamma-ray (γ -ray) photons, each having the same energy.

(a) Calculate, for one of the γ -ray photons:

(i) the photon energy, in J

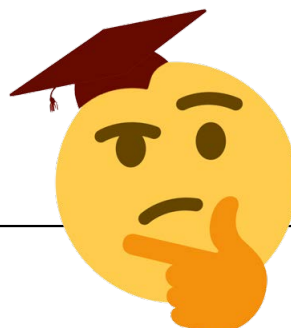
energy = J [2]

(ii) its momentum.

momentum = N s [2]

(b) State and explain the direction, relative to each other, in which the γ -ray photons are emitted.

.....
.....
.....
..... [2]



20 - (9702/42_Summer_2020_Q11) - Quantum Physics

- (a) The uppermost energy bands in a solid are known as the valence band (VB), the forbidden band (FB) and the conduction band (CB).

A copper wire is at room temperature.

Use band theory to explain why the resistance of the copper wire increases as its temperature increases.

.....

.....

.....

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.....

.....

..... [4]

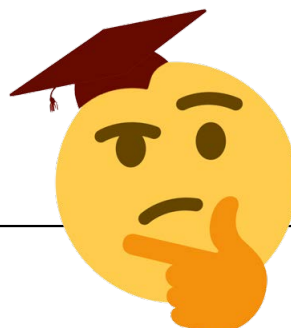
- (b) The structure of a copper crystal is to be examined using electron diffraction.

Electrons, having been accelerated from rest through a potential difference V , are incident on the crystal.

The de Broglie wavelength λ of the electrons is 2.6×10^{-11} m.

Calculate the accelerating potential difference V .

$V = \dots\dots\dots V$ [4]



21 – (9702/41_Winter_2020_Q11) – Quantum Physics

A photon of wavelength 540 nm collides with an isolated stationary electron, as illustrated in Fig. 11.1.

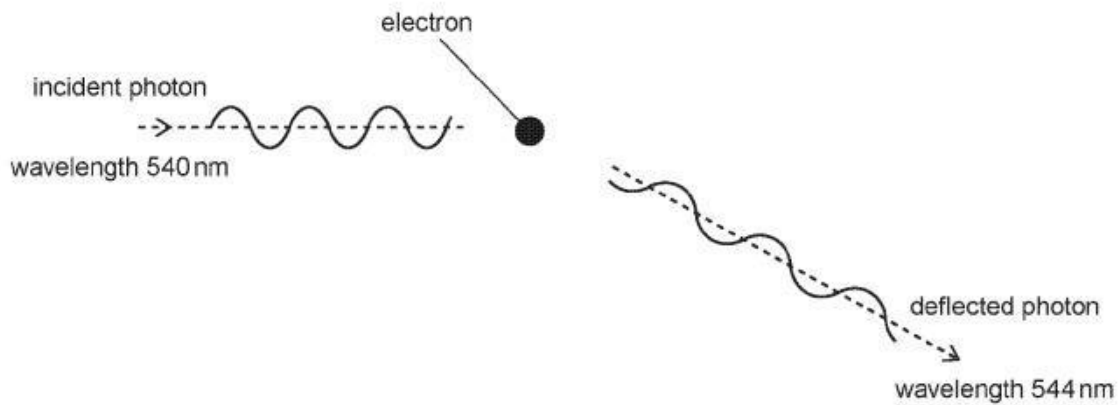


Fig. 11.1

The photon is deflected elastically by the electron.
The wavelength of the deflected photon is 544 nm.

(a) (i) State what is meant by a *photon*.

.....
.....
..... [2]

(ii) On Fig. 11.1, draw an arrow to indicate the approximate direction of motion of the deflected electron. [1]



(b) Calculate:

(i) the momentum of the deflected photon

momentum = N s [2]

(ii) the energy transferred to the deflected electron.

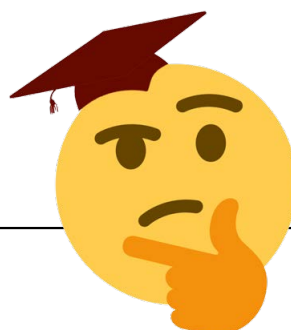
energy = J [2]

(c) Another photon of wavelength 540 nm collides with an isolated stationary electron.

Explain why it is not possible for the deflected photon to have a wavelength less than 540 nm.

.....
.....
..... [2]

[Total: 9]



22 - (9702/42_Winter_2020_Q11) - Quantum Physics

- (a) Electromagnetic radiation is incident on a metal surface.

It is observed that there is a minimum frequency of electromagnetic radiation below which emission of electrons does not occur.

This observation provides evidence for a particulate nature of electromagnetic radiation.

State **two** other observations associated with photoelectric emission that provide evidence for a particulate nature of electromagnetic radiation.

1.

.....

2.

.....

[2]

- (b) The maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is determined for different wavelengths λ of the electromagnetic radiation incident on the surface.

The variation with $\frac{1}{\lambda}$ of E_{MAX} is shown in Fig. 11.1.

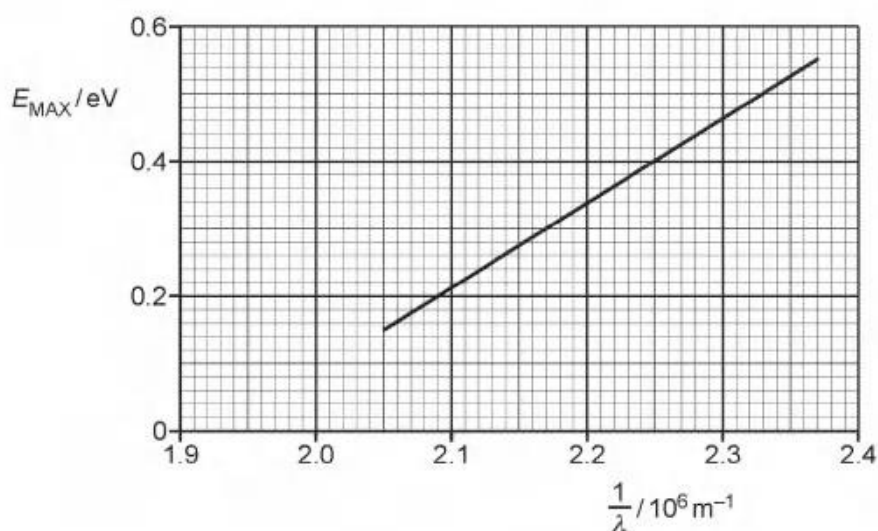
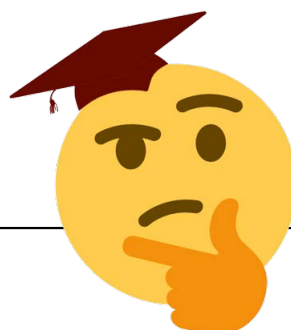


Fig. 11.1



- (i) Use Fig. 11.1 to determine the threshold frequency f_0 .

$$f_0 = \dots\dots\dots \text{Hz} \quad [2]$$

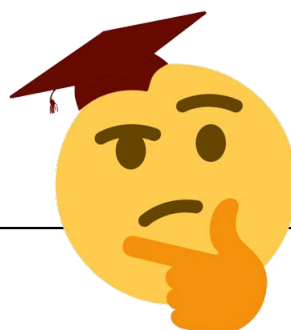
- (ii) Use the gradient of the line on Fig. 11.1 to determine a value for the Planck constant h . Explain your working.

$$h = \dots\dots\dots \text{Js} \quad [4]$$

- (c) The electromagnetic radiation is now incident on a metal with a larger work function energy than the metal in (b).

On Fig. 11.1, sketch the variation with $\frac{1}{\lambda}$ of E_{MAX} . [2]

[Total: 10]



23 – (9702/41_Summer_2021_Q6) – *Electric Fields, Quantum Physics, Particle & Nuclear Physics*

- (a) An isolated metal sphere of radius r is charged so that the electric field strength at its surface is E_0 .

On Fig. 6.1, sketch the variation of the electric field strength E with distance x from the centre of the sphere. Your sketch should extend from $x = 0$ to $x = 3r$.

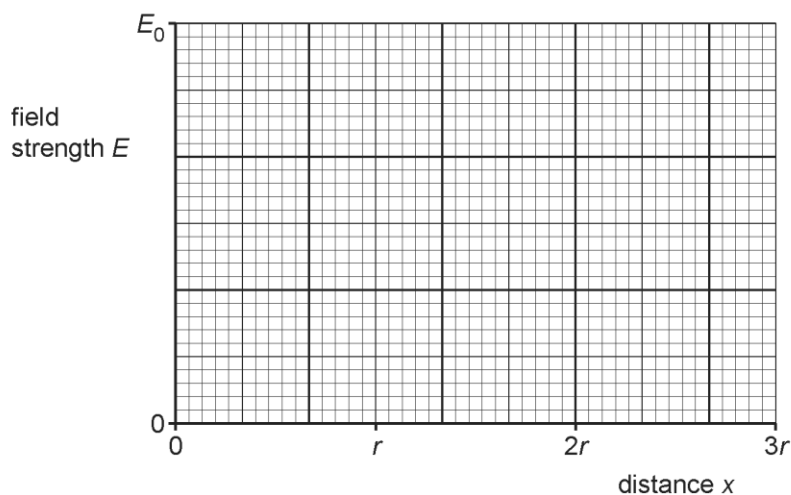


Fig. 6.1

[3]

- (b) The de Broglie wavelength of a particle is λ_0 when its momentum is p_0 .

On Fig. 6.2, sketch the variation with momentum p of the de Broglie wavelength λ of the particle for values of momentum from $\frac{p_0}{2}$ to p_0 .

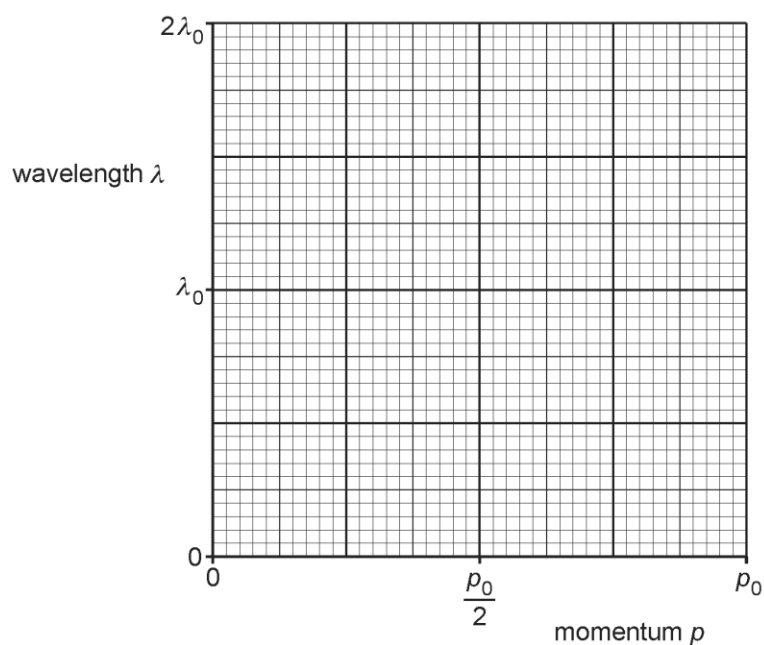
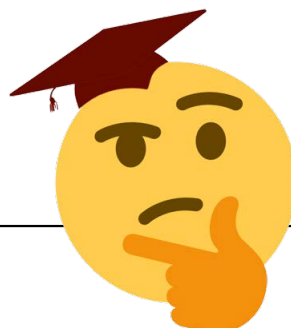


Fig. 6.2



(c) A radioactive isotope decays with a half-life of 15 s to form a stable product.

A fresh sample of the radioactive isotope at time $t = 0$ contains N_0 nuclei and no nuclei of the stable product.

On Fig. 6.3, sketch the variation with t of the number n of nuclei of the stable product for time $t = 0$ to time $t = 45$ s.

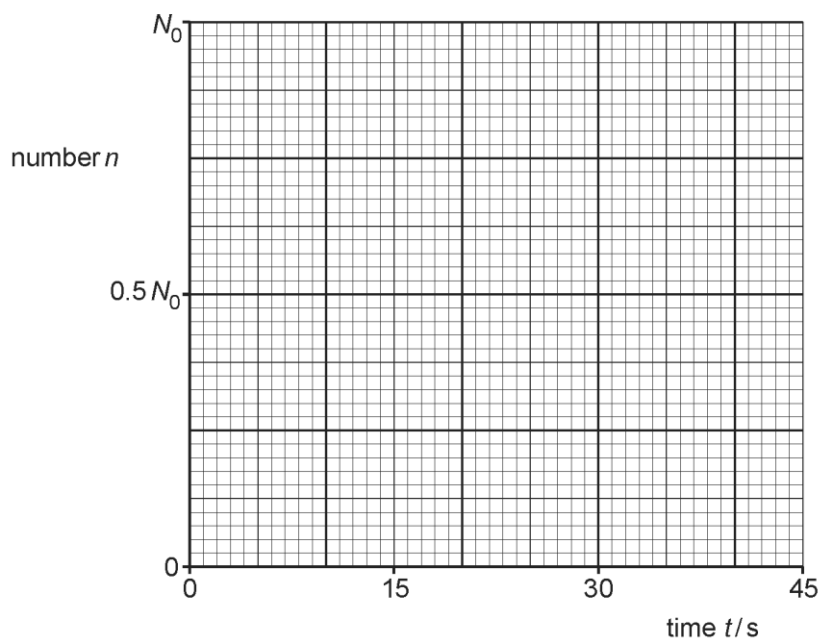
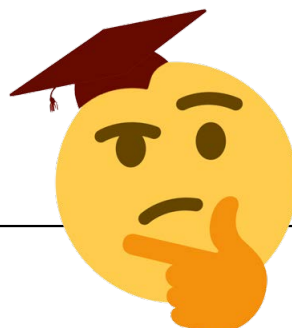


Fig. 6.3

[3]



24 - (9702/41_Summer_2021_Q11) - Quantum Physics

- (a) State how, in a modern X-ray tube, the intensity of the X-ray beam and its hardness are controlled.

intensity:

.....

hardness:

.....

[2]

- (b) A model of a limb consists of soft tissue and bone, as illustrated in Fig. 11.1.

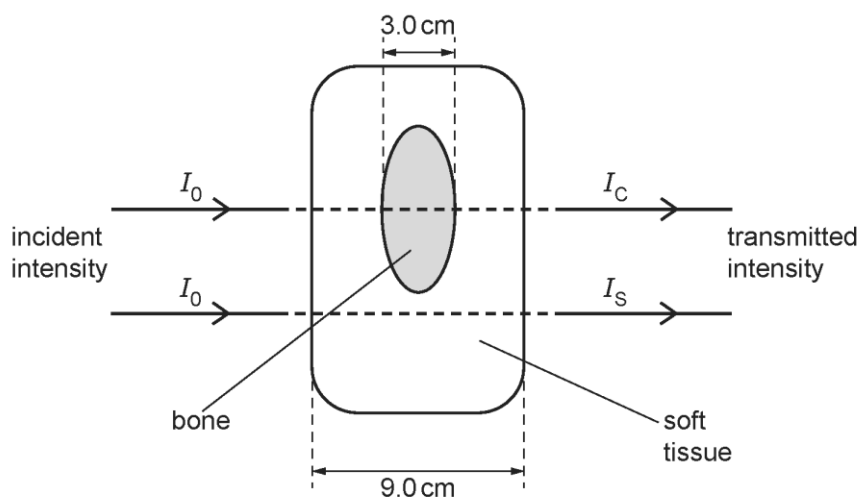


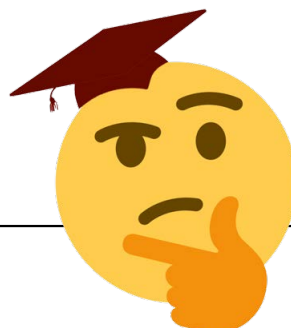
Fig. 11.1

The soft tissue has a thickness of 9.0 cm. The bone within the soft tissue has a thickness of 3.0 cm.

Data for the linear attenuation (absorption) coefficient μ of X-rays in soft tissue and in bone are shown in Table 11.1.

Table 11.1

	μ/cm^{-1}
soft tissue	0.92
bone	2.9



A parallel beam of X-rays of intensity I_0 is incident normally on the model.

Calculate, in terms of I_0 :

- (i) the transmitted intensity I_S through soft tissue alone

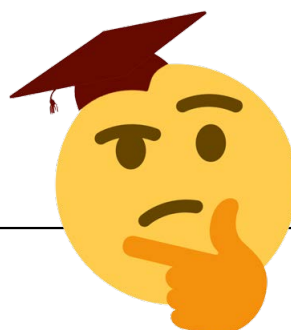
$$I_S = \dots\dots\dots I_0 \text{ [2]}$$

- (ii) the transmitted intensity I_C through soft tissue and bone.

$$I_C = \dots\dots\dots I_0 \text{ [2]}$$

- (c) By reference to your answers in (b), suggest, with a reason, whether good contrast on an X-ray image would be obtained.

.....
..... [1]



25 - (9702/41_Summer_2021_Q12) - Quantum Physics

- (a) Electromagnetic radiation of a single constant frequency is incident on a metal surface. This causes an electron to be emitted.

Explain why the maximum kinetic energy of the electron is independent of the intensity of the incident radiation.

.....

.....

.....

.....

..... [3]

- (b) Ultraviolet radiation of wavelength 250 nm is incident on the surface of a sheet of zinc. The maximum kinetic energy of the emitted electrons is 1.4 eV.

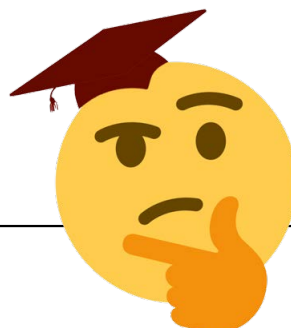
Determine, in eV:

- (i) the energy of a photon of the ultraviolet radiation

energy = eV [3]

- (ii) the work function energy of the surface of the zinc.

energy = eV [2]



26 - (9702/42_Summer_2021_Q12) - Quantum Physics

(a) State what is meant by a *photon*.

.....
.....
..... [2]

(b) A stationary nucleus of samarium-157 ($^{157}_{62}\text{Sm}$) emits a gamma-ray (γ -ray) photon of energy 0.57 MeV.

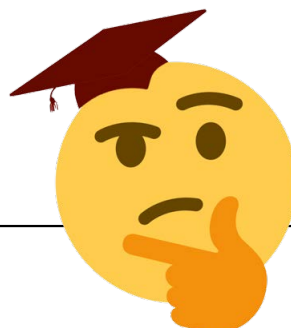
Determine, for one γ -ray photon:

(i) its wavelength

wavelength = m [2]

(ii) its momentum.

momentum = N s [2]

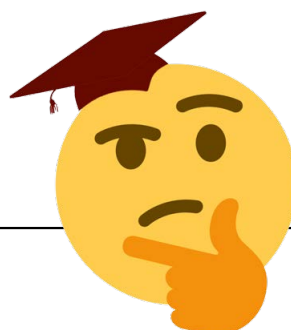


- (c) (i) Using your answer to (b)(ii), determine the speed of the samarium-157 nucleus after emission of the photon.

speed = ms^{-1} [2]

- (ii) By reference to your answer in (c)(i), explain quantitatively why the speed of the samarium-157 nucleus may be assumed to be negligible compared with the speed of the photon.

.....
..... [1]



27 – (9702/41_Winter_2021_Q10) – Quantum Physics

(a) State an experimental phenomenon that provides evidence for:

(i) the particulate nature of electromagnetic radiation

..... [1]

(ii) the wave nature of matter.

..... [1]

(b) A particle of matter moves with momentum p .

(i) State the equation that gives the effective wavelength λ of the particle. State the name of any other symbols used.

[2]

(ii) State the name given to the wavelength of the moving particle.

..... [1]

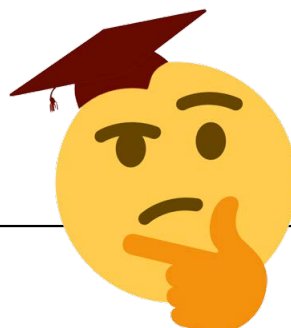
(c) Electrons are accelerated from rest through a potential difference (p.d.) of 4.8 kV.

(i) Show that the final speed of the electrons is $4.1 \times 10^7 \text{ ms}^{-1}$.

[2]

(ii) Calculate the effective wavelength of a beam of electrons moving at the speed in (c)(i).

wavelength = m [2]



28 - (9702/41_Summer_2022_Q7) - Quantum Physics

(a) State what is meant by a photon.

.....
.....
..... [2]

(b) Electromagnetic radiation of a varying frequency f and constant intensity I is used to illuminate a metal surface. At certain frequencies, electrons are emitted from the surface of the metal. The variation with f of the maximum kinetic energy E_{MAX} of the emitted electrons is shown in Fig. 7.1.

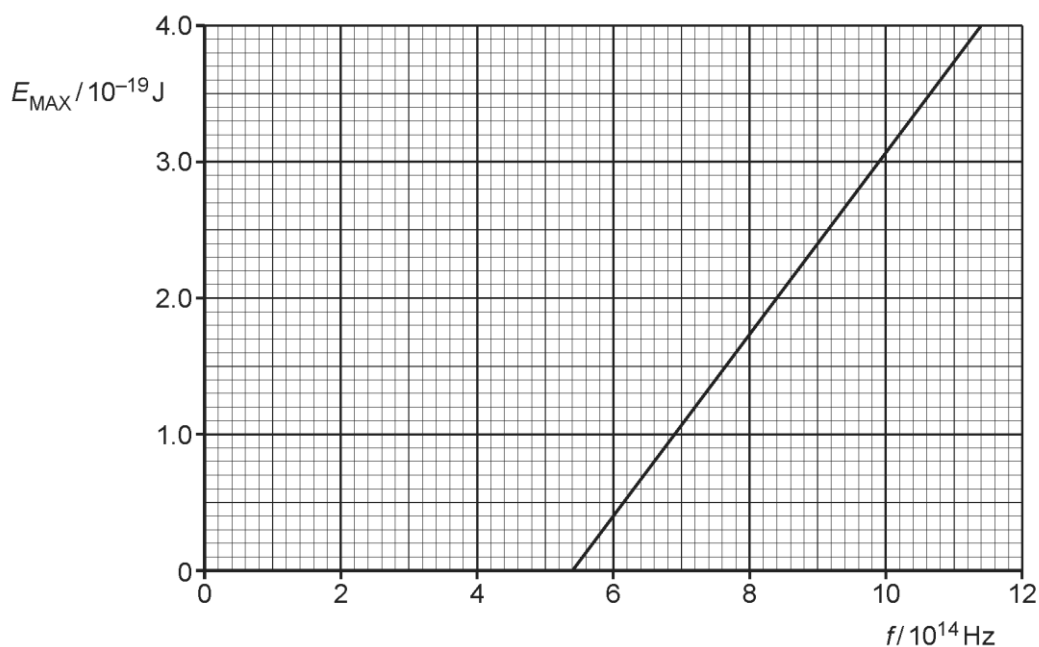
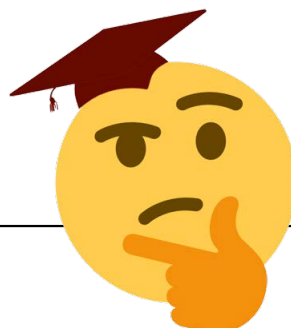


Fig. 7.1

(i) State the name of this phenomenon.

..... [1]



- (ii) Describe **three** conclusions that can be drawn from the graph in Fig. 7.1. The conclusions may be qualitative or quantitative.

1

.....

2

.....

3

.....

[3]

- (c) The experiment in (b) is repeated twice, each time making one change.

State, with a reason, how the graph obtained would compare with Fig. 7.1 when:

- (i) a different metal is used, but keeping the intensity I of the radiation the same

.....

.....

..... [2]

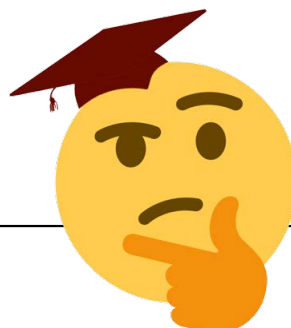
- (ii) the same metal is used, but with electromagnetic radiation of intensity $2I$.

.....

.....

..... [2]

[Total: 10]



29 – (9702/42_Summer_2022_Q8) – Quantum Physics

(a) State **one** piece of experimental evidence for:

(i) the particulate nature of electromagnetic radiation

..... [1]

(ii) the wave nature of matter.

..... [1]

(b) (i) Calculate the de Broglie wavelength λ of an alpha-particle moving at a speed of $6.2 \times 10^7 \text{ ms}^{-1}$.

$\lambda =$ m [3]

(ii) The speed v of the alpha-particle in (b)(i) is gradually reduced to zero.

On Fig. 8.1, sketch the variation with v of λ .

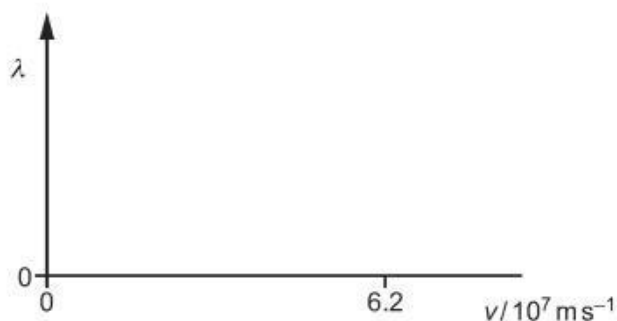


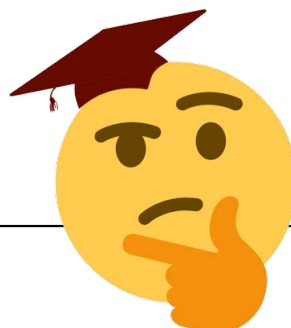
Fig. 8.1

[2]

(c) Suggest an explanation for why people are not observed to diffract when they walk through a doorway.

.....
.....
..... [1]

[Total: 8]



30 – (9702/41_Winter_2022_Q8) – Quantum Physics

- (a) State what is meant by the work function energy of a metal.

.....
.....
..... [2]

- (b) Ultraviolet radiation of frequency 1.36×10^{15} Hz is incident, in a vacuum, on a metal surface. The power of the radiation incident on the surface is 8.36 mW. Photoelectrons are emitted with a maximum kinetic energy of 3.09×10^{-19} J.

- (i) Determine the number of photons incident on the surface per unit time.

number per unit time = s^{-1} [2]

- (ii) Calculate the work function energy ϕ of the metal.

$\phi =$ J [2]

- (c) The frequency of the radiation incident on the surface in (b) is increased while the power remains constant.

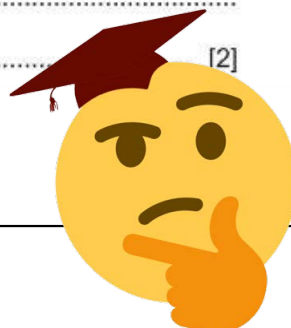
State and explain the effect of this change on:

- (i) the maximum kinetic energy of the photoelectrons

.....
.....
..... [2]

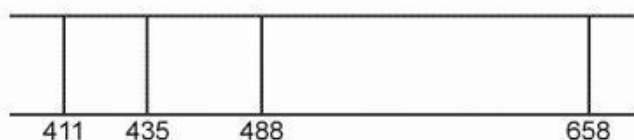
- (ii) the rate of emission of photoelectrons.

.....
.....
..... [2]



31 - (9702/42_Winter_2022_Q9) - Quantum Physics

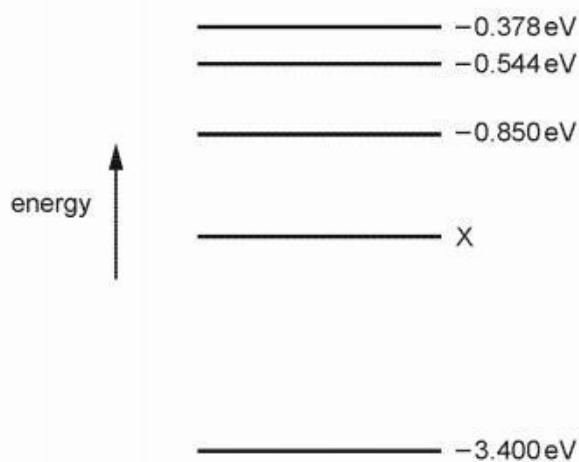
- (a) Fig. 9.1 shows the visible part of the emission spectrum from hydrogen gas in a laboratory on the Earth. The numbers indicate the wavelength, in nm, represented by each line.

**Fig. 9.1**

- (i) Explain how the emission spectrum provides evidence for the existence of discrete energy levels for the electron in a hydrogen atom.

.....
.....
.....
..... [3]

- (ii) Fig. 9.2 shows five of the energy levels in the hydrogen atom. The wavelengths of radiation shown in Fig. 9.1 relate to transitions to the -3.400 eV level in Fig. 9.2.

**Fig. 9.2** (not to scale)

Show that the energy level X is -1.51 eV .

[3]



- (b) The same part of the emission spectrum from hydrogen as in (a), observed in light from stars in a distant galaxy, is shown in Fig. 9.3. The numbers indicate the wavelengths in nm.

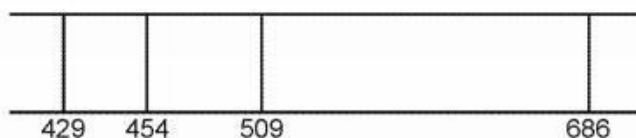


Fig. 9.3

The spectrum shows the same pattern as Fig. 9.1 but with different wavelengths.

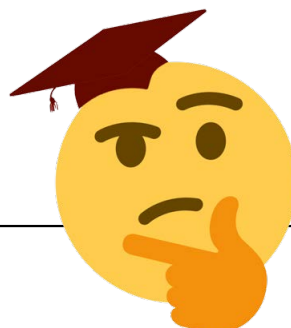
- (i) State the name of the phenomenon that gives rise to the change in the wavelengths.
..... [1]
- (ii) State what this phenomenon shows about the motion of the galaxy.
..... [1]
- (iii) Use one of the lines in Fig. 9.1, and the corresponding line in Fig. 9.3, to determine the speed of the distant galaxy relative to the observer.

speed = ms^{-1} [3]

- (c) The galaxy in (b) is known to be a distance of $5.7 \times 10^{24} \text{ m}$ from the Earth.

Use your answer in (b)(iii) to determine a value for the Hubble constant H_0 .

$H_0 = \dots\dots\dots \text{s}^{-1}$ [2]



32 - (9702/42_Summer_2023_Q8) - Quantum Physics

Fig. 8.1 shows the lowest four energy levels of an electron in an isolated atom.

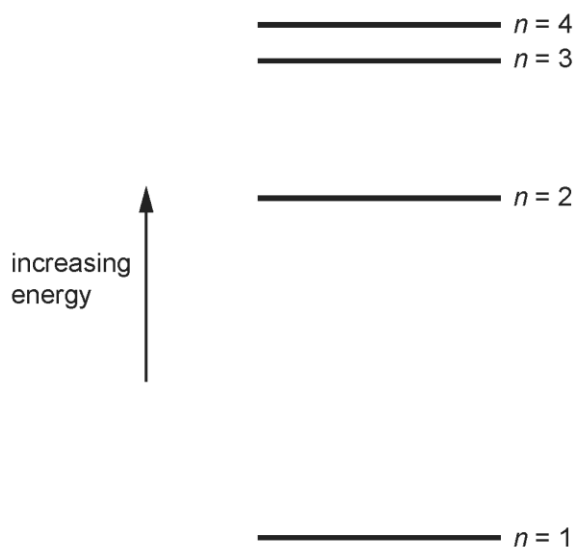


Fig. 8.1

Fig. 8.2 shows the lines in the emission spectrum of the atom that correspond to the transitions of the electron from $n = 3$ to $n = 1$ and from $n = 4$ to $n = 1$.

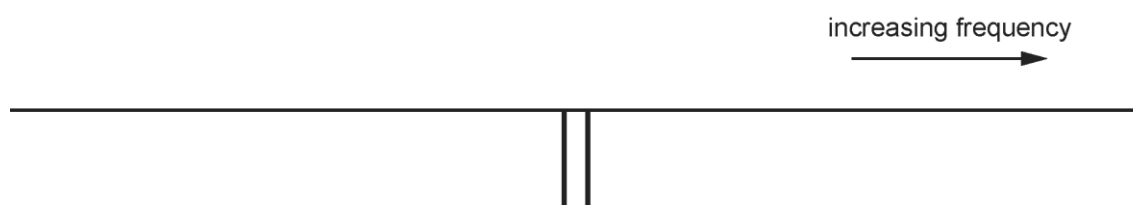


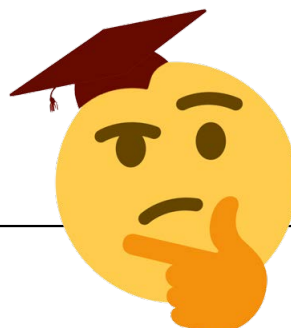
Fig. 8.2

- (a) Explain, with reference to photons, why there is a single frequency of electromagnetic radiation that corresponds to each of these transitions.

.....

 [2]

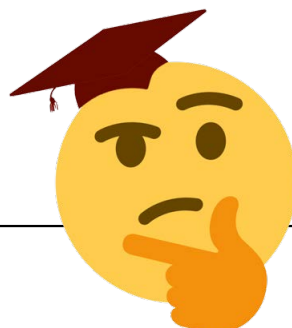
- (b) (i) On Fig. 8.2, draw a line that corresponds to the transition of the electron from $n = 2$ to $n = 1$.
 Label this line A. [2]
- (ii) On Fig. 8.2, draw a line that corresponds to the transition of the electron from $n = 3$ to $n = 2$.
 Label this line B. [2]



- (c) The frequency of radiation represented by line A is f_A .
The frequency of radiation represented by line B is f_B .
The energy of the ground state ($n = 1$) is E_1 .

Determine an expression, in terms of f_A , f_B , E_1 and the Planck constant h , for the energy E_3 of the energy level $n = 3$.

$$E_3 = \dots\dots\dots [2]$$



33 – (9702/41_Winter_2023_Q8) – Quantum Physics

- (a) (i) Show that the momentum p of a photon of electromagnetic radiation with wavelength λ is given by

$$p = \frac{h}{\lambda}$$

where h is the Planck constant.

[2]

- (ii) Use the expression in (a)(i) to show that a photon in free space that has a momentum of $9.5 \times 10^{-28} \text{ N s}$ is a photon of red light.

[1]

- (b) A beam of red light of intensity 160 W m^{-2} is incident normally on a plane mirror, as shown in Fig. 8.1. The momentum of each photon in the beam is $9.5 \times 10^{-28} \text{ N s}$.

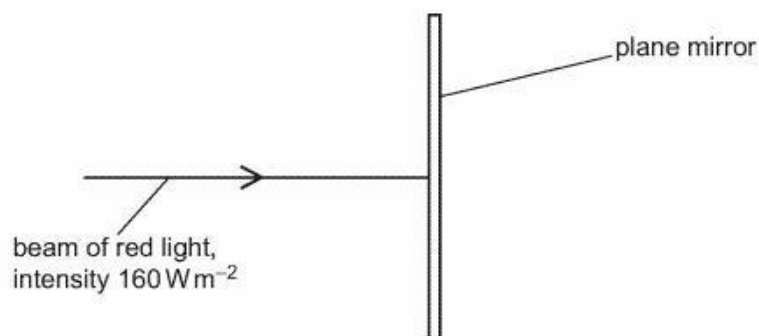


Fig. 8.1

All of the light is reflected by the mirror in the opposite direction to its original path. The cross-sectional area of the beam is $2.5 \times 10^{-6} \text{ m}^2$.



- (i) Show that the number of photons incident on the mirror per unit time is $1.4 \times 10^{15} \text{ s}^{-1}$.

[2]

- (ii) Use the information in (b)(i) to determine the pressure exerted by the light beam on the mirror.

pressure = Pa [3]

- (c) The beam of red light in (b) is now replaced with a beam of blue light of the same intensity.

Suggest and explain whether the pressure exerted on the mirror by the beam of blue light is less than, the same as, or greater than the pressure exerted by the beam of red light.

.....
.....
.....
..... [2]



34 – (9702/42_Winter_2023_Q8) – Quantum Physics

(a) State what is meant by a photon.

.....

.....

..... [2]

(b) When the surface of a metal plate is illuminated with electromagnetic radiation, electrons are sometimes emitted from the metal.

(i) State the name of this phenomenon.

..... [1]

(ii) It is observed that this phenomenon occurs only when the frequency of the electromagnetic radiation is greater than a certain minimum value, regardless of the intensity of the radiation.

Explain how this observation provides evidence for the existence of photons.

.....

.....

.....

.....

..... [3]

(c) Fig. 8.1 shows the variation of the maximum kinetic energy of the emitted electrons in (b) with the frequency of the incident radiation.

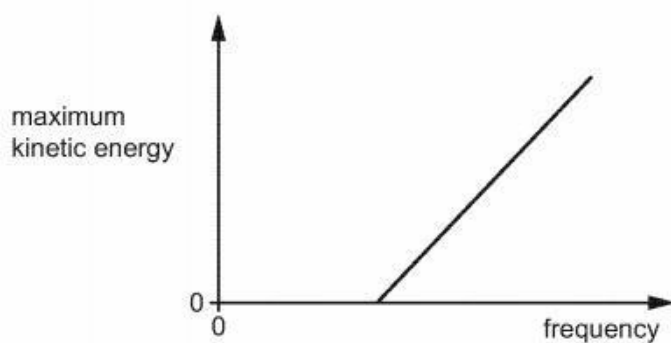
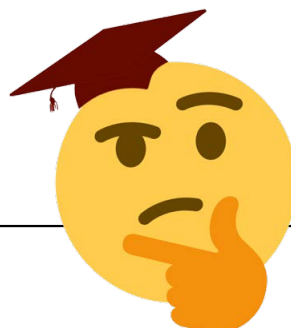


Fig. 8.1



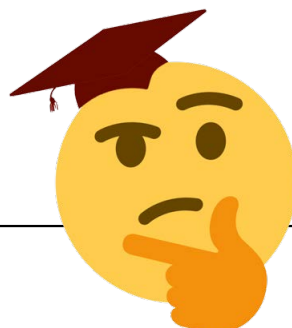
State the name of the quantity represented by:

- (i) the gradient of the line in Fig. 8.1

..... [1]

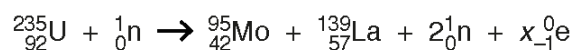
- (ii) the y-intercept of the extrapolated line in Fig. 8.1.

..... [1]



1 - (9702/41_Summer_2017_Q12) - Particle & Nuclear Physics

One possible nuclear reaction that takes place in a nuclear reactor is given by the equation



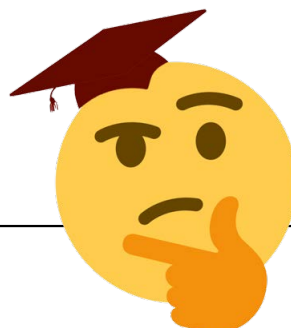
Data for the nuclei and particles are given in Fig. 12.1.

nucleus or particle	mass / u
${}_{92}^{235}\text{U}$	235.123
${}_{42}^{95}\text{Mo}$	94.945
${}_{57}^{139}\text{La}$	138.955
${}_0^1\text{n}$	1.00863
${}_{-1}^0\text{e}$	5.49×10^{-4}

Fig. 12.1

(a) Determine, for this nuclear reaction, the value of x .

$x = \dots\dots\dots [1]$



(b) (i) Show that the energy equivalent to 1.00 u is 934 MeV.

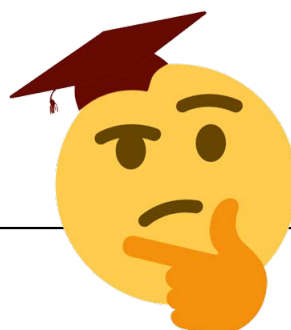
[3]

(ii) Calculate the energy, in MeV, released in this reaction. Give your answer to three significant figures.

energy = MeV [3]

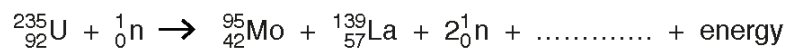
(c) Suggest the forms of energy into which the energy calculated in **(b)(ii)** is transformed.

.....
.....
.....
.....[2]



2 - (9702/42_Summer_2017_Q12) - Particle & Nuclear Physics

One nuclear reaction that can take place in a nuclear reactor may be represented, in part, by the equation



Data for a nucleus and some particles are given in Fig. 12.1.

nucleus or particle	mass /u
${}_{57}^{139}\text{La}$	138.955
${}_0^1\text{n}$	1.00863
${}_1^1\text{p}$	1.00728
${}_{-1}^0\text{e}$	5.49×10^{-4}

Fig. 12.1

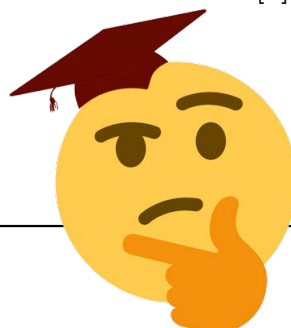
(a) Complete the nuclear reaction shown above. [1]

(b) (i) Show that the energy equivalent to 1.00 u is 934 MeV.

[3]

(ii) Calculate the binding energy per nucleon, in MeV, of lanthanum-139 (${}_{57}^{139}\text{La}$).

binding energy per nucleon = MeV [3]



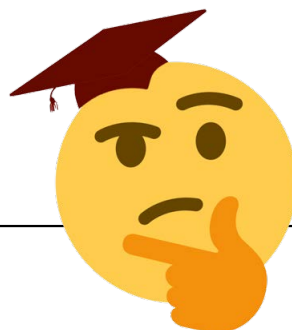
- (c) State and explain whether the binding energy per nucleon of uranium-235 (${}^{235}_{92}\text{U}$) will be greater, equal to or less than your answer in (b)(ii).

.....

.....

.....

.....[3]



3 - (9702/41_Winter_2017_Q9) - *Particle & Nuclear Physics*

- (a) In computed tomography (CT scanning), it is necessary to take a series of many X-ray images.

Outline briefly the principles of CT scanning.

.....

.....

.....

.....

.....

.....

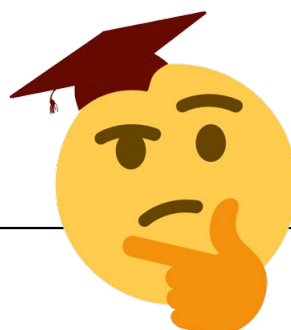
.....

.....

.....

.....

..... [4]



- (b) A student creates a model for CT scanning.
A section is divided into four voxels, with pixel numbers A, B, C and D, as shown in Fig. 9.1.

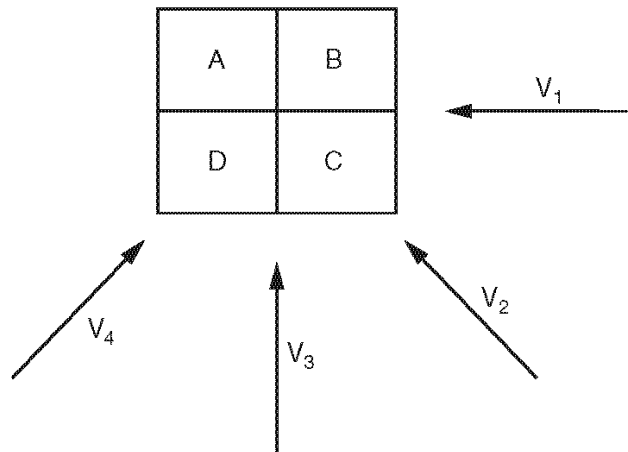


Fig. 9.1

The section is viewed from four different directions V_1 , V_2 , V_3 and V_4 , as shown in Fig. 9.1.

The detector readings for each direction are noted and then summed. The result is shown in Fig. 9.2.

47	59
44	32

Fig. 9.2

The background count is 26.

Determine the pixel numbers A, B, C and D as shown in Fig. 9.1.

A B

D C

[3]



4 - (9702/41_Winter_2017_Q12) - Particle & Nuclear Physics

- (a) A radiation detector is placed close to a radioactive source. The detector does not surround the source. Radiation is emitted in all directions and, as a result, the activity of the source and the measured count rate are different.

Suggest two other reasons why the activity and the measured count rate may be different.

1.

.....

2.

.....

[2]

- (b) The variation with time t of the measured count rate in (a) is shown in Fig. 12.1.

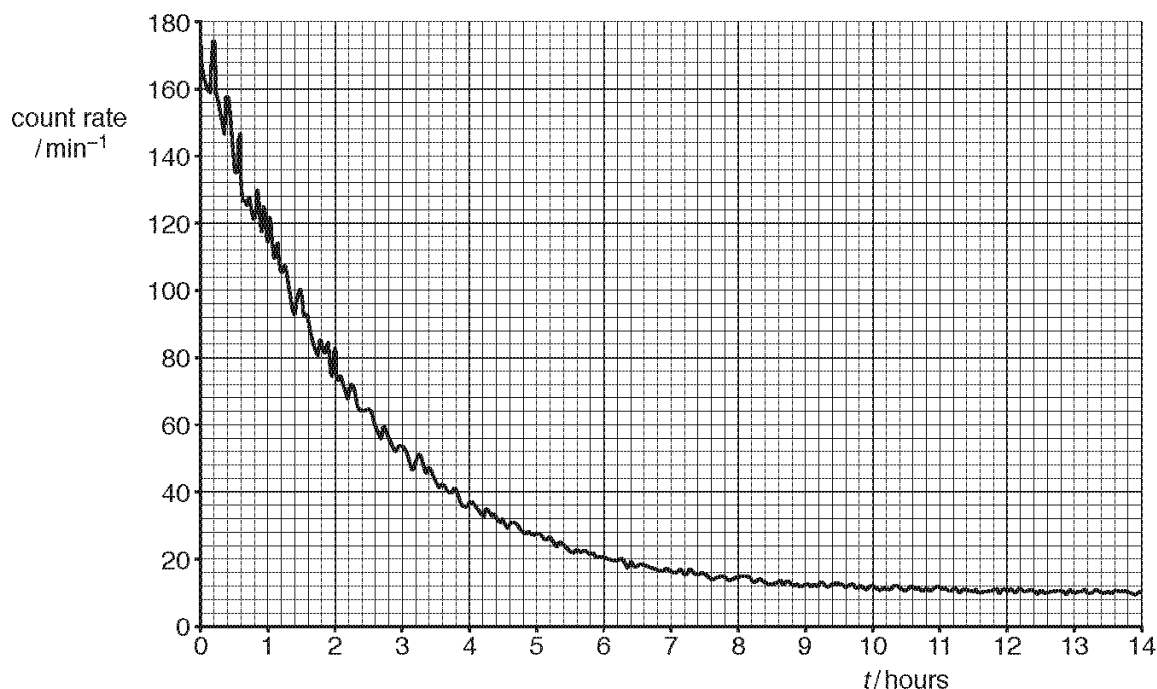
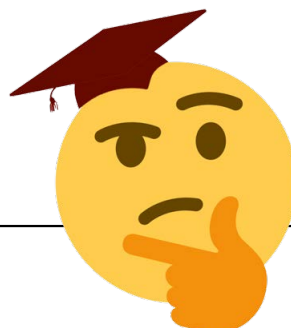


Fig. 12.1

- (i) State the feature of Fig. 12.1 that indicates the random nature of radioactive decay.

.....

..... [1]



(ii) Use Fig. 12.1 to determine the half-life of the radioactive isotope in the source.

half-life = hours [4]

- (c) The readings in (b) were obtained at room temperature.
A second sample of this isotope is heated to a temperature of 500 °C.
The initial count rate at time $t = 0$ is the same as that in (b).
The variation with time t of the measured count rate from the heated source is determined.

State, with a reason, the difference, if any, in

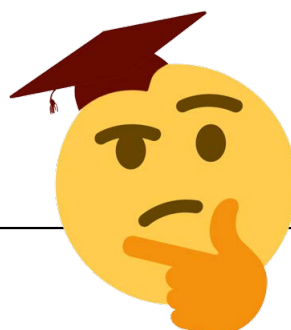
1. the half-life,

.....
.....
.....

2. the measured count rate for any specific time.

.....
.....
.....

[3]



5 - (9702/42_Winter_2017_Q12) - Particle & Nuclear Physics

The isotope iodine-131 ($^{131}_{53}\text{I}$) is radioactive with a decay constant of $8.6 \times 10^{-2} \text{ day}^{-1}$.
 β^{-} particles are emitted with a maximum energy of 0.61 MeV.

(a) State what is meant by

(i) *radioactive*,

.....
.....
.....[2]

(ii) *decay constant*.

.....
.....
.....[2]

(b) Explain why the emitted β^{-} particles have a range of energies.

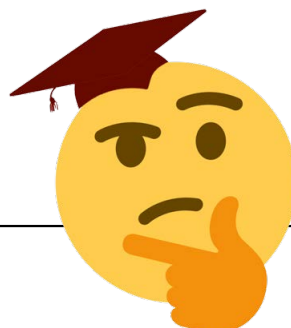
.....
.....
.....[2]

(c) A sample of blood contains $1.2 \times 10^{-9} \text{ g}$ of iodine-131.

Determine, for this sample of blood,

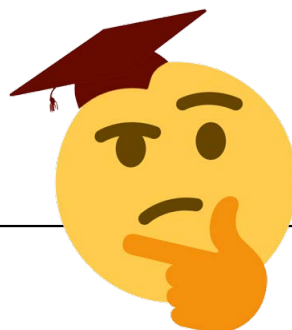
(i) the activity of the iodine-131,

activity = Bq [3]



- (II) the time for the activity of the iodine-131 to be reduced to $1/50$ of the activity calculated in (I).

time = days [2]



6 - (9702/42_Summer_2018_Q12) - Particle & Nuclear Physics

(a) State what is meant by *radioactive decay*.

.....

.....

.....

.....[2]

(b) An unstable nuclide P has decay constant λ_P and decays to form a nuclide D. This nuclide D is unstable and decays with decay constant λ_D to form a stable nuclide S. The decay chain is illustrated in Fig. 12.1.

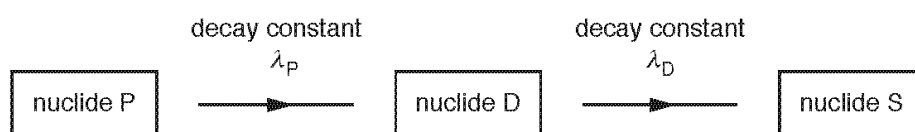


Fig. 12.1

The symbols P, D and S are not the nuclide symbols.

Initially, a radioactive sample contains only nuclide P.

The variation with time t of the number of nuclei of each of the three nuclides in the sample is shown in Fig. 12.2.

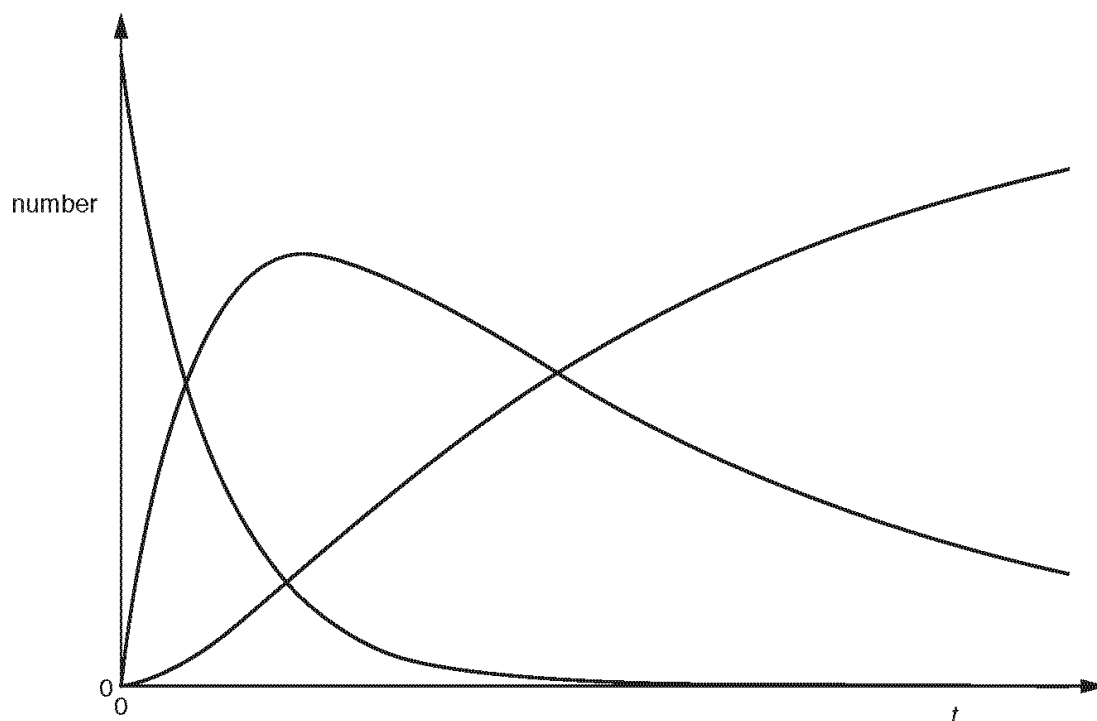
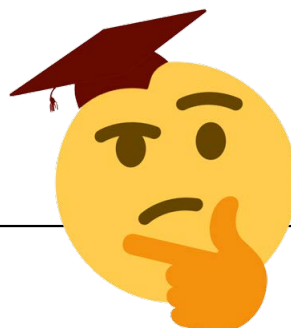


Fig. 12.2



(i) On Fig. 12.2, use the symbols P, D and S to identify the curve for each of the three nuclides. [2]

(ii) The half-life of nuclide P is 60.0 minutes.

Calculate the decay constant λ_P in s^{-1} , of this nuclide.

$$\lambda_P = \dots\dots\dots \text{s}^{-1} \quad [2]$$

(c) In the decay chain shown in Fig. 12.1, λ_P is approximately equal to $5\lambda_D$.

The decay chain of a different nuclide E is illustrated in Fig. 12.3.

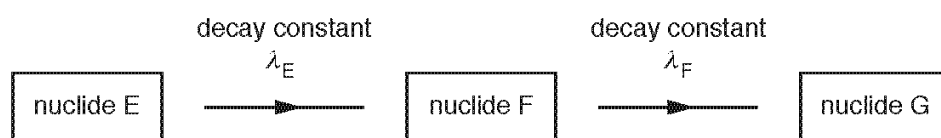
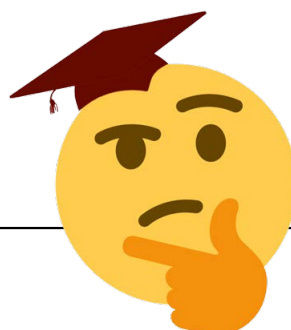


Fig. 12.3

The decay constant λ_F of nuclide F is very much larger than the decay constant λ_E of nuclide E.

By reference to the half-life of nuclide F, explain why the number of nuclei of nuclide F in the sample is always small.

.....
.....
.....[2]



7 - (9702/41_Summer_2018_Q13) - Particle & Nuclear Physics

(a) State what is meant by *radioactive decay*.

.....
.....
.....
.....[2]

(b) The variation with time t of the number N of technetium-101 nuclei in a sample of radioactive material is shown in Fig. 13.1.

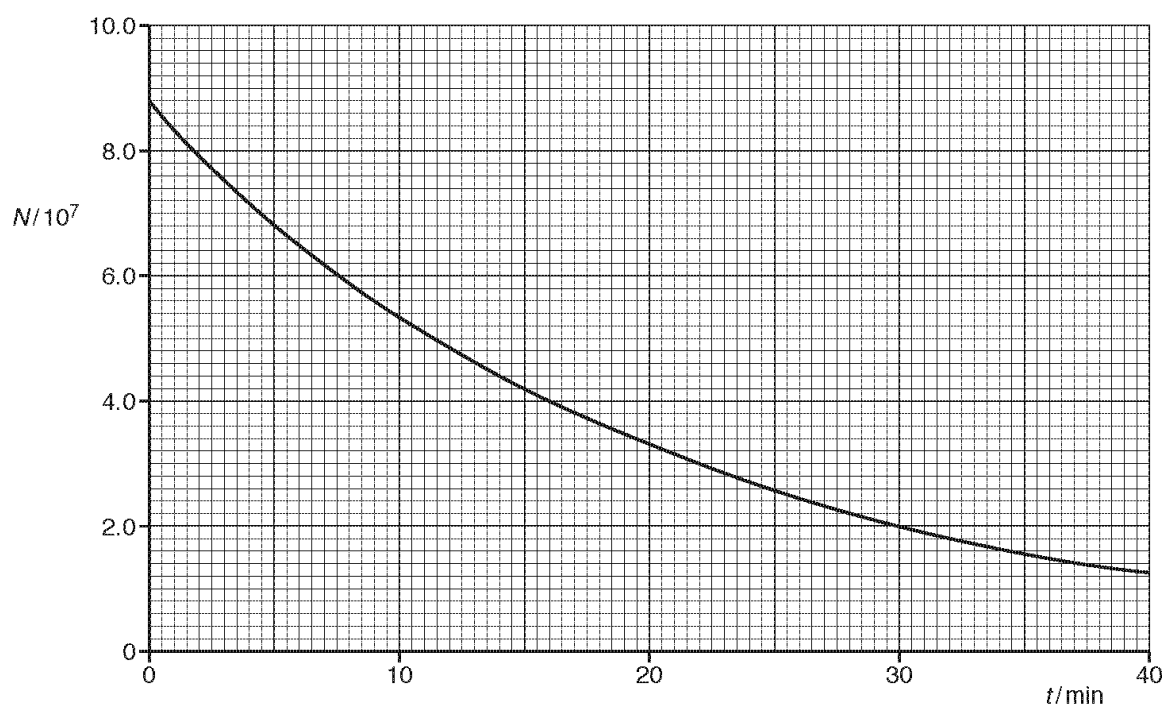
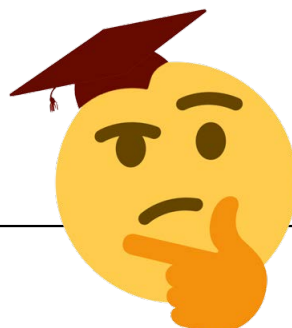


Fig. 13.1

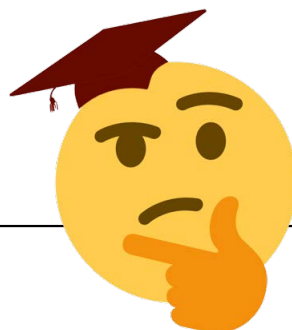


- (i) Use Fig. 13.1 to determine the activity, in Bq, of the sample of technetium-101 at time $t = 14.0$ minutes. Show your working.

activity = Bq [4]

- (ii) Without calculating the half-life of technetium-101, use your answer in (i) to determine the decay constant λ of technetium-101.

$\lambda = \dots\dots\dots \text{s}^{-1}$ [2]



8 - (9702/41_Winter_2018_Q12) - Particle & Nuclear Physics

(a) State what is meant by *radioactive decay*.

.....

.....

.....

.....[3]

(b) The variation with time t of the number N of undecayed nuclei in a sample of a radioactive isotope is shown in Fig. 12.1.

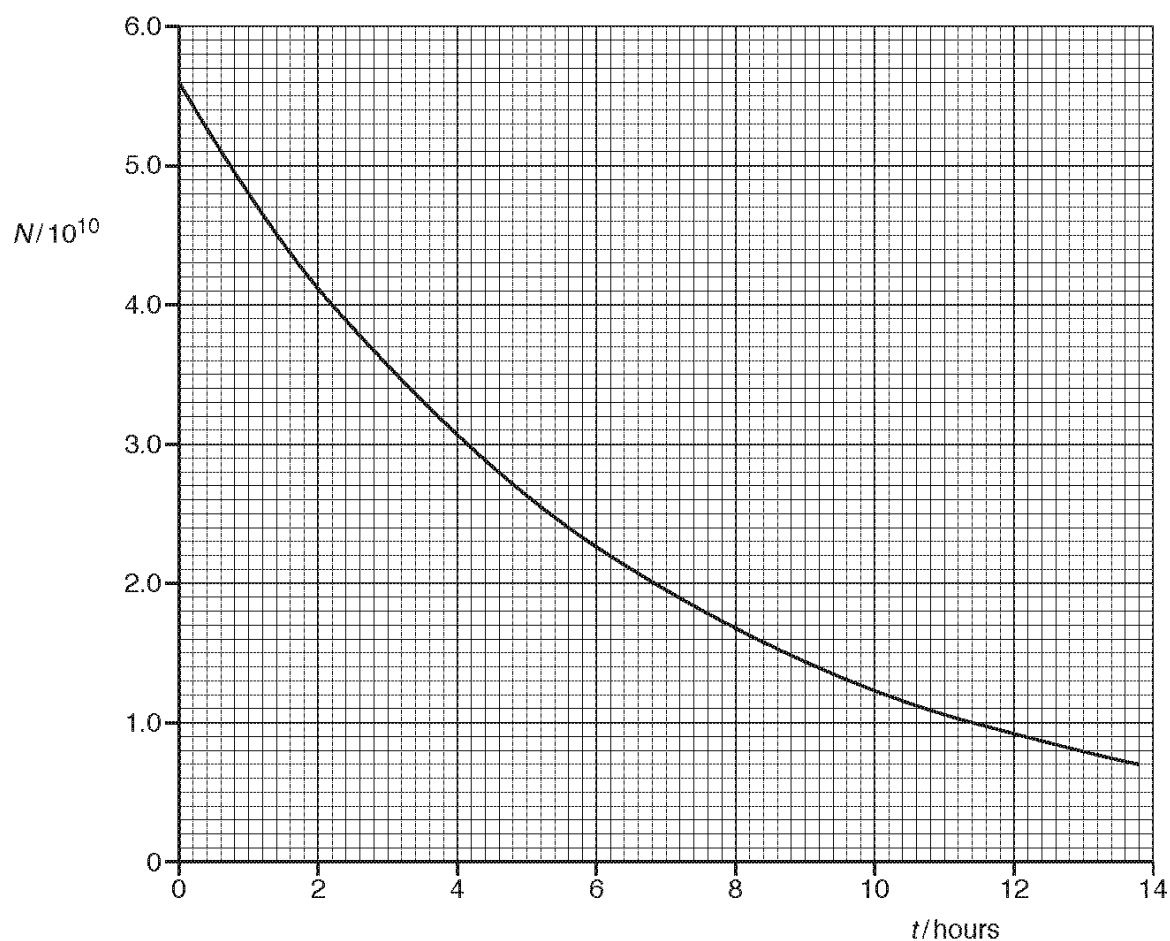
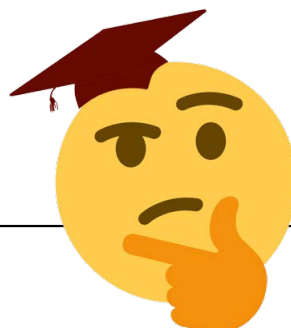


Fig. 12.1



- (i) Use the gradient of the line in Fig. 12.1 to determine the activity, in Bq, of the sample at time $t = 4.0$ hours. Show your working.

activity = Bq [3]

- (ii) Use your answer in (i) to show that the decay constant λ of the isotope is approximately $4 \times 10^{-5} \text{ s}^{-1}$.

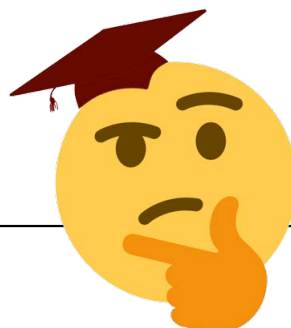
[2]

- (c) A sample of a different radioactive isotope has an initial activity of $4.6 \times 10^3 \text{ Bq}$. The sample must be stored safely until its activity is reduced to $1.0 \times 10^3 \text{ Bq}$.

The decay constant of the isotope is $5.5 \times 10^{-7} \text{ s}^{-1}$. The decay products are not radioactive.

Calculate the minimum time, in days, for which the sample must be stored.

time = days [3]



9 - (9702/42_Winter_2018_Q12) - Particle & Nuclear Physics

(a) State what is meant by *nuclear fusion* and *nuclear fission*.

nuclear fusion:

.....

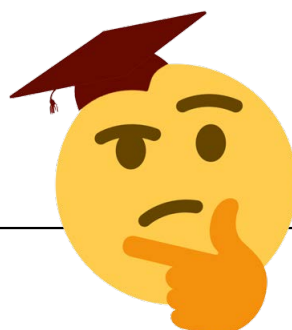
.....

nuclear fission:

.....

.....

[3]



(b) A nuclear reaction which may, in the future, be used for the generation of electrical energy is



(i) Name the particle x.

.....[1]

(ii) Data for the binding energy per nucleon E_B of some nuclei are given in Fig. 12.1.

		binding energy per nucleon $E_B/10^{-13}\text{J}$
deuterium	${}^2_1\text{H}$	1.7813
tritium	${}^3_1\text{H}$	4.5285
helium	${}^4_2\text{He}$	11.3290

Fig. 12.1

1. State the binding energy per nucleon of x.

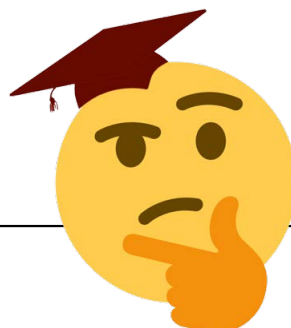
binding energy per nucleon = J

2. Calculate the energy change that takes place in this reaction.

energy change = J
[3]

(iii) Use your answer in (ii) **part 2** to determine the energy release when 2.0 g of deuterium (${}^2_1\text{H}$) reacts with 3.0 g of tritium (${}^3_1\text{H}$).

energy = J [1]



10 - (9702/41_Summer_2019_Q12) - Particle & Nuclear Physics

- (a) A sample of a radioactive isotope contains N nuclei of the isotope at time T . At time $(T + \Delta T)$, the sample contains $(N - \Delta N)$ nuclei of the isotope. The time interval ΔT is short.

Use the symbols N , ΔN , T and ΔT to give expressions for:

- (i) the average activity of the sample during the time ΔT

..... [1]

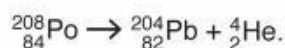
- (ii) the probability of decay of a nucleus in the time ΔT

..... [1]

- (iii) the decay constant λ of the isotope.

..... [1]

- (b) The isotope polonium-208 ($^{208}_{84}\text{Po}$) is radioactive and decays to form lead-204 ($^{204}_{82}\text{Pb}$). The nuclear equation for this decay is



Data for nuclear masses are given in Fig. 12.1.

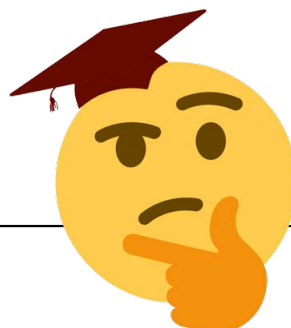
	mass/u
^4_2He	4.002 603
$^{204}_{82}\text{Pb}$	203.973 043
$^{208}_{84}\text{Po}$	207.981 245

Fig. 12.1

- (i) Determine, for the decay of one nucleus of polonium-208:

1. the change, in u, of the mass

mass change = u [1]



2. the total energy, in pJ, released.

energy = pJ [3]

- (ii) The polonium-208 nucleus is initially stationary. The initial kinetic energy of the ${}^4_2\text{He}$ nucleus (α -particle) is found to be less than the energy calculated in (i) **part 2**.

Suggest **two** possible reasons for this difference.

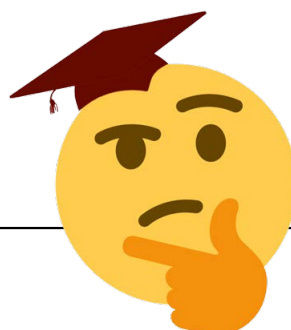
1.

.....

2.

.....

[2]



11 - (9702/42_Summer_2019_Q12) - Particle & Nuclear Physics

(a) State what is meant by the *binding energy* of a nucleus.

.....

.....

.....[2]

(b) Some masses are shown in Fig. 12.1.

	mass/u
proton (${}^1_1\text{p}$)	1.007
neutron (${}^1_0\text{n}$)	1.009
lanthanum-141 (${}^{141}_{57}\text{La}$) nucleus	140.911

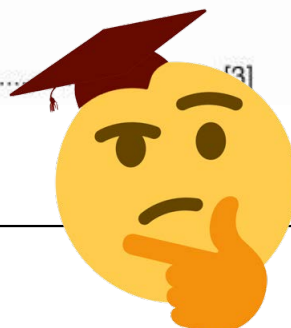
Fig. 12.1

Calculate the binding energy of a nucleus of lanthanum-141.

binding energy = J [4]

(c) The nuclide lanthanum-141 (${}^{141}_{57}\text{La}$) has a half-life of 3.9 hours.Initially, a radioactive source contains only lanthanum-141. The initial activity of the source is A_0 .(i) Calculate the time for the activity of the lanthanum-141 to be reduced to $0.40A_0$.

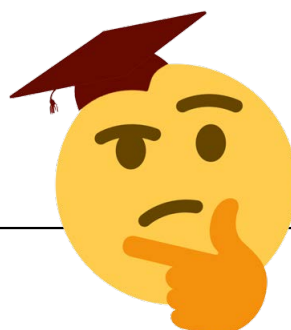
time = [3]



- (ii) Suggest why the total activity of the radioactive source measured at the time calculated in (i) may be greater than $0.40A_0$.

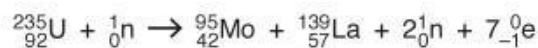
.....

.....[1]



12 - (9702/41_Winter_2019_Q12) - Particle & Nuclear Physics

One possible nuclear reaction that takes place is



Data for nuclei in this reaction are given in Fig. 12.1.

nucleus	mass/u	total mass of separate nucleons/u	mass defect/u	binding energy per nucleon/MeV
${}_{42}^{95}\text{Mo}$	94.906	95.765	0.859	8.443
${}_{57}^{139}\text{La}$	138.906	140.125	1.219	8.189
${}_{92}^{235}\text{U}$	235.044	236.909	1.865	.....

Fig. 12.1

- (a) Show that the energy equivalent to a mass of 1.00 u is 934 MeV.

[2]

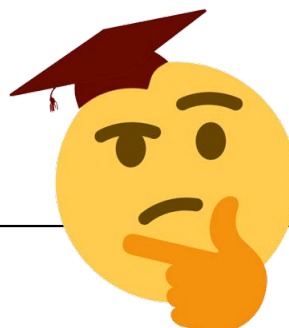
- (b) (i) Use data from Fig. 12.1 to calculate the binding energy per nucleon of a nucleus of uranium-235 (${}_{92}^{235}\text{U}$). Complete Fig. 12.1.

[2]

- (ii) The nucleon number of an isotope of the element rutherfordium is 267.

State whether the binding energy per nucleon of this isotope will be greater than, equal to or less than the binding energy per nucleon of uranium-235.

..... [1]



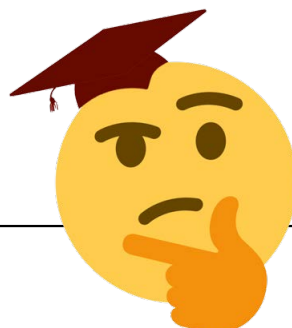
- (c) Calculate the total energy, in MeV, released in this nuclear reaction.

energy = MeV [2]

- (d) The nuclei in 1.2×10^{-7} mol of uranium-235 all undergo this reaction in a time of 25 ms.

Calculate the average power release during the time of 25 ms.

power = W [3]



13 - (9702/42_Winter_2019_Q12) - Particle & Nuclear Physics

Radon-222 ($^{222}_{86}\text{Ra}$) is a radioactive gas that decays randomly with a decay constant of $7.55 \times 10^{-3} \text{ hour}^{-1}$.

(a) State what is meant by:

(i) *random decay*

.....
..... [1]

(ii) *decay constant.*

.....
.....
..... [2]

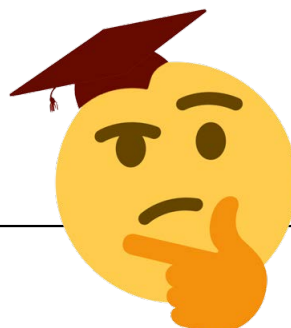
(b) The activity of radon gas in a sample of $4.80 \times 10^{-3} \text{ m}^3$ of air taken from a building is 0.600 Bq.

There are 2.52×10^{25} air molecules in a volume of 1.00 m^3 of air.

Calculate, for 1.00 m^3 of the air, the ratio

$$\frac{\text{number of air molecules}}{\text{number of radon atoms}}$$

ratio = [5]



14 - (9702/41_Summer_2020_Q12) - Particle & Nuclear Physics

- (a) The decay of a sample of a radioactive isotope is said to be random and spontaneous.

Explain what is meant by the decay being:

- (i) *random*

.....
..... [1]

- (ii) *spontaneous*.

.....
..... [1]

- (b) A radioactive isotope X has a half-life of 1.4 hours.

Initially, a pure sample of this isotope X has an activity of 3.6×10^5 Bq.

Determine the activity of the isotope X in the sample after a time of 2.0 hours.

activity = Bq [3]



(c) The variation with time t of the actual activity A of the sample in (b) is shown in Fig. 12.1.

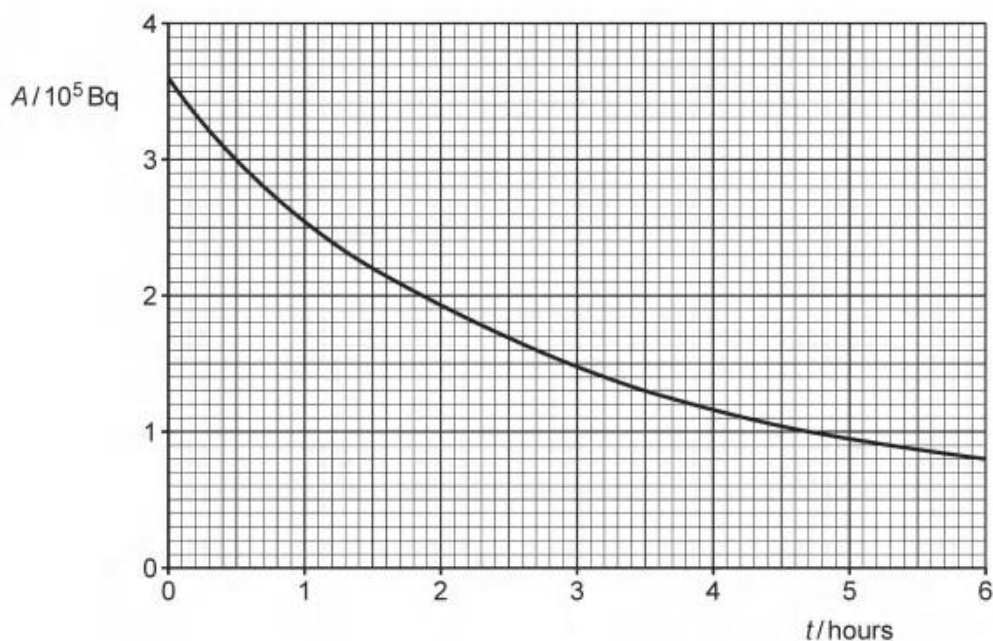


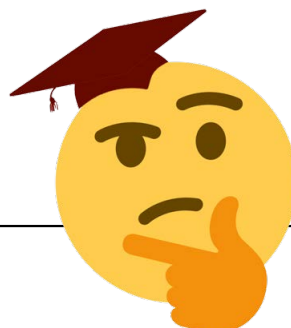
Fig. 12.1

- (i) The initial activity of isotope X in the sample is 3.6×10^5 Bq.

Use information from (b) to sketch, on the axes of Fig. 12.1, the variation with time t of the activity of a pure sample of isotope X. [1]

- (ii) Suggest an explanation for any difference between the actual activity of the sample shown in Fig. 12.1 and the curve you have drawn for the activity of isotope X.

.....
.....
..... [2]



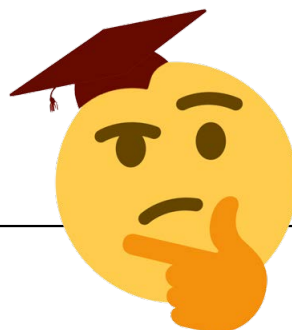
15 - (9702/42_Summer_2020_Q12) - Particle & Nuclear Physics

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

.....

.....

..... [2]



(b) Some masses are shown in Table 12.1.

Table 12.1

	mass/u
proton ${}^1_1\text{p}$	1.007 276
neutron ${}^1_0\text{n}$	1.008 665
helium-4 (${}^4_2\text{He}$) nucleus	4.001 506

Show that:

(i) the energy equivalence of 1.00 u is 934 MeV

[2]

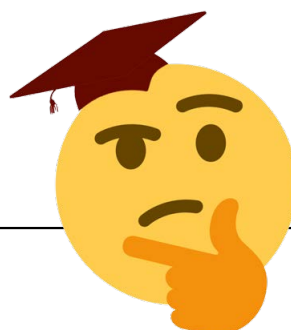
(ii) the binding energy per nucleon of a helium-4 nucleus is 7.09 MeV.

[2]

(c) Isotopes of hydrogen have binding energies per nucleon of less than 3 MeV.

Suggest why a nucleus of helium-4 does not spontaneously break down to become nuclei of hydrogen.

.....
.....
..... [2]



16 - (9702/41_Winter_2020_Q12) - Particle & Nuclear Physics

Iodine-131 ($^{131}_{53}\text{I}$) is a radioactive isotope with a decay constant of $9.9 \times 10^{-7} \text{ s}^{-1}$.

(a) State what is meant by:

(i) *radioactive*

.....
.....
..... [2]

(ii) *decay constant*.

.....
.....
..... [2]

(b) Some water becomes contaminated with iodine-131.
The activity of the iodine-131 in 1.0 kg of water is 560 Bq.

Determine the number of iodine-131 atoms in 1.0 kg of water.

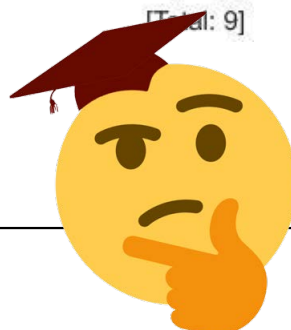
number = [2]

(c) Regulations require that the activity of iodine-131 in 1.0 kg of water is to be less than 170 Bq.

Calculate the time, in days, for the activity of the contaminated water in (b) to be reduced to 170 Bq.

time = days [3]

Total: 9]



17 - (9702/42_Winter_2020_Q12) - Particle & Nuclear Physics

(a) (i) Define nuclear *binding energy*.

.....

.....

..... [2]

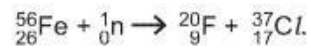
(ii) Explain what is meant by a *nuclear fission* reaction.

.....

.....

..... [2]

(b) A student suggests that one possible nuclear reaction is



The binding energy per nucleon of a nucleus varies with the nucleon number.

Use this variation to explain why the reaction would **not** result in an overall release of energy.

.....

.....

.....

.....

..... [3]

[Total: 7]



18 - (9702/41_Summer_2021_Q6) - *Electric Fields, Quantum Physics, Particle & Nuclear Physics*

- (a) An isolated metal sphere of radius r is charged so that the electric field strength at its surface is E_0 .

On Fig. 6.1, sketch the variation of the electric field strength E with distance x from the centre of the sphere. Your sketch should extend from $x = 0$ to $x = 3r$.

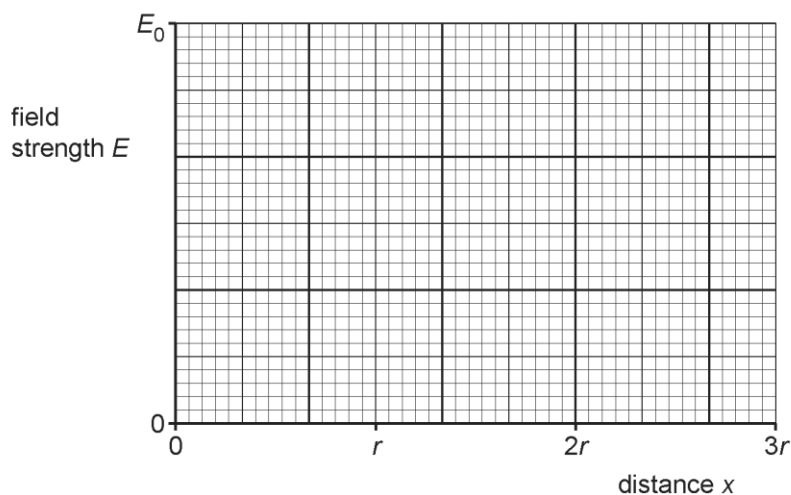


Fig. 6.1

[3]

- (b) The de Broglie wavelength of a particle is λ_0 when its momentum is p_0 .

On Fig. 6.2, sketch the variation with momentum p of the de Broglie wavelength λ of the particle for values of momentum from $\frac{p_0}{2}$ to p_0 .

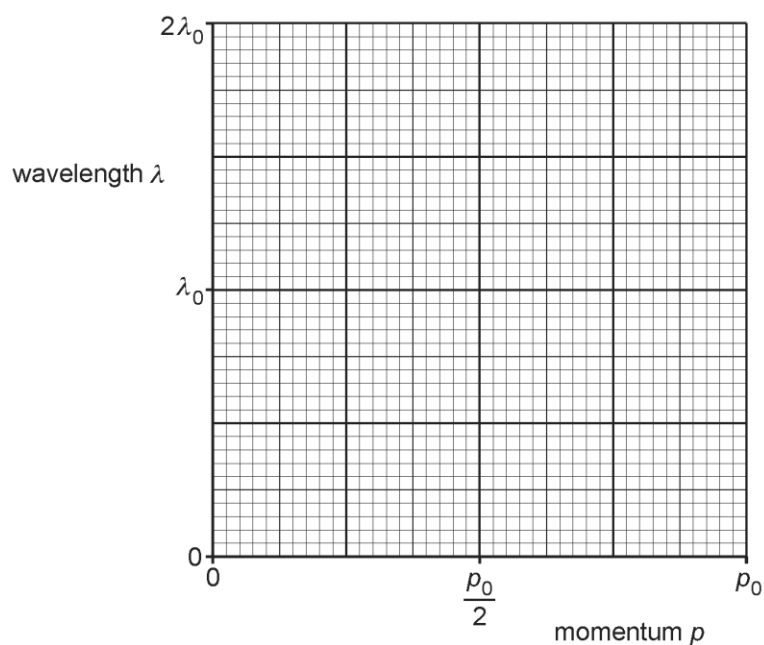
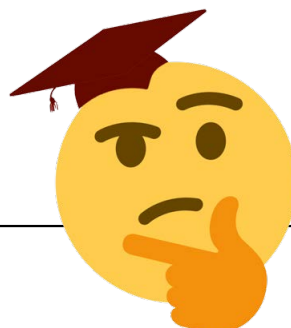


Fig. 6.2



(c) A radioactive isotope decays with a half-life of 15 s to form a stable product.

A fresh sample of the radioactive isotope at time $t = 0$ contains N_0 nuclei and no nuclei of the stable product.

On Fig. 6.3, sketch the variation with t of the number n of nuclei of the stable product for time $t = 0$ to time $t = 45$ s.

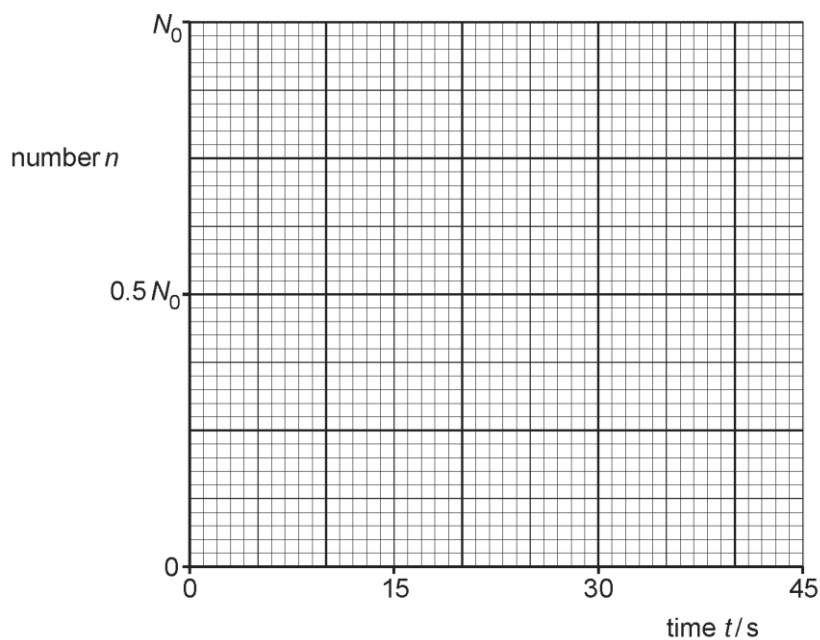
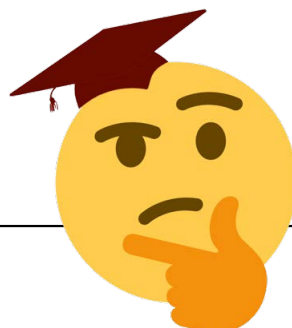


Fig. 6.3

[3]



19 – (9702/41_Winter_2021_Q12) – Particle & Nuclear Physics

(a) Define radioactive *decay constant*.

.....

.....

..... [2]

(b) A sample of radioactive iodine-131 ($^{131}_{53}\text{I}$) of mass $5.87 \times 10^{-10} \text{ kg}$ has an activity of $2.92 \times 10^9 \text{ Bq}$.

Determine the decay constant of iodine-131.

decay constant = s^{-1} [3]

(c) Suggest **two** reasons why a detector placed near to the sample in (b) would record a count rate much less than 2.92×10^9 counts per second.

1.

.....

2.

.....

[2]



20 – (9702/42_Winter_2021_Q12) – Particle & Nuclear Physics

(a) Radioactive decay is both random and spontaneous.

State what is meant by:

(i) *random*

.....
..... [1]

(ii) *spontaneous*.

.....
..... [1]

(b) A sample of radioactive material contains atoms of an unstable nuclide X. The activity of the sample due to the atoms of X is A . The variation with time t of $\ln A$ is shown in Fig. 12.1.

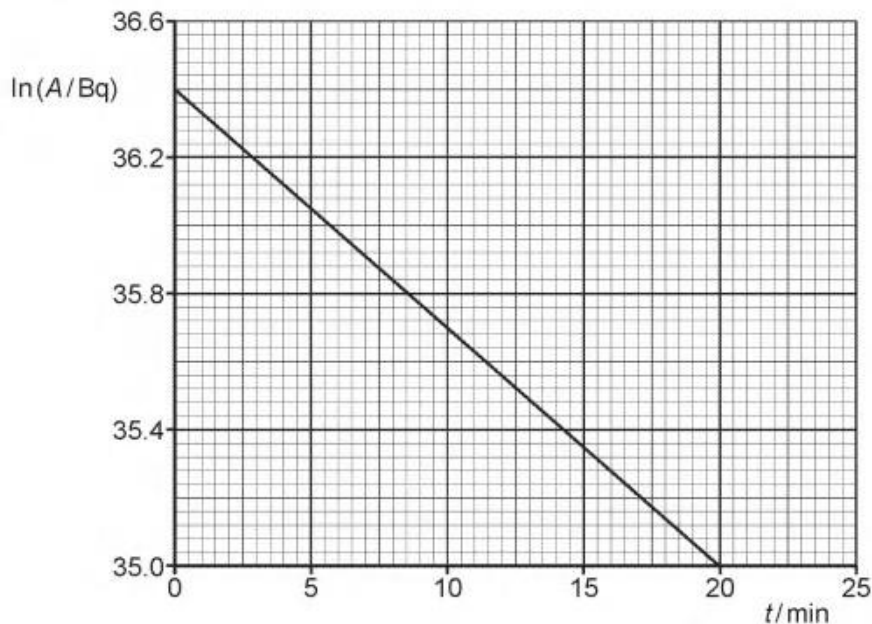


Fig. 12.1



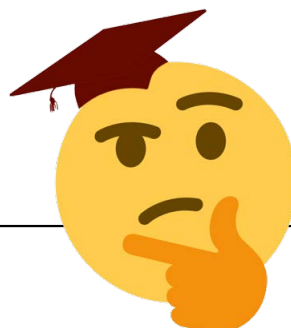
- (i) Use Fig. 12.1 to determine the half-life, in minutes, of nuclide X.

half-life = min [3]

- (ii) At time $t = 0$, the mass of the atoms of X in the sample is 5.66×10^{-7} kg.

Determine the nucleon number of X.

nucleon number = [3]



21 - (9702/41_Summer_2022_Q8) - Particle & Nuclear Physics

- (a) (i) State what is meant by nuclear binding energy.

.....
.....
..... [2]

- (ii) On Fig. 8.1, sketch a line to show the variation with nucleon number A of the binding energy per nucleon E of a nucleus.



Fig. 8.1

[2]

- (b) In one type of nuclear process, deuterium (${}^2_1\text{H}$) undergoes the reaction

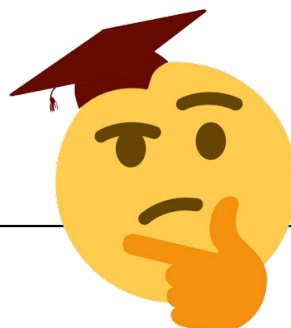


- (i) State the name of this type of nuclear process.

..... [1]

- (ii) Explain, with reference to your line in (a)(ii), why this reaction results in the release of energy.

.....
.....
..... [2]



(c) Table 8.1 shows the masses of the particles involved in the reaction in (b).

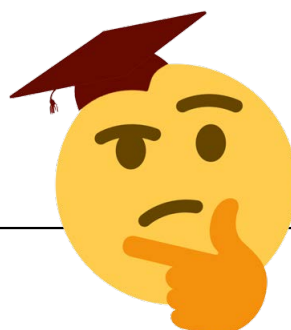
Table 8.1

particle	mass/u
${}^1_0\text{n}$	1.008 665
${}^2_1\text{H}$	2.014 102
${}^3_2\text{He}$	3.016 029

Calculate the energy released when 1.00 mol of deuterium undergoes the reaction.

energy = J [5]

[Total: 12]



22 - (9702/42_Summer_2022_Q10) - Particle & Nuclear Physics

(a) State what is meant by radioactive decay.

.....
.....
..... [2]

(b) A radioactive sample consists of an isotope X of half-life T that decays to form a stable product. Only X and the stable product are present in the sample.

At time $t = 0$, the sample has an activity of A_0 and contains N_0 nuclei of X.

(i) On Fig. 10.1, sketch the variation with t of the number N of nuclei of X present in the sample. Your line should extend from time $t = 0$ to time $t = 3T$.

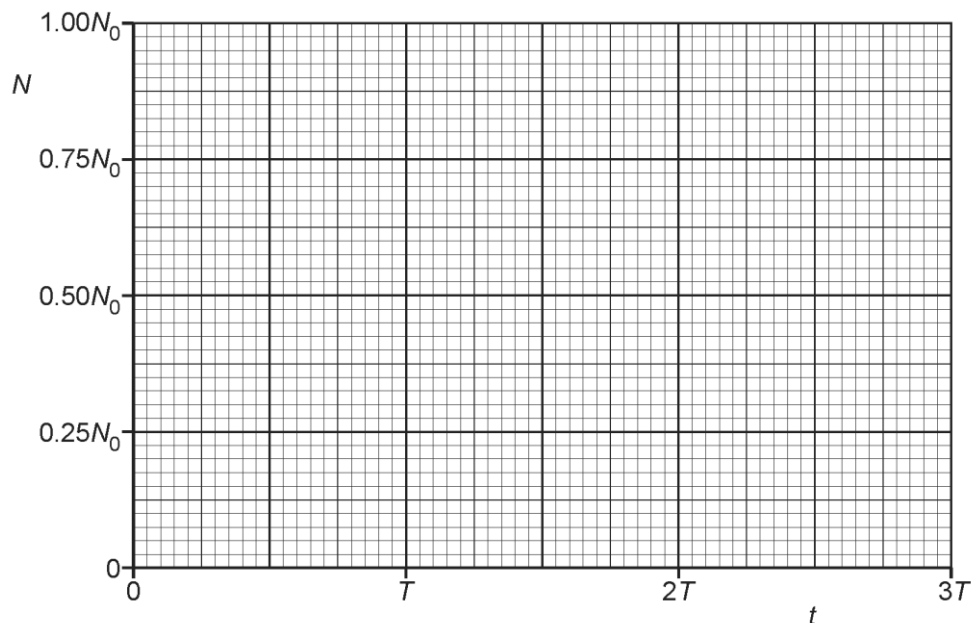


Fig. 10.1

[3]



- (ii) On Fig. 10.2, sketch the variation with N of the activity A of the sample for values of N between $N = 0$ and $N = N_0$.

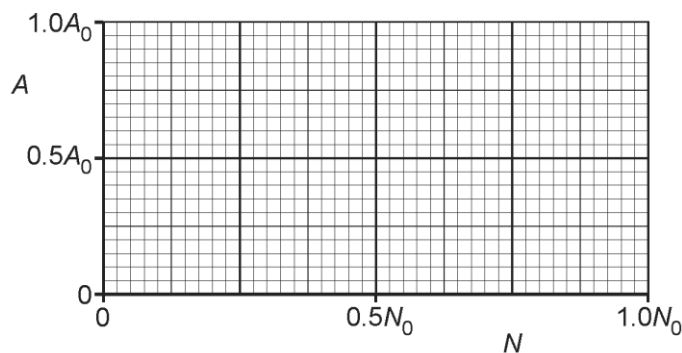


Fig. 10.2

[2]

- (c) State the name of the quantity represented by the gradient of your line in:

- (i) Fig. 10.1

..... [1]

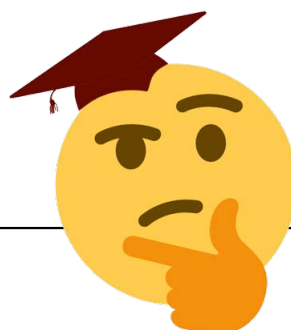
- (ii) Fig. 10.2.

..... [1]

- (d) For the sample in (b), calculate the fraction $\frac{N}{N_0}$ at time $t = 1.70T$.

$$\frac{N}{N_0} = \dots\dots\dots [2]$$

[Total: 11]



23 – (9702/41_Winter_2022_Q10) – Particle & Nuclear Physics

Carbon-15 ($^{15}_6\text{C}$) is an isotope of carbon that undergoes radioactive decay to nitrogen-15 ($^{15}_7\text{N}$), which is a stable isotope of nitrogen.

Radioactive decay is both a random and a spontaneous process.

(a) State what is meant by:

(i) random

.....
..... [1]

(ii) spontaneous.

.....
..... [1]

(b) A small sample of carbon-15 decays. The mass M of carbon-15 in the sample decreases with time t .

Fig. 10.1 shows the variation with t of the value of $\ln(M/10^{-16}\text{g})$.

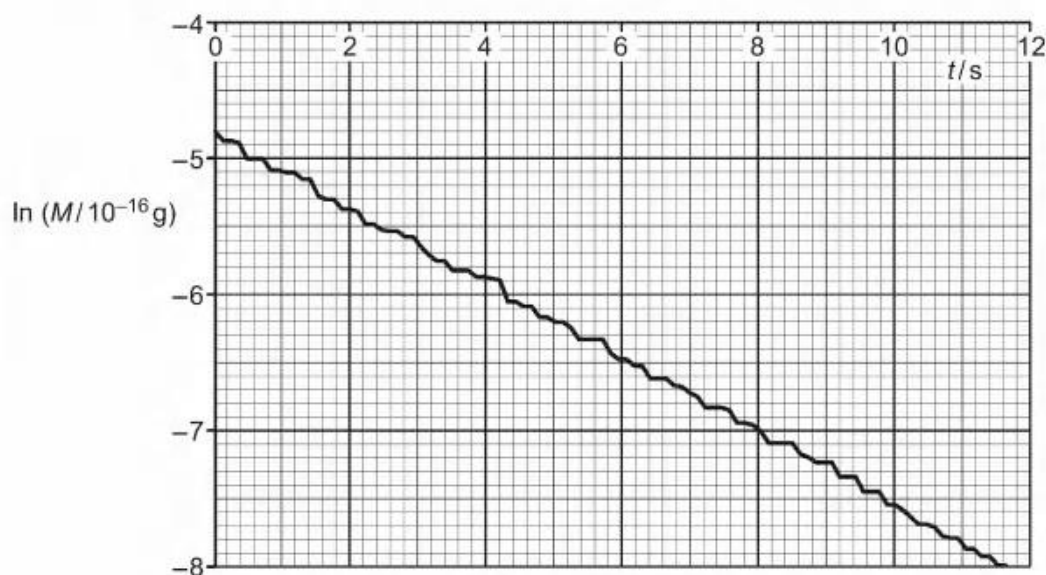


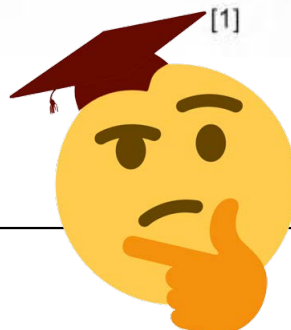
Fig. 10.1

(i) State how Fig. 10.1 demonstrates that radioactive decay is random.

.....
..... [1]

(ii) On Fig. 10.1, draw the straight line of best fit.

[1]



- (iii) Show that the decay constant λ of carbon-15 is given by the magnitude of the gradient of your line in (b)(ii).

[1]

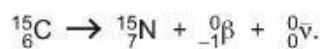
- (iv) Use your line in (b)(ii) to determine λ . Give a unit with your answer.

 $\lambda = \dots\dots\dots$ unit $\dots\dots\dots$ [2]

- (v) Use your answer in (b)(iv) to calculate the half-life of carbon-15.

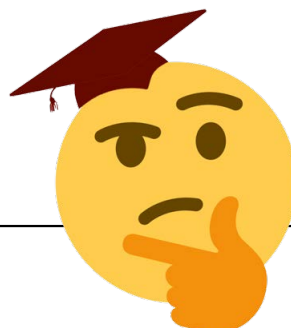
half-life = $\dots\dots\dots$ s [1]

- (c) The equation for the decay of carbon-15 can be written as



State and explain how the mass of the products of the decay must compare with the mass of the carbon-15 nucleus.

.....
.....
..... [2]



24 - (9702/41_Summer_2023_Q9) - Particle & Nuclear Physics

Carbon-11 is radioactive and decays by β^+ emission to form boron-11. Carbon-11 has a half-life of 20 minutes. Boron-11 is stable.

(a) Define half-life.

.....
..... [1]

(b) A sample contains N_0 nuclei of carbon-11 and no other nuclei at time $t = 0$.

On Fig. 9.1, sketch the variation with t of the number of nuclei of **boron-11** in the sample.

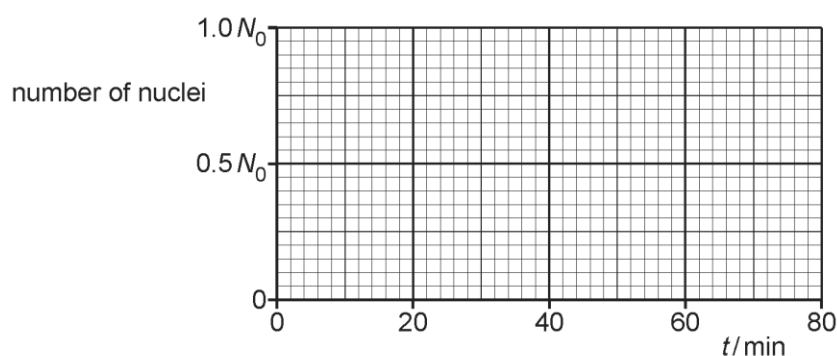


Fig. 9.1

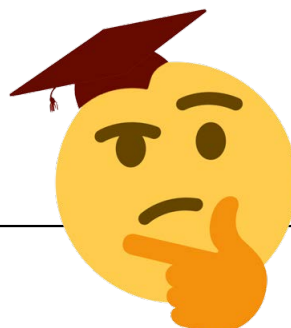
[3]

(c) (i) Explain, with reference to the random nature of radioactive decay, why the activity of the carbon-11 sample in (b) decreases with time.

.....
.....
..... [2]

(ii) State, with reasons, whether a radiation detector placed near to the sample of carbon-11 indicates a measured count rate from the sample that is less than, the same as or greater than the activity of the sample.

.....
.....
.....
.....
..... [3]



25 – (9702/42_Summer_2023_Q9) – Particle & Nuclear Physics

(a) Define mass defect.

.....

.....

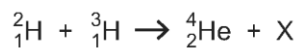
..... [2]

(b) Table 9.1 shows the mass defects of three nuclei.

Table 9.1

nucleus	mass defect/u
${}^2_1\text{H}$	0.002 388
${}^3_1\text{H}$	0.009 105
${}^4_2\text{He}$	0.030 377

The nuclear fusion process in a particular star is described by



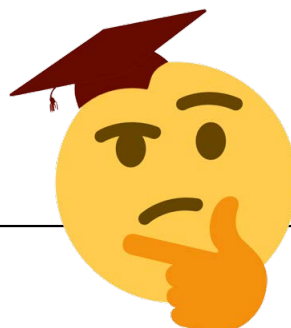
where X is a particle that has no mass defect.

(i) State the name of particle X.

..... [1]

(ii) Show that the energy released when one nucleus of ${}^4_2\text{He}$ is formed in this fusion reaction is $2.8 \times 10^{-12} \text{ J}$.

[3]



- (c) The star in (b) has a radius of $2.3 \times 10^9 \text{ m}$ and a luminosity of $1.4 \times 10^{28} \text{ W}$.
All the energy released from the formation of ${}^4_2\text{He}$ is radiated away from the star.
All the energy that is radiated from the star has been released in the formation of ${}^4_2\text{He}$.

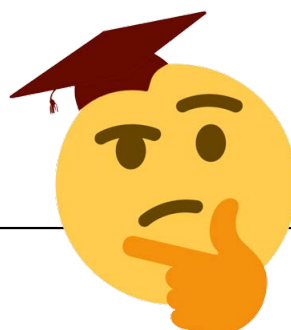
Determine:

- (i) the mass of ${}^4_2\text{He}$ produced per unit time by the fusion process

mass per unit time = kg s^{-1} [3]

- (ii) the surface temperature of the star.

temperature = K [2]



26 – (9702/41_Winter_2023_Q9) – Particle & Nuclear Physics

(a) State what is meant by nuclear fusion.

.....

.....

..... [2]

(b) On Fig. 9.1, sketch the variation of binding energy per nucleon with nucleon number A for values of A between 1 and 250.

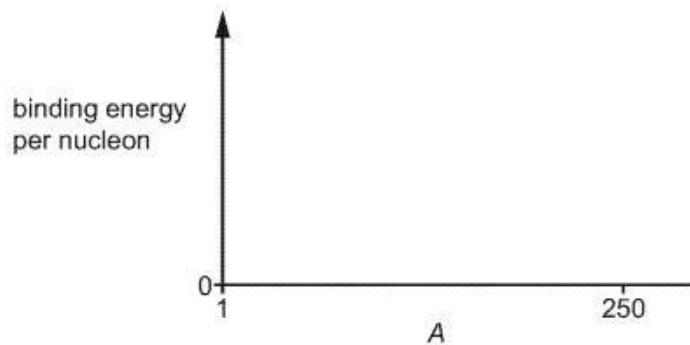


Fig. 9.1

[2]

(c) On your line in Fig. 9.1, label:

- (i) a point X that could represent a nucleus that undergoes alpha-decay [1]
- (ii) a point Y that could represent a nucleus that undergoes nuclear fusion. [1]



- (d) A nucleus Z undergoes nuclear fission to form strontium-93 (${}^{93}_{38}\text{Sr}$) and xenon-139 (${}^{139}_{54}\text{Xe}$) according to

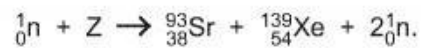


Table 9.1 shows the binding energies of the strontium-93 and xenon-139 nuclei.

Table 9.1

nucleus	binding energy/J
${}^{93}_{38}\text{Sr}$	1.25×10^{-10}
${}^{139}_{54}\text{Xe}$	1.81×10^{-10}

The fission of 1.00 mol of Z releases 1.77×10^{13} J of energy.

Determine the binding energy per nucleon, in MeV, of Z.

binding energy per nucleon = MeV [4]



27 - (9702/42_Winter_2023_Q9) - Particle & Nuclear Physics

Fluorine-18 ($^{18}_9\text{F}$) is a radioactive nuclide that is used as a tracer in positron emission tomography (PET scanning). Fluorine-18 decays to a nuclide of oxygen (O) according to



- (a) (i) State what is meant by a tracer.

.....
..... [1]

- (ii) State the symbol of the particle that is represented by X and the values of P, Q and R.

X: P:
Q: R: [2]

- (b) (i) Explain how the radioactive decay of fluorine-18 results in the emission from the body of the gamma-ray photons that are detected during a PET scan.

.....
.....
.....
..... [2]

- (ii) Explain how the detection of the gamma-ray photons is used to produce an image of the tissue being examined.

.....
.....
.....
..... [2]

- (c) The half-life of fluorine-18 is T .
A patient is injected with amount of substance n of fluorine-18.

- (i) Determine an expression for the initial value R_0 of the rate R of production of gamma-ray photons by the tracer, in terms of n , T and the Avogadro constant N_A .

$$R_0 = \dots\dots\dots$$



(ii) On Fig. 9.1, sketch the variation with time t of R .

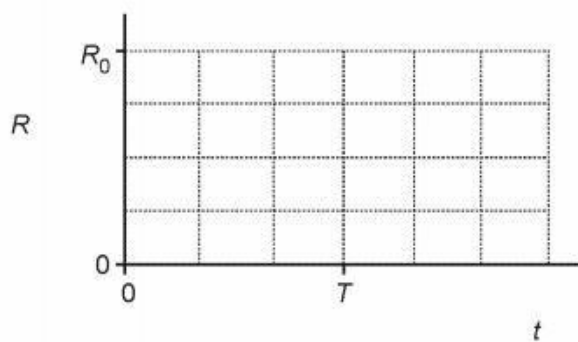
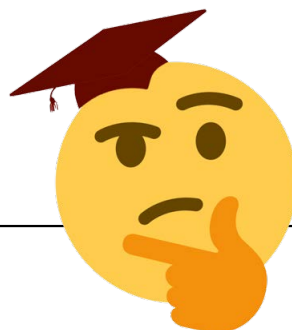


Fig. 9.1

[2]



1 - (9702/41_Winter_2020_Q10) - *Medical Imaging*

(a) Outline briefly the principles of computed tomography (CT scanning).

.....

.....

.....

.....

.....

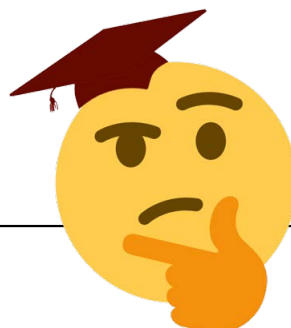
.....

.....

.....

.....

..... [5]



- (b) One section of a model designed to illustrate CT scanning is divided into four voxels. The pixel numbers K, L, M and N of the voxels are shown in Fig. 10.1.

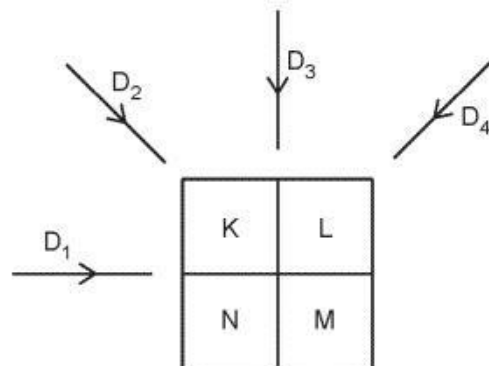


Fig. 10.1

The section is viewed, in turn, from four different directions D_1 , D_2 , D_3 and D_4 , as shown in Fig. 10.1.

The detector readings for each direction are noted and these are summed to give the values shown in Fig. 10.2.

42	45
51	30

Fig. 10.2

The background reading is 24.

Determine the pixel numbers K, L, M and N shown in Fig. 10.1.

K =

L =

M =

N =

[3]

[Total: 8]



2 - (9702/41_Summer_2021_Q4) - *Medical Imaging*

Outline the **use** of ultrasound to obtain diagnostic information about internal body structures.

.....

.....

.....

.....

.....

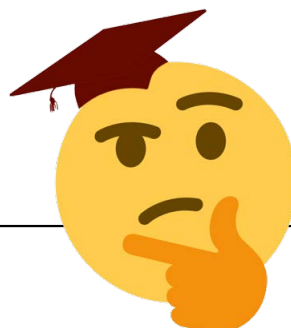
.....

.....

.....

.....

..... [5]



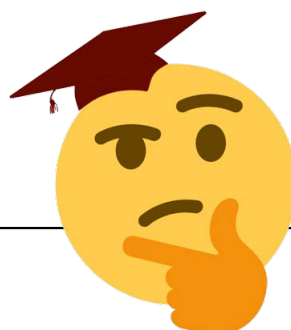
3 - (9702/42_Summer_2021_Q11) - Medical Imaging

(a) State the purpose of computed tomography (CT scanning).

.....
..... [1]

(b) Outline the principles of CT scanning.

.....
.....
.....
.....
.....
.....
.....
.....
.....
.....
..... [5]



4 - (9702/41_Winter_2021_Q11) - Medical Imaging

(a) State, for an X-ray image, what is meant by:

(i) *sharpness*

.....
..... [1]

(ii) *contrast*.

.....
..... [1]

(b) A parallel X-ray beam passes through a thickness of 2.3 cm of soft body tissue. The intensity of the emerging beam is 12% of the intensity of the incident beam.

Calculate the linear attenuation (absorption) coefficient μ of the soft body tissue. Give a unit with your answer.

$\mu =$ unit [3]

(c) In medical diagnosis, X-rays may be used to produce a single X-ray image or may be used in computed tomography (CT scanning).

Suggest an advantage and a disadvantage of CT scanning compared with single X-ray imaging for diagnosis.

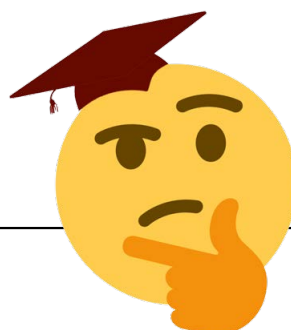
advantage:

.....

disadvantage:

.....

[2]



5 - (9702/42_Winter_2021_Q11) - Medical Imaging

- (a) A piezoelectric transducer containing a quartz crystal is used to obtain diagnostic information about internal structures.

Describe the function of the quartz crystal.

.....

.....

.....

..... [3]

- (b) (i) Define *specific acoustic impedance*.

.....

.....

..... [2]

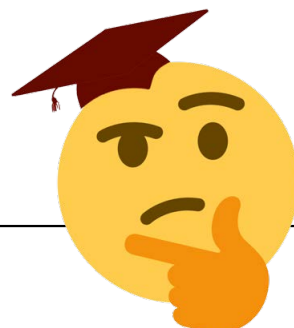
- (ii) Describe, qualitatively, how the specific acoustic impedances of two materials affect the intensity reflection coefficient at a boundary between the materials.

.....

.....

.....

..... [2]



6 - (9702/41_Summer_2022_Q9) - Medical Imaging

- (a) (i) Explain how X-rays are produced for use in medical diagnosis.

.....
.....
..... [3]

- (ii) State why X-ray images are taken of multiple sections of the body during computed tomography (CT) scanning.

..... [1]

- (b) An X-ray image is taken of the structure shown in Fig. 9.1.

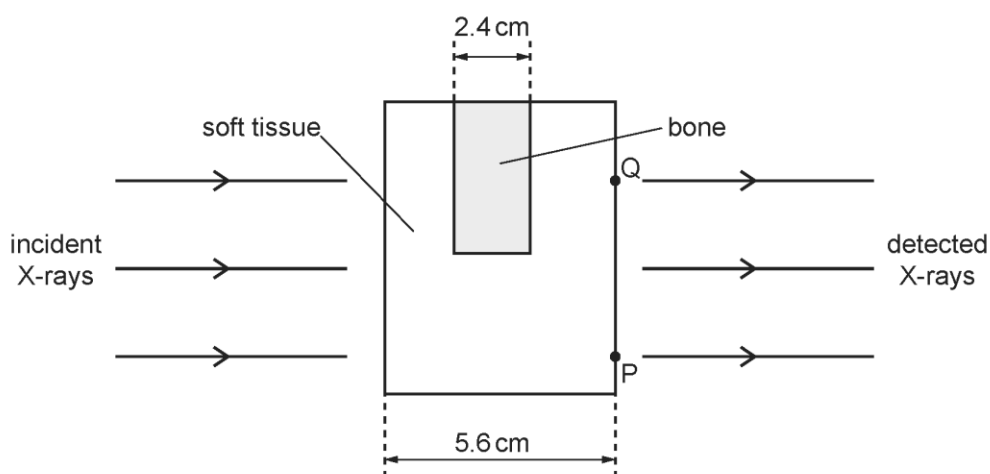
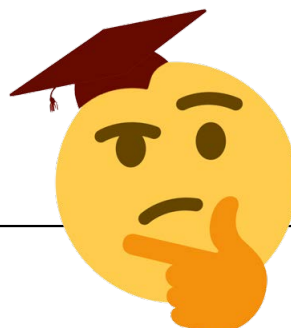


Fig. 9.1

The linear attenuation coefficient of bone is 3.4 cm^{-1} .

The linear attenuation coefficient of soft tissue is 0.89 cm^{-1} .

The incident X-rays are parallel and have a uniform intensity I_0 across the structure.



Determine, in terms of I_0 , the intensity of the detected X-rays from:

(i) point P

detected intensity = I_0 [2]

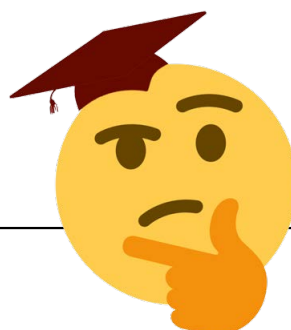
(ii) point Q.

detected intensity = I_0 [2]

(c) Explain, with reference to your answers in (b), whether the X-ray image of the structure in Fig. 9.1 has good contrast.

.....
.....
..... [1]

[Total: 9]



7 - (9702/42_Winter_2022_Q10) - Medical Imaging

Positron emission tomography (PET scanning) involves the detection of gamma-radiation in order to identify the position of origin of positrons in the body.

- (a) (i) Positrons are not naturally present in the body.

Explain how positrons come to be present in the body during PET scanning.

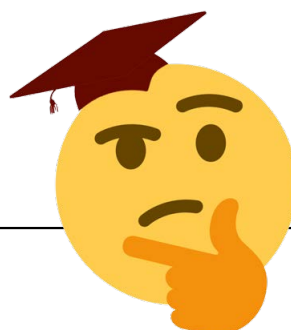
.....
.....
..... [2]

- (ii) Explain how positrons cause the emission of gamma-radiation from the body during PET scanning.

.....
.....
.....
..... [3]

- (b) Show that the wavelength of the gamma-radiation that is detected during PET scanning is approximately 2.4 pm. Explain your reasoning.

[4]



8 - (9702/42_Summer_2023_Q10) - Medical Imaging

- (a) X-rays for use in medical diagnosis are produced in an X-ray tube. In the X-ray tube, charged particles are accelerated towards a metal target by an applied potential difference (p.d.).

(i) State the name of the charged particles that are accelerated by the applied p.d.

..... [1]

(ii) Explain how X-rays are produced at the metal target.

.....

.....

.....

..... [2]

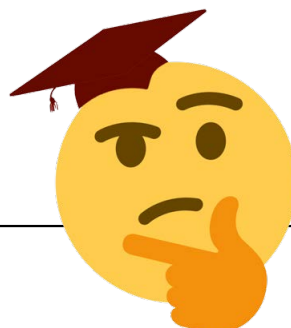
(iii) Calculate the minimum wavelength of X-rays produced when the applied p.d. is 5.80 kV.

wavelength = m [3]

(b) X-rays pass through a medium that has an attenuation coefficient of 1.4 cm^{-1} .

Calculate the percentage of the X-ray energy that is **absorbed** by a 2.8 cm thickness of this medium.

percentage absorbed = % [3]



9 - (9702/43_Summer_2023_Q8) - Medical Imaging

- (a) Table 8.1 shows some data relating to the properties of air, gel and body tissue. The data are given to three significant figures.

Table 8.1

material	density / kg m^{-3}	speed of sound / m s^{-1}	specific acoustic impedance / $\text{kg m}^{-2} \text{s}^{-1}$
air		340	440
gel	1200	1400	
tissue	1090		1.68×10^6

- (i) Show that the specific acoustic impedance of gel is $1.68 \times 10^6 \text{ kg m}^{-2} \text{s}^{-1}$.

[1]

- (ii) Complete Table 8.1 by calculating the missing values to three significant figures. Use the space below for any working that you need.

[2]

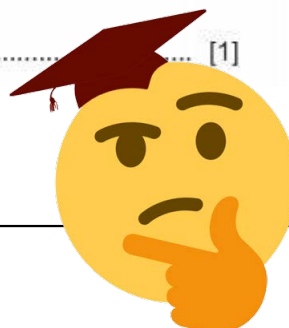
- (b) Use the information in (a) to calculate the intensity reflection coefficient for:

- (i) an air–tissue boundary

intensity reflection coefficient = [2]

- (ii) a gel–tissue boundary.

intensity reflection coefficient = [1]

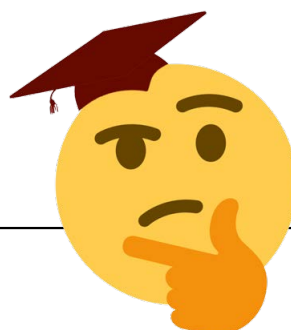


(c) Use your answers in (b) to explain why gel is applied to the skin during ultrasound scanning.

.....

.....

..... [2]



10 - (9702/41_Winter_2023_Q10) - Medical Imaging

Ultrasound and X-rays are both types of wave that are used in medical diagnosis to form images of internal body structures.

(a) Complete Table 10.1 to state, for each type of wave:

- the method of production of the wave
- whether the wave that is detected and used to form the image is the wave that has been absorbed, reflected or transmitted by the internal body structure.

Table 10.1

	ultrasound	X-rays
method of production		
detected wave (absorbed, reflected or transmitted)		

[4]

(b) (i) For one type of wave passing through tissue, the wave has 72% of its initial intensity after it has passed through 6.2 cm of the tissue.

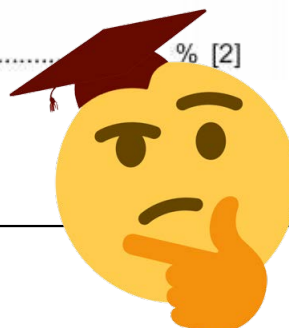
Calculate the linear attenuation coefficient μ of the tissue for this wave.

$$\mu = \dots\dots\dots \text{cm}^{-1} \quad [2]$$

(ii) Another wave of the same type as in (b)(i) passes through 9.3 cm of the same tissue.

Calculate the percentage of the initial intensity of the wave that is attenuated by the tissue.

$$\text{percentage attenuated} = \dots\dots\dots \% \quad [2]$$



1 - (9702/42_Summer_2022_Q9) - *Astronomy & Cosmology*

(a) (i) State Hubble's law.

.....

.....

..... [2]

(ii) Explain how cosmologists use observations of emission spectra from stars in distant galaxies to determine that the Universe is expanding.

.....

.....

.....

..... [2]

(b) Explain how Hubble's law and the idea of the expanding Universe lead to the Big Bang theory of the origin of the Universe.

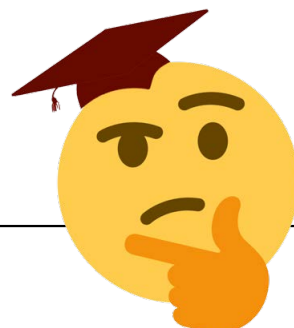
.....

.....

.....

..... [3]

[Total: 7]



2 - (9702/41_Summer_2022_Q10) - Astronomy & Cosmology

(a) State Wien's displacement law.

.....
..... [1]

(b) Fig. 10.1 shows the wavelength distributions of electromagnetic radiation emitted by two stars A and B.

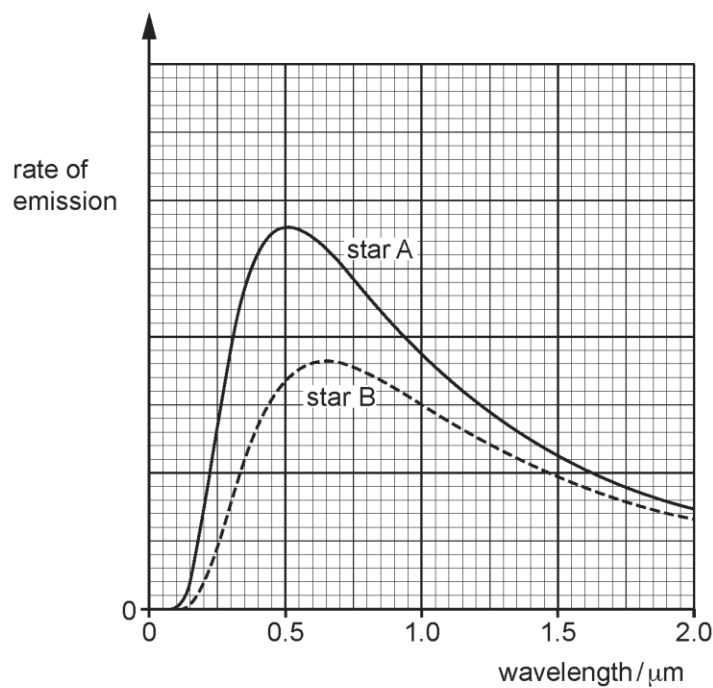
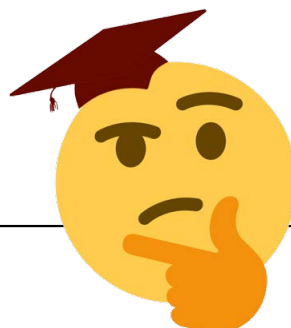


Fig. 10.1

The surface temperature of star A is known to be 5800 K.

(i) Determine the surface temperature of star B.

surface temperature = K [2]



- (ii) Star B appears less bright than star A when viewed from the Earth.

Use Fig. 10.1 to suggest, with a reason, how else the physical appearance of star B compares with that of star A.

.....
.....
..... [2]

- (c) The lines in Fig. 10.1 have been corrected for redshift.

- (i) State what is meant by redshift.

.....
.....
..... [2]

- (ii) Explain how cosmologists are able to determine that light from a distant star has undergone redshift.

.....
.....
..... [2]

[Total: 9]



3 - (9702/41_Winter_2022_Q9) - *Astronomy & Cosmology*

(a) State what is meant by the luminosity of a star.

..... [1]

(b) A star in the constellation Canis Major is a distance of 8.14×10^{16} m from the Earth and has a luminosity of 9.86×10^{27} W. The surface temperature of the star is 9830 K.

(i) Calculate the radiant flux intensity of the radiation from the star observed from the Earth. Give a unit with your answer.

radiant flux intensity = unit [2]

(ii) Determine the radius of the star.

radius = m [2]

(c) Explain how the surface temperature of a distant star may be determined from the wavelength spectrum of the light from the star.

.....
.....
.....
..... [3]



4 - (9702/41_Summer_2023_Q10) - *Astronomy & Cosmology*

- (a) State Hubble's law. Identify any symbols that you use.

.....
.....
.....
..... [2]

- (b) A star of luminosity $3.8 \times 10^{31} \text{ W}$ is at a distance of $1.8 \times 10^{24} \text{ m}$ from the Earth.

Calculate the radiant flux intensity at the Earth of the radiation emitted by the star.

radiant flux intensity = W m^{-2} [2]

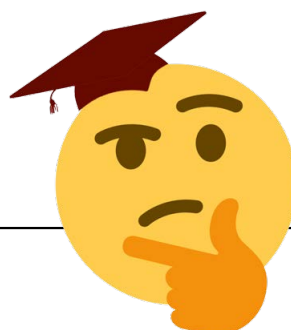
- (c) The star in (b) is in a distant galaxy. A spectral line in the light from this galaxy is known to have a wavelength of 486 nm. This spectral line in the light from the galaxy observed on the Earth has a wavelength of 492 nm.

- (i) Explain why the wavelength observed on the Earth is different from the wavelength that the galaxy is known to have emitted.

.....
.....
..... [2]

- (ii) Determine a value for the Hubble constant H_0 .

$H_0 = \dots\dots\dots \text{s}^{-1}$ [3]



5 - (9702/41_Winter_2023_Q3) - *Ideal Gases, Astronomy & Cosmology*

- (a) The product pV for an ideal gas is given by

$$pV = \frac{1}{3} Nm \langle c^2 \rangle$$

where p is the pressure of the gas and V is the volume of the gas.

- (i) State the meaning of the symbols N , m and $\langle c^2 \rangle$ in this equation.

N :

m :

$\langle c^2 \rangle$: [3]

- (ii) Use the equation of state for an ideal gas to show that the average translational kinetic energy E_k of a molecule of the gas at thermodynamic temperature T is given by

$$E_k = \frac{3}{2} kT.$$

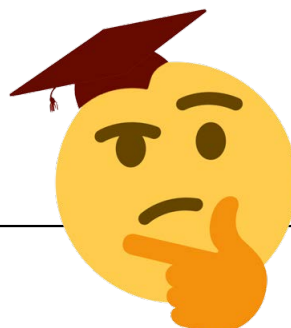
[2]

- (b) The surface of a star consists mainly of a gas that may be assumed to be ideal. The molecules of the gas have a root-mean-square (r.m.s.) speed of 9300 m s^{-1} .

The mass of a molecule of the gas is $3.34 \times 10^{-27} \text{ kg}$.

Determine, to three significant figures, the temperature of the surface of the star.

temperature = K [2]



- (c) The radiant flux intensity of the radiation from the star in (b) is $2.52 \times 10^{-8} \text{ W m}^{-2}$ when observed at a distance of $4.16 \times 10^{16} \text{ m}$ from the star.

(i) Calculate the luminosity of the star. Give a unit with your answer.

luminosity = unit [2]

(ii) Determine the radius of the star.

radius = m [2]

- (d) The gas at the surface of a star has a very high pressure.

Use the basic assumptions of the kinetic theory to suggest why, in practice, a gas at the surface of a star is unlikely to behave as an ideal gas.

.....
.....
.....
..... [2]



6 - (9702/42_Winter_2023_Q10) - *Astronomy & Cosmology*

- (a) State Wien's displacement law. Identify any symbols that you use.

.....

.....

..... [2]

- (b) A cosmology student observes the electromagnetic radiation received from a star in a galaxy. The student uses Wien's law to estimate the surface temperature of the star, a standard candle to estimate the distance to the galaxy, and the Stefan–Boltzmann law to estimate the radius of the star.

The student observes that the radiation from the star is redshifted.

- (i) State what is meant by a standard candle.

..... [1]

- (ii) State the reason why the radiation from the star is redshifted.

..... [1]

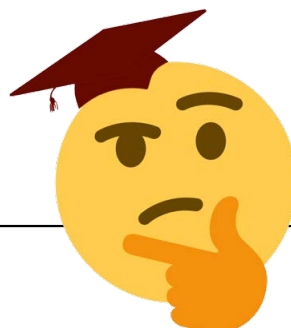
- (iii) The true values of the quantities observed or estimated are those that are corrected to allow for redshift. However, the student does not correct for redshift.

By placing one tick (✓) in each row, complete Table 10.1 to indicate how the observations and estimates made by the student compare with the true values.

Table 10.1

	student's uncorrected value		
	too low	the same	too high
wavelength of radiation			
surface temperature of star			
distance to star			
radius of star			

[4]



ANSWERS

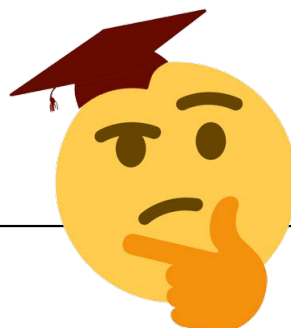


1 - (9702/41_Summer_2023_Q1) - Physical Quantities & Units

(a)(i)	force per unit mass	B1
(a)(ii)	force per unit positive charge	B1
(a)(iii)	similarity: - inversely proportional to distance (from point) - points of equal potential lie on concentric spheres - zero at infinite distance Any point, 1 mark	B1
	difference: - gravitational potential is (always) negative - electric potential can be positive or negative Any point, 1 mark	B1
(b)(i)	$g = GM / r^2$	M1
	$E = Q / 4\pi\epsilon_0 r^2$	M1
	algebra showing the elimination of r leading to $M / Q = (1 / 4\pi G\epsilon_0) (g / E)$	A1
(b)(ii)	$\alpha = 1 / (4\pi \times 6.67 \times 10^{-11} \times 8.85 \times 10^{-12}) = 1.35 \times 10^{20} \text{ (kg}^2 \text{ C}^{-2}\text{)}$ or $\alpha = (8.99 \times 10^9) / (6.67 \times 10^{-11}) = 1.35 \times 10^{20} \text{ (kg}^2 \text{ C}^{-2}\text{)}$	A1
(c)(i)	$E = \alpha g Q / M$ $= (1.35 \times 10^{20} \times 9.81 \times 4.80 \times 10^5) / (5.98 \times 10^{24})$ $= 106 \text{ N C}^{-1} \text{ or } 106 \text{ V m}^{-1}$	C1
		A1
(c)(ii)	same (direction)	B1

2 - (9702/42_Summer_2023_Q1) - Physical Quantities & Units, Dynamics

(a)	(gravitational) force is (directly) proportional to product of masses	B1
	force (between point masses) is inversely proportional to the square of their separation	B1
(b)	$GMm / R^2 = mR\omega^2$	M1
	$\omega = 2\pi / T$ and algebra leading to $4\pi^2 R^3 = GMT^2$	A1
	or	
	$GMm / R^2 = mv^2 / R$	(M1)
	$v = 2\pi R / T$ and algebra leading to $4\pi^2 R^3 = GMT^2$	(A1)
(c)	$4\pi^2 \times R^3 = 6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (24 \times 60 \times 60)^2$ $(R = 4.22 \times 10^7 \text{ m})$	C1
	$h = R - (6.37 \times 10^6)$	C1
	$h = (4.22 \times 10^7) - (6.37 \times 10^6)$ $= 3.6 \times 10^7 \text{ m}$	A1
(d)(i)	$\omega = 2\pi / T$	C1
	$= 2\pi / (24 \times 60 \times 60)$ $= 7.3 \times 10^{-5} \text{ rad s}^{-1}$	A1
(d)(ii)	orbit is from east to west	B1
	orbit is not equatorial / orbit is polar	B1

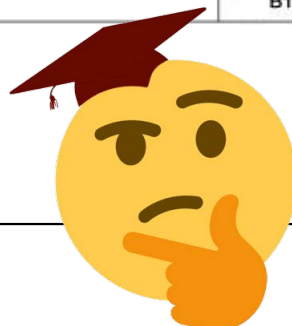


1 - (9702/41_Summer_2023_Q2) - Dynamics

(a)	horizontal force on sphere causes centripetal acceleration	B1
	weight of sphere is (now) equal to vertical component of tension or horizontal and vertical components (of force) (now) combine to give greater tension (in spring)	B1
	greater tension in spring so greater extension of spring	B1
(b)(i)	$r = 10.8 \times \sin 27^\circ = 4.9 \text{ cm}$	A1
(b)(ii)	$T \cos \theta = mg$ or $T \cos \theta = W$ and $W = mg$	C1
	$T \cos 27^\circ = 0.29 \times 9.81$ leading to $T = 3.2 \text{ N}$	A1
(b)(iii)	$\Delta T = 3.2 - (0.29 \times 9.81)$	C1
	$k = \Delta T / \Delta x$	A1
	$= [3.2 - (0.29 \times 9.81)] / [10.8 - 8.5]$	
	$= 0.15 \text{ N cm}^{-1}$	
(c)(i)	centripetal acceleration $= (T \sin \theta) / m$	C1
	$= (3.2 \times \sin 27^\circ) / 0.29$	
	$= 5.0 \text{ m s}^{-2}$	A1
(c)(ii)	$a = r\omega^2$ and $\omega = 2\pi / T$ or $a = v^2 / r$ and $v = 2\pi r / T$	C1
	$T = 2\pi \times \sqrt{(0.049 / 5.0)}$	A1
	$= 0.62 \text{ s}$	

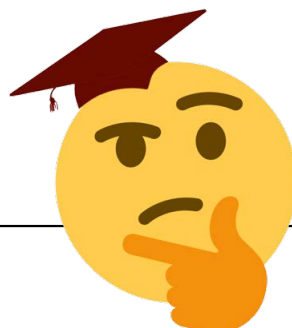
2 - (9702/42_Summer_2023_Q1) - Physical Quantities & Units, Dynamics

(a)	(gravitational) force is (directly) proportional to product of masses	B1
	force (between point masses) is inversely proportional to the square of their separation	B1
(b)	$GMm / R^2 = mR\omega^2$	M1
	$\omega = 2\pi / T$ and algebra leading to $4\pi^2 R^3 = GMT^2$	A1
	or	
	$GMm / R^2 = mv^2 / R$	(M1)
	$v = 2\pi R / T$ and algebra leading to $4\pi^2 R^3 = GMT^2$	(A1)
(c)	$4\pi^2 \times R^3 = 6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (24 \times 60 \times 60)^2$	C1
	$(R = 4.22 \times 10^7 \text{ m})$	
	$h = R - (6.37 \times 10^6)$	C1
	$h = (4.22 \times 10^7) - (6.37 \times 10^6)$ $= 3.6 \times 10^7 \text{ m}$	A1
(d)(i)	$\omega = 2\pi / T$	C1
	$= 2\pi / (24 \times 60 \times 60)$	A1
	$= 7.3 \times 10^{-5} \text{ rad s}^{-1}$	
(d)(ii)	orbit is from east to west	B1
	orbit is not equatorial / orbit is polar	B1



1 - (9702/41_Summer_2023_Q3) - Forces, Density & Pressure, Temperature

(a)	no <u>net</u> thermal energy is transferred (between them)	B1
(b)(i)	variation (of density with temperature) is linear or each temperature has a unique value of density	B1
(b)(ii)	- variation (of density with temperature) is not linear - region where the density does not vary with temperature - different temperatures have the same density <i>Any two points, 1 mark each</i>	B2
(c)(i)	boiling point = 80 °C	A1
(c)(ii)	$Q = Pt$ and $t = 21$ s (thermal energy supplied = $810 \times 21 = 17000$ J)	C1
	$c = Q / m\Delta\theta$	C1
	thermal energy absorbed by beaker = $42 \times 0.84 \times (80 - 25)$ (= 1940 J)	C1
	s.h.c. of liquid = $[(810 \times 21) - (42 \times 0.84 \times (80 - 25))] / [120 \times (80 - 25)]$ = $2.3 \text{ J g}^{-1} \text{ K}^{-1}$	A1
(d)	sketch: straight diagonal line from 25 °C to 100 °C and then horizontal at 100 °C	B1
	straight diagonal line starting at 25 °C with gradient approximately half that of the original line	B1



1 - (9702/41_Summer_2017_Q1) - Motion In A Circle, Gravitational Fields

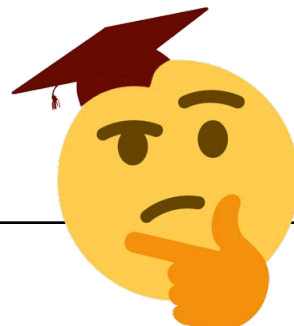
(a)	gravitational force (of attraction between satellite and planet)
	provides / is centripetal force (on satellite about the planet)
(b)	$M = (4/3) \times \pi R^3 \rho$
	$\omega = 2\pi / T$ or $v = 2\pi nR / T$
	$GM / (nR)^2 = nR\omega^2$ or v^2 / nR
	substitution clear to give $\rho = 3\pi n^3 / GT^2$
(c)	$n = (3.84 \times 10^5) / (6.38 \times 10^3) = 60.19$ or 60.2
	$\rho = 3\pi \times 60.19^3 / [(6.67 \times 10^{-11}) \times (27.3 \times 24 \times 3600)^2]$
	$\rho = 5.54 \times 10^3 \text{ kg m}^{-3}$

2 - (9702/42_Summer_2017_Q1) - Motion In A Circle, Gravitational Fields

(a)	force per unit mass
(b)(i)	$g = GM / r^2$
	$= (6.67 \times 10^{-11} \times 1.0 \times 10^{13}) / (3.6 \times 10^3)^2$
	$= 5.1 \times 10^{-5} \text{ N kg}^{-1}$
(b)(ii)	mass = $(960 / 9.81) \text{ kg}$
	weight on comet = $(960 / 9.81) \times 5.1 \times 10^{-5}$
	$= 5.0 \times 10^{-3} \text{ N}$
(c)	similarity: e.g. both attractive/pointed towards the comet e.g. same order of magnitude
	difference: e.g. radial/non-radial e.g. same (over surface)/varies (over surface)

3 - (9702/42_Winter_2017_Q1) - Motion In A Circle, Gravitational Fields

(a)	force proportional to <u>product</u> of masses and inversely proportional to square of separation	B1
	idea of <u>force</u> between <u>point</u> masses	B1
(b)	mass of Jupiter (M) = $(4/3) \pi R^3 \rho$	B1
	$\omega = 2\pi / T$ or $v = 2\pi nR / T$	B1
	$(m)\omega^2 x = GM(m)/x^2$ or $(m)v^2/x = GM(m)/x^2$	M1
	substitution and correct algebra leading to $\rho T^2 = 3\pi n^3 / G$	A1
(c)(i)	$n = (4.32 \times 10^5) / (7.15 \times 10^4)$ or $n = 6.04$	C1
	$\rho \times (42.5 \times 3600)^2 = (3\pi \times 6.04^3) / (6.67 \times 10^{-11})$	C1
	$\rho = 1.33 \times 10^3 \text{ kg m}^{-3}$	A1
(c)(ii)	Jupiter likely to be a gas/liquid (at high pressure) [allow other sensible suggestions]	B1



4 - (9702/41_Summer_2019_Q1) - Motion In A Circle, Gravitational Fields

(a)	$(F =) GMm/x^2$, where G is the (universal) gravitational constant	B1
(b)(i)	$GMm/x^2 = mv^2/x$ or $v^2 = GM/x$	C1
	$v^2 = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) / (3.4 \times 10^6 + 240 \times 10^3)$	A1
	so $v = 3.7 \times 10^3 \text{ m s}^{-1}$	
(b)(ii)	potential energy = $(-)GMm/x$	C1
	$E_A = (-)(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (3.64 \times 10^6)$	M1
	or	
	$E_B = (-)(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (5.00 \times 10^7)$	
	correct substitution and subtraction $E_B - E_A$ shown, leading to $\Delta E_p = 8.3 \times 10^9 \text{ J}$	A1
	or	
	$\phi = (-)GM/x$ and potential energy = $m\phi$	(C1)
	$\Delta\phi = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) \times [(1/(3.64 \times 10^6)) - (1/(5.00 \times 10^7))]$	(M1)
	$(= 1.27 \times 10^7 \text{ J kg}^{-1})$	
	$\Delta E_p = 1.27 \times 10^7 \times 650$	(A1)
(c)	kinetic energy or potential energy decreases	B1
	kinetic energy and potential energy decrease so total energy decreases	B1

5 - (9702/41_Winter_2019_Q1) - Gravitational Fields, Motion In A Circle

(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of (gravitational) force between point masses	B1
(b)(i)	above the equator	B1
	from west to east	B1
(b)(ii)	gravitational force provides/is the centripetal force	B1
	$GM/r^2 = r(2\pi/T)^2$	C1
	$(6.67 \times 10^{-11} \times M) = \{(4.23 \times 10^7)^3 \times 4\pi^2\} / (24 \times 3600)^2$	C1
	$M = 6.0 \times 10^{24} \text{ kg}$	A1

6 - (9702/42_Winter_2019_Q1) - Motion In A Circle, Gravitational Fields

(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of (gravitational) force between point masses	B1
(b)	gravitational force provides/is the centripetal force	B1
	$GM/R^2 = R\omega^2$ or $GM/R^2 = v^2/R$	M1
	$\omega = 2\pi/T$ or $v = 2\pi R/T$	M1
	algebra leading to $R^3/T^2 = GM/4\pi^2$	A1
(c)	$(6.67 \times 10^{-11} \times M) / 4\pi^2 = (4.38 \times 10^6)^3 / (2.44 \times 3600)^2$	C1
	$M = 6.45 \times 10^{23} \text{ kg}$	A1

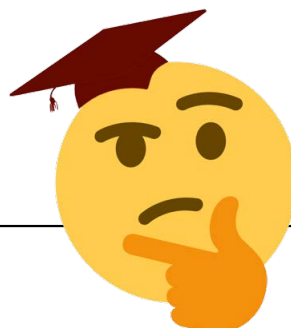


7 - (9702/41_Summer_2020_Q1) - Motion In A Circle, Gravitational Fields

(a)	force acting between two masses or force on mass due to another mass or force on mass in a gravitational field	B1
(b)	arc length = $r\theta$ $d = 1.5 \times 10^{17} \times 1.2 \times 10^{-5} = 1.8 \times 10^{12} \text{ m}$	A1
(c)(i)	$\omega = 2\pi / T$	C1
	$= 2\pi / (44.2 \times 365 \times 24 \times 3600)$	A1
	$= 4.5 \times 10^{-9} \text{ rad s}^{-1}$	
(c)(ii)	gravitational forces are equal or centripetal force about P is the same	C1
	$M_1 x \omega^2 = M_2 (d - x) \omega^2$ so $M_1 / M_2 = (d - x) / x$	A1
(c)(iii)	$x = 0.4d$	C1
	$6.67 \times 10^{-11} \times M_1 = (1.0 - 0.4) \times (1.8 \times 10^{12})^3 \times (4.5 \times 10^{-9})^2$	C1
	$M_1 = 1.1 \times 10^{30} \text{ kg}$	A1

8 - (9702/41_Winter_2021_Q1) - Motion In A Circle

(a)	constant speed or constant magnitude of velocity	B1
	acceleration (always) perpendicular to velocity	B1
(b)(i)	$F = mv^2 / r$ or $v = r\omega$ and $F = mr\omega^2$	C1
	$F = 790 \times 94^2 / 318$	A1
	$= 22\,000 \text{ N}$	
(b)(ii)	centripetal acceleration: same	B1
	maximum speed: greater	B1
	time taken for one lap of the track: greater	B1

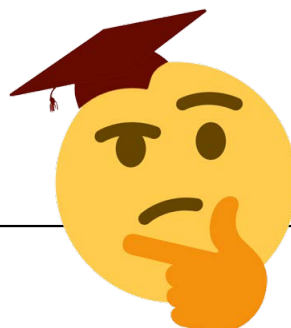


9 - (9702/42_Winter_2021_Q1) - Motion In A Circle

(a)	acceleration perpendicular to velocity	B1
(b)(i)	decreases	B1
(b)(ii)	(acceleration of) 9.8 m s^{-2} is caused by weight of car or centripetal force must be greater than weight of car	B1
	(acceleration $> 9.8 \text{ m s}^{-2}$) requires contact <u>force</u> from track or (centripetal force $>$ weight) requires contact <u>force</u> from track	B1
(c)	$\frac{1}{2}mv_y^2 = \frac{1}{2}mv_x^2 - mgh$	C1
	$a = v^2 / r$	C1
	$v_y^2 = 3.8^2 - 2 \times 9.81 \times 0.62$ so $v_y = 1.5 \text{ m s}^{-1}$	A1
	$a = 1.5^2 / 0.31 = 7.3 \text{ m s}^{-2}$ (which is less than 9.8 m s^{-2}) so no	
	or	
	$v_y = \sqrt{(9.81 \times 0.31)} = 1.74 \text{ m s}^{-1}$ so $v_x^2 = 1.74^2 + 2 \times 9.81 \times 0.62$ $v_x = 3.9 \text{ m s}^{-1}$ (which is greater than 3.8 m s^{-1}) so no	(A1)
(d)	acceleration is independent of mass so makes no difference or mass cancels in the equation so makes no difference	B1

10 - (9702/41_Winter_2023_Q4) - Oscillations, Motion In A Circle

(a)	(motion in which) acceleration is (directly) proportional to displacement	B1
	(motion in which): acceleration is (always) in the opposite <u>direction</u> to displacement or acceleration is (always) directed towards a fixed point	B1
(b)(i)	$\omega = 2\pi / T$	C1
	$\omega = 2\pi / 3.0$	A1
	$= 2.1 \text{ rad s}^{-1}$	
(b)(ii)	$E = \frac{1}{2}m\omega^2x_0^2$	C1
	$= \frac{1}{2} \times 0.81 \times 2.1^2 \times 0.036^2$	A1
	$= 2.3 \times 10^{-3} \text{ J}$	
(c)	sketch: line starting at (0, 0.036) and not reaching $x = \pm 0.036 \text{ m}$ at any other time	B1
	smooth curve, with no sudden changes in gradient, showing continuously decreasing magnitude of x from: maximum displacement at $t = 0$ to final displacement of zero where the gradient is also zero	B1
	displacement reaches final value of zero between $t = 0.75 \text{ s}$ and $t = 3.0 \text{ s}$ at the latest	B1



11 - (9702/42_Winter_2023_Q1) - Motion In A Circle

(a)	angle (subtended at centre of circle) when arc length = radius	B1
(b)	$\omega = 2\pi / T$	C1
	$= 2\pi / (1.0 \times 60 \times 60)$	A1
	$= 1.7 \times 10^{-3} \text{ rad s}^{-1}$	
(c)(i)	angle $= 1.7 \times 10^{-3} \times 1400$ $= 2.4 \text{ rad}$	A1
(c)(ii)	$L = \text{arc length} / \text{angle}$ $= 0.44 / 2.4$	C1
	or $L = 0.44 \times (3600 / 1400) / 2\pi$	
	$L = 0.18 \text{ m}$	A1
(c)(iii)	$a = r\omega^2$	C1
	$= 0.18 \times (1.745 \times 10^{-3})^2$	A1
	$= 5.5 \times 10^{-7} \text{ m s}^{-2}$	
(d)	centripetal acceleration is negligible compared with acceleration of free fall or numerical comparison establishing answer to (c)(iii) $\ll 9.81$	B1
	resultant force is negligible compared with weight (of modelling clay) (so variation is negligible) or force exerted by minute hand (approximately) equal (and opposite) to weight of modelling clay	B1



1 - (9702/41_Summer_2017_Q1) - Motion In A Circle, Gravitational Fields

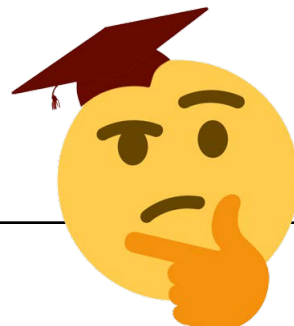
(a)	gravitational force (of attraction between satellite and planet) provides / is centripetal force (on satellite about the planet)
(b)	$M = (4/3) \times \pi R^3 \rho$ $\omega = 2\pi / T$ or $v = 2\pi nR / T$ $GM / (nR)^2 = nR\omega^2$ or v^2 / nR substitution clear to give $\rho = 3\pi n^3 / GT^2$
(c)	$n = (3.84 \times 10^5) / (6.38 \times 10^3) = 60.19$ or 60.2 $\rho = 3\pi \times 60.19^3 / [(6.67 \times 10^{-11}) \times (27.3 \times 24 \times 3600)^2]$ $\rho = 5.54 \times 10^3 \text{ kg m}^{-3}$

2 - (9702/42_Summer_2017_Q1) - Motion In A Circle, Gravitational Fields

(a)	force per unit mass
(b)(i)	$g = GM / r^2$ $= (6.67 \times 10^{-11} \times 1.0 \times 10^{13}) / (3.6 \times 10^3)^2$ $= 5.1 \times 10^{-5} \text{ N kg}^{-1}$
(b)(ii)	mass = $(960 / 9.81) \text{ kg}$ weight on comet = $(960 / 9.81) \times 5.1 \times 10^{-5}$ $= 5.0 \times 10^{-3} \text{ N}$
(c)	similarity: e.g. both attractive/pointed towards the comet e.g. same order of magnitude difference: e.g. radial/non-radial e.g. same (over surface)/varies (over surface)

3 - (9702/42_Winter_2017_Q1) - Motion In A Circle, Gravitational Fields

(a)	force proportional to <u>product</u> of masses and inversely proportional to square of separation	B1
	idea of <u>force</u> between <u>point</u> masses	B1
(b)	mass of Jupiter (M) = $(4/3) \pi R^3 \rho$	B1
	$\omega = 2\pi / T$ or $v = 2\pi nR / T$	B1
	$(m)\omega^2 x = GM(m)/x^2$ or $(m)v^2/x = GM(m)/x^2$	M1
	substitution and correct algebra leading to $\rho T^2 = 3\pi n^3 / G$	A1
(c)(i)	$n = (4.32 \times 10^5) / (7.15 \times 10^4)$ or $n = 6.04$	C1
	$\rho \times (42.5 \times 3600)^2 = (3\pi \times 6.04^3) / (6.67 \times 10^{-11})$	C1
	$\rho = 1.33 \times 10^3 \text{ kg m}^{-3}$	A1
(c)(ii)	Jupiter likely to be a gas/liquid (at high pressure) [allow other sensible suggestions]	B1

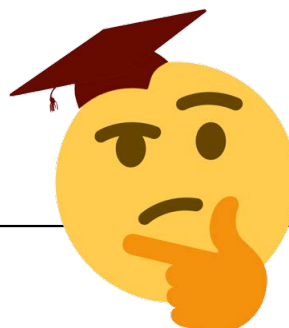


4 - (9702/41_Winter_2017_Q3) - Gravitational Fields

(a)	force per unit mass	B1
(b)	changes in height <u>much</u> less than radius of Earth	M1
	so (radial) field lines are almost parallel or $g = GM/R^2 \approx GM/(R+h)^2$	A1
(c)	gravitational force provides/is centripetal force	B1
	$GMm/r^2 = mv^2/r$	C1
	$v = (2\pi \times 1.5 \times 10^{11}) / (3600 \times 24 \times 365) = 2.99 \times 10^4 \text{ (ms}^{-1}\text{)}$	C1
	$6.67 \times 10^{-11} M = 1.5 \times 10^{11} \times (2.99 \times 10^4)^2$	C1
	$M = 2.0 \times 10^{30} \text{ kg}$	A1
	or	
	$GMm/r^2 = m\omega^2 r$	(C1)
	$\omega = 2\pi / (3600 \times 24 \times 365) = 1.99 \times 10^{-7} \text{ (rads}^{-1}\text{)}$	(C1)
	$6.67 \times 10^{-11} M = (1.5 \times 10^{11})^3 \times (1.99 \times 10^{-7})^2$	(C1)
	$M = 2.0 \times 10^{30} \text{ kg}$	(A1)
	or	
	$T^2 = 4\pi^2 r^3 / GM$	(C2)
	$M = 4\pi^2 \times (1.5 \times 10^{11})^3 / ((3600 \times 24 \times 365)^2 \times 6.67 \times 10^{-11})$	(C1)
	$= 2.0 \times 10^{30} \text{ kg}$	(A1)

5 - (9702/41_Summer_2018_Q1) - Gravitational Fields

(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of force between point masses	B1
(b)(i)	velocity changes/direction of motion changes/there is an acceleration/there is a resultant force so not in equilibrium	B1
(b)(ii)1.	gravitational force equals/is centripetal force	C1
	$GMm/R^2 = mR\omega^2$ and $\omega = 2\pi/T$ or $Gm/R^2 = mv^2/R$ and $v = 2\pi r/T$ or $GMm/R^2 = mR(2\pi/T)^2$	M1
	convincing algebra leading to $k = GM/4\pi^2$	A1
(b)(ii)2.	correct use of R^3/T^2 for one planet (c gives 3.54×10^{21} ; e and g both give 3.56×10^{21})	C1
	$3.5(5) \times 10^{21} = (6.67 \times 10^{-11} \times M) / 4\pi^2$	A1
	$M = 2.1 \times 10^{33} \text{ kg}$	
	two or three values of R^3/T^2 correctly calculated and used in a valid way to find a value for M based on more than one k	B1



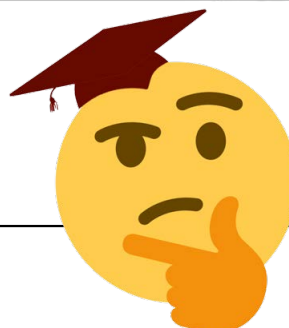
6 - (9702/42_Summer_2018_Q1) - Gravitational Fields

(a)(i)	direction of force on a (small test) <u>mass</u> or path in which a (small test) <u>mass</u> will move	B1
(a)(ii)	(at surface,) lines (of force) are radial	B1
	Earth has large radius/height above surface is small so lines are (approximately) parallel	B1
	parallel lines → constant field strength	B1
(b)	(change in) KE of rock = (change in) PE or $\frac{1}{2}mv^2 = GMm/R$	C1
	$(m)v^2 = (m)(2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / (1.7 \times 10^3 \times 10^3)$	C1
	$v = 2.4 \times 10^3 \text{ ms}^{-1}$	A1
	correct conclusion based on <u>comparison</u> of v with 2.8 km s^{-1}	B1
	or	
	(change in) KE of rock = (change in) PE	(C1)
	(at infinity) $E_p = (6.67 \times 10^{-11} \times 7.4 \times 10^{22} \times m) / (1.7 \times 10^3 \times 10^3)$ $= 2.9 \times 10^6 m$	(C1)
	E_K of rock = $\frac{1}{2} \times m \times (2.8 \times 10^3)^2 = 3.9 \times 10^6 m$	(A1)
	correct conclusion based on <u>comparison</u> of E_K and E_p values	(B1)
	or	

	(change in) KE of rock = (change in) PE or $\frac{1}{2}mv^2 = GMm/R$	(C1)
	$(m)(2800)^2 = (m)(2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / R$	(C1)
	$R = 1.3 \times 10^3 \text{ km}$	(A1)
	correct conclusion based on <u>comparison</u> of R with $1.7 \times 10^3 \text{ km}$	(B1)
	or	
	(change in) KE of rock = (change in) PE or $\frac{1}{2}mv^2 = GMm/R$	(C1)
	$(m)(2800)^2 = (m)(2 \times 6.67 \times 10^{-11} \times M) / (1.7 \times 10^6)$	(C1)
	$M = 1.0 \times 10^{23} \text{ kg}$	(A1)
	correct conclusion based on <u>comparison</u> of M with $7.4 \times 10^{22} \text{ kg}$	(B1)

7 - (9702/41_Winter_2018_Q1) - Gravitational Fields

(a)(i)	work done per unit mass	B1
	work done moving mass from infinity (to the point)	B1
(a)(ii)	(near Earth's surface change in) height $\ll$ radius or height <u>much</u> less than radius	B1
	potential inversely proportional to radius and radius approximately constant (so potential approximately constant)	B1
(b)	initial kinetic energy = (–) potential energy (at surface) or $\frac{1}{2}mv^2 = GMm/r$	B1
	$v^2 = (2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / (0.5 \times 3.5 \times 10^6)$	C1
	$v = 2.4 \times 10^3 \text{ ms}^{-1}$	A1



8 - (9702/42_Winter_2018_Q1) - Gravitational Fields

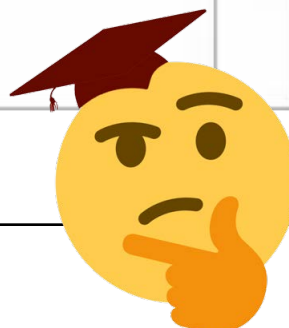
(a)(i)	force per unit mass	B1
(a)(ii)	acceleration = F/m , field strength = F/m , so equal	B1
(b)	smooth curve between R and $4R$ with negative gradient of decreasing magnitude	B1
	line passing through $(R, 1.00g)$ and $(2R, 0.25g)$	B1
	line ending at $(4R, 0.0625g)$	B1
(c)	$M = (4/3 \times \pi R^3)\rho$	C1
	$g = GM/(2R)^2$	C1
	$g = \frac{1}{2} \times 6.67 \times 10^{-11} \times \pi \times 3.4 \times 10^6 \times 4.0 \times 10^3$ $= 0.95 \text{ ms}^{-2}$	A1

9 - (9702/41_Summer_2019_Q1) - Motion In A Circle, Gravitational Fields

(a)	$(F =) GMm/x^2$, where G is the (universal) gravitational constant	B1
(b)(i)	$GMm/x^2 = mv^2/x$ or $v^2 = GM/x$	C1
	$v^2 = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) / (3.4 \times 10^6 + 240 \times 10^3)$	A1
	so $v = 3.7 \times 10^3 \text{ m s}^{-1}$	
(b)(ii)	potential energy = $(-)GMm/x$	C1
	$E_A = -(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (3.64 \times 10^6)$	M1
	or	
	$E_B = -(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (5.00 \times 10^7)$	
	correct substitution and subtraction $E_B - E_A$ shown, leading to $\Delta E_p = 8.3 \times 10^9 \text{ J}$	A1
	or	
	$\phi = (-)GM/x$ and potential energy = $m\phi$	(C1)
	$\Delta\phi = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) \times [(1/(3.64 \times 10^6)) - (1/(5.00 \times 10^7))]$ $(= 1.27 \times 10^7 \text{ J kg}^{-1})$	(M1)
(c)	kinetic energy or potential energy decreases	B1
	kinetic energy and potential energy decrease so total energy decreases	B1

10 - (9702/42_Summer_2019_Q1) - Gravitational Fields

(a)	$(F =) GMm/x^2$, where G is the (universal) gravitational constant	B1
(b)(i)	angle = $(1.2 \times 10^{-3}) / (8.0 \times 10^{-2}) = 1.5 \times 10^{-2} \text{ (rad)}$	B1
(b)(ii)	torque = $1.5 \times 10^{-2} \times 9.3 \times 10^{-10}$	A1
	= $1.4 \times 10^{-11} \text{ N m}$	
(c)(i)	force $\times 8.0 \times 10^{-2} = 1.4 \times 10^{-11}$	C1
	$(G \times 1.3 \times 7.5 \times 10^{-3} \times 8.0 \times 10^{-2}) / (6.0 \times 10^{-2})^2 = 1.4 \times 10^{-11}$	C1
	$G = 6.4 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	A1
(c)(ii)	Any one from: - law applies only to point masses/spheres are not point masses - radii of spheres not small compared with separation - spheres may not be uniform - the masses are not isolated - force between L and rod - spheres may be charged/may be electrostatic force (between spheres)	B1



11 – (9702/41_Winter_2019_Q1) – *Gravitational Fields, Motion In A Circle*

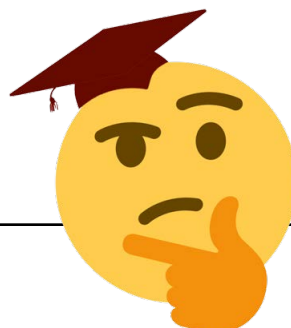
(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of (gravitational) force between point masses	B1
(b)(i)	above the equator	B1
	from west to east	B1
(b)(ii)	gravitational force provides/is the centripetal force	B1
	$GM/r^2 = r(2\pi/T)^2$	C1
	$(6.67 \times 10^{-11} \times M) = \{(4.23 \times 10^7)^3 \times 4\pi^2\} / (24 \times 3600)^2$	C1
	$M = 6.0 \times 10^{24} \text{ kg}$	A1

12 – (9702/42_Winter_2019_Q1) – *Motion In A Circle, Gravitational Fields*

(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of (gravitational) force between point masses	B1
(b)	gravitational force provides/is the centripetal force	B1
	$GM/R^2 = R\omega^2$ or $GM/R^2 = v^2/R$	M1
	$\omega = 2\pi/T$ or $v = 2\pi R/T$	M1
	algebra leading to $R^3/T^2 = GM/4\pi^2$	A1
(c)	$(6.67 \times 10^{-11} \times M) / 4\pi^2 = (4.38 \times 10^6)^3 / (2.44 \times 3600)^2$	C1
	$M = 6.45 \times 10^{23} \text{ kg}$	A1

13 – (9702/41_Summer_2020_Q1) – *Motion In A Circle, Gravitational Fields*

(a)	force acting between two masses or force on mass due to another mass or force on mass in a gravitational field	B1
(b)	arc length = $r\theta$ $d = 1.5 \times 10^{17} \times 1.2 \times 10^{-5} = 1.8 \times 10^{12} \text{ m}$	A1
(c)(i)	$\omega = 2\pi/T$	C1
	$= 2\pi / (44.2 \times 365 \times 24 \times 3600)$	A1
	$= 4.5 \times 10^{-9} \text{ rad s}^{-1}$	
(c)(ii)	gravitational forces are equal or centripetal force about P is the same	C1
	$M_1 x \omega^2 = M_2 (d - x) \omega^2$ so $M_1 / M_2 = (d - x) / x$	A1
(c)(iii)	$x = 0.4d$	C1
	$6.67 \times 10^{-11} \times M_1 = (1.0 - 0.4) \times (1.8 \times 10^{12})^3 \times (4.5 \times 10^{-9})^2$	C1
	$M_1 = 1.1 \times 10^{30} \text{ kg}$	A1

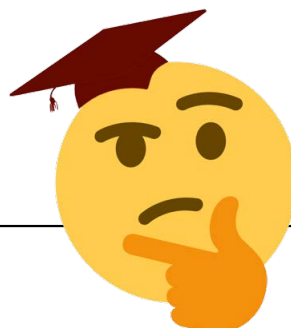


14 - (9702/42_Summer_2020_Q1) - Gravitational Fields

(a)	work done per unit mass	B1
	(work done to) move mass from infinity (to the point)	B1
(b)	curve from r to $4r$, with gradient of decreasing magnitude and starting at $(r, \pm\phi)$	B1
	line passing through $(2r, \pm0.5\phi)$ and $(4r, \pm0.25\phi)$	B1
	line showing potential is negative throughout	B1
(c)(i)	gravitational potential energy = $(-) GMm / R$	C1
	change = $(6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 3.4 \times 10^3) / (6.4 \times 10^6) \times [1/3 - 1/4]$	C1
	= $1.8 \times 10^{10} \text{ J}$	A1
(c)(ii)	rock loses potential energy	B1
	(so) kinetic energy increases so speed increases	B1
	or	
	force is attractive	(B1)
	moves towards planet so speeds up	(B1)

15 - (9702/41_Winter_2020_Q1) - Gravitational Fields

(a)(i)	region (of space)	B1
	where a particle experiences a force	B1
(a)(ii)	force per unit mass	B1
(b)	$g = GM / R^2$	C1
	= $(6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (3.39 \times 10^6)^2$	C1
	= 3.73 N kg^{-1}	A1
(c)	$0.99 \times 3.73 = (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / r^2$	C1
	$r = 3.41 \times 10^6 \text{ (m)}$	C1
	height = $(r - R)$	A1
	= $2 \times 10^4 \text{ m}$	
	or	
	$0.99 \times 3.73 = (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (R + h)^2$	(C1)
	$(R + h)^2 = 1.1596 \times 10^{13}$	
	$R + h = 3.41 \times 10^6 \text{ (m)}$	(C1)
	$h = 2 \times 10^4 \text{ m}$	(A1)
	or	
	$0.99 = (3.39 \times 10^6)^2 / r^2$	(C1)
	$r = 3.41 \times 10^6 \text{ (m)}$	(C1)
	height = $2 \times 10^4 \text{ m}$	(A1)

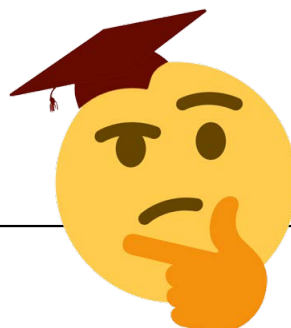


16 - (9702/42_Winter_2020_Q1) - Gravitational Fields

(a)	work done per unit mass	B1
	(work done) moving mass from infinity (to the point)	B1
(b)(i)	gravitational potential energy = $(-)\frac{GMm}{r}$	C1
	$\Delta E_p = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 2.4 \times 10^3 \times [(6.4 \times 10^6)^{-1} - (1.2 \times 10^7)^{-1}]$	C1
	or	
	$\Delta \phi = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times [(6.4 \times 10^6)^{-1} - (1.2 \times 10^7)^{-1}]$	(C1)
	$\Delta E_p = m\Delta\phi$	(C1)
	$\Delta E_p = 7.0 \times 10^{10} \text{ J}$	A1
(b)(ii)	$\frac{GMm}{r^2} = \frac{mv^2}{r}$	C1
	$v^2 = \frac{GM}{r}$	C1
	$= (6.67 \times 10^{-11} \times 6.0 \times 10^{24}) / (1.2 \times 10^7)$	
	$v = 5800 \text{ m s}^{-1}$	A1
(c)	any one point from: - smaller gain in energy required if orbit is west to east - smaller change in velocity if orbit is west to east - smaller gain in energy if orbit is in same direction as Earth's rotation - smaller change in velocity if orbit is in same direction as Earth's rotation - satellite already moving west to east at launch - Earth's rotation is from west to east	B1

17 - (9702/41_Summer_2021_Q1) - Gravitational Fields

(a)	force per unit mass	B1
(b)	$\frac{GMm}{r^2} = m\omega^2 r$ and $\omega = \frac{2\pi}{T}$ or $\frac{GMm}{r^2} = \frac{mv^2}{r}$ and $v = \frac{2\pi r}{T}$	C1
	$6.67 \times 10^{-11} \times 6.0 \times 10^{24} = r^3 \times [2\pi / (94 \times 60)]^2$	C1
	$r = 6.9 \times 10^6 \text{ m}$	A1
(c)(i)	$r^3 \omega^2 = \text{constant}$ or $r^3 / T^2 = \text{constant}$	C1
	$r^3 / (6.9 \times 10^6)^3 = (150 / 94)^2$ so $r = 9.4 \times 10^6 \text{ m}$	A1
	or	
	$\frac{GMT^2}{4\pi^2} = r^3$ and clear that M is 6.0×10^{24}	(C1)
	$6.67 \times 10^{-11} \times 6.0 \times 10^{24} = r^3 \times [2\pi / (150 \times 60)]^2$ so $r = 9.4 \times 10^6 \text{ m}$	(A1)
(c)(ii)	separation increases so (potential energy) increases or movement is against gravitational force so (potential energy) increases	B1
(c)(iii)	potential energy = $(-)\frac{GMm}{r}$	C1
	$\Delta E_p = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 1200 \times [(6.9 \times 10^6)^{-1} - (9.4 \times 10^6)^{-1}]$	C1
	$= 1.9 \times 10^{10} \text{ J}$	A1



18 - (9702/42_Summer_2021_Q1) - *Gravitational Fields*

(a)	(gravitational) force per unit mass	B1
(b)(i)	$g = GM / r^2$	C1
	$= (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (3.39 \times 10^6)^2$	A1
	$= 3.73 \text{ N kg}^{-1}$	
(b)(ii)	$a = r\omega^2$ and $\omega = 2\pi / T$ or $a = v^2 / r$ and $v = 2\pi r / T$	C1
	$a = 3.39 \times 10^6 \times (2\pi / (24.6 \times 3600))^2$	A1
	$= 0.0171 \text{ m s}^{-2}$	
(b)(iii)	force per unit mass $= 3.73 - 0.0171$ $= 3.71 \text{ N kg}^{-1}$	A1

19 - (9702/41_Winter_2021_Q2) - *Gravitational Fields*

(a)	work done per unit mass	B1
	(work done in) moving mass from infinity	B1
(b)(i)	(gravitational) fields from the Earth and Moon are in opposite directions	B1
	(resultant is zero where gravitational) fields are equal (in magnitude)	B1
(b)(ii)	$g \propto M / r^2$	C1
	$5.98 \times 10^{24} / x^2 = 7.35 \times 10^{22} / (3.84 \times 10^8 - x)^2$	A1
	leading to $x = 3.5 \times 10^8 \text{ (m)}$	
(b)(iii)	$\phi \text{ (Earth)} = (-)6.67 \times 10^{-11} \times (5.98 \times 10^{24} / 3.5 \times 10^8)$ and $\phi \text{ (Moon)} = (-)6.67 \times 10^{-11} \times (7.35 \times 10^{22} / 0.38 \times 10^8)$	C1
	$\phi = (-)6.67 \times 10^{-11} \times [(5.98 \times 10^{24} / 3.5 \times 10^8) + (7.35 \times 10^{22} / 0.38 \times 10^8)]$	C1
	$= -1.3 \times 10^6 \text{ J kg}^{-1}$	A1

20 - (9702/42_Winter_2021_Q2) - *Gravitational Fields*

(a)	(gravitational) field strength equals (gravitational) potential gradient	M1
	reference to minus sign	A1
(b)(i)	potential is zero at infinity	B1
	(gravitational) force is attractive	B1
	(test) mass getting closer (from infinity) loses potential energy	B1
(b)(ii)	- potential at (surface of) planet is smaller than at (surface of) moon - potential gradient at (surface of) planet is smaller than at (surface of) moon - magnitude of potential varies inversely with distance from centre near the spheres (point of) maximum potential is nearer to moon than planet Any two points, 1 mark each	B2
(b)(iii)	sketch: one curve, starting with gradient of decreasing magnitude at $2R$ and finishing with gradient of increasing magnitude at $D - R$	B1
	field strength shown as zero (only) near the point of maximum potential	B1
	negative field strength near one sphere and positive field strength near the other	B1



21 – (9702/41_Summer_2022_Q1) – Gravitational Fields

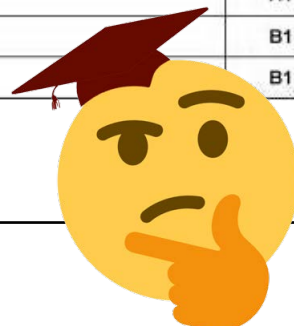
(a)(i)	(gravitational) force is (directly) proportional to product of masses	B1
	force (between point masses) is inversely proportional to the square of their separation	B1
(a)(ii)	$g = F / m$	C1
	$F = GMm / r^2$	A1
	and so	
	$g = [GMm / r^2] / m = GM / r^2$	
(b)(i)	$g = (6.67 \times 10^{-11} \times 7.35 \times 10^{22}) / (1.74 \times 10^8)^2 = 1.62 \text{ N kg}^{-1}$	A1
(b)(ii)	fields (due to Earth and the Moon) have equal magnitudes	B1
	fields (due to Earth and the Moon) are in opposite directions	B1
(b)(iii)	distance of X from Earth = $(3.84 \times 10^8 - x)$	C1
	$(G \times) 7.35 \times 10^{22} / x^2 = (G \times) 5.98 \times 10^{24} / (3.84 \times 10^8 - x)^2$	C1
	$x = 3.8 \times 10^7 \text{ m}$	A1

22 – (9702/42_Summer_2022_Q1) – Gravitational Fields

(a)(i)	work (done) per unit mass	B1
	work (done on mass) in moving mass from infinity (to the point)	B1
(a)(ii)	$E_p = \phi m$	B1
	$E_p = (-GM / r) \times m = -GMm / r$	
	or	
	$\phi = -GM / r$ and $E_p = \phi m = -GMm / r$	
(b)(i)	$\Delta E_p = 6.67 \times 10^{-11} \times 1.99 \times 10^{30} \times 2.20 \times 10^{14} \times [1 / (6.38 \times 10^{10}) - 1 / (8.44 \times 10^{11})]$	C1
	$= 4.23 \times 10^{23} \text{ J}$	A1
(b)(ii)	(gravitational) force is attractive so decrease	B1
	or (gravitational) force does work so decrease	
(b)(iii)	$\Delta E_p = \frac{1}{2} m (v_2^2 - v_1^2)$	C1
	$4.23 \times 10^{23} = \frac{1}{2} \times 2.20 \times 10^{14} \times (v^2 - 34\,100^2)$	C1
	$v (= 70800 \text{ m s}^{-1}) = 70.8 \text{ km s}^{-1}$	A1
(c)	both PE and KE equations include m , so path is unchanged	B1

23 – (9702/41_Winter_2022_Q1) – Gravitational Fields

(a)	$F = (Gm_1m_2) / r^2$	M1
	where G is the gravitational constant	A1
(b)	gravitational force provides the centripetal force	B1
	$mR\omega^2 = GMm / R^2$ and $\omega = 2\pi / T$	M1
	or	
	$mv^2 / R = GMm / R^2$ and $v = 2\pi R / T$	
	or	
(c)(i)	$4\pi^2 mR / T^2 = GMm / R^2$	
	correct completion of algebra to get $T^2 = (4\pi^2 / GM) R^3$, with identification of $(4\pi^2 / GM)$ as k	A1
(c)(ii)	$(24 \times 3600)^2 = (4\pi^2 \times R^3) / (6.67 \times 10^{-11} \times 6.0 \times 10^{24})$	C1
	$R = 4.2 \times 10^7 \text{ m}$	A1
(c)(iii)	(orbit) must be above the Equator	B1
	(direction) must be from west to east	B1

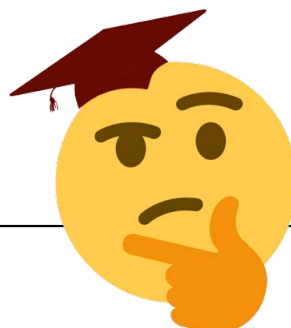


24 – (9702/42_Winter_2022_Q1) – Gravitational Fields

(a)	force per unit mass	B1
(b)(i)	lines drawn are radial from the surface	B1
	arrows show pointing towards planet	B1
(b)(ii)	field lines show force (on satellite) is towards centre of planet or velocity of satellite is perpendicular to field lines	B1
	(gravitational) force perpendicular to velocity causes centripetal <u>acceleration</u>	B1
(c)(i)	$T = 24 \text{ hours}$	C1
	$a = r\omega^2$ and $\omega = 2\pi / T$ or $a = v^2 / r$ and $v = 2\pi r / T$ or $a = 4\pi^2 r / T^2$	C1
	$a = (4\pi^2 \times 6.4 \times 10^6) / (24 \times 60 \times 60)^2$ $= 0.034 \text{ m s}^{-2}$	A1
(c)(ii)	identification of the two forces acting on the object as gravitational force and (normal) contact force	M1
	gravitational force and normal contact force are in opposite directions, and their resultant causes the (centripetal) acceleration	A1

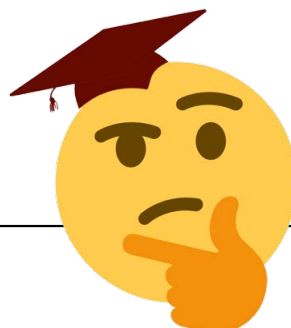
25 – (9702/41_Winter_2023_Q1) – Gravitational Fields

(a)(i)	direction of the force acting on a (test) mass placed at the point	B1
(a)(ii)	change in height negligible compared with radius (of Earth)	B1
	(so) field lines are (effectively) parallel	B1
(b)(i)	$Y = GM / R^2$	M1
	G is the gravitational constant	A1
(b)(ii)	gravitational force is (always) attractive or gravitational force (always) acts towards the centre of the sphere	B1
	force is in opposite direction to displacement or at a point to the right of the centre, force acts to the left or at a point to the left of the centre, force acts to the right	B1
(b)(iii)	sketch: smooth curve with decreasing positive gradient, starting at $(R, -Y)$ and reaching $3R$ with g still negative or smooth curve with increasing positive gradient, ending at $(-R, Y)$ and reaching $-3R$ with g still positive	B1
	both of the above curves, in correct quadrants	B1
	curve passing through $(\pm 2R, \pm 0.25 Y)$ and $(\pm 3R, \pm 0.11 Y)$	B1



26 - (9702/42_Winter_2023_Q2) - Gravitational Fields

(a)(i)	work done per unit mass	B1
	work (done) moving mass from infinity (to the point)	B1
(a)(ii)	$\phi = -GM / r$	C1
	$= -(6.67 \times 10^{-11} \times 7.3 \times 10^{22}) / (1.7 \times 10^6)$	
	$= -2.9 \times 10^6 \text{ J kg}^{-1}$	A1
(b)(i)	$E_p = m\phi$	B1
(b)(ii)	$\frac{1}{2}mv^2 + m\phi = 0$	M1
	correct algebra leading to $v = \sqrt{-2\phi}$	A1
(c)	speed $= \sqrt{2 \times 2.9 \times 10^6}$ $= 2400 \text{ m s}^{-1}$	A1
(d)	$\frac{1}{2}m\langle c^2 \rangle = (3/2)kT$	C1
	$3.34 \times 10^{-27} \times \langle c^2 \rangle = 3 \times 1.38 \times 10^{-23} \times 400$	C1
	$c_{r.m.s.} = 2200 \text{ m s}^{-1}$	A1
(e)	r.m.s. speed is an average so many molecules have speeds greater than the escape speed or there is a distribution of molecular speeds (around the r.m.s. value) so many molecules have speeds greater than the escape speed	B1



1 - (9702/42_Summer_2017_Q2) - Ideal Gases, Temperature, Thermal Properties Of Materials

(a)(i)	mean/average square speed/velocity
(a)(ii)	$pV = NkT$ or $pV = nRT$
	$\rho = Nm / V$ or $\rho = nN_A m / V$ and $k = nR / N$
	$E_K = \frac{1}{2} m \langle c^2 \rangle$ with algebra to $(3/2)kT$
(b)(i)	no (external) work done or $\Delta U = q$ or $w = 0$
	$q = N_A \times (3/2)k \times 1.0$
	$N_A k = R$ so $q = (3/2)R$
(b)(ii)	specific heat capacity = $\{(3/2) \times R\} / 0.028$
	$= 450 \text{ J kg}^{-1} \text{ K}^{-1}$

2 - (9702/41_Summer_2017_Q4) - Ideal Gases

(a)	random/haphazard
	constant velocity or speed in a straight line between collisions or distribution of speeds/different directions
(b)	(small) specks of light/bright specks/pollen grains/dust particles/smoke particles
	moving haphazardly/randomly/jerky/in a zigzag fashion
(c)(i)	$pV = \frac{1}{2} Nm \langle c^2 \rangle$
	$1.05 \times 10^5 \times 0.0240 = \frac{1}{2} \times 4.00 \times 10^{-3} \times \langle c^2 \rangle$
	$\langle c^2 \rangle = 1.89 \times 10^6$
	or
	$\frac{1}{2} m \langle c^2 \rangle = (3/2) kT$
	$0.5 \times (4.00 \times 10^{-3} / 6.02 \times 10^{23}) \times \langle c^2 \rangle = 1.5 \times 1.38 \times 10^{-23} \times 300$
	$\langle c^2 \rangle = 1.87 \times 10^6$
	or
	$nRT = \frac{1}{2} Nm \langle c^2 \rangle$
	$1.00 \times 8.31 \times 300 = \frac{1}{2} \times 4.00 \times 10^{-3} \times \langle c^2 \rangle$
	$\langle c^2 \rangle = 1.87 \times 10^6$
	$c_{r.m.s.} = 1.37 \times 10^3 \text{ m s}^{-1}$
(c)(ii)	$\langle c^2 \rangle \propto T$
	$\langle c^2 \rangle$ at $177^\circ\text{C} = 1.89 \times 10^6 \times (450/300)$
	$c_{r.m.s.}$ at $177^\circ\text{C} = 1.68 \times 10^3 \text{ m s}^{-1}$

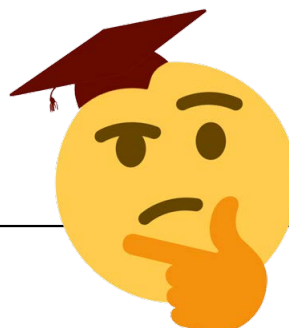


3 - (9702/42_Summer_2018_Q2) - Ideal Gases, Thermal Properties Of Materials

(a)	no intermolecular forces (so no potential energy)	B1
(b)(i)	mean square speed (of molecule(s))	B1
(b)(ii)	kelvin/thermodynamic/absolute <u>temperature</u>	B1
(c)(i)1.	$pV = NkT$	C1
	$4.7 \times 10^{-2} \times 2.6 \times 10^5 = N \times 1.38 \times 10^{-23} \times 446$	C1
	or	
	$pV = nRT$ and $N = nN_A$	(C1)
	$4.7 \times 10^{-2} \times 2.6 \times 10^5 = n \times 8.31 \times 446$	
	$n = 3.3$ (mol)	
	$N = 3.3 \times 6.02 \times 10^{23}$	(C1)
	$N = 2.0 \times 10^{24}$	A1
(c)(i)2.	average increase = $2900 / (2.0 \times 10^{24})$	A1
	= 1.5×10^{-21} J	
(c)(ii)	$\Delta E_K = (3/2)k(\Delta)T$	C1
	$1.5 \times 10^{-21} = (3/2) \times 1.38 \times 10^{-23} \times (\Delta)T$	
	$(\Delta)T$ in range 70–72 K	C1
	$T = 173 + 273 + 70$	A1
	= 520 K	

4 - (9702/41_Summer_2018_Q3) - Ideal Gases

(a)(i)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
(a)(ii)	(in ideal gas) no intermolecular forces so no potential energy	B1
	internal energy is (solely) kinetic energy (of particles)	B1
	(mean) kinetic energy (of particles) proportional to (thermodynamic) temperature of gas	B1
(b)	$pV = NkT$	C1
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times 298$	C1
	or	
	$pV = nRT$ and $N = n \times N_A$	(C1)
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = n \times 8.31 \times 298$	(C1)
	$n = 46.5$ (mol)	
	$N = 46.5 \times 6.02 \times 10^{23}$	
	$N = 2.8 \times 10^{25}$	A1



5 - (9702/41_Winter_2018_Q2) - Ideal Gases, Thermal Properties Of Materials

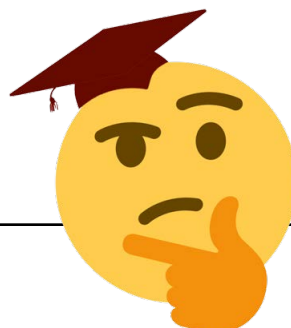
(a)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
(b)(i)	final temperature = initial temperature	B1
	no change in internal energy	B1
(b)(ii)	1. work done on gas (P→Q): 0	A1
	increase in internal energy (P→Q): (+)97.0 J	A1
	2. increase in internal energy (Q→R): -42.5 J	A1
	3. increase in internal energy (R→P): -54.5 J	A1
	thermal energy supplied (R→P): -91.5 J	A1

6 - (9702/42_Winter_2018_Q2) - Ideal Gases, Temperature, Thermal Properties Of Materials

(a)	gas that obeys equation $pV = \text{constant} \times T$	M1
	symbols p , V and T explained	A1
(b)(i)	$pV = \frac{1}{2} Nm \langle c^2 \rangle$ and $M = Nm$ (and so) $p = \frac{1}{3} \rho \langle c^2 \rangle$	C1
	$2.12 \times 10^7 = \frac{1}{3} \times [3.20 / (1.84 \times 10^{-23})] \times \langle c^2 \rangle$	C1
	$c_{r.m.s.} = 605 \text{ ms}^{-1}$	A1
(b)(ii)	1. $pV = nRT$ and $T = (22 + 273) \text{ K}$	C1
	$n = (2.12 \times 10^7 \times 1.84 \times 10^{-23}) / (8.31 \times 295)$ $= 159 \text{ mol}$	A1
	2. mass = $3.20 / (159 \times 6.02 \times 10^{23})$ or mass = $[2 \times (3/2) \times 1.38 \times 10^{-23} \times 295] / 605^2$	C1
	mass = $3.34 \times 10^{-26} \text{ kg}$	A1
(c)	$A = (3.34 \times 10^{-26}) / (1.66 \times 10^{-27})$ $= 20$	A1

7 - (9702/41_Summer_2019_Q2) - Ideal Gases, Temperature, Thermal Properties Of Materials

(a)(i)	$pV = nRT$	C1
	$n = (3.0 \times 10^5 \times 210 \times 10^{-6}) / (8.31 \times 270)$	C1
	$= 0.028 \text{ mol}$	A1
(a)(ii)	$V \propto T$ or $T = pV / nR$ with value of n from (i)	C1
	$T = (140 / 210) \times 270$ or $T = (3.0 \times 10^5 \times 140 \times 10^{-6}) / (8.31 \times 0.028)$ $= 180 \text{ K}$	A1
(a)(iii)	$W = p \Delta V$	C1
	$= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$	
	$= 21 \text{ J}$	A1



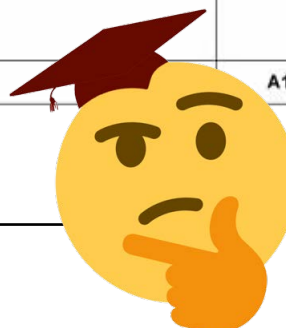
(b)	$\Delta U = w + q$	C1
	$= 21 - 53$	C1
	or	
	$\Delta U = (nN_A) \times (3/2)k\Delta T$	(C1)
	$= (0.0281 \times 6.02 \times 10^{23}) \times (3/2) \times 1.38 \times 10^{-23} \times (180 - 270)$	(C1)
	or	
	$\Delta U = (3/2)nR\Delta T$	(C1)
	$= (3/2) \times 0.0281 \times 8.31 \times (180 - 270)$	(C1)
	$\Delta U = (-)32 \text{ J}$	A1

8 - (9702/42_Summer_2019_Q2) - Ideal Gases, Thermal Properties Of Materials

(a)(i)	1. energy transfer <u>to</u> the system by heating	B1									
	2. (external) work done <u>on</u> the system	B1									
(a)(ii)	decrease in internal energy	B1									
(b)(i)	no change (in internal energy)	B1									
	(because) no change in temperature	B1									
(b)(ii)	work done $= p\Delta V$	C1									
	$= (-)1.6 \times 10^5 \times (2.4 - 0.87) \times 10^{-3}$										
	$= (-)240 \text{ J}$	A1									
(b)(iii)	first row all correct (0, 480, 480)	A1									
	second row all correct (-1100, 0, -1100)	A1									
	final column of third row calculated correctly from the two values above it, so that the final column adds up to 0	A1									
	second column in final row correct, with correct negative sign and first column in final row calculated correctly so that it adds to the second column to give the third column (fully correct table is:	A1									
	<table border="1"> <tr> <td>0</td><td>480</td><td>480</td></tr> <tr> <td>-1100</td><td>0</td><td>-1100</td></tr> <tr> <td>860</td><td>-240</td><td>620</td></tr> </table>	0	480	480	-1100	0	-1100	860	-240	620	
0	480	480									
-1100	0	-1100									
860	-240	620									

9 - (9702/41_Winter_2019_Q2) - Ideal Gases

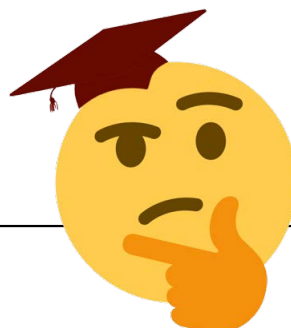
(a)	(total volume of molecules is) negligible	M1
	compared with volume occupied by the gas	A1
(b)(i)	$pV = NkT$	C1
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = N \times 1.38 \times 10^{-23} \times (273 + 23)$	C1
	or	
	$pV = nRT$	(C1)
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = n \times 8.31 \times (273 + 23)$	(C1)
	$n = 4.49 \text{ (mol)}$	
	$N = nN_A$	
	$= 4.49 \times 6.02 \times 10^{23}$	
	$N = 2.7 \times 10^{24}$	A1



(b)(ii)	volume of one atom = d^3 ($= 2.7 \times 10^{-29} \text{ m}^3$)	C1
	volume of all atoms = $2.7 \times 10^{-29} \times 2.7 \times 10^{24}$	C1
	$= 7 \times 10^{-5} \text{ m}^3$	A1
	or	
	volume of one atom = $(4/3)\pi r^3$ ($= 1.41 \times 10^{-29} \text{ m}^3$)	(C1)
	volume of all atoms = $2.7 \times 10^{24} \times 1.41 \times 10^{-29}$	(C1)
	$= 4 \times 10^{-5} \text{ m}^3$	(A1)
(c)	numerical comparison between answer to (b)(ii) and $2.4 \times 10^{-2} \text{ (m}^3\text{)}$ showing (b)(ii) is <u>much</u> less than $2.4 \times 10^{-2} \text{ (m}^3\text{)}$	B1

10 – (9702/42_Winter_2019_Q2) – Ideal Gases, Thermal Properties Of Materials

(a)(i)	specks of light moving haphazardly	B1
(a)(ii)	(gas) molecules collide with (smoke) particles or random motion of the (gas) molecules	M1
	<u>causes</u> the (haphazard) motion of the smoke particles or <u>causes</u> the smoke particles to change direction	A1
(b)(i)	$pV = nRT$	C1
	$n = (3.51 \times 10^5 \times 2.40 \times 10^{-3}) / (8.31 \times 290)$ or $n = (3.75 \times 10^5 \times 2.40 \times 10^{-3}) / (8.31 \times 310)$	C1
	or	
	$pV = NkT$	(C1)
	$n = (3.51 \times 10^5 \times 2.40 \times 10^{-3}) / (1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 290)$ or $n = (3.75 \times 10^5 \times 2.40 \times 10^{-3}) / (1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 310)$	(C1)
	$n = 0.350 \text{ mol}$ or 0.349 mol	A1
(b)(ii)	energy transfer = $(0.349 \text{ or } 0.35) \times 12.5 \times (310 - 290)$	C1
	$= 87.3 \text{ J}$ or 87.5 J	A1
(c)(i)	zero	A1
(c)(ii)	87.3 J or 87.5 J	A1
	increase	B1

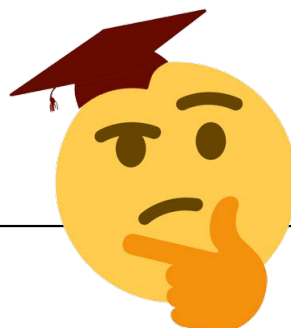


11 - (9702/41_Summer_2020_Q2) - *Ideal Gases, Thermal Properties Of Materials*

(a)	total potential energy and kinetic energy (of molecules/atoms)	M1
	reference to <u>random</u> motion of molecules/atoms	A1
(b)	(in ideal gas,) no intermolecular forces	B1
	no potential energy (so change in kinetic energy is change in internal energy)	B1
(c)	(random) potential energy of molecules does not change	M1
	(random) kinetic energy of molecules does not change	M1
	so internal energy does not change	A1
	or	
	decrease in total potential energy = gain in total kinetic energy	(M1)
	no external energy supplied	(M1)
	so internal energy does not change	(A1)
	or	
	no compression (of ball) so no work done on the ball	(M1)
	no resistive forces so no heating of the ball	(M1)
	so internal energy does not change	(A1)
(c)	or	
	no change of state so potential energy (of molecules) unchanged	(M1)
	no temperature rise so kinetic energy (of molecules) unchanged	(M1)
	so internal energy does not change	(A1)

12 - (9702/42_Summer_2020_Q2) - *Ideal Gases*

(a)	$\rho: Nm / V$	B1
	$\frac{1}{3}$: molecules move in three dimensions (not one) so $\frac{1}{3}$ in any (one) direction	B1
	$\langle c^2 \rangle$: molecules have different speeds so take average	M1
	of $(speed)^2$	A1
(b)	$pV = NkT$	C1
	$N = (3.0 \times 10^5 \times 6.0 \times 10^{-3}) / (1.38 \times 10^{-23} \times 290)$	C1
	$= 4.5 \times 10^{23}$	C1
	mass $= 20.7 / (4.5 \times 10^{23})$ $= 4.6 \times 10^{-23} \text{ g}$	A1

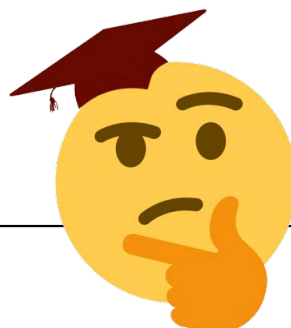


13 - (9702/41_Winter_2020_Q2) - *Ideal Gases, Temperature*

(a)	+q: thermal energy transfer to system	B1																
	+w: work done on system	B1																
(b)(i)	$(W =) 2.6 \times 10^5 \times (3.8 - 2.3) \times 10^{-3} = 390 \text{ J}$	A1																
(b)(ii)	no (total) change (in internal energy)	B1																
	gas returns to its original temperature	B1																
(c)	A to B row all correct (1370, -390, 980)	B1																
	B to C row all correct (0, 550, 550)	B1																
	C to A row: ΔU adds to the other two ΔU values to give zero	B1																
	C to A row: $w = 0$ and q adds to w to give ΔU value	B1																
	complete correct answer:																	
	<table><tr><td>change</td><td>q / J</td><td>w / J</td><td>$\Delta U / \text{J}$</td></tr><tr><td>A to B</td><td>(+)1370</td><td>-390</td><td>(+)980</td></tr><tr><td>B to C</td><td>0</td><td>(+)550</td><td>(+)550</td></tr><tr><td>C to A</td><td>-1530</td><td>0</td><td>-1530</td></tr></table>	change	q / J	w / J	$\Delta U / \text{J}$	A to B	(+)1370	-390	(+)980	B to C	0	(+)550	(+)550	C to A	-1530	0	-1530	
change	q / J	w / J	$\Delta U / \text{J}$															
A to B	(+)1370	-390	(+)980															
B to C	0	(+)550	(+)550															
C to A	-1530	0	-1530															

14 - (9702/42_Winter_2020_Q2) - *Ideal Gases, Temperature*

(a)	sum of potential energy and kinetic energy (of particles)	B1
	(total) energy of random motion of particles	B1
(b)(i)	$pV = nRT$	C1
	$2.60 \times 10^5 \times 2.30 \times 10^{-3} = n \times 8.31 \times 180$	A1
	$n = 0.400 \text{ mol}$	
(b)(ii)	$(2.30 \times 10^{-3}) / 180 = (3.80 \times 10^{-3}) / T$	C1
	or	
	$2.60 \times 10^5 \times 3.80 \times 10^{-3} = 0.400 \times 8.31 \times T$	
	$T = 297 \text{ K}$	A1
(c)(i)	$\Delta W = p\Delta V$	C1
	$= 2.60 \times 10^5 \times (2.30 - 3.80) \times 10^{-3}$	
	$= (-)390 \text{ J}$	A1
	negative because work is done by gas or negative because work is done against atmospheric pressure or negative because volume of gas increases	B1
(c)(ii)	$\Delta U = (980 - 390)$	A1
	$= 590 \text{ J}$	

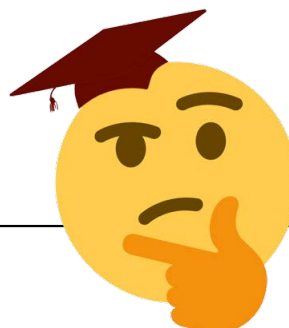


15 - (9702/41_Summer_2021_Q2) - Ideal Gases

(a)	$pV = NkT$	C1
	$N = (1.8 \times 10^{-3} \times 3.3 \times 10^5) / (1.38 \times 10^{-23} \times 310) = 1.4 \times 10^{23}$	A1
	or	
	$pV = nRT$ and $nN_A = N$	(C1)
	$N = (1.8 \times 10^{-3} \times 3.3 \times 10^5 \times 6.02 \times 10^{23}) / (8.31 \times 310) = 1.4 \times 10^{23}$	(A1)
(b)	speed of molecule decreases on impact with moving piston	B1
	mean square speed (directly) proportional to (thermodynamic) temperature	B1
	or mean square speed (directly) proportional to kinetic energy (of molecules)	
	or kinetic energy (of molecules) (directly) proportional to (thermodynamic) temperature	
	kinetic energy (of molecules) decreases (so temperature decreases)	B1
(c)(i)	$\Delta U = 3/2 \times k \times \Delta T \times N$	C1
	$= 3/2 \times 1.38 \times 10^{-23} \times (288 - 310) \times 1.4 \times 10^{23}$	C1
	$= -64 \text{ J}$	A1
(c)(ii)	decrease in internal energy is less than work done by gas	M1
	(thermal energy is) transferred <u>to</u> the gas (during the expansion)	A1

16 - (9702/42_Summer_2021_Q2) - Ideal Gases, Temperature

(a)	$pV = nRT$	C1
	$pV = nRT$ and $N = nN_A$	C1
	or	
	$pV = NkT$	
(b)(i)	$3.1 \times 10^{-3} \times 8.5 \times 10^5 = (N \times 290 \times 8.31) / (6.02 \times 10^{23})$	A1
	so $N = 6.6 \times 10^{23}$	
	or	
	$3.1 \times 10^{-3} \times 8.5 \times 10^5 = N \times 1.38 \times 10^{-23} \times 290$	
(b)(ii)	$\Delta U = 3/2 \times k \times \Delta T \times N$	C1
	$= 3/2 \times 1.38 \times 10^{-23} \times (190 - 290) \times 6.6 \times 10^{23}$	C1
	$= -1400 \text{ J}$	A1
(c)	$\Delta U = q + w$	M1
	$q = 0$ so $\Delta U = w$	A1

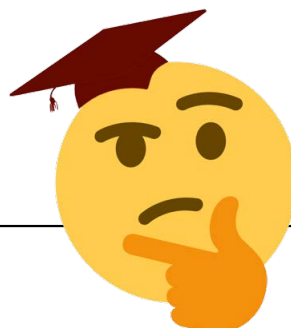


17 - (9702/42_Winter_2021_Q3) - Ideal Gases

(a)(i)	no loss of <u>kinetic</u> energy	B1
(a)(ii)	• <u>molecules</u> have negligible volume (compared with gas/container) • no forces between <u>molecules</u> (except during collisions) • <u>molecules</u> are in random motion • collisions are instantaneous Any two points, 1 mark each	B2
(b)(i)	$2mu$	A1
(b)(ii)	$2L / u$	A1
(b)(iii)	force = change in momentum / time = $2mu / (2L / u)$ $= mu^2 / L$	A1
(b)(iv)	pressure = force / area = $(mu^2 / L) / L^2$ $= mu^2 / L^3$	A1
(c)	$pV = NkT$	C1
	$NkT = \frac{1}{2}Nm\langle c^2 \rangle$ leading to $\frac{1}{2}m\langle c^2 \rangle = (3/2)kT$ <u>and</u> $\frac{1}{2}m\langle c^2 \rangle = E_k$	A1
(d)	$\frac{1}{2} \times 3.34 \times 10^{-27} \times \langle c^2 \rangle = (3/2) \times 1.38 \times 10^{-23} \times (25 + 273)$	C1
	r.m.s. speed = $1.9 \times 10^3 \text{ m s}^{-1}$	A1

18 - (9702/41_Summer_2022_Q3) - Ideal Gases

(a)(i)	a gas that obeys $pV \propto T$	M1												
	where p = pressure, V = volume, T = thermodynamic temperature	A1												
(a)(ii)	$T = (273 + 17) \text{ K}$	C1												
	$n = pV / RT$ $= (1.2 \times 10^5 \times 0.24) / [8.31 \times (273 + 17)]$ $= 12 \text{ mol}$	A1												
(b)(i)	work done = $p\Delta V$	C1												
	$= 1.2 \times 10^5 \times (0.24 - 0.08) = 19200 \text{ J } (= 19.2 \text{ kJ})$	A1												
(b)(ii)	AB work done correct (19.2)	A1												
	BC work done correct (0)	A1												
	CA increase in internal energy correct (0) and CA thermal energy correct (31.6)	A1												
	AB increase in internal energy calculated correctly from work done – 48.0	A1												
	BC increase in internal energy correctly calculated so the final column adds up to zero and BC thermal energy same as increase in internal energy	A1												
	(Fully correct table: <table><tr><td>AB</td><td>19.2</td><td>–48.0</td><td>–28.8</td></tr><tr><td>BC</td><td>0</td><td>28.8</td><td>28.8</td></tr><tr><td>CA</td><td>–31.6</td><td>31.6</td><td>0</td></tr></table>)	AB	19.2	–48.0	–28.8	BC	0	28.8	28.8	CA	–31.6	31.6	0	
AB	19.2	–48.0	–28.8											
BC	0	28.8	28.8											
CA	–31.6	31.6	0											



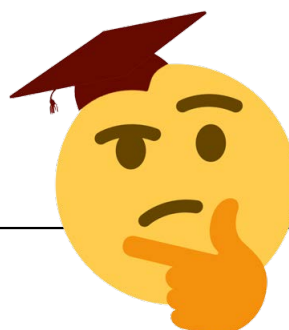
19 - (9702/42_Winter_2022_Q3) - Ideal Gases

(a)	p = pressure (of gas), V = volume (of gas) and k = Boltzmann constant	B1
	N = number of molecules	B1
	T = thermodynamic temperature	B1
(b)	$(pV = NkT \text{ and } pV = \frac{1}{2}Nm\langle c^2 \rangle \text{ leading to } NkT = \frac{1}{2}Nm\langle c^2 \rangle)$	M1
	algebra leading to $(3/2)kT = \frac{1}{2}m\langle c^2 \rangle$ and use of $\frac{1}{2}m\langle c^2 \rangle = E_k$ leading to $(3/2)kT = E_k$	A1
(c)(i)	$T = 296 \text{ K}$	C1
	$\frac{1}{2}m\langle c^2 \rangle = (3/2)kT$	C1
	$\frac{1}{2} \times 5.31 \times 10^{-26} \times u^2 = (3/2) \times 1.38 \times 10^{-23} \times 296$	
	$u = 480 \text{ m s}^{-1}$	A1
(c)(ii)	line passing through (P, u)	B1
	horizontal straight line	B1

20 - (9702/41_Summer_2023_Q4) - Ideal Gases, Temperature, Thermal Properties Of Materials

(a)	- particles are in (continuous) random motion - particles have negligible volume (compared with the gas) - negligible forces between particles (except during collisions) (all) collisions (perfectly) elastic - time of collision negligible (in comparison with time between collisions) Any two points, 1 mark each	B2
(b)(i)	(general starting equation) $pV = nRT$	C1
	$T = (2pV / nR)$ where R is the (molar) gas constant	A1
(b)(ii)	sketch: straight vertical line XY from $(V, 2p)$ to (V, p)	B1
	straight horizontal line YZ from (V, p) to $(2V, p)$	B1
	curve with gradient increasing from Z to X from $(2V, p)$ to $(V, 2p)$	B1
(b)(iii)	XY work done on gas correct (= 0)	B1
	ZX increase in internal energy correct (= 0)	B1
	YZ work done on gas correct (= $-pV$)	B1
	XY increase in internal energy such that the increase in internal energy column adds up to zero	B1
	all three thermal energies transferred such that $\Delta U = q + w$ in each row	B1
	(completely correct answer:	

change	ΔU	Q	w
X to Y	$-U$	$-U$	0
Y to Z	$[+U]$	$U + pV$	$-pV$
Z to X	0	$-W$	$[+W]$

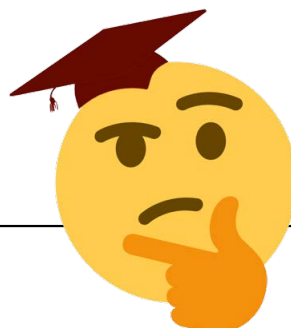


21 - (9702/42_Summer_2023_Q2) - Ideal Gases

(a)(i)	(gas that obeys $pV \propto T$ (for all values of p, V and T))	M1
	where T is thermodynamic temperature	A1
(a)(ii)	temperature = -273.15°C	A1
(b)(i)	$pV = NkT$	C1
	$N = (1.37 \times 10^5 \times 0.640) / (1.38 \times 10^{-23} \times (227 + 273))$	C1
	$= 1.27 \times 10^{25}$	A1
(b)(ii)	mass = $0.0424 / (1.27 \times 10^{25})$	A1
	$= 3.34 \times 10^{-27} \text{ kg}$	
(b)(iii)	$\frac{1}{2}m\langle c^2 \rangle = (3/2)kT$	C1
	$3.34 \times 10^{-27} \times v^2 = 3 \times 1.38 \times 10^{-23} \times 500$	C1
	$v = 2490 \text{ m s}^{-1}$	A1
	or	
	$pV = \frac{1}{2}(Nm) \langle c^2 \rangle$ and $Nm = \text{mass of gas}$	(C1)
	$0.0424 \times v^2 = 3 \times 1.37 \times 10^5 \times 0.640$	(C1)
	$v = 2490 \text{ m s}^{-1}$	(A1)
(c)	sketch: line from (0, 0) to (500, v)	B1
	line with decreasing positive gradient throughout	B1

22 - (9702/42_Summer_2023_Q3) - Ideal Gases, Temperature

(a)	<u>change</u> in internal energy = work done + energy transfer by heating	C1
	<u>increase</u> in internal energy = work done <u>on</u> system + energy transferred <u>to</u> the system by heating	A1
(b)(i)	AB change in internal energy: decrease	B1
	AB work done on gas: positive	B1
	BC change in internal energy: increase	B1
	BC work done on gas: zero	B1
(b)(ii)	more work done by gas in CD than is done on gas in AB or (no work done on gas in BC and DA so) (overall) gas does work	B1
	(overall) change in internal energy is zero	B1
	(must be an overall) input of thermal energy	B1

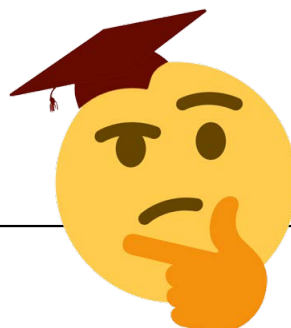


23 - (9702/41_Winter_2023_Q2) - Ideal Gases

(a)	(thermal) energy per unit mass (to change temperature)	B1
	(thermal) energy per unit change in temperature	B1
(b)(i)	work done = $p\Delta V$ $= (2.0 \times 10^5) \times (0.063 - 0.038) = 5000 \text{ J}$	A1
(b)(ii)	gas is expanding (against external pressure)	B1
	gas does work / work is done by gas, so (work done on gas is) negative	B1
(b)(iii)	$\Delta U = q + W$	C1
	$7600 = q + (-5000)$	A1
	$q = 12600 \text{ J}$	
(b)(iv)	specific heat capacity = $q / m\Delta T$	C1
	$= 12600 / (0.35 \times 56)$	
	$= 640 \text{ J kg}^{-1} \text{ K}^{-1}$	A1
(c)	same gain in internal energy so same temperature rise	B1
	no change in volume so no work done	B1
	or no work done so less thermal energy needed (for same change in internal energy)	
	less thermal energy needed (for same temperature change) so lower specific heat capacity	B1

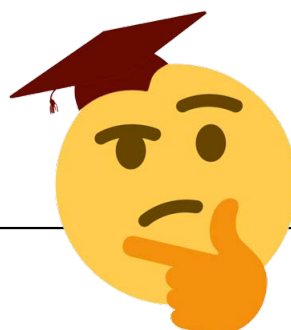
24 - (9702/41_Winter_2023_Q3) - Ideal Gases, Astronomy & Cosmology

(a)(i)	N : number of molecules (of the gas)	B1
	m : mass of one molecule (of the gas)	B1
	$\langle c^2 \rangle$: mean square speed (of molecules)	B1
(a)(ii)	$pV = NkT$	M1
	$NkT = \frac{1}{2}Nm\langle c^2 \rangle$ and $E_k = \frac{1}{2}m\langle c^2 \rangle$ leading to $E_k = (3/2)kT$	A1
(b)	$\frac{1}{2} \times 3.34 \times 10^{-27} \times 9300^2 = (3/2) \times 1.38 \times 10^{-23} \times T$	C1
	$T = 6980 \text{ K}$	A1
(c)(i)	$L = F \times 4\pi d^2$	C1
	$L = 2.52 \times 10^{-8} \times 4\pi \times (4.16 \times 10^{16})^2$	A1
	$= 5.48 \times 10^{26} \text{ W}$	
(c)(ii)	$L = 4\pi\sigma r^2 T^4$	C1
	$5.48 \times 10^{26} = 4\pi \times 5.67 \times 10^{-8} \times r^2 \times 6980^4$	
	$r = 5.69 \times 10^5 \text{ m}$	A1
(d)	(very high pressure so) molecules are (very) close together (<i>not just 'nearer'</i>)	B1
	forces between molecules are not negligible or volume of molecules not negligible compared with gas volume	B1



25 – (9702/42_Winter_2023_Q3) – *Ideal Gases*

(a)	sum of potential energy and kinetic energy (of particles)	B1
	(total) energy of random motion of particles	B1
(b)(i)	no thermal energy <u>transferred</u>	B1
	work is done on the spring (increasing the potential energy of particles)	M1
	so internal energy increases	A1
(b)(ii)	thermal energy transferred to water	B1
	work is done by water (expanding against atmosphere as it vaporises)	B1
	more thermal energy transferred than work done so internal energy increases	B1

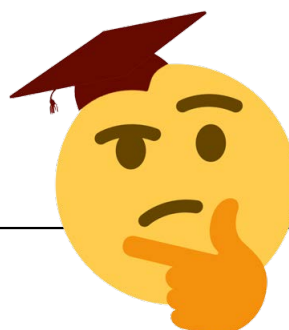


1 - (9702/42_Summer_2017_Q2) - Ideal Gases, Temperature, Thermal Properties Of Materials

(a)(i)	mean/average square speed/velocity
(a)(ii)	$pV = NkT$ or $pV = nRT$
	$\rho = Nm / V$ or $\rho = nN_A m / V$ and $k = nR / N$
	$E_K = \frac{1}{2} m \langle c^2 \rangle$ with algebra to $(3/2)kT$
(b)(i)	no (external) work done or $\Delta U = q$ or $w = 0$
	$q = N_A \times (3/2)k \times 1.0$
	$N_A k = R$ so $q = (3/2)R$
(b)(ii)	specific heat capacity = $\{(3/2) \times R\} / 0.028$
	$= 450 \text{ J kg}^{-1} \text{ K}^{-1}$

2 - (9702/41_Winter_2017_Q1) - Temperature, Thermal Properties Of Materials

(a)(i)	direction or rate of transfer of (thermal) energy or (if different,) not in thermal equilibrium/energy is transferred	B1
(a)(ii)	uses a property (of a substance) that changes with temperature	B1
(b)	- temperature scale assumes linear change of property with temperature - physical properties may not vary linearly with temperature - agrees only at fixed points Any 2 points.	B2
(c)(i)	$Pt = mc(\Delta)\theta$	C1
	$95 \times 6 \times 60 = 0.670 \times 910 \times \Delta\theta$	M1
	$\Delta\theta = 56^\circ\text{C}$ so final temperature = $56 + 24 = 80^\circ\text{C}$	A1
	or	
	$95 \times 6 \times 60 = 0.67 \times 910 \times (\theta - 24)$	(M1)
	so final temperature or $\theta = 80^\circ\text{C}$	(A1)
(c)(ii)	1. sketch: straight line from (0,24) to (6,80)	B1
	2. temperature drop due to energy loss = $(80 - 64) = 16^\circ\text{C}$	C1
	energy loss = $0.670 \times 910 \times (80 - 64) = 9800 \text{ J}$	A1
	or	
	energy to raise temperature to $64^\circ\text{C} = 0.670 \times 910 \times (64 - 24)$	(C1)
	$= 24400 \text{ J}$ loss = $(95 \times 6 \times 60) - 24400 = 9800 \text{ J}$	(A1)



3 - (9702/42_Summer_2018_Q3) - Temperature, Thermal Properties Of Materials

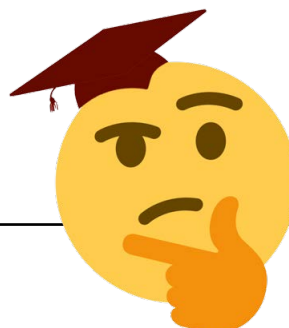
(a)	(during melting,) bonds between atoms/molecules are broken	B1
	potential energy of atoms/molecules is increased	B1
	no/little work done so required input of energy is thermal	B1
(b)(i)	$(\Delta Q =) mc\Delta\theta$	C1
	loss = $(160 \times 0.910 \times 15) + (330 \times 4.18 \times 15)$ $= 2.3 \times 10^4 \text{ J}$	A1
(b)(ii)	$2.3 \times 10^4 = (48 \times 2.10 \times 18) + 48L + (48 \times 4.18 \times 23)$	C1
	$48L = 1.66 \times 10^4$	A1
	$L = 350 \text{ J g}^{-1}$	

4 - (9702/42_Winter_2018_Q2) - Ideal Gases, Temperature, Thermal Properties Of Materials

(a)	gas that obeys equation $pV = \text{constant} \times T$	M1
	symbols p, V and T explained	A1
(b)(i)	$pV = \frac{1}{2} Nm\langle c^2 \rangle$ and $M = Nm$ (and so) $p = \frac{1}{2} \rho \langle c^2 \rangle$	C1
	$2.12 \times 10^7 = \frac{1}{2} \times [3.20 / (1.84 \times 10^{-23})] \times \langle c^2 \rangle$	C1
	$c_{\text{r.m.s.}} = 605 \text{ ms}^{-1}$	A1
(b)(ii)	1. $pV = nRT$ and $T = (22 + 273) \text{ K}$	C1
	$n = (2.12 \times 10^7 \times 1.84 \times 10^{-23}) / (8.31 \times 295)$ $= 159 \text{ mol}$	A1
	2. mass = $3.20 / (159 \times 6.02 \times 10^{23})$ or mass = $[2 \times (3/2) \times 1.38 \times 10^{-23} \times 295] / 605^2$	C1
	mass = $3.34 \times 10^{-26} \text{ kg}$	A1
(c)	$A = (3.34 \times 10^{-26}) / (1.66 \times 10^{-27})$ $= 20$	A1

5 - (9702/41_Summer_2019_Q2) - Ideal Gases, Temperature, Thermal Properties Of Materials

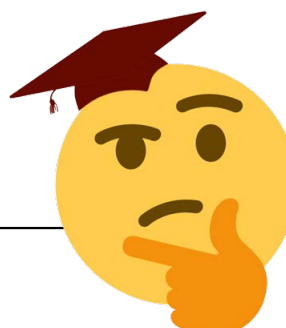
(a)(i)	$pV = nRT$	C1
	$n = (3.0 \times 10^5 \times 210 \times 10^{-6}) / (8.31 \times 270)$	C1
	$= 0.028 \text{ mol}$	A1
(a)(ii)	$V \propto T$ or $T = pV / nR$ with value of n from (i)	C1
	$T = (140 / 210) \times 270$ or $T = (3.0 \times 10^5 \times 140 \times 10^{-6}) / (8.31 \times 0.028)$ $= 180 \text{ K}$	A1
(a)(iii)	$W = p\Delta V$	C1
	$= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$	
	$= 21 \text{ J}$	A1



(b)	$\Delta U = w + q$	C1
	$= 21 - 53$	C1
	or	
	$\Delta U = (nN_A) \times (3/2)k_B\Delta T$	(C1)
	$= (0.0281 \times 6.02 \times 10^{23}) \times (3/2) \times 1.38 \times 10^{-23} \times (180 - 270)$	(C1)
	or	
	$\Delta U = (3/2)nR\Delta T$	(C1)
	$= (3/2) \times 0.0281 \times 8.31 \times (180 - 270)$	(C1)
	$\Delta U = (-)32 \text{ J}$	A1

6 - (9702/41_Winter_2019_Q3) - Temperature, Thermal Properties Of Materials

(a)	(thermal) energy per (unit) mass (to change state)	B1
	(heat transfer during) change of state at constant temperature	B1
(b)(i)	32 g	A1
(b)(ii)	temperature difference (between liquid and surroundings) does not change	B1
(b)(iii)	$VIt = mL$	C1
	$230 \times 1.2 \times 60 \times 10 = (56 \times L) + H$	C1
	or	
	$190 \times 1.0 \times 60 \times 10 = (32 \times L) + H$	
	$86 \times 600 = (56 - 32) \times L$	C1
	or	
	$230 \times 1.2 = (56 \times L) / (60 \times 10) + P$	(C1)
	or	
(b)(iv)	$190 \times 1.0 = (32 \times L) / (60 \times 10) + P$	
	$276 - 190 = (24 \times L) / 600$	(C1)
	$L = 2200 \text{ J g}^{-1}$	A1
(b)(iv)	$230 \times 1.2 \times 600 = (56 \times 2150) + H$	C1
	or	
	$190 \times 1.0 \times 600 = (32 \times 2150) + H$	
	$H = 45200$	A1
	rate = $45200 / 600$	
	$= 75 \text{ W}$	
	or	
	$230 \times 1.2 = (56 \times 2150) / (60 \times 10) + P$	(C1)
(b)(iv)	or	
	$190 \times 1.0 = (32 \times 2150) / (60 \times 10) + P$	
	rate (= P) = 75 W	(A1)

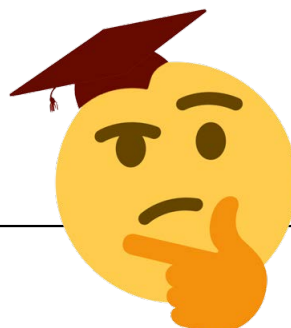


7 - (9702/41_Winter_2020_Q2) - *Ideal Gases, Temperature*

(a)	+q: thermal energy transfer to system	B1																
	+w: work done on system	B1																
(b)(i)	$(W =) 2.6 \times 10^5 \times (3.8 - 2.3) \times 10^{-3} = 390 \text{ J}$	A1																
(b)(ii)	no (total) change (in internal energy)	B1																
	gas returns to its original temperature	B1																
(c)	A to B row all correct (1370, -390, 980)	B1																
	B to C row all correct (0, 550, 550)	B1																
	C to A row: ΔU adds to the other two ΔU values to give zero	B1																
	C to A row: $w = 0$ and q adds to w to give ΔU value	B1																
	complete correct answer:																	
<table><tr><td>change</td><td>q / J</td><td>w / J</td><td>$\Delta U / \text{J}$</td></tr><tr><td>A to B</td><td>(+)1370</td><td>-390</td><td>(+)980</td></tr><tr><td>B to C</td><td>0</td><td>(+)550</td><td>(+)550</td></tr><tr><td>C to A</td><td>-1530</td><td>0</td><td>-1530</td></tr></table>			change	q / J	w / J	$\Delta U / \text{J}$	A to B	(+)1370	-390	(+)980	B to C	0	(+)550	(+)550	C to A	-1530	0	-1530
change	q / J	w / J	$\Delta U / \text{J}$															
A to B	(+)1370	-390	(+)980															
B to C	0	(+)550	(+)550															
C to A	-1530	0	-1530															

8 - (9702/42_Winter_2020_Q2) - *Ideal Gases, Temperature*

(a)	sum of potential energy and kinetic energy (of particles)	B1
	(total) energy of random motion of particles	B1
(b)(i)	$pV = nRT$	C1
	$2.60 \times 10^5 \times 2.30 \times 10^{-3} = n \times 8.31 \times 180$	A1
	$n = 0.400 \text{ mol}$	
(b)(ii)	$(2.30 \times 10^{-3}) / 180 = (3.80 \times 10^{-3}) / T$	C1
	or	
	$2.60 \times 10^5 \times 3.80 \times 10^{-3} = 0.400 \times 8.31 \times T$	
	$T = 297 \text{ K}$	A1
(c)(i)	$\Delta W = p\Delta V$	C1
	$= 2.60 \times 10^5 \times (2.30 - 3.80) \times 10^{-3}$	
	$= (-)390 \text{ J}$	A1
	negative because work is done by gas or negative because work is done against atmospheric pressure or negative because volume of gas increases	B1
(c)(ii)	$\Delta U = (980 - 390)$	A1
	$= 590 \text{ J}$	

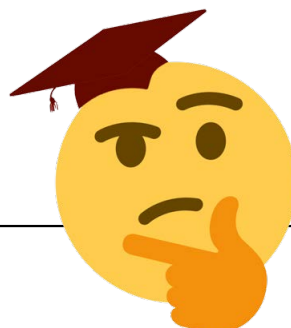


9 - (9702/42_Summer_2021_Q2) - Ideal Gases, Temperature

(a)	$pV = nRT$	C1
	$pV = nRT$ and $N = nN_A$ or $pV = NkT$	C1
	$3.1 \times 10^{-3} \times 8.5 \times 10^5 = (N \times 290 \times 8.31) / (6.02 \times 10^{23})$ so $N = 6.6 \times 10^{23}$ or $3.1 \times 10^{-3} \times 8.5 \times 10^5 = N \times 1.38 \times 10^{-23} \times 290$ so $N = 6.6 \times 10^{23}$	A1
(b)(i)	$(3.1 \times 10^{-3} \times 8.5 \times 10^5) / 290 = (6.3 \times 10^{-3} \times 2.7 \times 10^5) / T$ so $T = 190 \text{ K}$ or $6.3 \times 10^{-3} \times 2.7 \times 10^5 = 6.6 \times 10^{23} \times 1.38 \times 10^{-23} \times T$ so $T = 190 \text{ K}$	A1
(b)(ii)	$\Delta U = 3/2 \times k \times \Delta T \times N$	C1
	$= 3/2 \times 1.38 \times 10^{-23} \times (190 - 290) \times 6.6 \times 10^{23}$	C1
	$= -1400 \text{ J}$	A1
(c)	$\Delta U = q + w$	M1
	$q = 0$ so $\Delta U = w$	A1

10 - (9702/42_Summer_2022_Q3) - Temperature

(a)	(thermal) energy per unit mass	B1
	energy to change state between liquid and gas at constant temperature	B1
(b)(i)	$q = mL = 0.37 \times 2.3 \times 10^6$ $= 8.5 \times 10^5 \text{ J}$	A1
(b)(ii)	$pV = nRT$ and $T = 373 \text{ K}$	C1
	$n = 370 / 18$	C1
	$V = [(370 / 18) \times 8.31 \times 373] / (1.0 \times 10^5) = 0.64 \text{ m}^3$	A1
(b)(iii)	$w = p\Delta V$	C1
	$= 1.0 \times 10^5 \times 0.64$	A1
	$= 6.4 \times 10^4 \text{ J}$	
(b)(iv)	(water does work against atmosphere so) work done on water is negative	B1
	increase in internal energy $= (8.5 - 0.64) \times 10^5 = 7.9 \times 10^5 \text{ J}$	A1
(c)	valid reasoning of how work done by water is affected	M1
	correct use of first law to draw conclusion about effect on specific latent heat that is consistent with work done	A1

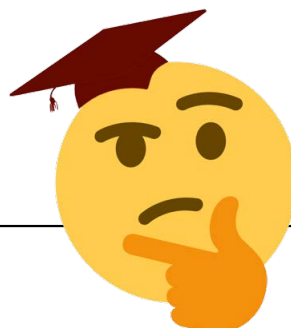


11 - (9702/43_Winter_2022_Q2) - Temperature

(a)	- resistance of a metal - volume of a gas at constant pressure - e.m.f. of a thermocouple <i>Any two points, 1 mark each</i>	B2
(b)(i)	$Q = mc\Delta T$	C1
	evidence of realisation that Q lost by water = Q gained by mercury	C1
	$18.7 \times 4.18 \times (37.4 - T) = 6.94 \times 0.140 \times (T - 23.0)$	C1
	$T = 37.2\text{ }^{\circ}\text{C}$	A1
(b)(ii)	use a liquid with a lower (specific) heat capacity (than mercury) or use a smaller mass of mercury	B1
(c)(i)	depends on properties of a real substance	B1
	$0\text{ }^{\circ}\text{C}$ is not absolute zero	B1
(c)(ii)	ideal gas	B1

12 - (9702/41_Summer_2023_Q3) - Forces, Density & Pressure, Temperature

(a)	no <u>net</u> thermal energy is transferred (between them)	B1
(b)(i)	variation (of density with temperature) is linear or each temperature has a unique value of density	B1
(b)(ii)	- variation (of density with temperature) is not linear - region where the density does not vary with temperature - different temperatures have the same density <i>Any two points, 1 mark each</i>	B2
(c)(i)	boiling point = $80\text{ }^{\circ}\text{C}$	A1
(c)(ii)	$Q = Pt$ and $t = 21\text{ s}$ (thermal energy supplied = $810 \times 21 = 17000\text{ J}$)	C1
	$c = Q / m\Delta\theta$	C1
	thermal energy absorbed by beaker = $42 \times 0.84 \times (80 - 25)$ (= 1940 J)	C1
	s.h.c. of liquid = $[(810 \times 21) - (42 \times 0.84 \times (80 - 25))] / [120 \times (80 - 25)]$ = $2.3\text{ J g}^{-1}\text{ K}^{-1}$	A1
(d)	sketch: straight diagonal line from $25\text{ }^{\circ}\text{C}$ to $100\text{ }^{\circ}\text{C}$ and then horizontal at $100\text{ }^{\circ}\text{C}$	B1
	straight diagonal line starting at $25\text{ }^{\circ}\text{C}$ with gradient approximately half that of the original line	B1

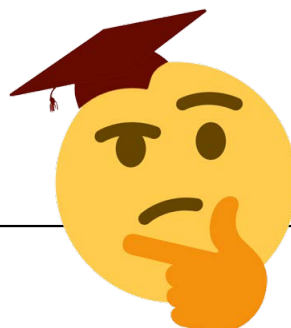


13 - (9702/41_Summer_2023_Q4) - Ideal Gases, Temperature, Thermal Properties Of Materials

(a)	- particles are in (continuous) random motion - particles have negligible volume (compared with the gas) - negligible forces between particles (except during collisions) (all) collisions (perfectly) elastic - time of collision negligible (in comparison with time between collisions) Any two points, 1 mark each	B2																
(b)(i)	(general starting equation) $pV = nRT$	C1																
	$T = (2pV / nR)$ where R is the (molar) gas constant	A1																
(b)(ii)	sketch: straight vertical line XY from $(V, 2p)$ to (V, p)	B1																
	straight horizontal line YZ from (V, p) to $(2V, p)$	B1																
	curve with gradient increasing from Z to X from $(2V, p)$ to $(V, 2p)$	B1																
(b)(iii)	XY work done on gas correct (= 0)	B1																
	ZX increase in internal energy correct (= 0)	B1																
	YZ work done on gas correct (= $-pV$)	B1																
	XY increase in internal energy such that the increase in internal energy column adds up to zero	B1																
	all three thermal energies transferred such that $\Delta U = q + w$ in each row (completely correct answer:	B1																
	<table border="1"> <thead> <tr> <th>change</th> <th>ΔU</th> <th>Q</th> <th>w</th> </tr> </thead> <tbody> <tr> <td>X to Y</td> <td>$-U$</td> <td>$-U$</td> <td>0</td> </tr> <tr> <td>Y to Z</td> <td>$[+U]$</td> <td>$U + pV$</td> <td>$-pV$</td> </tr> <tr> <td>Z to X</td> <td>0</td> <td>$-W$</td> <td>$[+W]$</td> </tr> </tbody> </table>	change	ΔU	Q	w	X to Y	$-U$	$-U$	0	Y to Z	$[+U]$	$U + pV$	$-pV$	Z to X	0	$-W$	$[+W]$	
change	ΔU	Q	w															
X to Y	$-U$	$-U$	0															
Y to Z	$[+U]$	$U + pV$	$-pV$															
Z to X	0	$-W$	$[+W]$															

14 - (9702/42_Summer_2023_Q3) - Ideal Gases, Temperature

(a)	<u>change</u> in internal energy = work done + energy transfer by heating	C1
	<u>increase</u> in internal energy = work done <u>on</u> system + energy transferred <u>to</u> the system by heating	A1
(b)(i)	AB change in internal energy: decrease	B1
	AB work done on gas: positive	B1
	BC change in internal energy: increase	B1
	BC work done on gas: zero	B1
(b)(ii)	more work done by gas in CD than is done on gas in AB or (no work done on gas in BC and DA so) (overall) gas does work	B1
	(overall) change in internal energy is zero	B1
	(must be an overall) input of thermal energy	B1

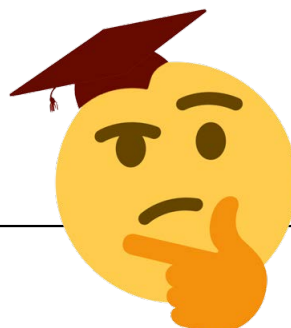


1 - (9702/42_Summer_2017_Q2) - Ideal Gases, Temperature, Thermal Properties Of Materials

(a)(i)	mean/average square speed/velocity
(a)(ii)	$pV = NkT$ or $pV = nRT$
	$\rho = Nm / V$ or $\rho = nN_A m / V$ and $k = nR / N$
	$E_K = \frac{1}{2} m \langle c^2 \rangle$ with algebra to $(3/2)kT$
(b)(i)	no (external) work done or $\Delta U = q$ or $w = 0$
	$q = N_A \times (3/2)k \times 1.0$
	$N_A k = R$ so $q = (3/2)R$
(b)(ii)	specific heat capacity = $\{(3/2) \times R\} / 0.028$
	$= 450 \text{ J kg}^{-1} \text{ K}^{-1}$

2 - (9702/41_Winter_2017_Q1) - Temperature, Thermal Properties Of Materials

(a)(i)	direction or rate of transfer of (thermal) energy or (if different,) not in thermal equilibrium/energy is transferred	B1
(a)(ii)	uses a property (of a substance) that changes with temperature	B1
(b)	- temperature scale assumes linear change of property with temperature - physical properties may not vary linearly with temperature - agrees only at fixed points Any 2 points.	B2
(c)(i)	$Pt = mc(\Delta)\theta$	C1
	$95 \times 6 \times 60 = 0.670 \times 910 \times \Delta\theta$	M1
	$\Delta\theta = 56^\circ\text{C}$ so final temperature = $56 + 24 = 80^\circ\text{C}$	A1
	or	
	$95 \times 6 \times 60 = 0.67 \times 910 \times (\theta - 24)$	(M1)
	so final temperature or $\theta = 80^\circ\text{C}$	(A1)
(c)(ii)	1. sketch: straight line from (0,24) to (6,80)	B1
	2. temperature drop due to energy loss = $(80 - 64) = 16^\circ\text{C}$	C1
	energy loss = $0.670 \times 910 \times (80 - 64) = 9800 \text{ J}$	A1
	or	
	energy to raise temperature to $64^\circ\text{C} = 0.670 \times 910 \times (64 - 24)$	(C1)
	$= 24400 \text{ J}$	(A1)
	loss = $(95 \times 6 \times 60) - 24400 = 9800 \text{ J}$	

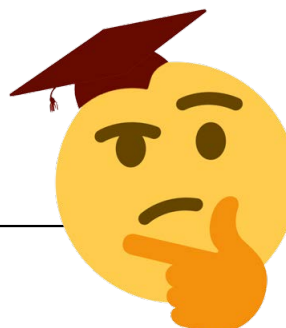


3 - (9702/42_Winter_2017_Q2) - Thermal Properties Of Materials

(a)	(thermal) energy <u>per</u> (unit) mass (to cause change of state)	B1
	(energy required to cause/released in) change of state at constant temperature	B1
(b)(i)	1. (work done on/against) the <u>atmosphere</u>	B1
	2. <u>water</u> as it turns from liquid to vapour	M1
	as potential energy of <u>molecules</u> increases	A1
	or	
	<u>surroundings</u> as its temperature rises	(M1)
	as energy is lost/transferred to surroundings	(A1)
(b)(ii)	$VI - h = M/t \times L$ (where h = power loss) or $L = (VI - Q)/M$ (where Q = energy loss)	C1
	$(14.2 \times 6.4) - (11.5 \times 5.2) = (9.1 - 5.0) \times L/300$ or $L = [(14.2 \times 6.4) - (11.5 \times 5.2)] \times 300 / (9.1 - 5.0)$	C1
	$L = 2300 \text{ J g}^{-1}$	A1

4 - (9702/42_Summer_2018_Q2) - Ideal Gases, Thermal Properties Of Materials

(a)	no intermolecular forces (so no potential energy)	B1
(b)(i)	mean square speed (of molecule(s))	B1
(b)(ii)	kelvin/thermodynamic/absolute <u>temperature</u>	B1
(c)(i)1.	$pV = NkT$	C1
	$4.7 \times 10^{-2} \times 2.6 \times 10^5 = N \times 1.38 \times 10^{-23} \times 446$	C1
	or	
	$pV = nRT$ and $N = nN_A$	(C1)
	$4.7 \times 10^{-2} \times 2.6 \times 10^5 = n \times 8.31 \times 446$	
	$n = 3.3$ (mol)	
	$N = 3.3 \times 6.02 \times 10^{23}$	(C1)
	$N = 2.0 \times 10^{24}$	A1
(c)(i)2.	average increase = $2900 / (2.0 \times 10^{24})$ $= 1.5 \times 10^{-21} \text{ J}$	A1
(c)(ii)	$\Delta E_k = (3/2)k(\Delta)T$	C1
	$1.5 \times 10^{-21} = (3/2) \times 1.38 \times 10^{-23} \times (\Delta)T$	
	$(\Delta)T$ in range 70–72 K	C1
	$T = 173 + 273 + 70$ $= 520 \text{ K}$	A1



5 - (9702/42_Summer_2018_Q3) - Temperature, Thermal Properties Of Materials

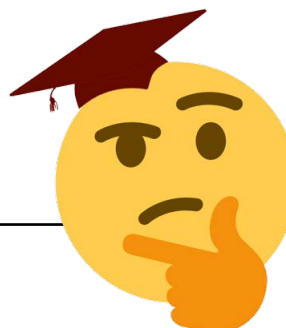
(a)	(during melting,) bonds between atoms/molecules are broken	B1
	potential energy of atoms/molecules is increased	B1
	no/little work done so required input of energy is thermal	B1
(b)(i)	$(\Delta Q =) mc\Delta\theta$	C1
	loss = $(160 \times 0.910 \times 15) + (330 \times 4.18 \times 15)$ = 2.3×10^4 J	A1
(b)(ii)	$2.3 \times 10^4 = (48 \times 2.10 \times 18) + 48L + (48 \times 4.18 \times 23)$	C1
	$48L = 1.66 \times 10^4$ $L = 350 \text{ J g}^{-1}$	A1

6 - (9702/41_Winter_2018_Q2) - Ideal Gases, Thermal Properties Of Materials

(a)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
(b)(i)	final temperature = initial temperature	B1
	no change in internal energy	B1
(b)(ii)	1. work done on gas (P→Q): 0	A1
	increase in internal energy (P→Q): (+)97.0 J	A1
	2. increase in internal energy (Q→R): -42.5 J	A1
	3. increase in internal energy (R→P): -54.5 J	A1
	thermal energy supplied (R→P): -91.5 J	A1

7 - (9702/42_Winter_2018_Q2) - Ideal Gases, Temperature, Thermal Properties Of Materials

(a)	gas that obeys equation $pV = \text{constant} \times T$	M1
	symbols p , V and T explained	A1
(b)(i)	$pV = \frac{1}{2} Nm\langle c^2 \rangle$ and $M = Nm$ (and so) $p = \frac{1}{3}\rho\langle c^2 \rangle$	C1
	$2.12 \times 10^7 = \frac{1}{3} \times [3.20 / (1.84 \times 10^{-23})] \times \langle c^2 \rangle$	C1
	$c_{\text{r.m.s.}} = 605 \text{ ms}^{-1}$	A1
(b)(ii)	1. $pV = nRT$ and $T = (22 + 273) \text{ K}$	C1
	$n = (2.12 \times 10^7 \times 1.84 \times 10^{-23}) / (8.31 \times 295)$ = 159 mol	A1
	2. mass = $3.20 / (159 \times 6.02 \times 10^{23})$ or mass = $[2 \times (3/2) \times 1.38 \times 10^{-23} \times 295] / 605^2$	C1
	mass = $3.34 \times 10^{-26} \text{ kg}$	A1
(c)	$A = (3.34 \times 10^{-26}) / (1.66 \times 10^{-27})$ = 20	A1

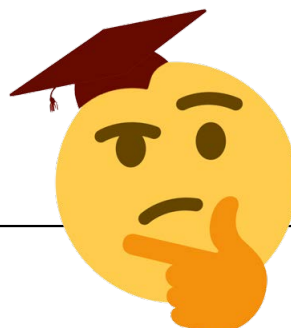


8 - (9702/42_Winter_2018_Q3) - Thermal Properties Of Materials

(a)	(thermal) energy per unit mass (to cause change of state)	B1
	(energy transfer during) change of state between solid and liquid at constant temperature	B1
(b)(i)	Any one from: - rate of increase in mass (of beaker and water) is constant - level of water rises at a constant rate - volume of water (in beaker) increases at a constant rate - constant time between drops - constant rate of dripping	B1
(b)(ii)	(electrical power supplied $\Rightarrow$) 12.8×4.60 $(= 58.9 \text{ W})$	C1
	(rate of transfer to ice $\Rightarrow$) $[(185.0 - 121.5) \times 332] / [5.00 \times 60]$ $(= 70.3 \text{ W})$	C1
	1. rate = 70.3 W	A1
	2. rate = $70.3 - 58.9$ $= 11.4 \text{ W}$	A1

9 - (9702/41_Summer_2019_Q2) - Ideal Gases, Temperature, Thermal Properties Of Materials

(a)(i)	$pV = nRT$	C1
	$n = (3.0 \times 10^5 \times 210 \times 10^{-6}) / (8.31 \times 270)$	C1
	$= 0.028 \text{ mol}$	A1
(a)(ii)	$V \propto T$ or $T = pV / nR$ with value of n from (i)	C1
	$T = (140 / 210) \times 270$ or $T = (3.0 \times 10^5 \times 140 \times 10^{-6}) / (8.31 \times 0.028)$ $= 180 \text{ K}$	A1
(a)(iii)	$W = p\Delta V$ $= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$ $= 21 \text{ J}$	C1
		A1
(b)	$\Delta U = w + q$	C1
	$= 21 - 53$	C1
	or	
	$\Delta U = (nN_A) \times (3/2)k\Delta T$	(C1)
	$= (0.0281 \times 6.02 \times 10^{23}) \times (3/2) \times 1.38 \times 10^{-23} \times (180 - 270)$	(C1)
	or	
	$\Delta U = (3/2)nR\Delta T$	(C1)
	$= (3/2) \times 0.0281 \times 8.31 \times (180 - 270)$	(C1)
	$\Delta U = (-)32 \text{ J}$	A1

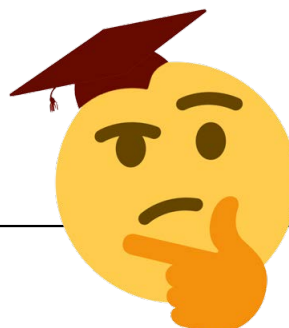


10 - (9702/42_Summer_2019_Q2) - *Ideal Gases, Thermal Properties Of Materials*

(a)(i)	1. energy transfer <u>to</u> the system by heating	B1								
	2. (external) work done <u>on</u> the system	B1								
(a)(ii)	<u>decrease</u> in internal energy	B1								
(b)(i)	no change (in internal energy)	B1								
	(because) no change in temperature	B1								
(b)(ii)	work done = $p\Delta V$	C1								
	= $(-1.6 \times 10^5 \times (2.4 - 0.87) \times 10^{-3})$									
	= (-240 J)	A1								
(b)(iii)	first row all correct (0, 480, 480)	A1								
	second row all correct (-1100, 0, -1100)	A1								
	final column of third row calculated correctly from the two values above it, so that the final column adds up to 0	A1								
	second column in final row correct, with correct negative sign and first column in final row calculated correctly so that it adds to the second column to give the third column (fully correct table is:	A1								
	<table border="1"> <tr> <td>0</td><td>480</td><td>480</td></tr> <tr> <td>-1100</td><td>0</td><td>-1100</td></tr> <tr> <td>860</td><td>-240</td><td>620</td></tr> </table>	0	480	480	-1100	0	-1100	860	-240	620
0	480	480								
-1100	0	-1100								
860	-240	620								

11 - (9702/42_Winter_2019_Q2) - *Ideal Gases, Thermal Properties Of Materials*

(a)(i)	specks of light moving haphazardly	B1
(a)(ii)	(gas) molecules collide with (smoke) particles or random motion of the (gas) molecules	M1
	<u>causes</u> the (haphazard) motion of the smoke particles or <u>causes</u> the smoke particles to change direction	A1
(b)(i)	$pV = nRT$	C1
	$n = (3.51 \times 10^5 \times 2.40 \times 10^{-3}) / (8.31 \times 290)$ or $n = (3.75 \times 10^5 \times 2.40 \times 10^{-3}) / (8.31 \times 310)$	C1
	or	
	$pV = NkT$	(C1)
	$n = (3.51 \times 10^5 \times 2.40 \times 10^{-3}) / (1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 290)$ or $n = (3.75 \times 10^5 \times 2.40 \times 10^{-3}) / (1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 310)$	(C1)
	$n = 0.350 \text{ mol or } 0.349 \text{ mol}$	A1
(b)(ii)	energy transfer = $(0.349 \text{ or } 0.35) \times 12.5 \times (310 - 290)$	C1
	= 87.3 J or 87.5 J	A1
(c)(i)	zero	A1
(c)(ii)	87.3 J or 87.5 J	A1
	increase	B1

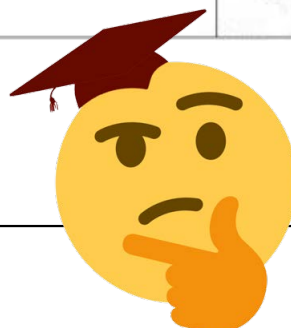


12 - (9702/41_Winter_2019_Q3) - Temperature, Thermal Properties Of Materials

(a)	(thermal) energy per (unit) mass (to change state)	B1
	(heat transfer during) change of state at constant temperature	B1
(b)(i)	32 g	A1
(b)(ii)	temperature difference (between liquid and surroundings) does not change	B1
(b)(iii)	$VIt = mL$	C1
	$230 \times 1.2 \times 60 \times 10 = (56 \times L) + H$ or $190 \times 1.0 \times 60 \times 10 = (32 \times L) + H$	C1
	$86 \times 600 = (56 - 32) \times L$	C1
	or	
	$230 \times 1.2 = (56 \times L) / (60 \times 10) + P$ or $190 \times 1.0 = (32 \times L) / (60 \times 10) + P$	(C1)
	$276 - 190 = (24 \times L) / 600$	(C1)
	$L = 2200 \text{ J g}^{-1}$	A1
(b)(iv)	$230 \times 1.2 \times 600 = (56 \times 2150) + H$ or $190 \times 1.0 \times 600 = (32 \times 2150) + H$	C1
	$H = 45200$	A1
	rate = $45200 / 600$ $= 75 \text{ W}$	
	or	
	$230 \times 1.2 = (56 \times 2150) / (60 \times 10) + P$ or $190 \times 1.0 = (32 \times 2150) / (60 \times 10) + P$	(C1)
	rate (= P) = 75 W	(A1)

13 - (9702/42_Winter_2019_Q3) - Thermal Properties Of Materials

(a)	(thermal) energy per unit mass (to change state)	B1
	change of state without any change of temperature	B1
(b)(i)	140 g	A1
(b)(ii)	temperature difference (between apparatus and surroundings) does not change	B1
(b)(iii)	$VIt = mL$	C1
	$((15.1 \times 3.6) + R) \times 600 = 140 \times L$ or $((7.3 \times 1.8) + R) \times 600 = 65 \times L$	C1
	$41.22 \times 600 = 75 \times L$	C1
	$L = 330 \text{ J g}^{-1}$	A1
(b)(iv)	$15.1 \times 3.6 \times 600 = (140 \times 330) - H$ or $7.3 \times 1.8 \times 600 = (65 \times 330) - H$	C1
	$H = 13600$	A1
	rate of gain = $13600 / 600$ $= 23 \text{ W}$	

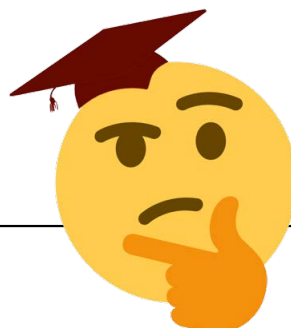


14 - (9702/41_Summer_2020_Q2) - *Ideal Gases, Thermal Properties Of Materials*

(a)	total potential energy and kinetic energy (of molecules/atoms)	M1
	reference to <u>random</u> motion of molecules/atoms	A1
(b)	(in ideal gas,) no intermolecular forces	B1
	no potential energy (so change in kinetic energy is change in internal energy)	B1
(c)	(random) potential energy of molecules does not change	M1
	(random) kinetic energy of molecules does not change	M1
	so internal energy does not change	A1
	or	
	decrease in total potential energy = gain in total kinetic energy	(M1)
	no external energy supplied	(M1)
	so internal energy does not change	(A1)
	or	
	no compression (of ball) so no work done on the ball	(M1)
	no resistive forces so no heating of the ball	(M1)
	so internal energy does not change	(A1)
(c)	or	
	no change of state so potential energy (of molecules) unchanged	(M1)
	no temperature rise so kinetic energy (of molecules) unchanged	(M1)
	so internal energy does not change	(A1)

15 - (9702/42_Summer_2020_Q3) - *Thermal Properties Of Materials*

(a)	(little/no volume change so) little/no external work done	B1
	thermal energy supplied to provide latent heat	M1
	internal energy increases	A1
(b)	(rapid) increase in volume	B1
	gas does work against the atmosphere	M1
	internal energy decreases	A1



16 - (9702/41_Winter_2021_Q3) - Thermal Properties Of Materials

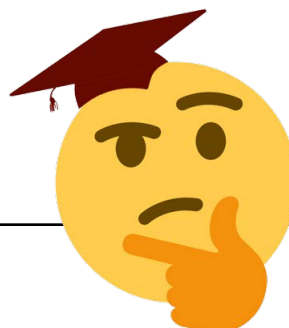
(a)	(thermal) energy per unit mass (to cause temperature change)	B1
	(thermal) energy per unit <u>change</u> in temperature	B1
(b)(i)	$(T =) pV / Nk$	B1
(b)(ii)	$(pV =) NkT = \frac{1}{2}Nm\langle c^2 \rangle$ or $pV = NkT$ and $pV = \frac{1}{2}Nm\langle c^2 \rangle$	M1
	leading to $\frac{1}{2}m\langle c^2 \rangle = (3/2)kT$ and $\frac{1}{2}m\langle c^2 \rangle = E_K$	A1
(b)(iii)	internal energy = ΣE_K (of molecules) + ΣE_P (of molecules) or no forces between molecules	B1
	potential energy of molecules is zero	B1
(c)(i)	increase in internal energy = Q + work done	B1
	constant volume so no work done	B1
(c)(ii)	$c = Q / Nm\Delta T$	C1
	$= [N \times (3/2)k\Delta T] / (Nm\Delta T) = 3k / 2m$	A1
(d)	(as it expands) gas does work (against the atmosphere/external pressure)	B1
	for same temperature rise) more (thermal) energy needed, so larger specific heat capacity	B1

17 - (9702/41_Winter_2022_Q2) - Thermal Properties Of Materials

(a)	- resistance of a metal - volume of a gas at constant pressure - e.m.f. of a thermocouple Any two points, 1 mark each	B2
(b)(i)	$Q = mc\Delta T$	C1
	evidence of realisation that Q lost by water = Q gained by mercury	C1
	$18.7 \times 4.18 \times (37.4 - T) = 6.94 \times 0.140 \times (T - 23.0)$	C1
	$T = 37.2^\circ\text{C}$	A1
(b)(ii)	use a liquid with a lower (specific) heat capacity (than mercury) or use a smaller mass of mercury	B1
(c)(i)	depends on properties of a real substance	B1
	0°C is not absolute zero	B1
(c)(ii)	ideal gas	B1

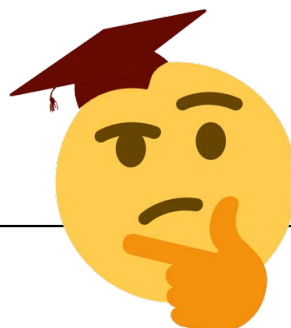
18 - (9702/42_Winter_2022_Q2) - Thermal Properties Of Materials

(a)	(thermal) energy per unit mass (to cause temperature change)	B1
	(thermal) energy per unit change in temperature	B1
(b)(i)	work done correct (Q)	B1
	increase in internal energy correct ($+E$)	B1
(b)(ii)	work done correct ($-W$) and increase in internal energy same as (b)(i)	B1
	thermal energy correct so that it adds to work done to give increase in internal energy	B1
(c)	more thermal energy needed so specific heat capacity is greater	B1



19 - (9702/41_Summer_2023_Q4) - Ideal Gases, Temperature, Thermal Properties Of Materials

(a)	- particles are in (continuous) random motion - particles have negligible volume (compared with the gas) - negligible forces between particles (except during collisions) (all) collisions (perfectly) elastic - time of collision negligible (in comparison with time between collisions) <i>Any two points, 1 mark each</i>	B2																
(b)(i)	(general starting equation) $pV = nRT$	C1																
	$T = (2pV / nR)$ where R is the (molar) gas constant	A1																
(b)(ii)	sketch: straight vertical line XY from $(V, 2p)$ to (V, p)	B1																
	straight horizontal line YZ from (V, p) to $(2V, p)$	B1																
	curve with gradient increasing from Z to X from $(2V, p)$ to $(V, 2p)$	B1																
(b)(iii)	XY work done on gas correct (= 0)	B1																
	ZX increase in internal energy correct (= 0)	B1																
	YZ work done on gas correct (= $-pV$)	B1																
	XY increase in internal energy such that the increase in internal energy column adds up to zero	B1																
	all three thermal energies transferred such that $\Delta U = q + w$ in each row (completely correct answer:	B1																
	<table><tr><td>change</td><td>ΔU</td><td>Q</td><td>w</td></tr><tr><td>X to Y</td><td>$-U$</td><td>$-U$</td><td>0</td></tr><tr><td>Y to Z</td><td>$[+U]$</td><td>$U + pV$</td><td>$-pV$</td></tr><tr><td>Z to X</td><td>0</td><td>$-W$</td><td>$[+W]$</td></tr></table>	change	ΔU	Q	w	X to Y	$-U$	$-U$	0	Y to Z	$[+U]$	$U + pV$	$-pV$	Z to X	0	$-W$	$[+W]$	
change	ΔU	Q	w															
X to Y	$-U$	$-U$	0															
Y to Z	$[+U]$	$U + pV$	$-pV$															
Z to X	0	$-W$	$[+W]$															



1 - (9702/41_Summer_2017_Q2) - Oscillations

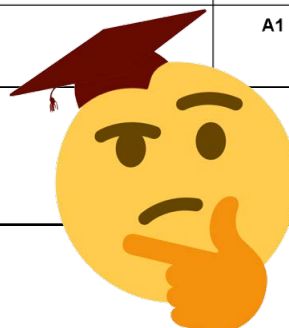
(a)	e.g. period = 3 / 2.5
	frequency = 0.83 Hz
(b)	light (damping)
(c)	at 2.7 s, $A_0 = 1.5$ (cm)
	energy = $\frac{1}{2} m \times 4\pi^2 f^2 A_0^2$
	= $\frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (1.5 \times 10^{-2})^2$
	= 5.51×10^{-4} (J)
	at 7.5 s, $A_0 = 0.75$ (cm)
	energy = $\frac{1}{4} \times 5.51 \times 10^{-4}$ or energy = $\frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (0.75 \times 10^{-2})^2$
	energy = 1.38×10^{-4} (J)
	change = $(5.51 \times 10^{-4} - 1.38 \times 10^{-4}) = 4.13$ J

2 - (9702/42_Summer_2017_Q3) - Oscillations, Electromagnetic Induction

(a)(i)	e.g. period = 6 / 2.5
	frequency = 0.42 Hz
(a)(ii)	energy = $\frac{1}{2} m \times 4\pi^2 f^2 y_0^2$
	= $\frac{1}{2} \times 0.25 \times 4\pi^2 \times 0.42^2 \times (1.5 \times 10^{-2})^2$
	= 2.0×10^{-4} J
(b)(i)	(induced) e.m.f. proportional to rate of change of magnetic flux (linkage) or cutting of magnetic flux
(b)(ii)	coil cuts flux/field (of moving magnet) <u>inducing</u> e.m.f. in coil
	(induced) current in resistor causes heating (effect)
	thermal energy/heat derived from energy of oscillations (of magnet)

3 - (9702/41_Winter_2017_Q2) - Oscillations

(a)	(angular frequency =) $2\pi \times$ frequency or 2π /period	B1
(b)(i)	1. displacement = 2.0 cm	A1
	2. amplitude = 1.5 cm	A1
(b)(ii)	reference to displacement of oscillations or displacement from equilibrium position or displacement from 2.0 cm	B1
	straight line indicates acceleration $\propto$ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1
(b)(iii)	$\omega^2 = (-)1/\text{gradient}$ or $\omega^2 = (-)\Delta a/\Delta s$ or $a = (-)\omega^2 x$ <u>and</u> correct value of x	C1
	= e.g. $(1.8/0.03)$ or $(0.9/0.015)$ or $(1.2/0.02)$ etc. or $0.9 = \omega^2 \times 0.015$	C1
	= 60	
	$f = \sqrt{60}/2\pi$ = 1.2 Hz	A1



4 - (9702/42_Winter_2017_Q3) - Oscillations

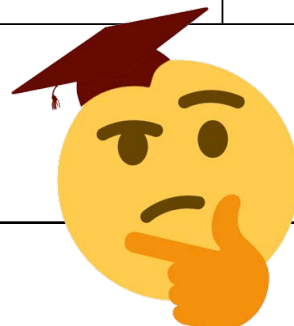
(a)(i)	angle (subtended) where arc (length) is equal to radius	M1
	(angle subtended) at the centre of a circle	A1
(a)(ii)	angular frequency = $2\pi \times$ frequency or $2\pi /$ period	B1
(b)(i)	c/ML^3 is a constant so acceleration is proportional to displacement	B1
	minus sign shows that acceleration and displacement are in opposite <u>directions</u>	B1
(b)(ii)	$c/ML^3 = (2\pi f)^2$	C1
	$c = 4\pi^2 \times 3.2^2 \times 0.24 \times 0.65^3$	C1
	$= 27 \text{ kg m}^3 \text{ s}^{-2}$	A1

5 - (9702/41_Summer_2018_Q2) - Oscillations

(a)(i)	straight line through origin indicates acceleration $\propto$ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1
(a)(ii)	$a = -\omega^2 y$ and $\omega = 2\pi f$	C1
	$4.5 = (2\pi \times f)^2 \times 8.0 \times 10^{-3}$ (or other valid read-off)	
	$f = 3.8 \text{ Hz}$	A1
(b)(i)	maximum displacement upwards/above rest/above the equilibrium position	B1
(b)(ii)	(just leaves plate when) acceleration = 9.81 ms^{-2}	C1
	$9.81 = (2\pi \times 3.8)^2 \times y_0$ or $9.81 = 563 \times y_0$	C1
	amplitude = 17 mm	A1

6 - (9702/42_Summer_2018_Q4) - Oscillations

(a)	acceleration proportional to displacement	B1
	acceleration <u>directed</u> towards fixed point or displacement and acceleration in opposite <u>directions</u>	B1
(b)(i)	1. amplitude decreases gradually so light damping or oscillations continue so light damping	B1
	2. loss of energy	B1
	due to friction in wheels or due to friction between wheels and surface (during slipping) or due to air resistance (on trolley)	B1
(b)(ii)1.	$\omega^2 = 2k/m$	C1
	$= (2 \times 230) / 0.950$	C1
	$\omega = 22 \text{ rad s}^{-1}$	A1
(b)(ii)2.	$T = 2\pi / \omega$	C1
	$T = (2\pi / 22) = 0.286 \text{ s}$	A1
	time = $1.5T$ $= 0.43 \text{ s}$	



7 - (9702/41_Winter_2018_Q3) - Oscillations

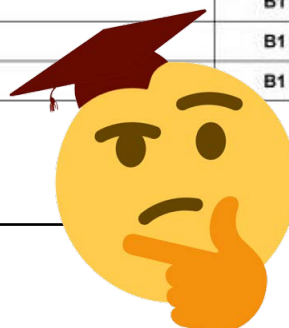
(a)	$\omega^2 = 2g/L$	C1
	$T = 2\pi/\omega$	C1
	$\omega^2 = (2 \times 9.81) / 0.19$	A1
	$\omega = 10.2 \text{ (rad s}^{-1}\text{)}$	
	$T = 2\pi/10.2$ $= 0.62 \text{ s}$	
(b)(i)	e.g. viscosity of liquid/friction within the liquid/viscous drag/friction between walls of tube and liquid	B1
(b)(ii)	(maximum) KE = $\frac{1}{2}mv_0^2$ and $v_0 = \omega x_0$ or energy = $\frac{1}{2}m\omega^2 x_0^2$	C1
	change = $\frac{1}{2} \times 18 \times 10^{-3} \times 103 \times [(2.0 \times 10^{-2})^2 - (0.95 \times 10^{-2})^2]$	C1
	$= 2.9 \times 10^{-4} \text{ J}$	A1

8 - (9702/42_Winter_2018_Q4) - Oscillations

(a)	(defining equation of s.h.m. is) $a = -kx$ where k is a constant or $a \propto -x$	B1
	g and L are constant (so $a \propto -x$ and hence s.h.m.)	B1
(b)	$T = 0.50 \text{ s}$ and $T = 2\pi/\omega$	C1
	$\omega^2 = 2g/L$	C1
	$L = (2 \times 9.81 \times 0.50^2) / 4\pi^2$	A1
	$= 0.12 \text{ m}$	
(c)(i)	Any one from: • viscosity of liquid • friction within the liquid • viscous drag • friction/resistance between walls of tube and liquid	B1
(c)(ii)	(maximum) KE = $\frac{1}{2}mv_0^2$ and $v_0 = \omega x_0$ or energy = $\frac{1}{2}m\omega^2 x_0^2$	C1
	ratio = $(1.3/2.0)^2$ $= 0.42$	A1

9 - (9702/41_Summer_2019_Q3) - Oscillations

(a)(i)	amplitude = 0.020 m	A1
(a)(ii)	$T = 0.60 \text{ s}$	C1
	$f = 1/T$ $= 1.7 \text{ Hz}$	A1
(a)(iii)	$a = (-)\omega^2 x$ and $[\omega = 2\pi f \text{ or } \omega = 2\pi/T]$	C1
	$a = (4\pi^2 / 0.60^2) \times 2.0 \times 10^{-2}$	A1
	$= 2.2 \text{ m s}^{-2}$	
(b)	$1.67 = (1/2\pi) \times [(24 \times 10^{-4} \times \rho \times 9.81) / 0.23]^{1/2}$	C1
	$\rho = 1.1 \times 10^3 \text{ kg m}^{-3}$	A1
(c)	wave starting with a peak at (0,6)	B1
	wave with same period (or slightly greater)	B1
	peak height decreasing successively	B1

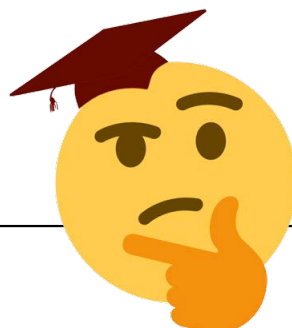


10 - (9702/42_Summer_2019_Q3) - Oscillations

(a)(i)	0.10 s or 0.30 s or 0.50 s or 0.70 s or 0.90 s	A1
(a)(ii)	0 or 0.40 s or 0.80 s	A1
(b)(i)	$\omega = 2\pi / T$	C1
	$= 2\pi / 0.40$	A1
	$= 16 \text{ rad s}^{-1}$	
(b)(ii)	$v_0 = \omega x_0$	C1
	$= 15.7 \times 2.5 \times 10^{-2}$	A1
	$= 0.39 \text{ m s}^{-1}$	
	or	
	tangent drawn at steepest part and working to show attempted calculation of gradient	(C1)
	leading to $v_0 = 0.39 \text{ m s}^{-1}$ (allow $\pm 0.15 \text{ m s}^{-1}$)	(A1)
(b)(iii)	$a_0 = \omega^2 x_0$	C1
	$a_0 = (15.7^2 \times 2.5 \times 10^{-2})$	A1
	$= 6.2 \text{ m s}^{-2}$	
	or	
	$a_0 = \omega v_0$	(C1)
	$a_0 = 15.7 \times 0.39$	(A1)
	$= 6.2 \text{ m s}^{-2}$	
(c)	period is shorter/lower	B1
	Any one from: - greater spring constant/stiffness (restoring) force is greater (for any given extension) - acceleration is greater (for any given extension) - greater energy/maximum speed (for a given amplitude)	B1

11 - (9702/41_Winter_2019_Q4) - Oscillations

(a)(i)	distance from a (reference) point in a given direction	B1
(a)(ii)	line is not straight or gradient is not constant	B1
(b)(i)	0.85–0.90 cm	A1
(b)(ii)	$a = -(2\pi f)^2 x$	C1
	e.g. $1.2 = 4\pi^2 \times f^2 \times (0.90 \times 10^{-2})$	C1
	$f = 1.8 \text{ Hz}$	A1
(c)	complete circle/ellipse enclosing the origin	B1
	closed shape passing through $(0, \pm v_0)$ and $(\pm x_0, 0)$	B1



12 - (9702/42_Winter_2019_Q4) - Oscillations

(a)(i)	loss of energy	B1
(a)(ii)	amplitude (of oscillations) decreases (with time)	B1
(b)(i)	$\omega = 2\pi / T$	C1
	$T = 0.80 \text{ s}$, so $\omega = 2\pi / 0.80$	A1
	$\omega = 7.9 \text{ rad s}^{-1}$	
(b)(ii)	$\omega^2 = 2k / M$	C1
	$7.9^2 = 2k / 1.2$	A1
	$k = 37 \text{ N m}^{-1}$	
(c)(i)	(one) smooth curve, not touching the f -axis, with two concave sides meeting at a peak in between them	B1
	(one) peak at 1.0ω	B1
(c)(ii)	- lower peak/(whole) line is lower - flatter <u>peak/peak</u> is less sharp - peak at (slightly) lower angular frequency/peak moves to left any two points, one mark each	B2

13 - (9702/41_Summer_2020_Q3) - Oscillations

(a)(i)	amplitude = 4.9 cm	A1
(a)(ii)	frequency = 2700 / 60	A1
	= 45 Hz	
(a)(iii)	$v_0 = x_0\omega$ and $\omega = 2\pi f$	C1
	$v_0 = 4.9 \times 10^{-2} \times 2\pi \times 45$	A1
	= 14 m s ⁻¹	
(a)(iv)	$v = \omega (x_0^2 - x^2)^{1/2}$	C1
	$= 2\pi \times 45 \times [(4.9 \times 10^{-2})^2 - (2.6 \times 10^{-2})^2]^{1/2}$	
	= 12 m s ⁻¹	A1
(b)	$F = ma$ and $a_0 = v_0\omega$ or $a_0 = x_0\omega^2$	C1
	$F = 0.64 \times 13.9 \times 2\pi \times 45$ or $0.64 \times 4.9 \times (2\pi \times 45)^2$	C1
	= 2500 N	A1



14 - (9702/42_Summer_2020_Q4) - Oscillations

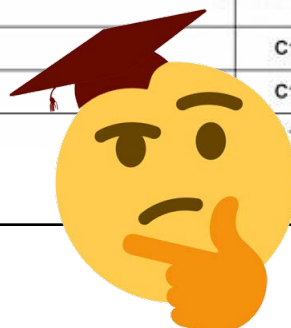
(a)	$(\omega = 2\pi / T \text{ and } T = 2.2 \text{ s so})$ $\omega = 2\pi / 2.2 = 2.9 \text{ rad s}^{-1}$	A1
(b)(i)	$\omega^2 = g / R$	C1
	$R = 9.81 / 2.86^2$ $= 1.2 \text{ m}$	A1
(b)(ii)	$v_0 = \omega x_0$	C1
	$= 2.9 \times 3.0 \times 10^{-2}$	A1
	$= 0.087 \text{ m s}^{-1}$	
(c)	smooth wave starting at 3.0 cm when $t = 0$	B1
	positions of peaks and troughs show same period (or slightly longer)	B1
	each peak and trough at lower amplitude than the previous one	B1

15 - (9702/41_Winter_2020_Q3) - Oscillations

(a)	acceleration (directly) proportional to displacement	B1
	acceleration in opposite <u>direction</u> to displacement	B1
	or acceleration (directed) towards equilibrium position	
(b)	$v = \omega(x_0^2 - x^2)^{1/2} \text{ and } \omega = 2\pi f$ or $v_0 = x_0 \omega \text{ and } \omega = 2\pi f$	C1
	substitution of any correct point from graph, e.g. for $x = 0$:	C1
	$0.25 = 2\pi f \times 8.8 \times 10^{-2}$	
	$f = 0.45 \text{ Hz}$	A1
(c)	$1 / 0.45 = 2\pi \times (L / 9.81)^{1/2}$	C1
	$L = 1.2 \text{ m}$	A1
(d)	ellipse about the origin with same intercepts on x-axis	B1
	ellipse about the origin crossing v-axis inside original loop	B1

16 - (9702/42_Winter_2020_Q3) - Oscillations

(a)	acceleration (directly) proportional to displacement	B1
	acceleration is in opposite <u>direction</u> to displacement	B1
	or acceleration is (directed) towards a fixed point	
(b)(i)	zero	B1
(b)(ii)	E_T is maximum potential energy $= mgh$	C1
	$E_T = 94 \times 10^{-3} \times 9.81 \times 0.90 \times 10^{-2}$	
	$= 8.3 \times 10^{-3} \text{ J}$	A1
(b)(iii)	$E_{MAX} = \frac{1}{2} m v_0^2 \text{ and } v_0 = \omega x_0$ or $E_{MAX} = \frac{1}{2} m (\omega x_0)^2$	C1
	$8.3 \times 10^{-3} = \frac{1}{2} \times 94 \times 10^{-3} \times \omega^2 \times (12.7 \times 10^{-2})^2$	A1
	...leading to $\omega = 3.3 \text{ rad s}^{-1}$	
(c)	$T = 2\pi / \omega$	C1
	$2\pi / 3.3 = 2\pi \times (L / 9.81)^{1/2}$	C1
	$L = 0.90 \text{ m}$	A1

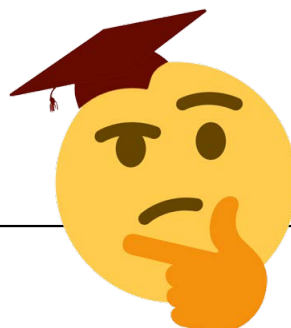


17 - (9702/41_Summer_2021_Q3) - Oscillations

(a)	acceleration (directly) proportional to displacement	B1
	acceleration is in opposite <u>direction</u> to displacement	B1
(b)	$\omega^2 = 2k / m$ and $\omega = 2\pi f$	C1
	$(2\pi f)^2 = (2 \times 130) / 0.84$	C1
	$f = 2.8 \text{ Hz}$	A1
(c)(i)	resonance	B1
(c)(ii)	oscillator supplies energy (continuously)	B1
	energy of trolley constant so energy must be dissipated or without loss of energy the amplitude would continuously increase	B1

18 - (9702/42_Summer_2021_Q3) - Oscillations

(a)	acceleration in opposite <u>direction</u> to displacement shown by – sign	B1
	g / L is constant	M1
	(so) acceleration is (directly) proportional to displacement	A1
(b)	$\omega^2 = g / L$	C1
	$\omega = 2\pi / T$ or $\omega = 2\pi f$ and $f = 1 / T$	C1
	$(2\pi / T)^2 = 9.81 / 0.18$	A1
	$T = 0.85 \text{ s}$	
(c)	energy $\propto x_0^2$	C1
	(after 3 cycles,) amplitude = $(0.94)^3 x_0$ = $0.83x_0$	C1
	ratio final energy / initial energy = 0.83^2 = 0.69	A1



19 - (9702/41_Winter_2021_Q4) - Oscillations

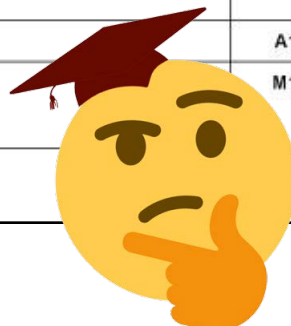
(a)(i)	5.0 cm	A1
(a)(ii)	$\omega = 2\pi / T$ or $\omega = 2\pi f$ and $f = 1 / T$	C1
	$\omega = 2\pi / 4.0$ $= 1.6 \text{ rad s}^{-1}$	A1
(a)(iii)	$v_0 = \omega x_0$	C1
	$= 1.57 \times 5.0$	A1
	$= 7.9 \text{ cm s}^{-1}$	
(b)	- initial pull was to the right - distance from X to trolley (at equilibrium) is 20 cm - period is 4.0 s - initial motion undamped - motion becomes damped at/from 12 s - damping is light - maximum speed at 1 s, 3 s, etc. / stationary at 2 s, 4 s, etc. Any three points, 1 mark each	B3
(c)	sketch: closed loop encircling (20, 0)	B1
	minimum L shown as 15 cm and maximum L shown as 25 cm	B1
	minimum v shown as -7.9 cm s^{-1} and maximum v shown as $+7.9 \text{ cm s}^{-1}$	B1

20 - (9702/42_Winter_2021_Q4) - Oscillations

(a)	straight line through the origin	B1
	negative gradient	B1
(b)	$a = (-)\omega^2 x$ and $T = 2\pi / \omega$	C1
	e.g. $\omega = \sqrt{(0.80 / 0.12)}$ (any correct pair of values of a and x) ($= 2.58 \text{ rad s}^{-1}$)	C1
	$T = 2\pi / 2.58$ $= 2.4 \text{ s}$	A1
(c)(i)	Point labelled P at one end of the line	B1
(c)(ii)	Point labelled Q at displacement with magnitude more than half but less than maximum	B1

21 - (9702/41_Summer_2022_Q4) - Oscillations

(a)	straight line through origin shows that a is proportional to x	B1
	negative gradient shows that a is in opposite direction to x	B1
(b)(i)	$a_0 = \omega^2 x_0$ or $a = -\omega^2 x$ or $\omega^2 = -\text{gradient}$	C1
	$\omega = \sqrt{(0.40 / 0.050)}$ $= 2.8 \text{ rad s}^{-1}$	A1
(b)(ii)	$k = \omega^2 L$ $= 2.8^2 \times 1.24$ $= 9.7 \text{ N s}^{-2}$	C1
		A1
(c)	(increasing L causes) ω to decrease or energy ($= \frac{1}{2} m \omega^2 x_0^2 = \frac{1}{2} m k x_0^2 / L$ (and L increases)	M1
	so amplitude increases	



22 - (9702/42_Summer_2022_Q4) - Oscillations

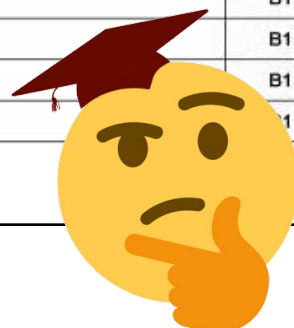
(a)	oscillations (of object) at maximum amplitude	B1
	when driving frequency equals natural frequency (of object)	B1
(b)(i)	$T = 2\pi / \omega$	C1
	$= 2\pi / 5.0\pi$	A1
	$= 0.40 \text{ s}$	
(b)(ii)	displacement scale labelled $-1.0, -0.5, (0), 0.5, 1.0$ on the 2 cm tick marks	B1
	t scale labelled $0.2, 0.4, 0.6, 0.8, 1.0, 1.2$ on the 2 cm tick marks	B1
(b)(iii)	$\phi = 2\pi \Delta t / T$	C1
	$= 2\pi \times 0.10 / 0.40$ or $2\pi \times 0.30 / 0.40$	
	$= 1.6 \text{ rad}$ or 4.7 rad	A1

23 - (9702/41_Winter_2022_Q3) - Oscillations

(a)	$a = -\omega^2 x$	M1
	a = acceleration, x = displacement from equilibrium position and ω = angular frequency	A1
(b)(i)	$x_0 = 0.12 \text{ m}$	A1
(b)(ii)	$v = \omega \sqrt{(x_0^2 - x^2)}$	C1
	two (x, v) pairs correctly read from Fig. 3.2 (one may be $(x_0, 0)$ or value of x_0 from (i))	
	e.g. $0.20 = \omega \sqrt{(0.12^2 - 0)}$ leading to $\omega = 1.7 \text{ rad s}^{-1}$	A1
(b)(iii)	$E = \frac{1}{2} M \omega^2 x_0^2$	C1
	$0.050 = \frac{1}{2} \times M \times 1.67^2 \times 0.12^2$	A1
	$M = 2.5 \text{ kg}$	
	or	
	$(E_K)_{\max} = \frac{1}{2} M v_0^2$	(C1)
	$0.050 = \frac{1}{2} M \times 0.20^2$	(A1)
	$M = 2.5 \text{ kg}$	
(c)(i)	loss of (total) energy (of system)	B1
	due to resistive forces	B1
(c)(ii)	closed loop surrounding the origin with maximum x at $\pm 0.080 \text{ m}$ passing through $v = 0$	B1
	maximum velocity shown as $\pm 0.10 \text{ m s}^{-1}$ passing through $x = 0$	B1

24 - (9702/42_Winter_2022_Q4) - Oscillations

(a)(i)	$x_0 = 8.0 \text{ cm}$	A1
(a)(ii)	$\omega = 2\pi / T$	C1
	$= 2\pi / 4.0 = 1.6 \text{ rad s}^{-1}$	A1
(a)(iii)	$E = \frac{1}{2} m \omega^2 x_0^2$	C1
	$= \frac{1}{2} \times 36 \times 1.6^2 \times 0.080^2$	C1
	$= 0.29 \text{ J}$	A1
(b)	dome-shaped curve, starting and ending at $E_K = 0$	B1
	maximum E_K shown as 0.29 J	B1
	position of peak shown at $h = 10.0 \text{ cm}$	B1
	line intercepts h -axis at $h = 2.0 \text{ cm}$ and at $h = 18.0 \text{ cm}$	B1

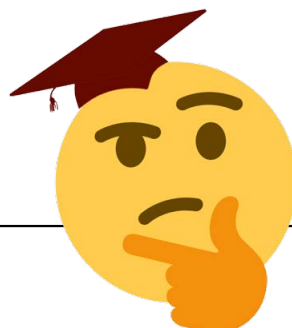


25 - (9702/42_Summer_2023_Q4) - Oscillations

(a)(i)	$\omega = 2\pi f$	C1
	$f = 9.7 / 2\pi$	A1
	$= 1.5 \text{ Hz}$	
(a)(ii)	amplitude $= \sqrt{11.6} = 3.4 \text{ cm}$	A1
(a)(iii)	$a_0 = \omega^2 x_0$	C1
	$= 9.7^2 \times 3.4 \times 10^{-2}$	A1
	$= 3.2 \text{ m s}^{-2}$	
(b)	sketch: straight line through the origin with negative gradient	B1
	line with negative gradient passing through $(+3.4, -a_0)$ and $(-3.4, +a_0)$	B1
	line with ends at $x = \pm 3.4 \text{ cm}$ and $a = \pm a_0$	B1
(c)	sum of potential energy and kinetic energy is constant	B1
	at maximum displacement, kinetic energy is zero or at maximum displacement, potential energy is maximum	B1
	at zero displacement, kinetic energy is maximum or at zero displacement, potential energy is minimum	B1

26 - (9702/41_Winter_2023_Q4) - Oscillations, Motion In A Circle

(a)	(motion in which) acceleration is (directly) proportional to displacement	B1
	(motion in which): acceleration is (always) in the opposite <u>direction</u> to displacement or acceleration is (always) directed towards a fixed point	B1
(b)(i)	$\omega = 2\pi / T$	C1
	$\omega = 2\pi / 3.0$	A1
	$= 2.1 \text{ rad s}^{-1}$	
(b)(ii)	$E = \frac{1}{2} m \omega^2 x_0^2$	C1
	$= \frac{1}{2} \times 0.81 \times 2.1^2 \times 0.036^2$	A1
	$= 2.3 \times 10^{-3} \text{ J}$	
(c)	sketch: line starting at $(0, 0.036)$ and not reaching $x = \pm 0.036 \text{ m}$ at any other time	B1
	smooth curve, with no sudden changes in gradient, showing continuously decreasing magnitude of x from maximum displacement at $t = 0$ to final displacement of zero where the gradient is also zero	B1
	displacement reaches final value of zero between $t = 0.75 \text{ s}$ and $t = 3.0 \text{ s}$ at the latest	B1



1 - (9702/42_Summer_2017_Q4) - Waves

(a)	pulse (of ultrasound)	
	* produced by quartz crystal/piezo-electric crystal	
	* gel/coupling medium (on skin) used to reduce reflection at skin	
	reflected from boundaries (between media)	
	reflected pulse/wave detected by (ultrasound) transmitter	
	reflected wave processed and displayed	
	* intensity of reflected pulse/wave gives information about boundary	
	* time delay gives information about depth of boundary	
	<i>max. 2 of additional detail points marked *</i>	
(b)	$I_T = I_0 \exp(-\mu x)$	
	$2.9 = \exp(4.6\mu)$	
	$\mu = 0.23 \text{ cm}^{-1}$	

2 - (9702/42_Winter_2017_Q4) - Waves

(a)	quartz/piezo-electric and crystal/transducer	B1
	p.d. across crystal causes it to distort	B1
	applying <u>alternating</u> p.d. causes oscillations/vibrations	B1
	when applied frequency is natural frequency, crystal resonates	B1
	natural frequency of crystal is in ultrasound range	B1
(b)	small(er) structures can be resolved/observed/identified	B1

3 - (9702/41_Summer_2018_Q4) - Waves

(a)	e.g. microphone weighing scales/pressure sensor lighters/spark generation watches/clocks/regulation of time	B1
(b)	<u>pulses</u> (of ultrasound)	B1
	reflected at boundaries (between media)	B1
	(reflected pulses) detected by (ultrasound) generator	B1
	Any three from: • time delay (between transmission and receipt) gives information about depth (of boundary) • intensity of reflected pulse gives information about (nature of) <u>boundary</u> • gel used to minimise reflection at skin/maximise transmission into skin • degree of reflection depends upon impedances of two media (at boundary)	B3



4 - (9702/41_Summer_2018_Q12) - Waves

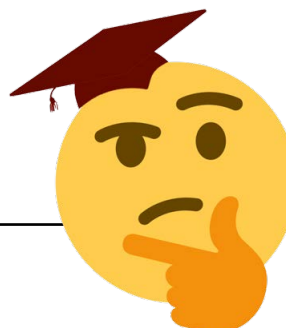
(a)(i)	$I = I_0 e^{-\mu x}$	C1
	$= I_0 \exp(-0.90 \times 2.8)$	A1
	$= 0.080 I_0$	
(a)(ii)	$I = I_0 \exp[(-0.90 \times 1.5) \times (-3.0 \times 1.3)]$	C1
	$= I_0 (0.259 \times 0.20)$	A1
	$= 0.0052 I_0$	
(b)(i)	difference in degrees of blackening	M1
	between structures	A1
(b)(ii)	large difference in intensities so good contrast	B1

5 - (9702/41_Winter_2018_Q4) - Waves

(a)	pulses (of ultrasound from generator)	B1
	reflected at boundaries (between media)	B1
	time delay (between transmission and receipt) gives information about depth	B1
	intensity of reflected pulse gives information about nature (of tissues)/type (of tissues)/boundary	B1
	Any two from: (reflected pulses) detected by the (ultrasound) generator - gel used to minimise reflection at skin/maximise transmission into skin - degree of reflection depends upon impedances of two media (at boundary)	B2
(b)(i)	product of density and speed	M1
	speed of ultrasound in medium	A1
(b)(ii)	Z_1 about equal to Z_2 results in negligible/no reflection	B1
	$Z_1 \gg Z_2$ (or $Z_1 \ll Z_2$) results in mostly reflection	B1

6 - (9702/41_Summer_2023_Q8) - Waves

(a)(i)	specific acoustic impedance = $1200 \times 1400 = 1.68 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$	A1
(a)(ii)	density of air shown in table as 1.29	A1
	speed of sound in tissue shown in table as 1540	A1
(b)(i)	intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$	C1
	$= (1680000 - 440)^2 / (1680000 + 440)^2$	
	$= 0.999$	A1
(b)(ii)	intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$	A1
	$= (1680000 - 1680000)^2 / (1680000 + 1680000)^2$	
	$= 0$	
(c)	without gel, (almost) all of the (incident) ultrasound is reflected (from skin)	B1
	with gel, (almost) all of the (incident) ultrasound is transmitted (into the body)	B1



1 - (9702/41_Summer_2017_Q3) - Communication

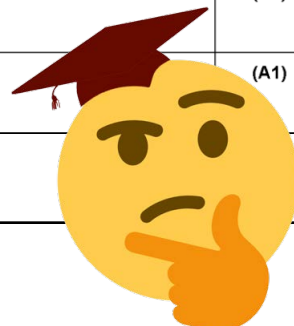
(a)(i)	signal consists of (a series of) 1s and 0s or offs and ons or highs and lows
(a)(ii)	component X: parallel-to-serial converter
	component Y: DAC/digital-to-analogue converter
(a)(iii)	sample the (analogue) signal
	at regular intervals and converts the analogue number to a digital number
(b)(i)	attenuation in fibre = 84×0.19 (= 16 dB)
	ratio = $16 + 28$
	= 44 dB
(b)(ii)	ratio / dB = $10 \lg (P_2 / P_1)$
	$44 = 10 \lg \{ (9.7 \times 10^{-3}) / P \}$
	or
	$-44 = 10 \lg (P / \{9.7 \times 10^{-3}\})$
	power = 3.9×10^{-7} W

2 - (9702/42_Summer_2017_Q5) - Communication

(a)	any two reasonable suggestions e.g. - signal can be regenerated/noise removed (not "no noise") - circuits more reliable - circuits cheaper to produce - multiplexing (is possible) - error correction/checking - easier encryption/better security
(b)(i)	samples the analogue signal
	at regular intervals and converts it (to a digital number)
(b)(ii)	1. smaller step depth
	2. smaller step height

3 - (9702/41_Winter_2017_Q4) - Communication

(a)	- acts as 'return' (conductor) for signal - shielding from noise/crosstalk/interference <i>Two sensible suggestions, 1 mark each.</i>	B2
(b)	- small bandwidth (there is) noise/interference/crosstalk - large attenuation/energy loss - reflections due to poor impedance matching <i>Two sensible suggestions, 1 mark each.</i>	B2
(c)	attenuation = $190 \times 14 \times 10^{-3}$ (= 2.66 dB)	C1
	ratio / dB = $(-10 \lg (P_2 / P_1))$	C1
	$2.66 = -10 \lg (P_{OUT} / P_{IN})$	C1
	$P_{OUT} / P_{IN} = 0.54$	
	fractional loss = $1 - (P_{OUT} / P_{IN}) = 1 - 0.54$	A1
	= 0.46	
	or	
	$2.66 = 10 \lg (P_{IN} / P_{OUT})$	(C1)
	$P_{IN} / P_{OUT} = 1.85$	
	fractional loss = $(P_{IN} - P_{OUT}) / P_{IN} = (1.85 - 1) / 1.85$	(A1)
	= 0.46	



4 - (9702/42_Winter_2017_Q5) - Communication

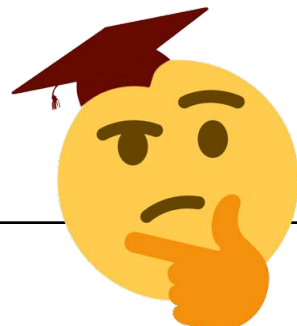
(a)	<table><tr><td>(0.2 ms)</td><td>8.0 (mV)</td><td colspan="4">1000</td></tr></table>						(0.2 ms)	8.0 (mV)	1000				B1							
	(0.2 ms)	8.0 (mV)	1000																	
<table><tr><td>(0.8 ms)</td><td>5.8 (mV)</td><td colspan="4">0101</td></tr></table>						(0.8 ms)	5.8 (mV)	0101				B1								
(0.8 ms)	5.8 (mV)	0101																		
(b)	series of steps						B1													
	all (step) changes are at 0.2 ms intervals						B1													
	steps with correct levels at correct times (1 mark if five levels correct; 2 marks if all levels correct)						B2													
	<table><tr><td>level</td><td>0</td><td>8</td><td>10</td><td>15</td><td>5</td><td>8</td></tr><tr><td>time / ms</td><td>0–0.2</td><td>0.2–0.4</td><td>0.4–0.6</td><td>0.6–0.8</td><td>0.8–1.0</td><td>1.0–1.2</td></tr></table>						level	0	8	10	15	5	8	time / ms	0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0	1.0–1.2
level	0	8	10	15	5	8														
time / ms	0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0	1.0–1.2														
(c)	smaller step heights (possible)						B1													
	smaller changes (in input signal) can be seen/reproduced/represented or (allows) more accurate <u>reproduction</u> (of the input signal)						B1													

5 - (9702/41_Summer_2018_Q5) - Communication

(a)(i)	west to east	B1
(a)(ii)	above the Equator	B1
(a)(iii)	value in range $(1-300) \times 10^9$ Hz	A1
(b)(i)	gain / dB = $10 \lg (P_2 / P_1)$	C1
	–195 = $10 \lg (P / 3000)$ or 195 = $10 \lg (3000 / P)$	C1
	power = 9.5×10^{-17} W	A1
(b)(ii)	up-link has been (greatly) attenuated (before reaching satellite) or down-link signal must be (greatly) amplified (before transmission back to Earth) or up-link has (much) smaller intensity/power than down-link	B1
	(different frequency) prevents down-link (signal) swamping up-link (signal)	B1

6 - (9702/42_Summer_2018_Q5) - Communication

(a)(i)	range of frequencies (of signal)	B1
(a)(ii)	advantage: e.g. better quality (of reproduction) greater rate of transfer of data less distortion	B1
	disadvantage: e.g. fewer stations (in any frequency range)	B1
(b)(i)	5.0 V	A1
(b)(ii)	maximum: 674 kHz	A1
	minimum: 626 kHz	A1
(b)(iii)	$T = 1 / (10 \times 10^3) = 1.0 \times 10^{-4}$ s minimum time = $T / 2$ $= 5.0 \times 10^{-5}$ s	A1



7 - (9702/41_Winter_2018_Q5) - Communication

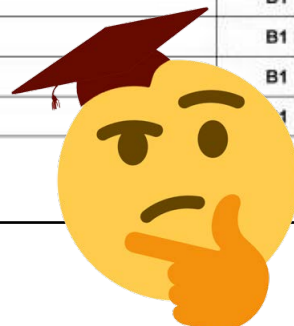
(a)	Any two reasonable suggestions e.g.: - noise can be eliminated/(signal/data) can be regenerated - bits can be added to correct for errors - data compression/multiplexing (is possible) - signal can be encrypted/better security	B2
(b)	sketch: series of seven steps	B1
	each step width 2 ms	B1
	correct levels in correct order (2, 5, 14, 4, 9, 11, 7) (1 mark for 6 levels correct, 2 marks for 7 levels correct)	A2
(c)(i)	step width reduced or higher frequencies can be reproduced	B1
(c)(ii)	step height reduced or smaller changes in signal (intensity) can be reproduced	B1

8 - (9702/42_Winter_2018_Q5) - Communication

(a)	amplitude of carrier (wave) varies	B1
	variation in synchrony with displacement of information signal	B1
(b)(i)	wavelength = $(3.0 \times 10^6)/(900 \times 10^3)$ $= 3.3 \times 10^2 \text{ m}$	A1
(b)(ii)	amplitude varies (continuously) between a maximum and a minimum	B1
	variations repeat 5000 times each second or variations repeat every 0.2 ms or variations above and below 4.0 V	B1
(b)(iii)	10000 Hz	A1
(c)(i)	Any two from: (orbit is) above the Equator (orbit is) from west to east/same direction as Earth's rotation - orbit is circular/orbit has a particular radius	B2
(c)(ii)	1. minimal reflection/absorption/attenuation by <u>atmosphere</u> or maximum penetration of/transmission through <u>atmosphere</u>	B1
	2. uplink signal is greatly attenuated/must be greatly amplified	B1
	prevents downlink signal swamping the uplink signal	B1

9 - (9702/41_Summer_2019_Q4) - Communication

(a)(i)	loss of (signal) power/amplitude/intensity	B1
(a)(ii)	unwanted/random signal	B1
	superposed on (transmitted) signal	B1
(b)	noise can be eliminated (from digital signals) or signal can be regenerated (from digital signals)	B1
(c)(i)	0101	A1
(c)(ii)	1000 at $t = 4.0 \text{ ms}$	B1
	0110 at $t = 5.0 \text{ ms}$ and 0100 at $t = 6.0 \text{ ms}$	B1
(d)	series of equally-spaced steps of width 1 ms	B1
	each step in correct time interval (0–1 ms, 1–2 ms, 2–3 ms, 3–4 ms)	B1
	correct step heights (2, 6, 4 and 5)	1



10 - (9702/42_Summer_2019_Q4) - Communication

(a)	product of density and speed	M1
	speed of sound in medium	A1
(b)	Any two from: - if $Z_A \gg Z_B$ then ratio is (nearly) zero or if $Z_B \gg Z_A$ then ratio is (nearly) zero or if Z_B and Z_A are very different then ratio is (nearly) zero or the greater the difference the lower the ratio - if $Z_A \approx Z_B$ then ratio is (nearly) 1 or if $Z_A = Z_B$ then ratio is 1 or the smaller the difference the closer the ratio to 1 (not 'large') $I_T / I_0 = 1 - [(Z_A - Z_B)^2 / (Z_A + Z_B)^2]$	B2
(c)	$I = I_0 e^{-\mu x}$	C1
	$0.34 = \exp(-23 \times x)$	C1
	$x = 0.047 \text{ m}$	A1

11 - (9702/42_Summer_2019_Q5) - Communication, Electronics

(a)(i)	loss of (signal) power/amplitude/intensity	B1
(a)(ii)	unwanted/random signal	B1
	superposed on (transmitted) signal	B1
(b)(i)	attenuation = $10 \lg(P_2 / P_1)$	C1
	attenuation per unit length = $(1/L) \times 10 \lg(P_2 / P_1)$	C1
	$= (1/52) \times 10 \lg[(2.5 \times 10^{-3}) / (7.8 \times 10^{-16})]$	
	$= 2.4 \text{ dB km}^{-1}$	A1
(b)(ii)	gain / dB = $10 \lg(P_2 / P_1)$	C1
	$115 = 10 \lg[P / (7.8 \times 10^{-16})]$	
	$P = 2.5 \times 10^{-4} \text{ W}$	A1

12 - (9702/41_Winter_2019_Q5) - Communication

(a)(i)	provides return for the signal	B1
	shields signal from noise	B1
(a)(ii)	e.g. connection between aerial and TV set	B1
(b)(i)	gain / dB = $10 \lg(P_1 / P_2)$	C1
	$32 = 10 \lg\{P_{\text{MIN}} / (7.6 \times 10^{-6})\}$	A1
	$P_{\text{MIN}} = 0.012 \text{ W}$	
(b)(ii)	attenuation per unit length = $(1/L) \times 10 \lg(P_1 / P_2)$	C1
	$6.3 = (1/L) \times 10 \lg(2.6 / 0.012)$	
	$L = 3.7 \text{ km}$	A1



13 - (9702/42_Winter_2019_Q5) - Communication

(a)(i)	product of density and speed	M1
	speed of sound in the medium	A1
(a)(ii)	$Z_B = 1.8 \times 10^3 \times 4.1 \times 10^3$ $= 7.4 \times 10^6 \text{ kg m}^2 \text{ s}^{-1}$	A1
(b)	$\alpha = (1.7 - 1.3)^2 / (1.7 + 1.3)^2 = 0.018$ fraction = 0.98	A1
(c)(i)	reduction in power/intensity (of wave)	M1
	as the wave passes through the medium	A1
(c)(ii)	1. ratio = $e^{-\mu x}$	C1
	= 0.90	A1
	2. ratio = 0.62	A1
(d)	fraction = $0.898 \times 0.617 \times 0.98$ = 0.54	A1

14 - (9702/42_Winter_2019_Q6) - Communication

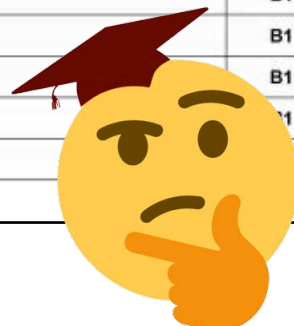
(a)	period = $5.0 \mu\text{s}$, so frequency = $2.0 \times 10^5 \text{ Hz}$	A1
(b)	sketch: three equally spaced vertical lines sitting on f-axis	B1
	two outer vertical lines of equal length and central line longer	B1
	three vertical lines (and no others) shown at frequencies 190 kHz, 200 kHz and 210 kHz	B1

15 - (9702/41_Summer_2020_Q4) - Communication

(a)(i)	product of density and speed	M1
	speed of ultrasound in medium	A1
(a)(ii)	the greater the difference between Z_1 and Z_2 , the closer the ratio is to 1 or if difference between Z_1 and Z_2 large, ratio is close to 1	B1
	the closer together Z_1 and Z_2 , the closer the ratio is to 0 or if difference between Z_1 and Z_2 small, ratio close to 0	B1
(b)(i)	loss of intensity/amplitude/power (of the wave)	B1
(b)(ii)	$I = I_0 e^{-\mu x}$	C1
	$0.35 = e^{-0.046\mu}$	A1
	$\mu = 23 \text{ m}^{-1}$	

16 - (9702/42_Summer_2020_Q5) - Communication

(a)	pulses of ultrasound	B1
	ultrasound incident on quartz crystal	B1
	waves make crystal oscillate	B1
	oscillations (of crystal) generates an e.m.f. (across the crystal)	B1
(b)	specific acoustic impedances of air and skin are very different	B1
	intensity reflection coefficient depends on difference between acoustic impedance	B1
	most ultrasound reflected so little transmission	B1



17 - (9702/41_Summer_2020_Q6) - Communication

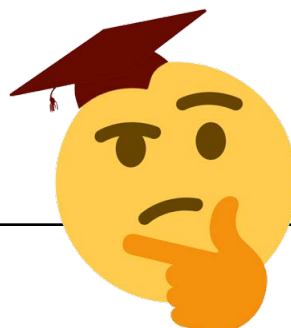
(a)(i)	greater information carrying capacity	B1
(a)(ii)	power/energy is radiated	B1
	signal picked up by adjacent fibre/wire	B1
(b)	ratio / dB = $10 \lg(P_2 / P_1)$	C1
	$13 = 10 \lg [P / (1.0 \times 10^{-3})]$ and so $P = 20 \text{ mW}$	A1
(c)	$45 \times 0.18 = 10 \lg (20 / P)$	C1
	$P = 3.1 \text{ mW}$	A1

18 - (9702/42_Summer_2020_Q6) - Communication

(a)	- greater bandwidth - less noise - less attenuation or fewer repeaters - less crosslinking or greater security Any three points, 1 mark each	B3
(b)(i)	ratio / dB = $10 \lg(P_1 / P_2)$	C1
	$21 = 10 \lg [(6.3 \times 10^{-17}) / P]$	A1
	$P = 5.0 \times 10^{-19} \text{ W}$	
(b)(ii)	attenuation per unit length = $(1 / 4.5 \times 10^3) \times 10 \lg [(9.8 \times 10^{-3}) / (6.3 \times 10^{-17})]$	C1
	$= 0.032 \text{ dB km}^{-1}$	A1

19 - (9702/41_Winter_2020_Q4) - Communication

(a)	quartz crystal	B1
	alternating p.d. across crystal causes it to vibrate	B1
	resonance occurs when frequency of p.d. matches natural frequency of crystal	B1
	natural frequency of crystal is in ultrasound range	B1
(b)	$I = I_0 e^{-\mu x}$	C1
	$I / I_0 = e^{-1.2 \times 3.5}$	C1
	$= 0.015$	
	ratio / dB = $-10 \lg (1 / 0.015)$ or $10 \lg (0.015)$	C1
	$= -18 \text{ dB}$	A1



20 - (9702/42_Winter_2020_Q4) - Communication

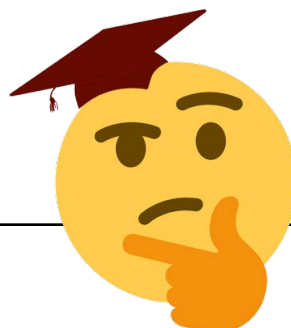
(a)	any two points from: - signal can be regenerated/noise can be removed - signal can be encrypted - signal can be checked for errors - multiplexing is possible <u>circuits</u> are more reliable/cheaper <u>data</u> can be transmitted at a greater <u>rate</u>	B2
(b)(i)	right-hand zero underlined (011 <u>0</u>)	B1
(b)(ii)	analogue signals given as: 3.0, 4.8, 1.0	B1
	0011 at 0.30 ms and 0001 at 0.50 ms	B1
	0100 at 0.40 ms	B1
(c)	series of steps, all of width 0.1 ms	B1
	steps levels, in order, at output voltage 0, 5, 6, 3 and 4 mV	B2
	2 marks: all levels correct 1 mark: one level incorrect and all others correct or one level omitted and last step shown at 1 mV	

21 - (9702/42_Winter_2020_Q7) - Communication

(a)	X-ray photon produced when electron is decelerated	B1
	larger acceleration results in larger photon energy	B1
	continuous range of accelerations so continuous spectrum of wavelengths/frequencies	B1
(b)	electron in (inner shell of) target atom is excited (on collision)	B1
	electron de-excites causing emission of a photon	B1
	discrete energy levels so discrete photon wavelengths	B1

22 - (9702/42_Summer_2021_Q4) - Communication

(a)(i)	frequency (modulation)	B1
(a)(ii)	1. zero	B1
	2. frequency (of 1.2 MHz) varies by ± 50 kHz	B1
	frequency varies (by ± 50 kHz) at a rate of 8000 times per second	B1
(b)(i)	wavelength = $(3.00 \times 10^8) / (240 \times 10^3)$	C1
	(= 1250 m)	A1
	= 1.25 km	
(b)(ii)	bandwidth = 30 kHz	A1
(b)(iii)	frequency = 15 kHz	A1



23 - (9702/41_Summer_2021_Q5) - Communication

(a)	amplitude of the carrier wave varies	M1
	in synchrony with the displacement of the (information) signal	A1
(b)(i)	wavelength = $(3.0 \times 10^8) / (300 \times 10^3)$ = 1000 m	A1
(b)(ii)	bandwidth = 16 kHz	A1
(b)(iii)	frequency = 8 kHz	A1
(c)	attenuation = $10 \lg (P_1 / P_2)$	C1
	$73 = 10 \lg (P_T / P_R)$	C1
	$73 = 10 \lg (P_T x^2 / 0.082 P_T)$ or $x^2 / 0.082 = 10^{7.3}$	
	$x = 1300$ m	A1

24 - (9702/41_Winter_2021_Q5) - Communication

(a)	- noise can be removed/signal can be regenerated - extra bits can be added for error-checking - signal can be encrypted (for increased security) - data compression/multiplexing is possible Any two points, 1 mark each	B2
(b)(i)	4ms: 0101 and 8ms: 0100	B1
(b)(ii)	sketch: horizontal line continues to 8ms, then new horizontal line from 8ms to 12ms	B1
	level of line after 8ms is 4 mV	B1
(c)	sketch: series of steps of width 2 ms	B1
	step heights at 0, 2, 4, 6, 4, 6 mV 2 marks if all correct, 1 mark if only one incorrect	B2

25 - (9702/42_Winter_2021_Q5) - Communication

(a)(i)	unmodulated (radio) waves would interfere with each other or not modulating would require aerials too long (to be practical)	B1
(a)(ii)	advantage: - can transmit higher frequencies - higher quality reproduction - less prone to interference - same frequency can be used in different areas (any one point)	B1
	disadvantage: - takes up greater bandwidth - shorter range of transmission - requires a greater number of transmitting aerials (any one point)	B1
(b)	AM amplitude: min. 8 mV and max. 12 mV	B1
	AM frequency: min. 100 kHz and max. 100 kHz	B1
	FM amplitude: min. 10 mV and max. 10 mV	B1
	FM frequency: min. 90 kHz and max. 110 kHz	B1
(c)	8.4 kHz	A1



1 - (9702/42_Summer_2017_Q6) - Electric Fields, Current Of Electricity

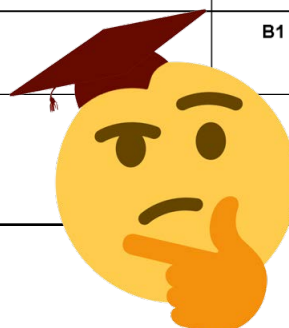
(a)	force proportional to product of charges and inversely proportional to the square of the separation reference to point charges
(b)(i)	(near to each sphere,) fields are in opposite directions or point (between spheres) where fields are equal and opposite or point (between spheres) where field strength is zero so same (sign of charge)
(b)(ii)	(at $x = 5.0 \text{ cm}$,) $E = 3.0 \times 10^3 \text{ V m}^{-1}$ and $a = qE/m$ $E = (1.60 \times 10^{-19} \times 3.0 \times 10^3) / (1.67 \times 10^{-27})$ $= 2.9 \times 10^{11} \text{ ms}^{-2}$
(c)	field strength or E is potential gradient or field strength is rate of change of (electric) potential (field strength) maximum at $x = 6 \text{ cm}$

2 - (9702/41_Winter_2017_Q5) - Electric Fields, Electromagnetic Induction

(a)(i)	force proportional to <u>product</u> of charges and inversely proportional to <u>square</u> of separation	A1
(a)(ii)	curve starting at (R, F_C)	B1
	passing through $(2R, 0.25F_C)$	B1
	passing through $(4R, 0.06F_C)$	B1
(b)	graph: $E = 0$ when current constant (0 to t_1 , t_2 to t_3 , t_4 to t_5)	B1
	stepped from t_1 to t_2 and t_3 to t_4	B1
	(steps) in opposite directions	B1
	later one larger in magnitude	B1

3 - (9702/42_Winter_2017_Q6) - Electric Fields

(a)	electric field lines are radial/normal to surface (of sphere)	B1
	electric field lines <u>appear</u> to originate from centre (of sphere)	B1
(b)(i)	tangent drawn at $x = 6.0 \text{ cm}$ and gradient calculation attempted	C1
	$E = 9.0 \times 10^4 \text{ NC}^{-1}$ (1 mark if in range ± 1.2 ; 2 marks if in range ± 0.6)	A2
	or	
	correct pair of values of V and x read from curved part of graph and substituted into $V = q/4\pi\epsilon_0 x$	(C1)
	to give $q = 3.6 \times 10^{-8} \text{ C}$	(C1)
	(then $E = q/4\pi\epsilon_0 x^2$ and $x = 6 \text{ cm}$ gives) $E = 9.0 \times 10^4 \text{ NC}^{-1}$	(A1)
	or	
	($E = q/4\pi\epsilon_0 x^2$ and $V = q/4\pi\epsilon_0 x$ and so) $E = V/x$	(C1)
	giving $E = 5.4 \times 10^3 / 0.060$	(C1)
	$= 9.0 \times 10^4 \text{ NC}^{-1}$	(A1)
(b)(ii)	($R =$) 2.5 cm	B1
	potential inside a conductor is constant or field strength inside a conductor zero (so gradient is zero)	B1



4 - (9702/41_Summer_2018_Q6) - *Electric Fields*

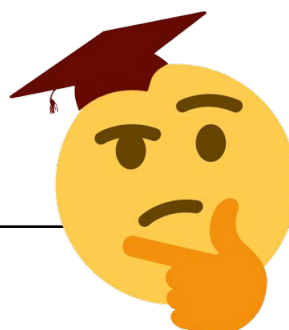
(a)	force per unit charge	B1
(b)	$E = Q / (4\pi\epsilon_0 r^2)$	C1
	$2.0 \times 10^4 = Q / (4\pi \times 8.85 \times 10^{-12} \times 0.26^2)$	A1
	charge = 1.5×10^{-7} C	
(c)	charge (= $Q [52/26]^2$) = 4Q	C1
	additional charge = 3Q	A1

5 - (9702/41_Winter_2018_Q6) - *Electric Fields*

(a)(i)	work done per unit charge	B1
	work done moving positive charge from infinity (to the point)	B1
(a)(ii)	field strength = potential gradient	M1
	'-' sign included or directions discussed	A1
(b)(i)	gain in kinetic energy (= loss in potential energy) = charge $\times$ p.d. or $qV = \frac{1}{2}mv^2$	M1
	so v is independent of separation (because separation not in expressions)	A1
(b)(ii)	(at $x = 0.40$ cm), potential = $(-) 75 \times 0.40 / 1.2$ (= $(-) 25$ V)	C1
	$\frac{1}{2}mv^2 = qV$	C1
	$\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 25$	
	or	
	$a = Vq/dm$ and $v^2 = 2as$	(C1)
	$v^2 = (2 \times 75 \times 2 \times 1.60 \times 10^{-19} \times 0.40 \times 10^{-2}) / (1.2 \times 10^{-2} \times 4 \times 1.66 \times 10^{-27})$	(C1)
	$v = 4.9 \times 10^4 \text{ ms}^{-1}$	A1

6 - (9702/42_Winter_2018_Q6) - *Electric Fields*

(a)(i)	work done per unit charge	B1
	work done moving positive charge from infinity (to the point)	B1
(a)(ii)	field strength = potential gradient	M1
	negative sign included or directions discussed	A1
(b)	horizontal straight lines, at non-zero potential, within the spheres	B1
	magnitude of potential greater at surface of sphere A than at surface of sphere B	B1
	concave curve between A and B, with a minimum nearer to B	B1
	lines show <u>V positive</u> all the way from 0 to D	B1



7 - (9702/41_Summer_2019_Q5) - *Electric Fields*

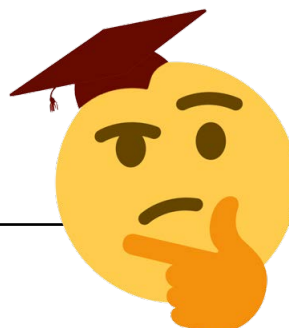
(a)	force per unit charge	B1
	(force on) positive charge	B1
(b)(i)	field changes <u>direction</u> (between A and B)/field is zero at a point (between A and B)	M1
	so charges have same sign	A1
(b)(ii)	Any one from: - field is (also) influenced by charge B - charge A is not isolated/is not the only charge present - field is due to two/both charges - field is the resultant of two fields	B1
(b)(iii)	$E = Q / (4\pi\epsilon_0 x^2)$	C1
	at $x = 10 \text{ cm}$, $E_A = E_B$	C1
	$Q_A / 10^2 = Q_B / 5^2$	A1
	$Q_A / Q_B = 4.0$	

8 - (9702/42_Summer_2019_Q6) - *Electric Fields*

(a)	work done per unit charge	B1
	(work done) moving positive charge from infinity	B1
(b)	straight line with non-zero gradient from $x = 0$ to $x = d$	B1
	line with gradient of constant sign and end-points between which $\Delta V = V_0$ and $\Delta x = d$	B1
	line passes through $(d, 0)$ and $(0, +V_0)$ with negative gradient throughout	B1
(c)	V constant (and non-zero) from $0 \rightarrow R$ and from $(D - R) \rightarrow D$	B1
	equal (non-zero) values of (magnitude of) V at R and $(D - R)$.	B1
	curve (with a minimum) from R to $(D - R)$ with V always positive	B1
	minimum at mid-point of curve	B1

9 - (9702/41_Winter_2019_Q6) - *Electric Fields*

(a)	$(E =) Q / 4\pi\epsilon_0 r^2$	M1
	where ϵ_0 is permittivity (of free space)	A1
(b)(i)	field does not change direction/field does not become zero	M1
	so (charges have) opposite (sign)	A1
(b)(ii)	minimum is at the midpoint (between the charges)	M1
	so (magnitudes are the) same	A1
(c)	force = field strength $\times$ charge and force = mass $\times$ acceleration or acceleration is proportional to field strength	B1
	(from $x = 3.0 \text{ cm}$) to $x = 5.0 \text{ cm}$: acceleration decreases	B1
	at $x = 5.0 \text{ cm}$: acceleration is a minimum	B1
	from $x = 5.0 \text{ cm}$ (to $x = 7.0 \text{ cm}$): acceleration increases	B1



10 - (9702/42_Winter_2019_Q9) - *Electric Fields*

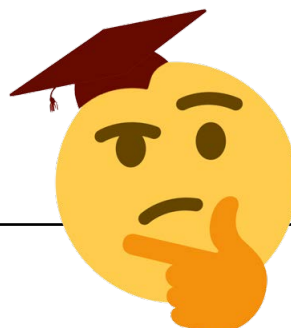
(a)	work done per unit charge	B1
	(work done) moving positive charge from infinity	B1
(b)(i)	energy = $4.8 \times 1.60 \times 10^{-13}$ = 7.7×10^{-13} J	A1
(b)(ii)	$E_F = Qq / 4\pi\epsilon_0 d^2$	C1
	$Q = 79e$ and $q = 2e$	C1
	$7.68 \times 10^{-13} = (79 \times 2 \times \{1.60 \times 10^{-19}\}^2) / (4\pi \times 8.85 \times 10^{-12} \times d)$	C1
	$d = 4.7 \times 10^{-14}$ m	A1
(c)	(diameter must be) less than/equal to 10^{-13} or 10^{-14} m	B1

11 - (9702/41_Summer_2020_Q5) - *Electric Fields*

(a)	similarity: both are radial or both have inverse square (variations)	B1
	difference: direction is always/only towards the mass or direction can be towards or away from charge	B1
(b)	field strength = $Q / 4\pi\epsilon_0 x^2$	C1
	$E = Q / 36\pi\epsilon_0 R^2$	A1
(c)(i)	fields (due to each sphere) are in same direction	B1
(c)(ii)	charges on spheres attract/affect each other or charge distribution on each sphere distorted by the other sphere or charges on the surface of the spheres move	B1
	spheres are not point charges (at their centres)	B1

12 - (9702/42_Summer_2020_Q7) - *Electric Fields*

(a)	force per unit charge	M1
	(force on) positive charge	A1
(b)(i)	no electric field inside a conductor	B1
	$R = 4.5$ cm	A1
(b)(ii)	$E = Q / (4\pi\epsilon_0 x^2)$	C1
	clear correct read-off of a pair of values of E and x	C1
	e.g. $Q = 18 \times 10^5 \times 4\pi \times 8.85 \times 10^{-12} \times (4.5 \times 10^{-2})^2$ = 4.0×10^{-7} C or 4.1×10^{-7} C	A1
(c)	At 8.0 cm, $E = 5.75 \times 10^5$ V m ⁻¹	C1
	$F = Eq$ and $a = F/m$	C1
	$F = (5.75 \times 10^5 \times 2 \times 1.6 \times 10^{-19}) / (4 \times 1.66 \times 10^{-27})$ = 2.8×10^{13} m s ⁻²	A1



13 - (9702/41_Winter_2020_Q5) - *Electric Fields*

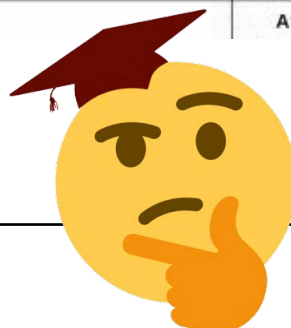
(a)	work done per unit charge	B1
	(work done on charge) moving positive charge from infinity	B1
(b)(i)	$(2.0 \times 10^{-6}) / 4\pi\epsilon_0(4.0 \times 10^{-2}) + Q / 4\pi\epsilon_0(8.0 \times 10^{-2}) = 0$	C1
	$Q = 4.0 \times 10^{-9} \text{ C}$	A1
	Q given with negative sign	B1
(b)(ii)	change = 1200 V	A1
(c)	$\frac{1}{2}mv^2 = qV$	C1
	$\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 1200$	C1
	$v = 3.4 \times 10^5 \text{ m s}^{-1}$	A1

14 - (9702/42_Winter_2020_Q5) - *Electric Fields*

(a)(i)	region (of space)	B1
	where a particle experiences a force	B1
(a)(ii)	similarity – any one point from: - both have an inverse square variation - both decrease with distance - both are radial	B1
	difference – any one point from: - gravitational field always towards (the mass) - electric field can be towards or away from (the charge)	B1
(b)(i)	$E = Q / 4\pi\epsilon_0 x^2$	C1
	$Q = 4\pi \times 8.85 \times 10^{-12} \times 84 \times 0.15^2$	A1
	$= 2.1 \times 10^{-10} \text{ C}$	
(b)(ii)	$E = 84 \times (0.15 / 0.45)^2$	C1
	or	
	$E = (2.1 \times 10^{-10}) / (4\pi \times 8.85 \times 10^{-12} \times 0.45^2)$	
(c)	$E = 9.3 \text{ V m}^{-1}$	A1
	line at $E = 0$ from $x = 0$ to $x = 0.15 \text{ m}$	B1
	smooth curve with decreasing negative gradient throughout, from $x = 0.15 \text{ m}$ to $x = 0.45 \text{ m}$, passing through (0.15, 84)	B1
	line passing through (0.45, 9.3)	B1

15 - (9702/43_Winter_2020_Q5) - *Electric Fields*

(a)	work done per unit charge	B1
	(work done on charge) moving positive charge from infinity	B1
(b)(i)	$(2.0 \times 10^{-6}) / 4\pi\epsilon_0(4.0 \times 10^{-2}) + Q / 4\pi\epsilon_0(8.0 \times 10^{-2}) = 0$	C1
	$Q = 4.0 \times 10^{-9} \text{ C}$	A1
	Q given with negative sign	B1
(b)(ii)	change = 1200 V	A1
(c)	$\frac{1}{2}mv^2 = qV$	C1
	$\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 1200$	C1
	$v = 3.4 \times 10^5 \text{ m s}^{-1}$	A1



16 - (9702/42_Summer_2021_Q5) - *Electric Fields*

(a)	from $x = 0$ to $x = r$: horizontal line at $V = 1.0V_0$	B1
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude starting at $(r, 1.0V_0)$	B1
	line passing through $(2r, \frac{1}{2}V_0)$ and $(3r, \frac{1}{3}V_0)$	B1
(b)	line with negative gradient from $\lambda = \frac{1}{2}\lambda_0$ to $\lambda = \lambda_0$	B1
	line passing through $(\lambda_0, 0)$	B1
	curve with negative gradient of decreasing magnitude passing through $(\frac{1}{2}\lambda_0, E_{\text{MAX}})$ and $(\frac{1}{3}\lambda_0, 2E_{\text{MAX}})$	B1
(c)	$1.0T_{\frac{1}{2}}$ shown at $\frac{1}{2}N_0$ and $2.0T_{\frac{1}{2}}$ shown at $\frac{1}{4}N_0$	B1
	line starting at $(0, 0)$ and reaching $(T, N_0 - N)$	B1
	line starting at $(0, 0)$ and reaching original curve at $(1.0T_{\frac{1}{2}}, \frac{1}{2}N_0)$	B1

17 - (9702/41_Summer_2021_Q6) - *Electric Fields, Quantum Physics, Particle & Nuclear Physics*

(a)	from $x = 0$ to $x = r$: $E = 0$	B1
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude passing through (r, E_0)	B1
	line passing through $(2r, E_0/4)$ and $(3r, E_0/9)$	B1
(b)	from $p = p_0/2$ to $p = p_0$: curve with negative gradient of decreasing magnitude passing through (p_0, λ_0)	B1
	line passing through $(\frac{1}{2}p_0, 2\lambda_0)$	B1
(c)	from $t = 0$ to $t = 45$ s: curve with positive gradient of decreasing magnitude starting at $(0, 0)$	B1
	line passing through $(15, \frac{1}{2}N_0)$	B1
	line passing through $(30, 0.75N_0)$ and $(45, 0.88N_0)$	B1

18 - (9702/41_Summer_2022_Q2) - *Electric Fields*

(a)(i)	(vertically) downwards	B1
(a)(ii)	magnetic force (on sphere) is perpendicular to its velocity	B1
	magnetic force perpendicular to velocity is the centripetal force or magnetic force perpendicular to velocity causes centripetal acceleration or acceleration perpendicular to velocity is centripetal (acceleration) or magnetic force does not change the speed of the sphere or magnetic force has constant magnitude	B1
(b)	$mg = Eq$	C1
	$E = (1.6 \times 10^{-10} \times 9.81) / (0.27 \times 10^{-9})$ $= 5.8 \text{ N C}^{-1}$	A1
(c)	centripetal force = magnetic force or $Bqv = mv^2 / r$	B1
	$B = mv / qr$	C1
	$= (1.6 \times 10^{-10} \times 0.78) / (0.27 \times 10^{-9} \times 3.4) = 0.14 \text{ T}$	A1

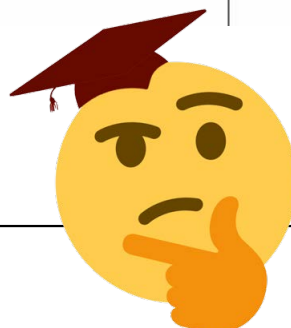


19 - (9702/42_Summer_2022_Q2) - Electric Fields

(a)	(electric) force is (directly) proportional to product of charges	B1
	force (between point charges) is inversely proportional to the square of their separation	B1
(b)(i)	(electric) force is perpendicular to velocity (of particles)	B1
	force (perpendicular to velocity) causes centripetal acceleration or force does not change the speed of the particles or force has constant magnitude	B1
(b)(ii)	$F = e^2 / 4\pi\epsilon_0 x^2$	C1
	$= (1.60 \times 10^{-19})^2 / [4\pi \times 8.85 \times 10^{-12} \times (2 \times 1.59 \times 10^{-10})^2]$	A1
	$= 2.28 \times 10^{-9} \text{ N}$	
(b)(iii)	$F = m\omega^2$ and $\omega = 2\pi / T$ or $F = mv^2 / r$ and $v = 2\pi r / T$	C1
	$F = 4\pi^2 mr / T^2$	C1
	$T = \sqrt{[4\pi^2 \times 9.11 \times 10^{-31} \times 1.59 \times 10^{-10} / (2.28 \times 10^{-9})]}$	
	$= 1.58 \times 10^{-15} \text{ s}$	A1
(c)(i)	- electron and positron interact - positron is anti-particle of electron (pair) annihilation occurs Any two points, 1 mark each	B2
	mass of the electron and positron converted into photon energy	B1
(c)(ii)	PET scanning	B1

20 - (9702/42_Summer_2022_Q5) - Electric Fields

(a)	charge / potential (difference)	M1
	charge is charge on one plate, and potential is p.d. across the plates	A1
(b)	p.d. across both capacitors = E	B1
	$Q_T = Q_1 + Q_2$	B1
	$C_T E = C_1 E + C_2 E$ hence $C_T = C_1 + C_2$	B1
(c)(i)	$[(1/22) + (1/47)]^{-1} = 15 \mu\text{F}$	A1
(c)(ii)	energy = $\frac{1}{2} C V^2$	C1
	$= \frac{1}{2} \times 15 \times 10^{-6} \times 12^2$	A1
	$= 1.1 \times 10^{-3} \text{ J}$	
(c)(iii)	initial p.d. (across $22 \mu\text{F}$) = $12 \times (15/22)$ $= 8.2 \text{ V}$	C1
	or	
	final p.d. across both capacitors = $6.0 \times (22/15)$ $= 8.8 \text{ V}$	
	$V = V_0 \exp[-t / (2.7 \times 10^6 \times 15 \times 10^{-6})]$	C1
	$6.0 = 8.2 \exp[-t / (2.7 \times 10^6 \times 15 \times 10^{-6})]$ or $8.8 = 12 \exp[-t / (2.7 \times 10^6 \times 15 \times 10^{-6})]$	A1
	$t = 13 \text{ s}$	

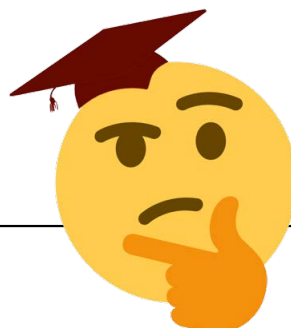


21 - (9702/41_Winter_2022_Q4) - Electric Fields

(a)	(field line indicates) direction of force	B1
	force on a positive charge	B1
(b)(i)	one straight line perpendicular to plates, starting on one plate and finishing on the other	B1
	five straight lines perpendicular to plates between the plates, uniformly spaced	B1
	downwards arrows on lines	B1
(b)(ii)	$E = V/d$	C1
	$= 2400/0.046$	A1
	$= 5.2 \times 10^4 \text{ N C}^{-1}$	
(c)(i)	smooth curve in region of field and straight line outside field	B1
	direction of deflection shown as downwards in region of field	B1
(c)(ii)	helium nucleus has double the charge but four times the mass	B1
	velocity parallel to plates same and acceleration perpendicular to plates smaller (for helium)	B1
	final speed is lower (for helium)	B1

22 - (9702/42_Winter_2022_Q5) - Electric Fields

(a)	work done per unit charge	B1
	work done (on charge) in moving positive charge from infinity (to the point)	B1
(b)(i)	radius = 0.060 m	A1
(b)(ii)	$V = Q/4\pi\epsilon_0 x$	C1
	$Q = (-) 850 \times 4\pi \times 8.85 \times 10^{-12} \times 0.060$	
	or	
	$Q = (-) 850 \times 0.060 / 8.99 \times 10^9$	
	(any correct pair of V and x values from curve)	
	$Q = -5.7 \times 10^{-9} \text{ C}$	A1
(c)(i)	$E_p = Q^2 / 4\pi\epsilon_0 x$	C1
	$= (5.67 \times 10^{-9})^2 / (4\pi \times 8.85 \times 10^{-12} \times 0.46)$	
	$= 6.3 \times 10^{-7} \text{ J}$	A1
(c)(ii)	- force is repulsive so spheres move apart - force in direction of motion so speed increases - potential energy converted to kinetic energy so speed increases - force decreases with distance so acceleration decreases - momentum is conserved (at zero) (and masses are equal) so velocities are always equal and opposite Any three points, 1 mark each	B3

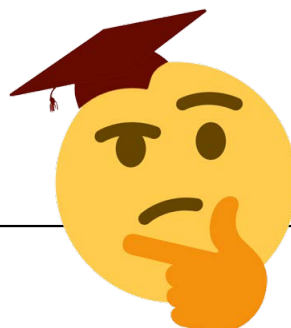


23 - (9702/41_Winter_2023_Q5) - Electric Fields

(a)	work done per unit charge	B1
	work (done on charge) moving positive charge from infinity (to the point)	B1
(b)	Any three points from: Up to 2 points from: - radius of sphere X is 2.0 m - radius of sphere Y is 4.0 m - radius of Y is double the radius of X Up to 2 points from: - charge on X is negative - charge on Y is positive - spheres carry opposite charges Up to 1 point from: - magnitudes of charges on the spheres are equal	B3
(c)	particle is attracted to X or repelled from Y or resultant force on particle is towards X / away from Y / to the left	B1
	particle accelerates towards X / away from Y / to the left	B1
	(magnitude of) acceleration of particle increases	B1

24 - (9702/42_Winter_2023_Q5) - Electric Fields

(a)	(electric) force is (directly) proportional to product of charges	B1
	(electric) force (between point charges) is inversely proportional to the square of their separation	B1
(b)	$F = Q^2 / 4\pi\epsilon_0 x^2$ $6.3 \times 10^{-17} = Q^2 / [4\pi \times 8.85 \times 10^{-12} \times (3.8 \times 10^{-6})^2]$	C1
	charge = 3.2×10^{-18} C	A1
(c)(i)	negative	B1
(c)(ii)	four straight lines perpendicular to the plates, starting on one plate and finishing on the other	B1
	lines equally spaced	B1
	arrows indicating direction downwards	B1
(c)(iii)	$E = V / d$	C1
	$mg = EQ$	C1
	mass = $(1200 \times 3.2 \times 10^{-19}) / (9.81 \times 0.052)$ = 7.5×10^{-16} kg	A1



1 - (9702/42_Summer_2017_Q7) - Capacitance

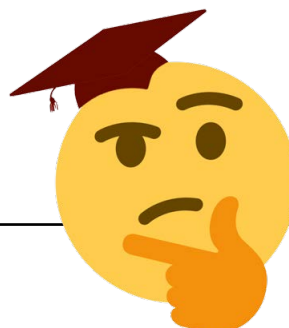
(a)	equal and opposite charges on the plates so no resultant charge
	+ve and –ve charges separated so energy stored
(b)	charge / potential difference
	reference to charge on one plate and p.d. between plates
(c)	energy = $\frac{1}{2} CV^2$ or energy = $\frac{1}{2} QV$ and $C = Q / V$
	$(1 / 16) \times \frac{1}{2} CV_0^2 = \frac{1}{2} CV^2$
	$V = \frac{1}{4} V_0$

2 - (9702/41_Winter_2017_Q6) - Capacitance

(a)(i)	$1/T = 1/(2C) + 1/C$	C1
	$T = \frac{2}{3}C$ or 0.67C	A1
(a)(ii)	same charge on Q as on combination	B1
	so p.d. is 6.0 V	B1
(b)	P: p.d. will decrease (from 3.0 V)	B1
	to zero	B1
	Q: p.d. will increase (from 6.0 V)	B1
	to 9.0 V	B1

3 - (9702/42_Summer_2018_Q6) - Capacitance

(a)	capacitance = charge / potential	M1
	charge is (numerically equal to) charge on one plate	A1
	potential is potential difference between plates	A1
(b)(i)	two in series, in parallel with the other (correct symbols)	A1
(b)(ii)	two in parallel connected to one in series (correct symbols)	A1
(c)(i)	capacitance = 1.2 μF	A1
(c)(ii)	1. $Q = CV$	C1
	$= 1.2 \times 8.0$	A1
	$= 9.6 \mu\text{C}$	
	2. $E = \frac{1}{2} QV$ and $V = Q/C$ or $E = \frac{1}{2} CV^2$ and $V = Q/C$ or $E = \frac{1}{2} Q^2/C$	C1
	$E = \frac{1}{2} (9.6 \times 10^{-6})^2 / (3.0 \times 10^{-6})$ $= 1.5 \times 10^{-5} \text{ J}$	A1



4 - (9702/41_Summer_2018_Q7) - Capacitance

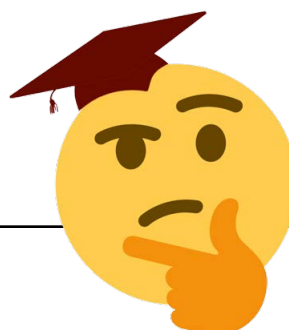
(a)	(capacitance =) charge / potential	M1
	charge is (numerically equal to) charge on one plate	A1
	potential is potential difference between plates	A1
(b)(i)	$4.5 \times 10^{-6} \text{ C}$	A1
(b)(ii)	$9.0 \times 10^{-8} \text{ C}$	A1
(b)(iii)	capacitance = $(9.0 \times 10^{-8}) / 120$	C1
	$= 7.5 \times 10^{-10} \text{ F}$	A1
(c)	total capacitance is halved	B1
	current is halved	B1

5 - (9702/41_Summer_2019_Q6) - Capacitance

(a)	Any valid two points e.g.: - to store (electrical) energy - smoothing/reduce ripple (on direct voltages/currents) - to block d.c. - timing/time delay (circuits) - in oscillator (circuits) - in tuning (circuits) - to prevent arcing/sparks	B2
(b)	clear indication of equal charge on each capacitor	B1
	$E = V_1 + V_2 + V_3$ and $V = Q/C$	M1
	completion of algebra leading to $1/C = 1/C_1 + 1/C_2 + 1/C_3$	A1
(c)(i)	three capacitors connected in parallel	B1
(c)(ii)	parallel combination of three capacitors connected in series with one capacitor	B1

6 - (9702/41_Winter_2020_Q6) - Capacitance

(a)(i)	charge per unit potential (difference)	M1
	charge on one plate <u>and</u> potential difference across the plates	A1
(a)(ii)	any three points from: - smoothing - timing/(time) delay - tuning - oscillator - blocking d.c. - surge protection - temporary power supply	B3
(b)	(capacitors in series have combined capacitance =) $8 \mu\text{F}$	C1
	capacitance = $8 + 24$ $= 32 \mu\text{F}$	A1



7 - (9702/42_Winter_2020_Q6) - Capacitance

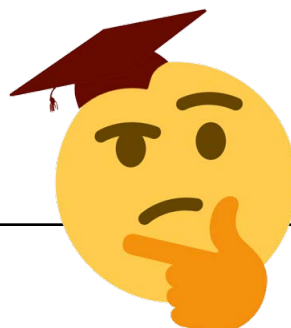
(a)(i)	charge per unit potential (difference)	M1
	charge on one plate and potential difference between the plates	A1
(a)(ii)	any three points from: - smoothing - timing/(time) delaying - tuning - oscillator - blocking d.c. - surge protection - temporary power supply	B3
(b)(i)	parallel combination of two in series and a single capacitor	B1
(b)(ii)	one capacitor in series with two in parallel	B1

8 - (9702/42_Summer_2021_Q6) - Capacitance

(a)	potential difference applied between the plates	M1
	causes charge separation (between the plates)	A1
	or causes energy to be stored (between the plates)	
(b)(i)	$I = Q / t$	M1
	clear substitution of $Q = CV$ and $f = 1 / t$, leading to $I = fCV$	A1
(b)(ii)	$2.5 \times 10^{-6} = 50 \times C \times 180$	C1
	$C = 280 \text{ pF}$	A1
(c)	(total) capacitance increases	B1
	greater charge (for each cycle/discharge) so greater (average) current	B1
	or V and f are constant so (average) current increases	
	or I is (directly) proportional to C so (average) current increases	

9 - (9702/41_Summer_2021_Q7) - Capacitance

(a)	charge / potential	M1
	charge is on one plate, potential is p.d. between the plates	A1
(b)(i)	$I = Q / t$	M1
	charge = CV and time = $1 / f$ leading to $I = fCV$	A1
(b)(ii)	$4.8 \times 10^{-6} = 150 \times 60 \times C$	C1
	$C = 530 \text{ pF}$	A1
(c)	(total) capacitance is halved	B1
	charge (for each cycle/discharge) is halved	B1
	or since f and V are constant, current is proportional to capacitance	
	current = $2.4 \text{ }\mu\text{A}$	B1



10 - (9702/41_Winter_2021_Q6) - Capacitance

(a)	$Q = CV$ and $E = \frac{1}{2}CV^2$	B1
(b)(i)	$C_N = CL / (L - D)$	B1
(b)(ii)	(charge is unchanged by moving the plates so) $Q_N = CV$	B1
(b)(iii)	$V_N = Q_N / C_N$ $= (CV) / [CL / (L - D)]$ $= V(L - D) / L$	B1
(c)	oppositely charged plates attract, so energy stored decreases	B1

11 - (9702/42_Winter_2021_Q6) - Capacitance

(a)	work done per unit charge	B1
	(work done in) moving positive charge from infinity	B1
(b)	$C = Q / V$	C1
	$V = Q / (4\pi\epsilon_0 r)$ and so $C = Q / [Q / (4\pi\epsilon_0 r)] = 4\pi\epsilon_0 r$	A1
(c)	$Q = 4\pi\epsilon_0 rV = 4\pi \times 8.85 \times 10^{-12} \times 0.13 \times 4500$ $(= 6.5 \times 10^{-8} \text{ C})$	C1
	$(Q - q) / 13 = q / 5.2$	C1
	$5.2Q - 5.2q = 13q$, so $q = (5.2 / 18.2)Q$	A1
	$q = (5.2 / 18.2) \times 6.5 \times 10^{-8}$ $= 1.9 \times 10^{-8} \text{ C}$	
	or	
	$V_T = Q_T / C_T$ $= 6.5 \times 10^{-8} / [4\pi \times 8.85 \times 10^{-12} \times (0.13 + 0.052)]$ $(= 3210 \text{ V})$	(C1)
	$q = 4\pi \times 8.85 \times 10^{-12} \times 0.052 \times 3210$ $= 1.9 \times 10^{-8} \text{ C}$	(A1)

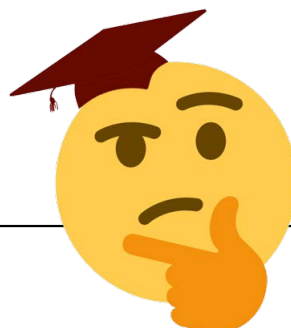
12 - (9702/41_Winter_2022_Q5) - Capacitance

(a)(i)	$Q = CV$	C1
	$Q_0 = 24 \times 470 \times 10^{-6}$ $= 0.011 \text{ C}$	A1
(a)(ii)	$I_0 = 24 / 5600$ $= 4.3 \times 10^{-3} \text{ A}$	A1
(a)(iii)	$\tau = RC$	C1
	$= 5600 \times 470 \times 10^{-6}$	A1
	$= 2.6 \text{ s}$	
(a)(iv)	line with negative gradient throughout passing through $(0, I_0)$	B1
	exponential decay curve asymptotic to t -axis	B1
(b)(i)	current in wire P gives rise to a magnetic field	B1
	as current (in P) changes, wire Q cuts (magnetic) flux (of wire P)	B1
	cutting magnetic flux causes induced e.m.f. (across Q)	B1
(b)(ii)	sketch shows line with a negative gradient throughout	



13 - (9702/42_Winter_2022_Q6) - Capacitance

(a)	- p.d. across resistor = p.d. across capacitor - current (in resistor) proportional to p.d. across it - current causes capacitor to lose charge - charge (on capacitor) proportional to p.d. so p.d. decreases <i>Any two points, 1 mark each</i>	B2
	rate of change of p.d. decreases as p.d. decreases	B1
(b)	$Q_0 = 0.90 \text{ mC}$ and at $t = \text{one time constant}$, $Q = Q_0 \exp(-1)$	B1
	at $t = \text{one time constant}$, $Q = 0.90 \exp(-1) = 0.33 \text{ mC}$	M1
	evidence of graph reading: when $Q = 0.33 \text{ mC}$, $t = 5.5 \text{ s}$	A1
	or	
	evidence of two correct sets of readings for Q and t from the graph	(B1)
	correct substitution of Q and t values into $Q_2 = Q_1 \exp[(t_1 - t_2) / \tau]$	(M1)
	calculation to give $\tau = 5.5 \text{ s}$	(A1)
	or	
	read-off of half-life as 3.75 s	(B1)
	use of $Q = Q_0 \exp(-t / \tau)$ to show that $\tau = \text{half-life} / \ln 2$	(M1)
	$\tau = 3.75 / \ln 2 = 5.4 \text{ s}$	(A1)
(b)	or	
	tangent drawn on $Q-t$ graph and value of Q at exact same time as tangent read from graph	(M1)
	gradient of tangent correctly calculated	(A1)
	$\tau = Q / \text{gradient}$ used to correctly calculate a value for τ as 5.5 s	(A1)
(c)(i)	$C = Q / V$	C1
	$= [(0.90 \times 10^{-3}) / 7.5] = 1.2 \times 10^{-4} \text{ C}$	A1
	$= 120 \mu\text{F}$	
(c)(ii)	$R = \tau / C$	C1
	$= 5.5 / (1.2 \times 10^{-4}) (= 45800 \Omega)$	A1
	$= 46 \text{ k}\Omega$	

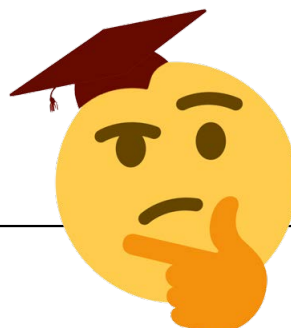


14 - (9702/42_Summer_2023_Q5) - Capacitance

(a)(i)	$Q_A = CV$	A1
(a)(ii)	$E_A = \frac{1}{2}CV^2$	A1
(b)(i)	some of the charge transfers to (the plates of) capacitor B	B1
	transfer is because the p.d.s across the capacitors are not equal or transfer stops when the p.d.s across the capacitors become equal	B1
(b)(ii)	$V_A = V_B$	M1
	charge on A + charge on B = CV	M1
	$CV_B + 3CV_B = CV$ leading to $V_B = V/4$	A1
	or	
	$C_T = 4C$	(M1)
	$Q_T = CV$	(M1)
	$V_B = CV/4C = V/4$	(A1)
(b)(iii)	$\Delta E = \frac{1}{2}CV^2 - nCV^2$, where n is a multiple that is less than $\frac{1}{2}$ or total final energy = $\frac{1}{2} \times 4C \times (V/4)^2$ = $\frac{1}{8}CV^2$	C1
	$\Delta E = \frac{1}{2}CV^2 - \frac{1}{8}CV^2$	A1
	= $\frac{3}{8}CV^2$	

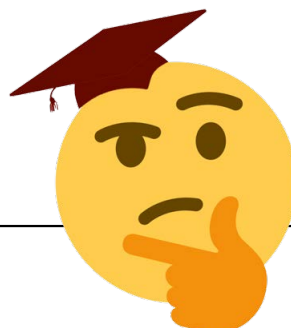
15 - (9702/43_Summer_2023_Q5) - Capacitance

(a)(i)	correct circuit symbol for a diode shown correctly connected in series with the wires leading into and out of the dotted box	B1
(a)(ii)	smoothing / V_{OUT} is smoothed	B1
(b)(i)	frequency = $1/0.04$	A1
	= 25 Hz	
(b)(ii)	$V = V_0 \exp(-t/RC)$ and $\tau = RC$ or $V = V_0 \exp(-t/\tau)$	C1
	$3.25 = 5.50 \exp(-0.020/\tau)$ leading to $\tau = 0.038$ s	A1
(b)(iii)	$\tau = RC$	C1
	capacitance = $0.038/14000$	A1
	= 2.7×10^{-6} F	
(c)	V_{IN} has constant magnitude in both positive and negative directions	B1
	(so) V_{OUT} is (now) constant / V_{OUT} does not vary with time	B1



16 - (9702/42_Winter_2023_Q6) - Capacitance

(a)(i)	energy stored = area under graph	C1
	$= \frac{1}{2} \times 450 \times 10^{-6} \times 8.0 = 1.8 \times 10^{-3} \text{ J or } 1.8 \text{ mJ}$	A1
(a)(ii)	$C = Q / V \text{ or } E = \frac{1}{2} CV^2$	C1
	$C = (450 \times 10^{-6}) / 8.0 \text{ or } (2 \times 1.8 \times 10^{-3}) / 8.0^2$ $= 5.6 \times 10^{-5} \text{ F}$	A1
(b)(i)	$V = V_0 \exp(-t / RC) \text{ and } \tau = RC$	C1
	$V = V_0 \exp(-t / \tau)$	A1
	$V_0 = 8.0 \text{ V, and at one time constant, } t = \tau$	
	$V / 8.0 = \exp(-\tau / \tau), \text{ so } \ln(V / 8.0) = -1.0 \text{ or } -\ln(V / 8.0) = 1.0$	
(b)(ii)	[t read from graph at $-\ln(V / 8.0) = 1.0$]: $\tau = 3.2 \text{ s}$	A1
(b)(iii)	$\tau = RC$	C1
	$R = 3.2 / (5.6 \times 10^{-5})$ $= 5.7 \times 10^4 \Omega$	A1



1 - (9702/42_Summer_2017_Q6) - *Electric Fields, Current Of Electricity*

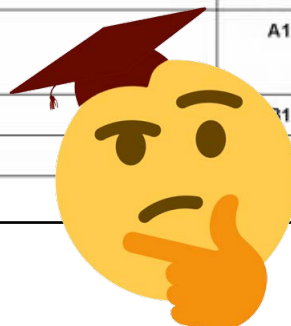
(a)	force proportional to product of charges and inversely proportional to the square of the separation reference to point charges
(b)(i)	(near to each sphere,) fields are in opposite directions or point (between spheres) where fields are equal and opposite or point (between spheres) where field strength is zero so same (sign of charge)
(b)(ii)	(at $x = 5.0 \text{ cm}$,) $E = 3.0 \times 10^3 \text{ V m}^{-1}$ and $a = qE/m$ $E = (1.60 \times 10^{-19} \times 3.0 \times 10^3) / (1.67 \times 10^{-27})$ $= 2.9 \times 10^{11} \text{ ms}^{-2}$
(c)	field strength or E is potential gradient or field strength is rate of change of (electric) potential (field strength) maximum at $x = 6 \text{ cm}$

2 - (9702/41_Summer_2021_Q8) - *Current Of Electricity*

(a)	$V^+ = 3.0 \times 3.0 / (2.5 + 3.0)$ $= 1.6 \text{ V}$	C1 A1
(b)	V^- is $+2.0 \text{ V}$ or $V^- > V^+$ output is negative so (LED) does not emit light	B1 B1
(c)	at 0°C , $V^- = 1.7 \text{ V}$ or for all temperatures above 0°C , resistance of thermistor $< 4.2 \text{ k}\Omega$ V^- always greater than V^+ (so no switching)	B1 B1
(d)	(at 20°C ,) $R_T = 1.8 \text{ k}\Omega$ $2.5 / 3.0 = 1.8 / R$ or $[R / (R + 1.8)] \times 3.0 = 1.6$ $R = 2.2 \text{ k}\Omega$	C1 C1 A1

3 - (9702/41_Summer_2023_Q5) - *Current Of Electricity*

(a)(i)	correct circuit symbol for a diode shown correctly connected in series with the wires leading into and out of the dotted box	B1
(a)(ii)	smoothing / V_{OUT} is smoothed	B1
(b)(i)	frequency $= 1 / 0.04$ $= 25 \text{ Hz}$	A1
(b)(ii)	$V = V_0 \exp(-t / RC)$ and $\tau = RC$ or $V = V_0 \exp(-t / \tau)$ $3.25 = 5.50 \exp(-0.020 / \tau)$ leading to $\tau = 0.038 \text{ s}$	C1 A1
(b)(iii)	$\tau = RC$ capacitance $= 0.038 / 14000$ $= 2.7 \times 10^{-6} \text{ F}$	C1 A1
(c)	V_{IN} has constant magnitude in both positive and negative directions (so) V_{OUT} is (now) constant / V_{OUT} does not vary with time	B1

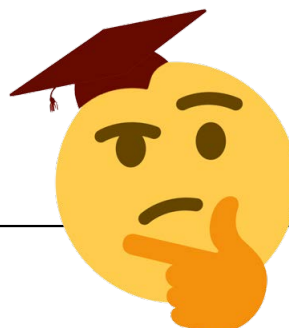


1 - (9702/41_Summer_2017_Q6) - D.c. Circuits, Electronics

(a)(i)	lamp needs 'high' power/'large' current/'large' voltage
	op-amp can deliver only a small current/small voltage
(a)(ii)	correct symbol for relay coil connected between output and earth
	switch between mains supply and lamp
(b)(i)	vary light intensity at which lamp is switched on/off
(b)(ii)	so that relay operates for only one current/voltage direction
	or so that relay/lamp operates for either dark or light conditions
(c)	when light level increases, LDR resistance decreases
	($R_{\text{LDR low}}$) so $V^- > V^+$, so V_{OUT} negative/-5 V (must be consistent with B1 mark)
	or
	when light level decreases, LDR resistance increases
	($R_{\text{LDR high}}$) so $V^- < V^+$, so V_{OUT} is positive/+5 V (must be consistent with B1 mark)
	lamp comes on as light level decreases or lamp goes off as light level increases

2 - (9702/43_Summer_2021_Q8) - Current Of Electricity, D.c. Circuits

(a)	$V^- = 3.0 \times 3.0 / (2.5 + 3.0)$	C1
	$= 1.6 \text{ V}$	A1
(b)	V^- is +2.0 V or $V^- > V^+$	B1
	output is negative so (LED) does not emit light	B1
(c)	at 0 °C, $V^- = 1.7 \text{ V}$ or for all temperatures above 0 °C, resistance of thermistor $< 4.2 \text{ k}\Omega$	B1
	V^- always greater than V^+ (so no switching)	B1
(d)	(at 20 °C,) $R_T = 1.8 \text{ k}\Omega$	C1
	$2.5 / 3.0 = 1.8 / R$	C1
	or $[R / (R + 1.8)] \times 3.0 = 1.6$	
	$R = 2.2 \text{ k}\Omega$	A1

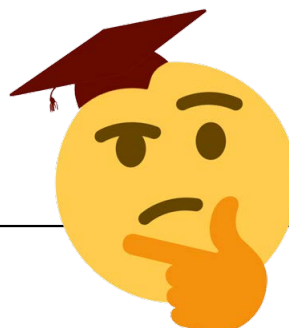


1 - (9702/41_Summer_2017_Q6) - D.c. Circuits, Electronics

(a)(i)	lamp needs 'high' power/'large' current/'large' voltage
	op-amp can deliver only a small current/small voltage
(a)(ii)	correct symbol for relay coil connected between output and earth
	switch between mains supply and lamp
(b)(i)	vary light intensity at which lamp is switched on/off
(b)(ii)	so that relay operates for only one current/voltage direction
	or so that relay/lamp operates for either dark or light conditions
(c)	when light level increases, LDR resistance decreases
	($R_{\text{LDR low}}$) so $V^- > V^+$, so V_{OUT} negative/-5 V (must be consistent with B1 mark)
	or
	when light level decreases, LDR resistance increases
	($R_{\text{LDR high}}$) so $V^- < V^+$, so V_{OUT} is positive/+5 V (must be consistent with B1 mark)
	lamp comes on as light level decreases or lamp goes off as light level increases

2 - (9702/42_Summer_2017_Q8) - Electronics

(a)(i)	circle around both diodes
(a)(ii)	indicates (whether) temperature
	(is) above or below a set value
(b)(i)	(when resistance of C $> R_V$) $V^- > V^+$ or $V^+ < 3V$
	or
	p.d. across $R_V < \text{p.d. across } R/Y/3V$
	or
	p.d. across C $> \text{p.d. across } R/X/3V$
(b)(ii)	op-amp output is negative
	(only) green
	resistance of C becomes less than R_V
	or $V^- < V^+$
(c)	green (LED) goes out
	blue (LED) comes on
	changes/determines <u>temperature</u> at which LEDs switch



3 - (9702/41_Winter_2017_Q7) - Electronics

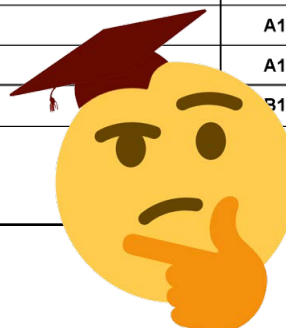
(a)(i)	gain of amplifier is very large	B1
	V^- is at earth (potential)	B1
	for amplifier not to saturate	M1
	difference between V^- and V^+ must be very small or V^- must be equal to V^+	A1
	or	
	if $V^- = V^+$ then feedback voltage	(M1)
	acts to reduce gap until $V^- = V^+$ when stable	(A1)
(a)(ii)	input impedance is infinite	B1
	(so) current in R_1 = current in R_2	B1
	$(V_{IN} - 0) / R_1 = (0 - V_{OUT}) / R_2$	B1
	(gain =) $V_{OUT} / V_{IN} = -R_2 / R_1$	B1
(b)	graph: correct inverted shape (straight diagonal line from (0,0) to a negative potential, then a horizontal line, then a straight diagonal line back to the t -axis at the point where $V_{IN} = 0$)	B1
	horizontal line at correct potential of (-9.0V)	B1
	both ends of horizontal line occur at correct times (coinciding with when $V_{IN} = 2.0\text{V}$)	B1

4 - (9702/42_Winter_2017_Q7) - Electronics

(a)(i)	(part of) the output is combined with the input	M1
	reference to potential/voltage/signal	A1
(a)(ii)	- increased (operating) stability - increased bandwidth/range of frequencies over which gain is constant - less distortion (of output) Any 2 points.	B2
(b)(i)	1. gain = $3.6 / (48 \times 10^{-3})$	C1
	= 75	A1
	2. gain = $1 + R_F / R$	C1
	$75 = 1 + (92.5 \times 10^3) / R$	
	$R = 1300 \Omega$	A1
(b)(ii)	for 68 mV, gain $\times V_{IN} = 5.1\text{ (V)}$ or output voltage would be greater than the supply voltage	M1
	amplifier would saturate (at 5.0 V) or output voltage = 5.0 (V)	A1

5 - (9702/42_Summer_2018_Q7) - Electronics

(a)(i)	(fraction of) output is combined with the input	M1
	output (fraction) <u>subtracted/deducted</u> from input	A1
(a)(ii)	Any two valid points e.g. - greater bandwidth/gain constant over a larger range of frequencies - smaller gain	B2
(b)(i)	gain = $1 + (6400 / 800)$	
	= 9.0	A1
(b)(ii)	1. (+)5.4 V	A1
	2. -9.0 V	A1
(b)(iii)	replace the 6400Ω resistor with a thermistor	B1



6 - (9702/41_Summer_2018_Q8) - Electronics

(a)(i)	(fraction of) output is combined with the input	M1
	output (fraction) subtracted/deducted from input	A1
(a)(ii)	any two valid points e.g.: - greater bandwidth/gain constant over a larger range of frequencies/greater bandwidth - smaller gain	B2
(b)(i)	gain = $(-9600/800)$	C1
	= -12	A1
(b)(ii)	1. 1.2V	B1
	2. -6V	B1
(b)(iii)	replace the 9600Ω resistor with an LDR	B1

7 - (9702/41_Winter_2018_Q7) - Electronics

(a)(i)	gain is constant	M1
	for all frequencies	A1
(a)(ii)	no time delay between input (voltage) and output (voltage)	B1
	clear reference to <u>change</u> (s) in input and/or output (voltages)	B1
(b)	diagram: V_{IN} connected to V^+ only	B1
	midpoint between resistors R_1 and R_2 connected to V^- only	B1
(c)(i)	-3.6V	A1
(c)(ii)	(+)5.0V	A1

8 - (9702/42_Winter_2018_Q7) - Electronics

(a)	$R/R_T = 2.4/1.8$ or at 4.0°C , $R_T = 3.2\text{ k}\Omega$	C1
	hence $R/3.2 = 2.4/1.8$	A1
	$R = 4.3\text{ k}\Omega$	
(b)	$R_T = 3.37\text{ k}\Omega$ or R_T is greater (than $3.2\text{ k}\Omega$)	B1
	$V^+ > V^-$	M1
	hence output is +5.0V	A1
(c)	correct LED symbol	B1
	two diodes shown connected, in parallel and with opposite polarities, between V_{OUT} and earth	M1
	diodes labelled to show correct polarities consistent with (b) (G pointing from V_{OUT} to earth and B pointing from earth to V_{OUT} if (b) correct)	A1



9 - (9702/42_Summer_2019_Q5) - Communication, Electronics

(a)(i)	loss of (signal) power/amplitude/intensity	B1
(a)(ii)	unwanted/random signal	B1
	superposed on (transmitted) signal	B1
(b)(i)	attenuation = $10 \lg(P_2 / P_1)$	C1
	attenuation per unit length = $(1 / L) \times 10 \lg(P_2 / P_1)$ = $(1 / 52) \times 10 \lg[(2.5 \times 10^{-3}) / (7.8 \times 10^{-16})]$	C1
	= 2.4 dB km^{-1}	A1
(b)(ii)	gain / dB = $10 \lg(P_2 / P_1)$ $115 = 10 \lg[P / (7.8 \times 10^{-16})]$	C1
	$P = 2.5 \times 10^{-4} \text{ W}$	A1

10 - (9702/41_Summer_2019_Q7) - Electronics

(a)(i)	(amplifier) gain is very large/infinite	B1
	for amplifier not to saturate, $V^+ = V^-$ or feedback (loop) ensures $V^+ = V^-$	B1
	V^+ is at earth/0 V so V^- is (almost) at earth/0 V	B1
(a)(ii)	gain = $(-5200 / 800)$ or $(-5.2 / 0.80)$	C1
	= -6.5	A1
(b)	(at saturation,) $V_{\text{OUT}} = 5 \text{ V}$	C1
	p.d. across R = $5 - 2.3$ = 2.7 (V)	C1
	resistance = $2.7 / (30 \times 10^{-3})$ = 90Ω	A1
	or	
	$R_{\text{diode}} = 2.3 / 0.030 = 77 \Omega$	(C1)
	$R_{\text{total}} = 5.0 / 0.030 = 167 \Omega$	
	$R_{\text{resistor}} (= 167 - 77) = 90 \Omega$	(A1)
	or	
	$R_{\text{diode}} = 2.3 / 0.030 = 77 \Omega$	(C1)
	$77 / (R_{\text{resistor}} + 77) \times 5 = 2.3$	
	$R_{\text{resistor}} = 90 \Omega$	(A1)
	or	
	$R_{\text{diode}} = 2.3 / 0.030 = 77 \Omega$	(C1)
	$R_{\text{resistor}} = 77 \times (2.7 / 2.3)$	
	$R_{\text{resistor}} = 90 \Omega$	(A1)



11 - (9702/42_Summer_2019_Q9) - *Electronics*

(a)(i)	relay coil shown connected between diode and earth	B1
	switch shown connected across lamp	B1
(a)(ii)	Any one from: • (for diode to conduct) current flow is into output of op-amp • when earth is at higher potential diode is forward biased • diode blocks current when output positive • diode must conduct	M1
	so V_{OUT} is negative	A1
(b)(i)	strain gauge	B1
(b)(ii)	light-dependent resistor	B1

12 - (9702/41_Winter_2019_Q7) - *Electronics*

(a)(i)	all frequencies are amplified equally	B1
(a)(ii)	no drop in output voltage (when there is a current)	B1
(b)(i)	gain = $1 + R_F / R_{IN}$ = $1 + (4000 / 800)$	C1
	= 6.0	A1
(b)(ii)	$2.0 / V_{IN} = 6.0$ $V_{IN} = (+)0.33 \text{ V}$	A1
(b)(iii)	5.0 V	A1
(b)(iv)	$V = 5.0 - 2.2 (= 2.8 \text{ V})$	C1
	$R = V / I$ = $2.8 / 0.020$ = 140Ω	A1

13 - (9702/42_Winter_2019_Q10) - *Electronics, Quantum Physics*

(a)	(as temperature rises) electrons in valence band gain energy	B1
	electrons jump to conduction band	B1
	holes are left in the valence band	B1
	increased <u>number</u> (density) of charge carriers causes lower resistance	B1
(b)(i)	$V^- = V^+$	C1
	$1.50 / 1.20 = R_T / 1.76$	C1
	$R_T = 2.2 \text{ (k}\Omega\text{)}$	C1
	temperature = 14°C	A1
(b)(ii)	(For LED to conduct,) V_{OUT} must be negative	B1
	$V^- > V^+$	B1
	R_T must be lower so temperature must be above (b)(i) value	B1



14 - (9702/41_Summer_2020_Q7) - *Electronics*

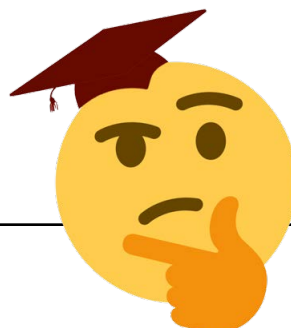
(a)	output signal proportional to input signal	B1
	output signal has same sign/polarity as input signal	B1
(b)(i)	gain = V_{OUT} / V_{IN} = $2.6 / 0.084$ = 31	A1
(b)(ii)	$31 = 1 + (15 \times 10^3) / R$	C1
	$R = 500 \Omega$	A1
(c)(i)	e.g. cathode-ray oscilloscope/CRO	B1
(c)(ii)	gain is reduced	B1
	(so) V_{OUT} is smaller	B1

15 - (9702/42_Summer_2020_Q8) - *Electronics*

(a)(i)	constant gain for all frequencies	B1
(a)(ii)	unchanged	B1
(b)(i)	(open loop) gain of op-amp is infinite	B1
	feedback loop ensures $V^+ \approx V^-$ or any difference between V^+ and V^- results in saturated output	B1
	non-inverting input is 0 V so inverting input also at 0 V	B1
(b)(ii)	input = $(40 \times 1.5) / (40 + 110)$	C1
	= 0.40 V	A1
(b)(iii)	gain = $(-)(100 + 230) / 150$ or feedback current = $0.40 / (150 \times 10^3)$ (A)	C1
	p.d. = $[(100 + 230) / 150] \times 0.40$	A1
	= 0.88 V	
(c)	(magnitude of) gain decreases	M1
	voltmeter reading decreases	A1

16 - (9702/41_Winter_2020_Q7) - *Electronics*

(a)	two resistors connected in series between earth and positive of battery and no extra connections	B1
	one resistor and thermistor connected in series between earth and positive of battery and no extra connections	B1
	midpoints of the two potential dividers connected, one each, to the op-amp input terminals	B1
	thermistor in correct place in potential divider circuit (either the upper part of the potential divider leading to V^+ or the lower part of the potential divider leading to V^-)	B1
(b)(i)	value greater than 1000Ω	A1
(b)(ii)	non-zero value less than 1000Ω	A1



17 - (9702/42_Winter_2020_Q8) - Electronics

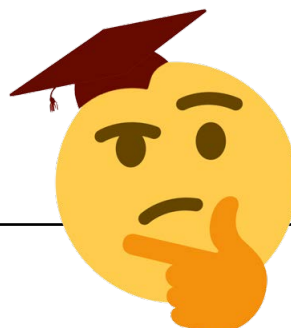
(a)(i)	gain is the same for all frequencies	B1
(a)(ii)	no (time) delay in change in output when input is changed	B1
(b)(i)	(at saturation,) $V_{OUT} = 5.0 \text{ V}$	C1
	gain = $5.0 / 0.40$ = 12.5 or 13	A1
(b)(ii)	$12.5 = 1 + (R / 800)$	C1
	$R = 9200 \Omega$	A1

18 - (9702/42_Summer_2021_Q7) - Electronics

(a)(i)	no current enters/leaves the input	B1
(a)(ii)	gain is the same for all frequencies	B1
(b)(i)	$V_{IN} = 1.5 \times 400 / (400 + 1100) = 0.40 \text{ V}$ or $V_{IN} = 1.5 - (1.5 \times 1100 / 1500) = 0.40 \text{ V}$ or $(1.5 - V_{IN}) / 1100 = V_{IN} / 400$ so $V_{IN} = 0.40 \text{ V}$	A1
(b)(ii)	gain = $(-) R_f / R_i$	C1
	$V_{OUT} / 0.40 = (360 + 100) / 96$	C1
	$V_{OUT} = 1.9 \text{ V}$	A1
(b)(iii)	resistance of thermistor decreases	B1
	(magnitude of) gain decreases so reading decreases	B1
(b)(iv)	(at gain 12.5) V_{OUT} is 5.0 V , so (above gain 12.5) output becomes saturated	B1

19 - (9702/41_Winter_2021_Q7) - Electronics

(a)	- infinite (open-loop) gain - infinite slew rate - infinite input impedance - zero output impedance - infinite bandwidth Any two points, 1 mark each	B2
(b)	X: thermistor and Y: relay	B1
(c)(i)	(any) difference in voltage at the inputs causes output to saturate (because gain is very large)	B1
	saturates positively if $V^+ > V^-$ and saturates negatively if $V^+ < V^-$	B1
(c)(ii)	comparator	B1
(c)(iii)	temperature	M1
	above a particular value	A1
(c)(iv)	to adjust the temperature (at which the lamp illuminates/extinguishes)	B1

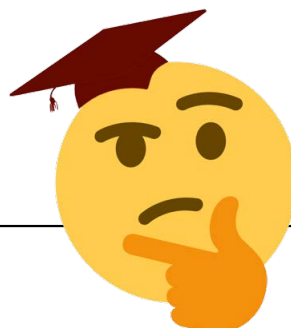


20 - (9702/42_Winter_2021_Q7) - Electronics

(a)	output voltage / input voltage	M1
	input (voltage) is difference between (inverting and non-inverting) inputs	A1
(b)	- reduces the gain - greater bandwidth - more stable <i>Any two points, 1 mark each</i>	B2
(c)(i)	inverting amplifier	B1
(c)(ii)	X marked anywhere between right-hand edge of 480Ω resistor, left-hand edge of $1.2\text{ k}\Omega$ resistor and the inverting input	B1
(c)(iii)	gain = $(-R_f / R_i)$	C1
	= $(-1200 / 480)$	A1
	= -2.5	
(c)(iv)	$V_{IN} = 6.5 / (-2.5)$ $= -2.6\text{ V}$	A1
(c)(v)	$(-2.5) \times (-5.4) = +13.5\text{ V}$, and so output saturates $V_{OUT} = (+)8.0\text{ V}$	A1

21 - (9702/41_Summer_2023_Q7) - Electronics

(a)	wavelength associated with a <u>moving</u> particle	B1
(b)(i)	(electron) diffraction	B1
(b)(ii)	beam spreads out indicating diffraction or light and dark regions indicate an interference pattern	B1
	electron beam is behaving as a wave	B1
(c)(i)	central blob and concentric rings	B1
	rings closer together (than previously)	B1
(c)(ii)	(greater p.d. so) electrons to have greater momentum	B1
	greater momentum so decrease in (de Broglie) wavelength	B1
	lower (de Broglie) wavelength (for same grating spacing in crystal) causes: smaller diffraction angle or smaller angle of intensity maxima (for each order) or decrease in fringe spacing in diffraction pattern	B1



1 - (9702/41_Summer_2017_Q7) - Magnetic Fields

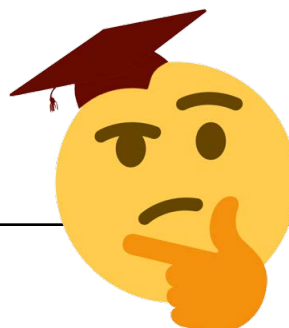
(a)	(magnetic) force (always) normal to velocity/direction of motion
	(magnitude of magnetic) force constant or speed is constant/kinetic energy is constant
	so provides the centripetal force
(b)	increase in KE = loss in PE or $\frac{1}{2}mv^2 = qV$
	$p = mv$ with algebra leading to $p = \sqrt{2mqV}$
(c)	$Bqv = mv^2 / r$
	$mv = Bqr$ or $p = Bqr$
	$(2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2} = B \times 1.60 \times 10^{-19} \times 0.074$
	$B = 5.0 \times 10^{-4} \text{ T}$
(d)	greater momentum
	($p = Bqr$ and) so r increased

2 - (9702/41_Summer_2017_Q8) - Magnetic Fields

strong (uniform) magnetic field
* <u>nuclei</u> precess/rotate about field (direction)
radio frequency pulse/RF pulse (applied)
* RF or pulse is at Larmor frequency / frequency of precession
causes resonance / excitation (of nuclei)/nuclei to absorb energy
on relaxation/de-excitation, nuclei emit RF/pulse
* (emitted) RF/pulse detected and processed
non-uniform field (superposed on uniform field)
allows positions of (resonating) <u>nuclei</u> to be determined
* allows for position of detection to be changed/different slices to be studied
max. 2 of additional detail points marked *

3 - (9702/42_Summer_2017_Q9) - Magnetic Fields

(a)(i)	Hall voltage depends on thickness of slice
	thinner slice, larger Hall voltage
(a)(ii)	Hall voltage depends on current in slice
(b)	sinusoidal wave, one cycle
	at $\theta = 0$ and at $\theta = 360^\circ$, $V_H = V_{\text{MAX}}$
	at $\theta = 180^\circ$, $V_H = -V_{\text{MAX}}$



4 - (9702/41_Winter_2017_Q8) - *Magnetic Fields, Electromagnetic Induction*

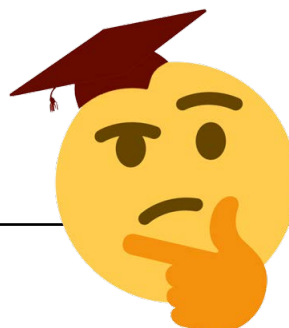
(a)	DERQ and CFSP	B1
(b)(i)	force (on charge) due to magnetic field = force due to electric field or $Bqv = Eq$ or $v = E/B$	B1
	$E = V_H/d$	B1
	$V_H = Bvd$	B1
(b)(ii)	use of $I = nAqv$ and $A = dt$	M1
	algebra clear leading to $V_H = BI/ntq$	A1
(c)	(in metal,) n is very large	M1
	(therefore) V_H is small	A1

5 - (9702/42_Winter_2017_Q9) - *Magnetic Fields*

(a)	region (of space)	B1
	where an object/particle experiences a force	B1
(b)	electric and magnetic fields normal to each other	B1
	velocity of particle normal to both fields	B1
	forces (on particle) due to fields are in opposite directions	B1
	forces are equal for particles with a particular speed/for a selected speed/for speed given by $v = E(q)/B(q)$	B1
(c)(i)	path labelled Q shown undeviated	B1
(c)(ii)	reasonable curve in field and no 'kink' on entering, labelled V	B1
	deviated 'upwards'	B1

6 - (9702/42_Summer_2018_Q8) - *Magnetic Fields*

(a)	electric and magnetic fields at right-angles to one another (<i>may be shown on a clearly labelled diagram</i>)	B1
	particle enters fields (with velocity) normal to the (two) fields (<i>may be shown on a clearly labelled diagram</i>)	B1
	no deviation for particles with selected velocity	B1
(b)	magnetic force equals/is the centripetal force	C1
	$Bqv = mv^2/r$	C1
	$M = Bqriv$	M1
	$= (94 \times 10^{-3} \times 1.6 \times 10^{-19} \times 0.075) / (3.4 \times 10^4)$	
	division by 1.66×10^{-27} shown, to give $m = 20 \text{ u}$	A1
(c)	sketch: semicircle clear (in same direction)	B1
	with larger radius	B1



7 - (9702/41_Summer_2018_Q9) - *Magnetic Fields, Alternating Currents*

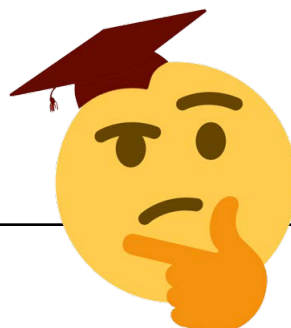
(a)	using Fleming's left-hand rule force on wire is upwards	B1
	by Newton's third law, force on magnet is downwards	B1
(b)(i)	$F = BIL$	C1
	$= 3.7 \times 10^{-3} \times 5.1 \times 8.5 \times 10^{-2}$	A1
	$= 1.6 \times 10^{-3} \text{ N}$	
(b)(ii)	$F = 1.6 \times 10^{-3} \text{ N}$	A1
(c)	sketch: sinusoidal wave with two cycles	B1
	amplitude $2.3 \times 10^{-3} \text{ N}$	B1
	period 0.05 s	B1

8 - (9702/42_Summer_2018_Q11) - *Magnetic Fields*

(a)	<u>X-ray image(s) taken of one slice</u>	M1
	(many images) taken from <u>different angles</u>	A1
	(computer) produces 2D image <u>of slice</u>	B1
	(this is) repeated for (many) <u>slices</u>	M1
	to build up a 3D image (of structure)	A1
(b)(i)	combining of <u>images</u> involves (very) large number of calculations	B1
(b)(ii)	CT scan consists of (very) many (single X-ray) images	B1

9 - (9702/41_Winter_2018_Q8) - *Magnetic Fields*

(a)	region where there is a force	M1
	experienced by a current-carrying conductor/moving charge/(permanent) magnet	A1
(b)(i)	single path, deflection in 'upward' direction	B1
	acceptable circular arc in whole field	B1
	no 'kinks' at start or end of curvature, and straight outside region of field	B1
(b)(ii)	force (on particle) is normal to velocity/direction of motion/direction of speed	B1
(c)	magnetic force provides/is the centripetal force	B1
	$Bqv = mv^2/r$ or $r = mv/Bq$	C1
	(if q is doubled), new speed = $2v$	A1



10 - (9702/42_Winter_2018_Q8) - *Magnetic Fields*

(a)	force per unit current	B1
	force per unit length (of wire)	B1
	current normal to (magnetic) field	B1
(b)(i)	forces (on PQ and RS) are horizontal	B1
	(hence they create) no moment about the pivot	B1
	or	
	forces (on PQ and RS) are equal and opposite	(B1)
	(hence there is) no <u>net</u> force (on the two sections)	(B1)
(b)(ii)	realisation of the need to apply moments	C1
	$BILx = mgy$	C1
	$B \times 2.7 \times 1.2 \times 10^{-2} \times 7.5 = 45 \times 10^{-6} \times 9.81 \times 8.8$	
	$B = 1.6 \times 10^{-2} \text{ T}$	A1

11 - (9702/41_Summer_2019_Q8) - *Magnetic Fields, Electromagnetic Induction*

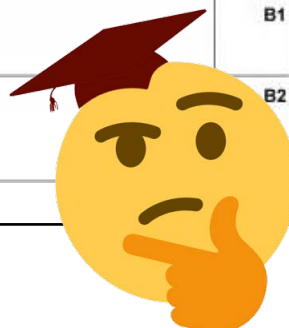
(a)(i)	region where a force is exerted on: a magnetic pole or a moving charge or a current-carrying wire	B1
(a)(ii)	arrow on axis of solenoid pointing downwards labelled P	B1
(b)(i)	<u>direction</u> of induced e.m.f./current	M1
	(tends to) oppose the change causing it	A1
(b)(ii)	magnetic field in solenoid is increasing	B1
	field in coil in opposite direction to oppose increase	B1
	arrow inside or just above small coil pointing in opposite direction to P	B1
(c)	e.m.f. = $N \Delta \phi / \Delta t$	C1
	$= (75 \times 1.4 \times 10^{-3} \times 2 \times 7.0 \times 10^{-4}) / 0.12$	C1
	$= 1.2 \times 10^{-3} \text{ V}$	A1

12 - (9702/42_Summer_2019_Q8) - *Magnetic Fields*

(a)(i)	$v_N = 3.4 \times 10^7 \times \sin 30^\circ$ $= 1.7 \times 10^7 \text{ m s}^{-1}$	A1
(a)(ii)	$mv^2 / r = Bqv$ or $r = mv / Bq$	C1
	$r = (9.11 \times 10^{-31} \times 1.7 \times 10^7) / (3.2 \times 10^{-3} \times 1.60 \times 10^{-19})$	C1
	$= 0.030 \text{ m}$	A1
(b)	zero	B1
(c)	helix/coil	B1

13 - (9702/41_Summer_2019_Q9) - *Magnetic Fields*

(a)	nuclei precess	B1
	precession is about direction of magnetic field	B1
	frequency of precession depends on field strength	B1
	or frequency of precession is in radio-frequency range	
(b)	Any two points from: - frequency (of precession) depends on position - to locate position of (spinning) nuclei - to change region where nuclei are detected	B2



14 - (9702/42_Winter_2019_Q7) - *Magnetic Fields*

	X-rays are used	B1
	section (of object) is scanned	B1
	scans/images taken at many angles/directions or images of each section are 2-dimensional	B1
	images of (many) sections are combined	B1
	(to give) 3-dimensional image of (whole) structure	B1

15 - (9702/41_Winter_2019_Q8) - *Magnetic Fields*

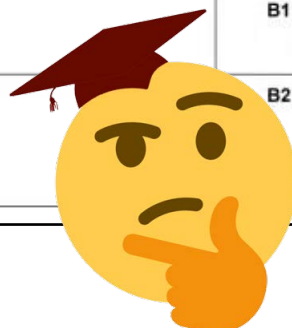
(a)	concentric circles (around the wire)	M1
	at least 3 circles shown, all with increasing separation	A1
	direction anticlockwise	B1
(b)(i)	$B = (4\pi \times 10^{-7} \times 6.2) / (2\pi \times 3.1 \times 10^{-2})$	C1
	$= 4.0 \times 10^{-5} \text{ T}$	A1
(b)(ii)	$F = BIL$ or $F/L = BI$	C1
	$F/L = 4.0 \times 10^{-5} \times 8.5$	A1
	$= 3.4 \times 10^{-4} \text{ N m}^{-1}$	
(c)	correct application of Newton's 3rd law to the forces or F/L is proportional to the product of the two currents	M1
	so same magnitude	A1

16 - (9702/42_Winter_2019_Q8) - *Magnetic Fields, Electromagnetic Induction*

(a)	magnitude: (force =) Bqv	B1
	direction: $P \rightarrow Q$ or $E \rightarrow F$ or $S \rightarrow R$ or $H \rightarrow G$	B1
(b)(i)	EHSP and FGRQ	B1
(b)(ii)	PE or QF or RG or SH	B1
(c)(i)	any one correct starting point from: • (mass of 1 atom =) $27 \times 1.66 \times 10^{-27}$ • (amount of substance per unit volume =) $2.7 / 27$ • 27 g (of substance) contains 6.02×10^{23} atoms • (2.7 g mass contains) 0.1 mol • (1 cm^3 volume contains) 0.1 mol • (1 m^3 volume contains) 10^5 mol	C1
	$n = (2.7 \times 10^3) / (27 \times 1.66 \times 10^{-27}) = 6.0 \times 10^{28}$ or $n = (2.7 / 27) \times 10^5 \times 6.02 \times 10^{23} = 6.0 \times 10^{28}$	A1
(c)(ii)	$V_H = (0.15 \times 4.6) / (6.0 \times 10^{28} \times 0.090 \times 10^{-3} \times 1.60 \times 10^{-19})$	C1
	$= 8.0 \times 10^{-7} \text{ V}$	A1

17 - (9702/41_Winter_2019_Q9) - *Magnetic Fields*

(a)	nuclei precess	B1
	precession is about (direction of magnetic) field or frequency of precession is in radio-frequency range	B1
(b)	• frequency (of precession) depends on field strength • to locate/find position of (spinning) nuclei • to change region where nuclei are detected	B2
	any two points, one mark each	

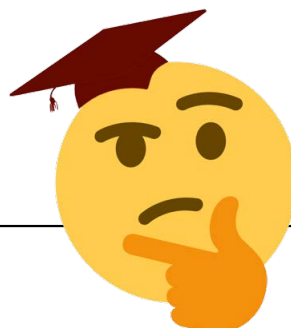


18 - (9702/41_Summer_2020_Q8) - *Magnetic Fields, Electromagnetic Induction*

(a)	magnetic field normal to current	B1
	newton per ampere	B1
	newton per metre	B1
(b)(i)	current in wire QL gives rise to a force or wire QL is perpendicular to the magnetic field	B1
	force on wire QL is vertical	B1
	force does not act through the pivot	B1
(b)(ii)	forces act through the same line or forces are horizontal	B1
	forces are equal (in magnitude) and opposite (in direction)	B1
(c)(i)	change = $mg \times (\Delta)L$	C1
	$= 1.3 \times 10^{-4} \times 9.81 \times 2.6 \times 10^{-2} = 3.3 \times 10^{-6} \text{ N m}^{-1}$	A1
(c)(ii)	change = $B \times (\Delta)I \times L \times x$	C1
	$3.3 \times 10^{-5} = B \times 1.2 \times 0.85 \times 10^{-2} \times 5.6 \times 10^{-2}$	C1
	$B = 0.058 \text{ T}$	A1

19 - (9702/42_Summer_2020_Q9) - *Magnetic Fields*

(a)(i)	force is downwards/down the page or current is (right) to left	B1
	by left-hand rule, field is into plane of paper	B1
(a)(ii)	magnetic force provides the centripetal force	C1
	$Bqv = mv^2 / r$	C1
	$v = Bqr / m$	A1
	$= (8.0 \times 10^{-4} \times 1.60 \times 10^{-19} \times 6.4 \times 10^{-2}) / (9.11 \times 10^{-31})$ $= 9.0 \times 10^8 \text{ m s}^{-1}$	
(b)(i)	arrow showing field direction down the page	B1
(b)(ii)	$Bqv = Eq$ or $v = E / B$	C1
	$E = 9.0 \times 10^8 \times 8.0 \times 10^{-4}$	A1
	$= 7.2 \times 10^5 \text{ N C}^{-1}$	
(c)	straight line/undeviated	B1
	condition for no deflection depends only on v or condition for no deflection does not depend on m or q	B1



20 - (9702/41_Winter_2020_Q8) - *Magnetic Fields*

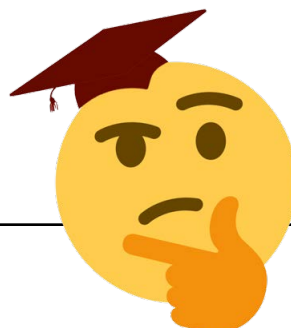
(a)(i)	downwards	B1
(a)(ii)	PQRS and JKLM	B1
(b)	(as charge separates) an electric field is created (between opposite faces)	B1
	(maximum value is reached when) electric force (on electron) is equal and opposite to magnetic force (on electron)	B1
(c)	$V_H = BI / ntq$	C1
	$= (4.6 \times 10^{-3} \times 6.3 \times 10^{-4}) / (1.3 \times 10^{29} \times 0.10 \times 10^{-3} \times 1.60 \times 10^{-19})$	
	$= 1.4 \times 10^{-12} \text{ V}$	A1
(d)	semiconductors have a (much) smaller value for n	B1
	V_H for semiconductors is (much) larger so more easily measured	B1

21 - (9702/42_Winter_2020_Q10) - *Magnetic Fields*

(a)	concentric circles centred on the wire	B1
	separation of lines increasing with distance from wire	B1
	arrows show anti-clockwise direction	B1
(b)(i)	current in (each) wire creates a magnetic field (at the other wire)	B1
	current (in wire) at 90° to field causes force	B1
(b)(ii)	force on each wire towards other wire/attractive	B1
(c)	Newton's third law pair of forces so yes (forces are equal)	B1
	or force proportional to product of both currents so yes (forces are equal)	

22 - (9702/42_Summer_2021_Q8) - *Magnetic Fields*

(a)	- force per unit length - force per unit current - length/current perpendicular to field 1 mark for any two points, 2 marks for all three points	B2
(b)	change in potential energy = change in kinetic energy or $qV = \frac{1}{2}mv^2$	B1
	$v = \sqrt{2qV / m}$	A1
(c)(i)	magnetic force = centripetal force or $Bqv = mv^2 / r$	M1
	clear substitution of expression for v and correct algebra leading to $q / m = 2V / B^2 r^2$	A1
(c)(ii)	$q / m = (2 \times 230) / [(0.38 \times 10^{-3})^2 \times 0.14^2]$	C1
	$= 1.6 \times 10^{11} \text{ C kg}^{-1}$	A1
(c)(iii)	(for α -particle,) q / m is (much) smaller	B1
	r would be <u>much</u> larger	B1



23 - (9702/41_Summer_2021_Q9) - *Magnetic Fields*

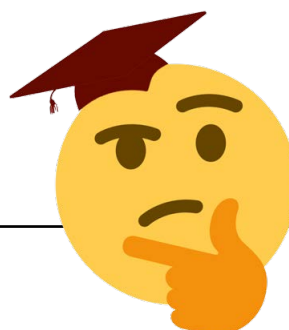
(a)	region where there is a force exerted on	M1
	a current-carrying conductor	A1
	or a moving charge	
	or a magnetic material/magnetic pole	
(b)(i)	face PSWW shaded	B1
(b)(ii)	accumulating electrons cause an electric field (between the faces)	B1
	force due to electric field opposes force due to magnetic field	B1
	accumulation stops when magnetic force equals electric force	B1
(c)(i)	number density of charge carriers	B1
(c)(ii)	PV or QT or SW	B1
(d)	(for semiconductor,) n is (much) smaller so V_H (much) larger	B1

24 - (9702/42_Summer_2021_Q9) - *Magnetic Fields, Electromagnetic Induction*

(a)	(particle is) stationary/not moving	B1
	(particle is) moving parallel to the (magnetic) field	B1
(b)	magnetic field around each coil is circular	B1
	or each coil is normal to magnetic field due to adjacent coils	
	current in coil interacts with (magnetic) field to exert force (on coil)	B1
	force is normal to both coil and magnetic field	B1
	or force parallel to axis (of coil)	
	forces between coils are attractive so spring contracts	B1
(c)	(oscillating) coils cut magnetic flux	B1
	or as separation of coils changes, magnetic flux changes	
	cutting flux causes induced e.m.f. in coils	B1
	changing (induced) e.m.f. causes changing current (in coil)	B1

25 - (9702/41_Winter_2021_Q8) - *Magnetic Fields*

(a)	newton per ampere per metre	M1
	where current/wire is perpendicular to magnetic field	A1
(b)(i)	$F = BIL \sin \theta$	C1
	$B = 1.0 / (5.0 \times 0.060 \times \sin 50^\circ)$	A1
	$= 4.4 \text{ mT}$	
(b)(ii)	(from Fleming's left-hand rule) force on wire is upwards, so reading decreases	B1
(b)(iii)	frame will rotate (so that PQ becomes perpendicular to the field)	B1



26 - (9702/42_Winter_2021_Q8) - Magnetic Fields

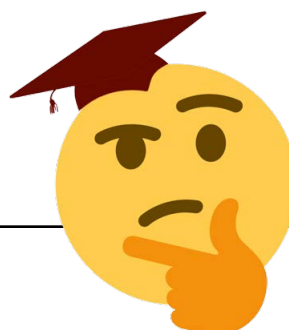
(a)(i)	arrow from Q pointing downwards, labelled B	B1
(a)(ii)	arrow from Q pointing towards P, labelled F	B1
(b)(i)	force is proportional to product of both currents (I and $2I$) or Newton's third law	B1
	forces are equal	B1
(b)(ii)	opposite	B1

27 - (9702/42_Winter_2021_Q9) - Magnetic Fields

(a)(i)	emission of electrons (from a metal surface)	B1
	when electromagnetic radiation is incident (on electrons)	B1
a(ii)	<u>minimum</u> energy required for an electron to leave surface	B1
(b)(i)	threshold (frequency)	B1
(b)(ii)	- photons are (discrete) packets of energy - energy of photons depends on frequency (of EM radiation) - electrons can only absorb a single photon (of energy) Any two points, 1 mark each	B2
	emission only possible if photon energy is at least the work function	B1
(b)(iii)	work function = $hf_0 = 6.63 \times 10^{-34} \times 6.93 \times 10^{14}$	C1
	$= 4.59 \times 10^{-19}$ (J)	A1
	$= 4.59 \times 10^{-19} / 1.60 \times 10^{-19}$ (eV)	
	$= 2.87$ eV	

28 - (9702/43_Winter_2021_Q9) - Magnetic Fields

(a)	constant voltage	M1
	that produces/dissipates same power as (the mean power of) the alternating voltage	A1
(b)(i)	(maximum) rate of cutting of (magnetic) flux doubles	B1
	(peak and hence) r.m.s. induced e.m.f. doubles	B1
(b)(ii)	sketch: (sinusoidal) wave of period 10 ms	B1
	peak E shown as ± 34 V	B2
	(1 mark out of 2 awarded if peak E shown as ± 17 V or ± 24 V)	
(c)	current in the coil results in forces that oppose its rotation or current in the resistor dissipates the energy of rotation	B1
	coil stops rotating	B1

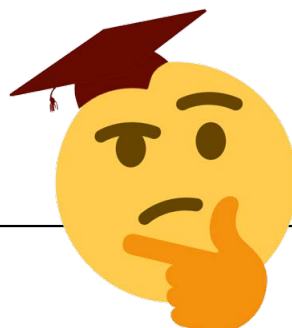


29 - (9702/41_Summer_2022_Q6) - *Magnetic Fields*

(a)	product of (magnetic) flux density and area	M1
	where area is perpendicular to the (magnetic) field	A1
(b)(i)	$N\Phi = BAN$	C1
	$= 400 \times 10^{-3} \times 0.12^2 \times 8$	C1
	$= 0.046 \text{ Wb}$	A1
(b)(ii)	(line is a) straight line	B1
(b)(iii)	(induced) e.m.f. = rate of change of flux linkage	C1
	e.m.f. $= N\Phi / t$	A1
	$= 0.046 / 0.60$	
	$= 0.077 \text{ V}$	
(c)	(induced e.m.f. causes) current flow (in the coil)	B1
	either	
	current (in magnetic field) causes forces to act on the coil	B1
	(opposite sides of) coil forced inwards	B1
	or	
	current causes dissipation of energy in the resistance of the coil	(B1)
	temperature of the coil rises	(B1)

30 - (9702/42_Summer_2022_Q6) - *Magnetic Fields*

(a)	there must be a current (in the wire)	B1
	(wire) must be at a non-zero angle to the magnetic field	B1
(b)(i)	arrow from X pointing horizontally to the left	B1
	arrow from Y pointing diagonally upwards and to the left at about 45°	B1
	arrow from Z pointing horizontally to the right	B1
(b)(ii)	(flux densities at W and X are approximately) equal	B1
	(flux density at) Y greater than (flux density at) Z	B1
(c)	current in wire creates magnetic field around wire	B1
	(each) wire sits in the magnetic field created by the other	B1
	(for each wire,) current / wire is perpendicular to magnetic field (due to other wire), (so) experiences a (magnetic) force	B1



31 - (9702/42_Summer_2022_Q7) - Magnetic Fields

(a)	induced e.m.f. is (directly) proportional to rate	M1
	of change of (magnetic) flux (linkage)	A1
(b)	V_2 stepped, all at non-zero values, between $t = 0$ and $t = 0.40$ s	B1
	V_2 shown with same non-zero magnitude up to $t = 0.15$ s and after $t = 0.25$ s but with a different magnitude between these times	B1
	V_2 shown with a magnitude between $t = 0.15$ s and $t = 0.25$ s that is three times the magnitude before $t = 0.15$ s and after $t = 0.25$ s	B1
	V_2 shown with same sign up to $t = 0.15$ s and after $t = 0.25$ s, and opposite sign in between	B1
(c)(i)	changing current in coil causes changing (magnetic) field or changing (magnetic) flux causes induced e.m.f. in ring	B1
	induced e.m.f. in ring causes current in ring	B1
	(magnetic) field due to (induced) current in ring interacts with (coil's) field to cause upwards force (on ring) or (induced) current in ring perpendicular to (coil's magnetic) field causes upwards force (on ring)	B1
(c)(ii)	both magnetic fields reverse direction so ring still jumps up or current (in ring) and (coil's) field both reverse so ring still jumps up	B1

32 - (9702/41_Winter_2022_Q6) - Magnetic Fields

(a)(i)	PQRS and WXYZ	B1
(a)(ii)	force on charge carriers is perpendicular to both (magnetic) field and current	B1
	as charge carriers are deflected to one side, an electric field is set up	B1
	(steady V_H when) electric and magnetic forces on charge carriers are equal (and opposite)	B1
(b)(i)	n : number density of charge carriers	B1
	t : distance PW (or SZ or QX or RY)	B1
	q : charge on each charge carrier	B1
(b)(ii)	V_H inversely proportional to t	B1
	(so t needs to be small for) V_H to be large enough to measure	B1

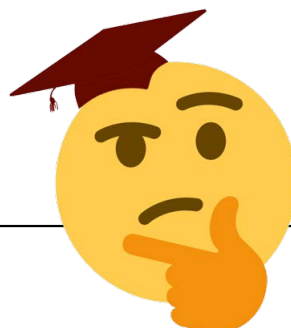
33 - (9702/42_Winter_2022_Q7) - Magnetic Fields

(a)	force per unit current	M1
	force per unit length	M1
	current / wire is perpendicular to (magnetic) field (lines)	A1
(b)(i)	current (in coil) is perpendicular to magnetic field (so force on wire)	B1
	force (on wire) is perpendicular to current and field (so is vertical) or current and field are both horizontal (so force is vertical)	B1
(b)(ii)	$NBIL = mg$	C1
	$B = (2.16 \times 10^{-3} \times 9.81) / (40 \times 3.94 \times 0.0300)$	C1
	$= 4.48 \times 10^{-3} \text{ T}$	A1
(b)(iii)	(magnetic) forces (on balance and newton meter) are (equal and) opposite	B1
	reading $= 0.563 - (2.16 \times 10^{-3} \times 9.81)$ $= 0.542 \text{ N}$	A1



34 - (9702/41_Summer_2023_Q6) - *Magnetic Fields, Electromagnetic Induction*

(a)	a region where a force acts on	M1
	a current-carrying conductor	A1
	or	
	a moving charge	
(b)	a magnetic material / magnetic pole	B1
	concentric circles around the wire	
	spacing between circles increases with distance from wire	
	arrows showing direction of field is clockwise	
(c)(i)	$F = BIL$	C1
	force per unit length = BI	A1
	$= 2.6 \times 10^{-3} \times 5.0$	
	$= 0.013 \text{ N m}^{-1}$	
(c)(ii)	to the right	B1
(c)(iii)	force (per unit length) has the same magnitude due to Newton's 3rd law	B1
	$0.013 = 1.5 \times 10^{-3} \times I$	A1
	current = 8.7 A	



1 - (9702/42_Summer_2017_Q3) - Oscillations, Electromagnetic Induction

(a)(i)	e.g. period = $6 / 2.5$ frequency = 0.42 Hz
(a)(ii)	energy = $\frac{1}{2} m \times 4\pi^2 f^2 y_0^2$ $= \frac{1}{2} \times 0.25 \times 4\pi^2 \times 0.42^2 \times (1.5 \times 10^{-2})^2$ $= 2.0 \times 10^{-4} \text{ J}$
(b)(i)	(induced) e.m.f. proportional to rate of change of magnetic flux (linkage) or cutting of magnetic flux
(b)(ii)	coil cuts flux/field (of moving magnet) <u>inducing</u> e.m.f. in coil (induced) current in resistor causes heating (effect) thermal energy/heat derived from energy of oscillations (of magnet)

2 - (9702/41_Summer_2017_Q9) - Electromagnetic Induction

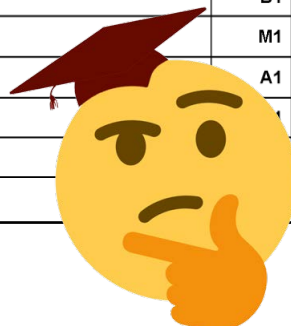
(a)(i)	core reduces loss of (magnetic) flux linkage/improves flux linkage
(a)(ii)	reduces (size of eddy) currents in core (so that) heating of core is reduced
(b)	alternating voltage gives rise to changing magnetic flux in core (changing) flux links the secondary coil induced e.m.f. (in secondary) only when flux is changing/cut

3 - (9702/41_Winter_2017_Q5) - Electric Fields, Electromagnetic Induction

(a)(i)	force proportional to <u>product</u> of charges and inversely proportional to <u>square</u> of separation	A1
(a)(ii)	curve starting at (R, F_c)	B1
	passing through $(2R, 0.25F_c)$	B1
	passing through $(4R, 0.06F_c)$	B1
(b)	graph: $E = 0$ when current constant (0 to t_1 , t_2 to t_3 , t_4 to t_5)	B1
	stepped from t_1 to t_2 and t_3 to t_4	B1
	(steps) in opposite directions	B1
	later one larger in magnitude	B1

4 - (9702/41_Winter_2017_Q8) - Magnetic Fields, Electromagnetic Induction

(a)	DERQ and CFSP	B1
(b)(i)	force (on charge) due to magnetic field = force due to electric field or $Bqv = Eq$ or $v = E/B$ $E = V_H/d$ $V_H = Bvd$	B1 B1 B1
(b)(ii)	use of $I = nAqv$ and $A = dt$ algebra clear leading to $V_H = BI/ntq$	M1 A1
(c)	(in metal,) n is very large (therefore) V_H is small	



5 - (9702/42_Winter_2017_Q8) - Electromagnetic Induction

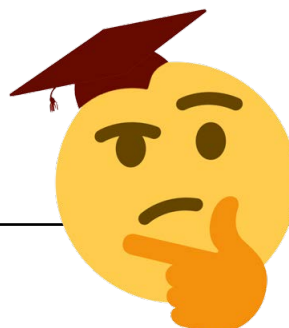
(a)(i)	DERQ and CFSP	B1
(a)(ii)	charge carriers moving normal to (magnetic) field	B1
	charge carriers experience a <u>force</u> normal to I (and B)	B1
	charge build-up sets up electric field across the slice or build-up of charges results in a p.d. across the slice	B1
	charge stops building up/ V_H becomes constant when $F_B = F_E$	B1
(b)	V_H inversely proportional to n /number density of charge carriers	B1
	number density of charge carriers (n) lower in semiconductors so V_H larger for semiconductor slice	B1
	or	
	V_H proportional to v /drift velocity	(B1)
	(for same current) drift velocity (v) higher in semiconductors so V_H larger for semiconductor slice	(B1)

6 - (9702/42_Summer_2018_Q9) - Electromagnetic Induction

(a)	(magnetic) flux density $\times$ area	B1
	magnetic flux density normal to area or reference to cross-sectional area or $\times \sin$ (angle between B and A)	B1
	$\times$ number of turns on coil	B1
(b)	e.m.f. = BAN/t or e.m.f. = rate of change of flux <u>linkage</u>	C1
	$= (7.5 \times 10^{-3} \times \pi \times \{1.2 \times 10^{-2}\}^2 \times 160) / 0.15$	A1
	$= 3.6 \times 10^{-3} \text{ V}$	
(c)	sketch: zero for 0–0.10 s, 0.25–0.35 s, and 0.425–0.55 s, and non-zero outside these ranges	B1
	two horizontal steps, with zero voltage either side	B1
	with same polarity	B1
	correct values (1st step 3.6 mV and 2nd step 7.2 mV)	B1

7 - (9702/41_Summer_2018_Q10) - Electromagnetic Induction

(a)	induced <u>e.m.f.</u> proportional to rate	M1
	of <u>change</u> of (magnetic) <u>flux</u> (linkage) or of <u>cutting</u> (magnetic) <u>flux</u>	A1
(b)	current in coil produces flux	B1
	(by Faraday's law) changing flux induces e.m.f. in ring	B1
	current in ring causes field (around ring)	B1
	(by Lenz's law) field around ring opposes field around coil	B1



8 - (9702/41_Winter_2018_Q9) - Electromagnetic Induction

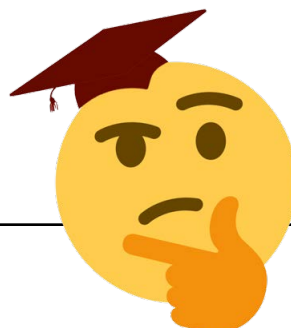
(a)	(induced) e.m.f. proportional/equal to <u>rate</u>	M1
	of change of (magnetic) flux (linkage)	A1
(b)(i)	induced e.m.f. = $(\Delta B)AN / \Delta t$	C1
	$= (2 \times 0.19 \times 1.5 \times 10^{-4} \times 120) / 0.13$ $= 0.053 \text{ V}$	A1
(b)(ii)	reading on voltmeter connected to coil C / V: 0 0.053 0 (all three values required)	A1
	reading on voltmeter connected to Hall probe / V: zero in middle column	B1
	final column correct sign (negative)	B1
	final column correct magnitude (0.20)	B1

9 - (9702/42_Winter_2018_Q9) - Electromagnetic Induction

(a)	$0 \rightarrow t_1$ horizontal straight line at non-zero value of V_H and $t_3 \rightarrow t_4$ horizontal straight line at different non-zero V_H	B1
	$t_1 \rightarrow t_3$ straight diagonal line with negative gradient and graph line starts at $(0, V_0)$ and ends at $(t_4, -2V_0)$	B1
(b)	$E = 0$ for $0 \rightarrow t_1$ and $t_3 \rightarrow t_4$	B1
	E is non-zero at all points between $t_1 \rightarrow t_3$	M1
	E has constant magnitude between $t_1 \rightarrow t_3$	A1

10 - (9702/41_Summer_2019_Q8) - Magnetic Fields, Electromagnetic Induction

(a)(i)	region where a force is exerted on: a magnetic pole or a moving charge or a current-carrying wire	B1
(a)(ii)	arrow on axis of solenoid pointing downwards labelled P	B1
(b)(i)	<u>direction</u> of induced e.m.f./current	M1
	(tends to) oppose the change causing it	A1
(b)(ii)	magnetic field in solenoid is increasing	B1
	field in coil in opposite direction to oppose increase	B1
	arrow inside or just above small coil pointing in opposite direction to P	B1
(c)	e.m.f. = $N\Delta\phi / \Delta t$	C1
	$= (75 \times 1.4 \times 10^{-3} \times 2 \times 7.0 \times 10^{-4}) / 0.12$	C1
	$= 1.2 \times 10^{-3} \text{ V}$	A1



11 - (9702/42_Summer_2019_Q10) - Electromagnetic Induction

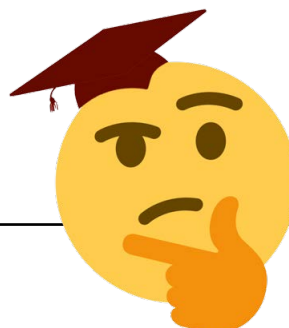
(a)	(induced) e.m.f. proportional to rate	M1
	of change of (magnetic) flux (linkage)	A1
(b)	current in primary coil gives rise to magnetic flux	B1
	changing (magnetic) flux in core links with secondary coil	B1
	induced e.m.f. (in secondary coil) causes current in load/resistor	B1
(c)	correct application of turns ratio: to peak voltage ratio, giving $(V_0 / 220) = (450 / 2700)$ or to r.m.s. voltage ratio, giving $(V_{r.m.s.} / 156) = (450 / 2700)$	C1
	correct application of $\sqrt{2}$ factor: to peak applied e.m.f., giving $220 / \sqrt{2}$ or to peak output e.m.f., giving $37 / \sqrt{2}$	C1
	$V_{r.m.s.} = 26 \text{ V}$	A1

12 - (9702/42_Winter_2019_Q8) - Magnetic Fields, Electromagnetic Induction

(a)	magnitude: (force $\Rightarrow$) Bqv	B1
	direction: $P \rightarrow Q$ or $E \rightarrow F$ or $S \rightarrow R$ or $H \rightarrow G$	B1
(b)(i)	EHSP and FGRQ	B1
(b)(ii)	PE or QF or RG or SH	B1
(c)(i)	any one correct starting point from: • (mass of 1 atom $\Rightarrow$) $27 \times 1.66 \times 10^{-27}$ • (amount of substance per unit volume $\Rightarrow$) $2.7 / 27$ • 27 g (of substance) contains 6.02×10^{23} atoms • (2.7 g mass contains) 0.1 mol • (1 cm^3 volume contains) 0.1 mol • (1 m^3 volume contains) 10^5 mol	C1
	$n = (2.7 \times 10^3) / (27 \times 1.66 \times 10^{-27}) = 6.0 \times 10^{28}$ or $n = (2.7 / 27) \times 10^5 \times 6.02 \times 10^{23} = 6.0 \times 10^{28}$	A1
(c)(ii)	$V_H = (0.15 \times 4.6) / (6.0 \times 10^{28} \times 0.090 \times 10^{-3} \times 1.60 \times 10^{-19})$	C1
	$= 8.0 \times 10^{-7} \text{ V}$	A1

13 - (9702/42_Winter_2019_Q11) - Electromagnetic Induction, Alternating Currents

(a)	(induced) e.m.f. proportional to rate	M1
	of change of (magnetic) flux (linkage)	A1
(b)(i)	any two from t_1, t_3, t_5, t_7	A1
(b)(ii)	t_2 and t_4 or t_8 and t_6	A1
(c)	e.m.f. $= N \Delta \phi / \Delta t$	C1
	$= (2 \times 9.4 \times 10^{-4} \times 5.0 \times \pi \times (1.8 \times 10^{-2})^2 \times 63) / (6.0 \times 10^{-3})$	C1
	$= 0.10 \text{ V}$	A1



14 - (9702/41_Summer_2020_Q8) - *Magnetic Fields, Electromagnetic Induction*

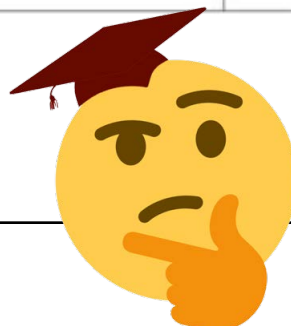
(a)	magnetic field normal to current	B1
	newton per ampere	B1
	newton per metre	B1
(b)(i)	current in wire QL gives rise to a force or wire QL is perpendicular to the magnetic field	B1
	force on wire QL is vertical	B1
	force does not act through the pivot	B1
(b)(ii)	forces act through the same line or forces are horizontal	B1
	forces are equal (in magnitude) and opposite (in direction)	B1
(c)(i)	change = $mg \times (\Delta)L$	C1
	$= 1.3 \times 10^{-4} \times 9.81 \times 2.6 \times 10^{-2} = 3.3 \times 10^{-6} \text{ N m}^{-1}$	A1
(c)(ii)	change = $B \times (\Delta)I \times L \times x$	C1
	$3.3 \times 10^{-6} = B \times 1.2 \times 0.85 \times 10^{-2} \times 5.6 \times 10^{-2}$	C1
	$B = 0.058 \text{ T}$	A1

15 - (9702/41_Summer_2020_Q9) - *Electromagnetic Induction*

(a)(i)	e.m.f. = $(\Delta)B \times AN / t$	C1
	$= 45 \times 10^{-3} \times \pi \times (1.8 \times 10^{-2})^2 \times 350 / 0.20 = 0.080 \text{ V}$	A1
(a)(ii)	0 to 0.2 s: straight horizontal line at 0.080 V or –0.080 V	B1
	0.2 s to 0.4 s: zero	B1
	0.4 s to 0.8 s: straight horizontal line at 0.040 V or –0.040 V	B1
	opposite polarity to 0 to 0.2 s line	B1
(b)	either disc cuts flux lines (of the magnet) or there is a changing flux in the disc	B1
	(by Faraday's law) e.m.f. is induced in the disc	B1
	e.m.f. causes (eddy) currents in the disc	B1
	current in the magnetic field (of the magnet) causes force on disc	B1

16 - (9702/42_Summer_2020_Q10) - *Electromagnetic Induction*

(a)	(induced) electromotive force is proportional to rate of change of (magnetic) flux (linkage)	M1
		A1
(b)(i)	to change magnitude of potential difference	B1
(b)(ii)	magnitude of e.m.f. varies as rate of change of flux changes	B1
	direction of e.m.f. changes when direction of change of flux reverses/when flux changes from increasing to decreasing	B1
	flux is continuously increasing and decreasing, so polarity of e.m.f. is continuously switching	B1
(b)(iii)	to reduce energy/power losses or to reduce eddy currents	B1



17 - (9702/41_Winter_2020_Q9) - *Electromagnetic Induction*

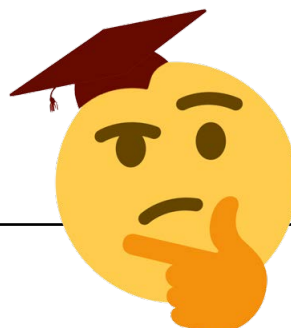
(a)	flux density $\times$ area	M1
	where flux is normal to area	A1
	or	
	flux density $\times$ area $\times \sin \theta$	(M1)
	where θ is angle between flux direction and (plane of) area	(A1)
(b)(i)	(alternating) current creates changing (magnetic) flux	B1
	core links (magnetic) flux with secondary coil	B1
	changing flux (in secondary) causes induced e.m.f.	B1
(b)(ii)	rate of change of flux is not constant	B1
	(induced) e.m.f. is proportional to rate of change of flux	B1
(c)	reduces induced currents in core	B1
	hence reduces energy losses (in core)	B1

18 - (9702/42_Winter_2020_Q9) - *Electromagnetic Induction, Alternating Currents*

(a)(i)	(induced) e.m.f. (directly) proportional to rate	M1
	of change of magnetic flux (linkage)	A1
(a)(ii)	e.m.f. = 0 apart from thin pulses at t_1 and t_2	B1
	rectangular pulses centred on t_1 and t_2 , of widths 2 small squares and 1 small square respectively	B1
	e.m.fs. at t_1 and t_2 have opposite polarities	B1
	magnitude of e.m.f. at t_2 double the magnitude of e.m.f. at t_1	B1
(b)	V_H shown as zero before ($t_1 - 2$ squares) and after ($t_2 + 2$ squares) and rises to a constant non-zero value between t_1 and t_2	M1
	change at t_1 shown as 2 small squares wide and change at t_2 shown as 1 small square wide	A1

19 - (9702/42_Summer_2021_Q9) - *Magnetic Fields, Electromagnetic Induction*

(a)	(particle is) stationary/not moving	B1
	(particle is) moving parallel to the (magnetic) field	B1
(b)	magnetic field around each coil is circular or each coil is normal to magnetic field due to adjacent coils	B1
	current in coil interacts with (magnetic) field to exert force (on coil)	B1
	force is normal to both coil and magnetic field or force parallel to axis (of coil)	B1
	forces between coils are attractive so spring contracts	B1
(c)	(oscillating) coils cut magnetic flux or as separation of coils changes, magnetic flux changes	B1
	cutting flux causes induced e.m.f. in coils	B1
	changing (induced) e.m.f. causes changing current (in coil)	B1



20 - (9702/41_Summer_2021_Q10) - Electromagnetic Induction

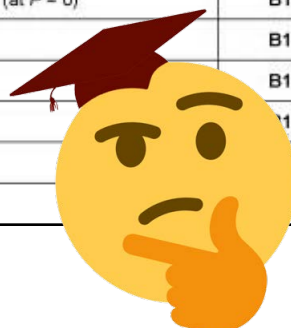
(a)	direction of (induced) e.m.f.	M1
	is such as to oppose the <u>change</u> causing it	A1
(b)	ring cuts (magnetic) flux and causes induced e.m.f. in ring	B1
	(induced) e.m.f. causes (eddy/induced) currents (in ring)	B1
	currents (in ring) cause magnetic field (around ring)	M1
	two fields interact to cause resistive/opposing force	A1
	or	
	current (in ring) is in a magnetic field	(M1)
	which causes resistive force	(A1)
	or	
	currents (in ring) dissipate thermal energy	(M1)
	(thermal) energy comes from energy of oscillations	(A1)
(c)	current cannot pass all the way around the ring	B1
	(induced) currents smaller	B1
	smaller resistive force (so more oscillations)	B1
	or smaller <u>rate</u> of dissipation of energy (so more oscillations)	

21 - (9702/41_Winter_2021_Q9) - Electromagnetic Induction

(a)	constant voltage	M1
	that produces/dissipates same power as (the mean power of) the alternating voltage	A1
(b)(i)	(maximum) rate of cutting of (magnetic) flux doubles	B1
	(peak and hence) r.m.s. induced e.m.f. doubles	B1
(b)(ii)	sketch: (sinusoidal) wave of period 10 ms	B1
	peak E shown as $\pm 34\text{ V}$	B2
	(1 mark out of 2 awarded if peak E shown as $\pm 17\text{ V}$ or $\pm 24\text{ V}$)	
(c)	current in the coil results in forces that oppose its rotation	B1
	or current in the resistor dissipates the energy of rotation	
	coil stops rotating	B1

22 - (9702/42_Winter_2021_Q10) - Electromagnetic Induction

(a)(i)	to increase the magnetic flux linkage (between the coils)	B1
(a)(ii)	to reduce energy losses	B1
	by reducing induced currents	B1
(b)(i)	maximum $V_{\text{OUT}} = 12\,000 \times (625 / 25\,000)$ $= 300\text{ V}$	A1
(b)(ii)	r.m.s. current $= 300 / (640 \times \sqrt{2})$ $= 0.33\text{ A}$	A1
(b)(iii)	sketch: sinusoidal shape in positive half of the graph, sitting with 'minima' resting on the time-axis (at $P = 0$)	B1
	each 'cycle' shown repeating every 20 ms	B1
	maximum P shown as 140 W	B1
(c)	power curve is symmetrical about the midpoint (on the power axis)	B1
	mean power is half the peak power	B1



23 - (9702/43_Winter_2021_Q10) - Electromagnetic Induction

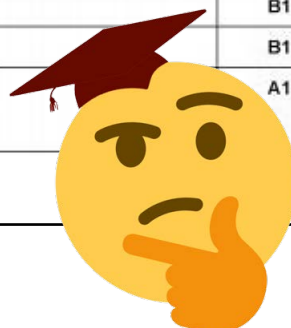
(a)(i)	photoelectric effect	B1
(a)(ii)	electron diffraction	B1
(b)(i)	$\lambda = h / p$	M1
	h is the Planck constant	A1
(b)(ii)	de Broglie (wavelength)	B1
(c)(i)	$\frac{1}{2}mv^2 = eV$	C1
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 1.60 \times 10^{-19} \times 4800$ <u>so</u> $v = 4.1 \times 10^7 \text{ m s}^{-1}$	A1
(c)(ii)	$\lambda = h / mv$	C1
	$= 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 4.1 \times 10^7)$	
	$= 1.8 \times 10^{-11} \text{ m}$	A1

24 - (9702/42_Winter_2022_Q8) - Electromagnetic Induction

(a)	direction of induced e.m.f.	M1
	such as to (produce effects that) oppose the change that caused it	A1
(b)(i)	$X = 0.85 \text{ A}$	A1
	$Y = 2\pi / 0.040$	C1
	$= 160 \text{ rad s}^{-1}$	A1
(b)(ii)	two cycles of a sinusoidal curve with a period of 0.040 s	B1
	correct phase (i.e. V_2 max / min at $t = 0, 0.02, 0.04, 0.06$ and 0.08 s , and V_2 zero at $t = 0.01, 0.03, 0.05, 0.07 \text{ s}$)	B1
	maximum / minimum V_2 shown (consistently) at $\pm 6.5 \text{ V}$	B1
(b)(iii)	(magnitude of) V_2 is proportional to rate of change of (magnetic) flux	B1
	V_2 is proportional to <u>gradient</u> of I_1-t curve V_2 has maximum magnitude when I_1-t curve is steepest V_2 is zero when I_1-t curve is horizontal / a maximum or minimum V_2 changes sign when sign of gradient of I_1-t curve changes Any two points, 1 mark each	B2

25 - (9702/41_Summer_2023_Q6) - Magnetic Fields, Electromagnetic Induction

(a)	a region where a force acts on	M1
	a current-carrying conductor	A1
	or	
	a moving charge	
	or	
	a magnetic material / magnetic pole	
(b)	concentric circles around the wire	B1
	spacing between circles increases with distance from wire	B1
	arrows showing direction of field is clockwise	B1
(c)(i)	$F = BIL$	C1
	force per unit length $= BI$	A1
	$= 2.6 \times 10^{-3} \times 5.0$	
	$= 0.013 \text{ N m}^{-1}$	
(c)(ii)	to the right	B1
(c)(iii)	force (per unit length) has the same magnitude due to Newton's 3rd law	B1
	$0.013 = 1.5 \times 10^{-3} \times I$	A1
	current $= 8.7 \text{ A}$	

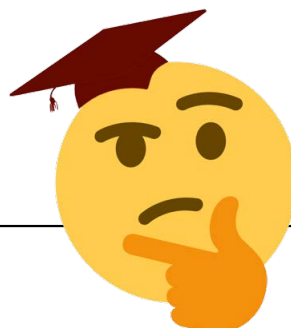


26 - (9702/42_Summer_2023_Q6) - Electromagnetic Induction

(a)(i)	product of (magnetic) flux density and area	M1
	area perpendicular to the (magnetic) field	A1
(a)(ii)	flux = $B \times \pi r^2$	C1
	= $0.17 \times \pi \times 0.36^2$	
	= 6.9×10^{-2} Wb	A1
(b)	time for one revolution = $1/25$ s	C1
	e.m.f. = rate of cutting flux or $\Delta\Phi/\Delta t$	C1
	= 0.069×25	A1
	= 1.7 V	
(c)	current (in disc) is perpendicular to magnetic field or current causes force to act on disc	B1
	force opposes rotation of disc	B1
	left-hand rule indicates current is from rim to axle	B1

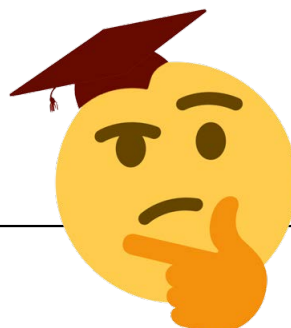
27 - (9702/41_Winter_2023_Q6) - Electromagnetic Induction

(a)	- force per unit length - force per unit current - length / current perpendicular to field 1 mark for any two points, 2 marks for all three points	B2
(b)(i)	into the page	B1
(b)(ii)	$F = Bqv$	C1
	= $4.8 \times 10^{-3} \times 1.6 \times 10^{-19} \times 1.7 \times 10^7 = 1.3 \times 10^{-14}$ N	A1
(b)(iii)	arrow at point X pointing down the page	B1
(b)(iv)	$F = mv^2 / r$	C1
	$1.3 \times 10^{-14} = (9.11 \times 10^{-31}) \times (1.7 \times 10^7)^2 / r$	C1
	($r = 0.020$ m)	
	$d = 2r$	A1
	$d = 0.040$ m	
(c)	path shows upwards deflection such that the curvature is always anticlockwise within the field	B1
	circular path with larger radius	B1
	line enters field at X and leaves field at distance $2d$ vertically from X	B1



28 - (9702/42_Winter_2023_Q7) - Electromagnetic Induction

(a)(i)	$V_H = BI / ntq$ $= (4.0 \times 10^{-6} \times 5.4) / (1.5 \times 10^{16} \times 1.8 \times 10^{-3} \times 1.60 \times 10^{-19}) = 5.0 \text{ V}$	A1
(a)(ii)	sketch: straight diagonal line from (0, 0) to $t = 0.020 \text{ s}$ and straight diagonal line between two non-zero V_H values of same sign from $t = 0.040$ to 0.050 s	B1
	horizontal straight line at $V_H = 5.0 \text{ V}$ from $t = 0.020$ to 0.040 s	B1
	horizontal straight line at $V_H = 2.5 \text{ V}$ from $t = 0.050$ to 0.080 s	B1
(b)(i)	e.m.f. = rate of change of (magnetic) flux (linkage)	C1
	$E = NA \Delta B / \Delta t$ or $E = NA \times \text{gradient (at } t = 0.010 \text{ s)}$	C1
	$E = 3000 \times 3.4 \times 10^{-4} \times (4.0 \times 10^{-6}) / (0.020) = 2.0 \times 10^{-4} \text{ V}$	A1
(b)(ii)	sketch: line showing non-zero E from $t = 0$ to $t = 0.020 \text{ s}$ and from $t = 0.040 \text{ s}$ to $t = 0.050 \text{ s}$, and $E = 0$ at all other times	B1
	'top hats' showing constant non-zero E from $t = 0$ to $t = 0.020 \text{ s}$ and from $t = 0.040 \text{ s}$ to $t = 0.050 \text{ s}$	B1
	magnitude of E shown as $2.0 \times 10^{-4} \text{ V}$ in both non-zero sections	B1
	sign of E in the $t = 0$ to $t = 0.020 \text{ s}$ region opposite to the sign of E in the $t = 0.040 \text{ s}$ to $t = 0.050 \text{ s}$ region	B1

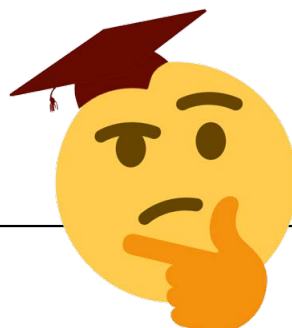


1 - (9702/41_Winter_2017_Q10) - Alternating Currents

(a)	heating depends on $\text{current}^2/I^2$	B1
	and $\text{current}^2/I^2$ is always positive	B1
	or	
	a.c. changes direction (every half cycle)	(B1)
	but heating effect is independent of current direction	(B1)
	or	
	voltage and current are always in phase in a resistor	(B1)
	so $V \times I$ is always positive	(B1)
	or	
	sketch graph drawn showing power against time	(B1)
	comment that power is always positive	(B1)
(b)(i)	for same power (transmission, higher voltage) $\rightarrow$ lower current	B1
	lower current $\rightarrow$ less power loss in (transmission) cables	B1
(b)(ii)	- voltage can be (easily) stepped up/down - transformers only work with a.c. - generators produce a.c. - easier to rectify than invert <i>Two sensible suggestions, 1 mark each.</i>	B2

2 - (9702/42_Winter_2017_Q11) - Alternating Currents

(a)(i)	circles drawn only around the top left and bottom right diodes	B1
(a)(ii)	B shown as (+)ve and A shown as (-)ve	B1
(b)(i)	$V_{r.m.s.} (= 5.6 / \sqrt{2}) = 4.0 \text{ V}$	A1
(b)(ii)	$380 = 2\pi f$ or $f = 60.5 \text{ Hz}$	C1
	number $(= 2f) = 120$	A1
(c)(i)	peak values (all) unchanged	B1
	(all) minima shown at 4.0 V	B1
	three lines from near peak showing concave curves after leaving dotted line not 'kinked' and not cutting the peak reaching <u>candidate's</u> minimum at the point where the decay meets the next dotted line	B1
	three lines drawn along the dotted lines showing rise in voltage from minima back to peak values	B1
(c)(ii)	<u>mean</u> p.d. is higher or <u>r.m.s.</u> p.d. is higher or capacitor supplies energy <u>to resistor</u>	M1
	so (mean) power increases	A1



3 - (9702/41_Summer_2018_Q9) - *Magnetic Fields, Alternating Currents*

(a)	using Fleming's left-hand rule force on wire is upwards	B1
	by Newton's third law, force on magnet is downwards	B1
(b)(i)	$F = BIL$	C1
	$= 3.7 \times 10^{-3} \times 5.1 \times 8.5 \times 10^{-2}$	A1
	$= 1.6 \times 10^{-3} \text{ N}$	
(b)(ii)	$F = 1.6 \times 10^{-3} \text{ N}$	A1
(c)	sketch: sinusoidal wave with two cycles	B1
	amplitude $2.3 \times 10^{-3} \text{ N}$	B1
	period 0.05 s	B1

4 - (9702/42_Winter_2018_Q10) - *Alternating Currents*

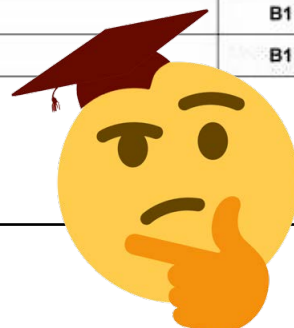
(a)	$V_0 = \sqrt{2} \times V_{\text{r.m.s.}} = \sqrt{2} \times 9.9 (= 14 \text{ V})$ and $\omega = 2\pi f = 2\pi \times 50 (= 314 \text{ rad s}^{-1})$	C1
	$V = 14 \sin 314t$	A1
(b)	enables (resonating) nuclei to be located	B1
	resonant frequency depends on magnetic field strength	B1
	Any one from: • non-uniform field is (accurately) calibrated • (non-uniform) field may be varied to enable detection in different positions • unique (magnetic) field strength/frequency at each point	B1
(c)	$I = I_0 \exp(-\mu x)$	C1
	$I = I_0 [\exp(-\mu x)_{\text{bone}} \times \exp(-\mu x)_{\text{soft tissue}}]$	C1
	$I = I_0 [\exp(-2.9 \times 0.40) \times \exp(-0.92 \times 1.4)]$	
	$I/I_0 = 0.0865$	C1
	ratio/dB = $10 \lg 0.0865$ $= -11 \text{ dB}$	A1

5 - (9702/41_Summer_2019_Q10) - *Alternating Currents*

(a)	$V_{\text{MAX}} = 15 \text{ V}$	A1
(b)	$210 = 2\pi / T$	C1
	$T = 0.0299 \text{ s}$	C1
	$(t_2 - t_1) = 0.060 \text{ s}$	A1

6 - (9702/41_Winter_2019_Q10) - *Alternating Currents*

(a)(i)	lower right and upper left diodes circled	B1
(a)(ii)	maximum = $7.0\sqrt{2}$	A1
	$= 9.9 \text{ V}$	
(b)(i)	correct symbol for capacitor, shown connected in parallel with R	B1
(b)(ii)	1. (ripple) decreases	B1
	2. (ripple) increases	B1



7 - (9702/42_Winter_2019_Q11) - Electromagnetic Induction, Alternating Currents

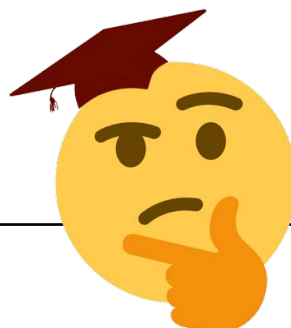
(a)	(induced) e.m.f. proportional to rate	M1
	of change of (magnetic) flux (linkage)	A1
(b)(i)	any two from t_1 , t_3 , t_5 , t_7	A1
(b)(ii)	t_2 and t_4 or t_6 and t_8	A1
(c)	e.m.f. = $N\Delta\Phi / \Delta t$	C1
	$= (2 \times 9.4 \times 10^{-4} \times 5.0 \times \pi \times (1.8 \times 10^{-2})^2 \times 63) / (6.0 \times 10^{-3})$	C1
	$= 0.10 \text{ V}$	A1

8 - (9702/42_Winter_2020_Q9) - Electromagnetic Induction, Alternating Currents

(a)(i)	(induced) e.m.f. (directly) proportional to rate	M1
	of change of magnetic flux (linkage)	A1
(a)(ii)	e.m.f. = 0 apart from thin pulses at t_1 and t_2	B1
	rectangular pulses centred on t_1 and t_2 , of widths 2 small squares and 1 small square respectively	B1
	e.m.fs. at t_1 and t_2 have opposite polarities	B1
	magnitude of e.m.f. at t_2 double the magnitude of e.m.f. at t_1	B1
(b)	V_H shown as zero before ($t_1 - 2$ squares) and after ($t_2 + 2$ squares) and rises to a constant non-zero value between t_1 and t_2	M1
	change at t_1 shown as 2 small squares wide and change at t_2 shown as 1 small square wide	A1

9 - (9702/42_Summer_2021_Q10) - Alternating Currents

(a)	the steady current or the direct current	M1
	that produces the same heating effect (as the alternating current)	A1
(b)(i)	peak current = 2.6 A and r.m.s. current = 1.8 A	A1
(b)(ii)	peak current = 2.0 A and r.m.s. current = 2.0 A	A1
(c)(i)	$k = 2\pi f$	C1
	$= 2\pi \times 50$	A1
	$= 310 \text{ rad s}^{-1}$	
(c)(ii)	power = V_{RMS}^2 / R or power = $V_0^2 / 2R$	C1
	$R = (240 / \sqrt{2})^2 / 3200$ or $R = 240^2 / (2 \times 3200)$	A1
	$R = 9.0 \Omega$	

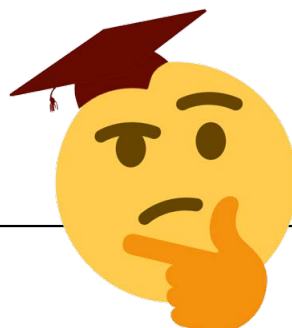


10 – (9702/41_Summer_2022_Q5) – *Alternating Currents*

(a)(i)	conversion (from a.c.) to d.c.	B1
(a)(ii)	full-wave (rectification)	B1
(b)(i)	P labelled – and Q labelled +	B1
(b)(ii)	V_{OUT} scale labelled 4 and 8 on the 2 cm tick marks	B1
	$T = 2\pi / \omega$ $= 2\pi / 25\pi$ $= 0.08 \text{ s}$	C1
	t scale labelled 0.02, 0.04, 0.06, 0.08, 0.10, 0.12 on the 2 cm tick marks	A1
(c)(i)	correct symbol used for capacitor and capacitor connected in parallel with the $1.2 \text{ k}\Omega$ resistor.	B1
(c)(ii)	straight lines or curves, with negative decreasing gradients, drawn between adjacent peaks, from top of first peak to meet line going up to next peak	B1
	lines, from one peak to the line going up to the next peak, show a drop in p.d. of $1\frac{1}{2}$ small squares	B1
(c)(iii)	$V = 0.90 \times 6.0 (= 5.4 \text{ V})$	C1
	or	
	discharge time (for each cycle) = 0.034 s	
	$V = V_0 \exp(-t / RC)$	C1
	$5.4 = 6.0 \exp[-0.034 / (1.2 \times 10^3 \times C)]$	
	$C = 2.7 \times 10^{-4} \text{ F}$	A1

11 – (9702/41_Winter_2022_Q7) – *Alternating Currents*

(a)(i)	peak voltage = $4.2 \times \sqrt{2}$ (= 5.9 V)	B1
	power = V^2 / R $= 5.9^2 / 760 = 0.046 \text{ W}$ or 46 mW	A1
(a)(ii)	sketch shows peak(s) in power at 46 mW	B1
	correct shape (sinusoidal wave sitting on t -axis)	B1
	four cycles of repeating pattern shown, with $P = 0$ at 0, 10, 20, 30, 40 μs	B1
(a)(iii)	line is symmetrical about 23 mW	B1
(b)(i)	(alternating p.d. makes) the crystal vibrate	B1
	vibrations (of crystal) causes air to vibrate	B1
	frequency is in ultrasound range	B1
(b)(ii)	(air makes) crystal vibrate, which causes an e.m.f. to be generated across the (second) crystal	B1

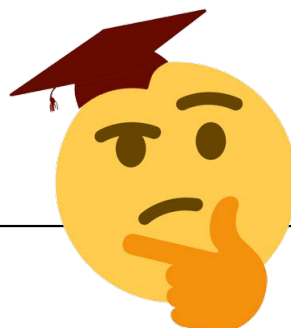


12 - (9702/42_Summer_2023_Q7) - Alternating Currents

(a)(i)	full-wave (rectification)	B1
(a)(ii)	lower left diode shown pointing left	B1
	lower right and upper left diodes shown pointing left	B1
(a)(iii)	arrow indicating current direction in resistor to the right	B1
(b)(i)	sketch: periodic line showing minimum $V_{OUT} = 0$ and maximum $V_{OUT} = +V_0$	B1
	line showing peak V_{OUT} at $t = 0, 0.5T, 1.0T, 1.5T$ and $2.0T$, with V_{OUT} going to zero half-way in between each peak	B1
	line showing correct modulated sine shape	B1
(b)(ii)	sketch: sinusoidal curve with troughs sitting on the time axis	B1
	peak power at $t = 0, 0.5T, 1.0T, 1.5T$ and $2.0T$ and zero power half-way in between each peak	B1
(b)(iii)	same power-time graph with or without rectification, so same V_{rms} or V^2 -time graph is same for both V_{OUT} and V_{IN} , so same V_{rms} or power does not depend on sign of V , so same V_{rms}	B1

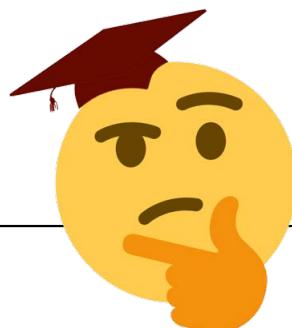
13 - (9702/41_Winter_2023_Q7) - Alternating Currents

(a)(i)	$P = I_0^2 R$	A1
(a)(ii)	$P = 4I_0^2 R$	A1
(b)	sketch: square wave of period T , with P always non-zero	B1
	horizontal lines, from 0 to $0.5T$ and from $1.0T$ to $1.5T$, all at the same level that the scale indicates to be $I_0^2 R$	B1
	horizontal lines, from $0.5T$ to $1.0T$ and from $1.5T$ to $2.0T$, at a level that is four times higher than the lower lines	B1
(c)(i)	$\langle P \rangle = (5/2)I_0^2 R$	A1
(c)(ii)	$\langle P \rangle = I_{rms}^2 R$	C1
	$I_{rms}^2 R = (5/2)I_0^2 R$	A1
	$I_{rms} = \sqrt{(5/2)} I_0$	



14 - (9702/42_Winter_2023_Q4) - Alternating Currents

(a)(i)	amplitude $= \frac{1}{2} \times 7.2 \times 10^{-15}$ $= 3.6 \times 10^{-15} \text{ m}$	A1
(a)(ii)	$\omega = 2\pi / (0.20 \times 10^{-6})$ $= 3.1 \times 10^7 \text{ rad s}^{-1}$	A1
(a)(iii)	$v_0 = \omega x_0$	C1
	$v_0 = 3.1 \times 10^7 \times 3.6 \times 10^{-15} = 1.1 \times 10^{-7} \text{ m s}^{-1}$	A1
(b)(i)	$I_0 = nA v_0 e$	C1
	$= 8.5 \times 10^{28} \times 4.3 \times 10^{-4} \times 1.1 \times 10^{-7} \times 1.60 \times 10^{-19}$	
	$= 0.64 \text{ A}$	A1
(b)(ii)	sketch: two cycles of sinusoidal curve of amplitude I_0 and period $0.20 \mu\text{s}$	B1
	correct phase, with $I = +I_0$ at $t = 0$	B1
(b)(iii)	equation of form $I = I_0 \cos \omega t$	M1
	value of I_0 used matches answer to (b)(i) and value of ω used matches answer to (a)(ii)	A1
	[if (a)(ii) and (b)(i) correct then $I = 0.64 \cos (3.1 \times 10^7 t)$]	
(b)(iv)	$I_{r.m.s.} = I_0 / \sqrt{2}$ $= 0.64 / \sqrt{2}$ $= 0.45 \text{ A}$	A1



1 - (9702/41_Summer_2017_Q5) - Quantum Physics

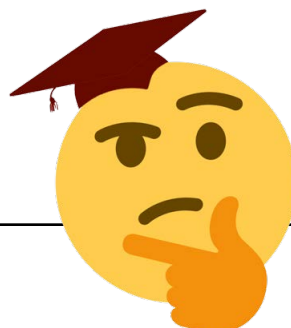
(a)	(loss in) kinetic energy of α -particle = $Qq / 4\pi\epsilon_0 r$ or $7.7 \times 10^{-13} = Qq / 4\pi\epsilon_0 r$
	$7.7 \times 10^{-13} = 8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / r$
	$r = 4.7 \times 10^{-14} \text{ m}$
	r is closest distance of approach so radius less than this
(b)	force = $Qq / 4\pi\epsilon_0 r^2 = 4u \times a$
	$8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / (4.7 \times 10^{-14})^2 = 4 \times 1.66 \times 10^{-27} \times a$
	$a = 2.5 \times 10^{27} \text{ m s}^{-2}$
(c)	so that single interactions between nucleus and α -particle can be studied or so that multiple deflections with nucleus do not occur

2 - (9702/41_Summer_2017_Q10) - Quantum Physics

(a)(i)	penetration of beam
	greater hardness means greater penetration/shorter wavelength/higher frequency/higher photon energy
(a)(ii)	greater accelerating potential difference or greater p.d. between anode and cathode
(b)	$I = I_0 \exp(-\mu x)$
	ratio = $(\exp \{-1.5 \times 2.9\}) / (\exp \{-4.0 \times 0.95\}) = \exp \{-0.55\}$
	= 0.58

3 - (9702/42_Summer_2017_Q10) - Quantum Physics

(a)	two from: • frequency below which electrons not ejected • <u>maximum</u> energy of electron depends on frequency • <u>maximum</u> energy of electrons does not depend on intensity • instantaneous emission of electrons
(b)(i)	(λ_0 is the) threshold wavelength or wavelength corresponding to threshold frequency or maximum wavelength for emission of electrons
(b)(ii)1.	intercept = $1/\lambda_0 = 2.2 \times 10^6 \text{ m}^{-1}$
	$\lambda_0 = 4.5 \times 10^{-7} \text{ m}$ or 450 nm
(b)(ii)2.	gradient = hc
	gradient = 2.0×10^{-25} or correct substitution into gradient formula
	$h = (2.0 \times 10^{-25}) / (3.0 \times 10^8) = 6.7 \times 10^{-34} \text{ J s}$
(c)	line: same gradient
	straight line, positive gradient, intercept at greater than 2.2×10^6 when candidate's line extrapolated



4 - (9702/41_Summer_2017_Q11) - Quantum Physics

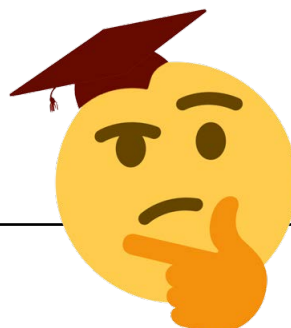
(a)	electrons (in gas atoms/molecules) interact with photons
	photon energy causes electron to move to higher energy level/to be excited
	photon energy = difference in energy of (electron) energy levels
	when electrons de-excite, photons emitted in all directions (so dark line)
(b)(i)	photon energy $\propto 1/\lambda$
	energy = 1.68 eV
	or
	$E = hc/\lambda$
	$E = 6.63 \times 10^{-34} \times 3.0 \times 10^8 / (740 \times 10^{-9})$ $= 2.688 \times 10^{-19} \text{ J}$
(b)(ii)	energy = 1.68 eV
	3.4 eV $\rightarrow$ 1.5 eV
	3.4 eV $\rightarrow$ 0.85 eV
	3.4 eV $\rightarrow$ 0.54 eV
all correct and none incorrect 2/2	
2 correct and 1 incorrect or only 2 correctly drawn 1/2	

5 - (9702/42_Summer_2017_Q11) - Quantum Physics

(a)	loss of (electric) potential energy = gain in kinetic energy
	or $qV = \frac{1}{2}mv^2$ or $E_k = p^2/2m = qV$
(b)(i)	$p = mv$ with algebra leading to $p = \sqrt{2mqV}$
	particle/electron has a wavelength (associated with it)
(b)(ii)	dependent on its momentum
	or
	when/because particle is moving
	$p = (2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2}$
(c)	$\lambda = (6.63 \times 10^{-34}) / (5.91 \times 10^{-24})$
	$= 1.12 \times 10^{-10} \text{ m}$
	wavelength is similar to separation of atoms
(c)	so diffraction observed

6 - (9702/42_Winter_2017_Q10) - Quantum Physics

(a)	λ_0 marked and graph line passing through $E_{\text{MAX}} = 0$ at $\lambda = \lambda_0$	B1
	graph line with λ always $< \lambda_0$	B1
	negative gradient with correct concave curvature	B1
(b)	curve with negative gradient and correct concave curvature	M1
	not touching either axis	A1



7 - (9702/41_Winter_2017_Q11) - Quantum Physics

(a)	packet/quantum of energy of electromagnetic/EM radiation	B1
(b)(i)	$E = hf$	C1
	$1.1 \times 10^6 \times 1.60 \times 10^{-19} = 6.63 \times 10^{-34} \times f$	
	$f = 2.7 \times 10^{20} (2.65 \times 10^{20}) \text{ Hz}$	A1
(b)(ii)	$p = h/\lambda = hf/c$	C1
	$= (6.63 \times 10^{-34} \times 2.65 \times 10^{20}) / (3.00 \times 10^8)$	
	or	
	$p = E/c$	
(c)	$= (1.1 \times 1.60 \times 10^{-13}) / (3.00 \times 10^8)$	
	$p = 5.9 \times 10^{-22} (5.87 \times 10^{-22}) \text{ N s}$	A1
	$123 \times 1.66 \times 10^{-27} \times v = 5.87 \times 10^{-22}$	C1
	$v = 2.9 \times 10^3 \text{ ms}^{-1}$	A1

8 - (9702/42_Summer_2018_Q10) - Quantum Physics

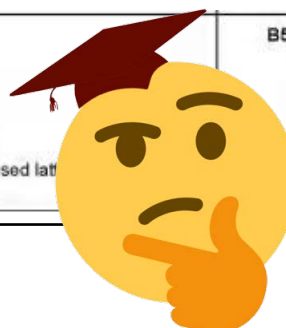
(a)	emission of electron	B1
	when electromagnetic radiation incident (on surface)	B1
(b)(i)	packet/quantum/discrete amount of <u>energy</u>	M1
	of electromagnetic radiation	A1
(b)(ii)	$E = hc/\lambda$	C1
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (420 \times 10^{-9})$	A1
	$= 4.7 \times 10^{-19} \text{ J}$	
(b)(iii)	sodium: yes	B1
	zinc: no	

9 - (9702/41_Summer_2018_Q11) - Quantum Physics

(a)(i)	packet/quantum/discrete amount of <u>energy</u>	M1
	of electromagnetic radiation	A1
(a)(ii)	(maximum) energy of emitted electrons is independent of intensity	B1
	or	
	no emission of electrons below the threshold frequency regardless of intensity	
	or	
(b)	no emission of electrons when photon energy is less than work function (energy) regardless of intensity	B1
	in darkness: conduction band empty so high resistance	
	in daylight: electrons in valence band absorb photons	
	in daylight: electrons 'jump' to conduction band	
	this leaves holes in valence band	
	more charge carriers in daylight so resistance decreases	

10 - (9702/41_Winter_2018_Q10) - Quantum Physics

	Any five points from: - as temperature rises electrons gain energy - electrons enter conduction band (positively charged) holes left in valence band - more charge carriers (so resistance decreases) (as temperature rises,) lattice vibrations increase - effect of increase in number of electrons or holes or charge carriers outweighs effect of increased lattice vibrations (so resistance decreases)	B5
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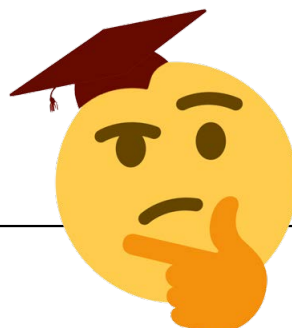


11 - (9702/41_Winter_2018_Q11) - Quantum Physics

(a)	discrete amount/quantum/packet of <u>energy</u>	M1
	of electromagnetic radiation	A1
(b)(i)	energy = hc/λ	C1
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (0.51 \times 10^6 \times 1.60 \times 10^{-19})$ $= 2.4 \times 10^{-12} \text{ m}$	A1
(b)(ii)	$p = h/\lambda$ $= (6.63 \times 10^{-34}) / (2.44 \times 10^{-12})$ or $p = E/c$ $= (0.51 \times 1.60 \times 10^{-13}) / (3.00 \times 10^8)$ $p = 2.7 \times 10^{-22} \text{ N s}$	C1
		A1
	(c)(i) $E = c^2 \Delta m$	C1
	$\Delta m = (0.51 \times 1.60 \times 10^{-13}) / (3.00 \times 10^8)^2$ $= 9.1 \times 10^{-31} \text{ kg}$	A1
(c)(ii)	(momentum is conserved so) nucleus must have momentum in opposite direction to photon	B1

12 - (9702/42_Winter_2018_Q11) - Quantum Physics

(a)	discrete amount/quantum/packet of <u>energy</u>	M1
	of electromagnetic radiation	A1
(b)	mostly dark/dark background	B1
	coloured lines	B1
(c)(i)	6	A1
(c)(ii)	1. maximum photon energy = $13.6 - 0.85$ $(= 12.75 \text{ eV})$	C1
	maximum kinetic energy = $(13.6 - 0.85) - 5.6$ $= 7.2 \text{ eV}$	A1
	2. energy = hc/λ	C1
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / [(13.6 - 0.85) \times 1.60 \times 10^{-19}]$	C1
	$= 9.8 \times 10^{-8} \text{ m}$	A1



13 - (9702/42_Summer_2019_Q7) - Quantum Physics

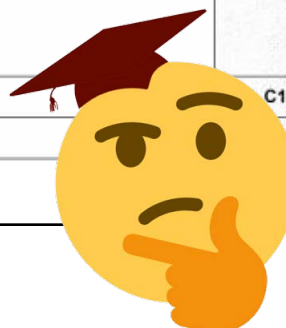
(a)	Any five from: • (as temperature rises) energy of electrons increases • electrons (have enough energy to) cross forbidden band • electrons enter conduction band • leaving holes in valence band • both holes and electrons act as charge carriers • more charge carriers results in lower resistance • increased lattice vibrations outweighed by increase in (number of) charge carriers	B5
(b)	(at 10 °C resistance is) 2.55 kΩ	C1
	new potential difference = $9.00 \times 2.55 / (2.55 + 12.0)$ = 1.58 V	C1
	change in p.d. = 0.58 V	A1
(c)	change of resistance with temperature is not linear	B1
	change in potential with resistance is not linear or potential divider equation is non-linear	B1

14 - (9702/41_Summer_2019_Q11) - Quantum Physics

(a)	Any three points from: • (max) energy of emitted electrons depends on frequency • (max) energy of emitted electrons does not depend on intensity • rate of emission of electrons depends on intensity (at constant frequency) • existence of frequency below which no emission of electrons • instantaneous emission of electrons • increasing the frequency at constant intensity decreases the rate of emission of electrons	B3
(b)(i)	photon energy = hc / λ	C1
	= $(6.63 \times 10^{-34} \times 3.0 \times 10^8) / (380 \times 10^{-9})$ (= 5.23×10^{-19} J)	C1
	= 3.3 eV	A1
(b)(ii)	photon energy must be greater than work function (energy)	B1
	so sodium and calcium	B1
(c)	$\lambda = h / p$	C1
	$p = (6.63 \times 10^{-34}) / (380 \times 10^{-9})$ = 1.74×10^{-27} N s	C1
	force = $1.74 \times 10^{-27} \times 7.6 \times 10^{14}$ = 1.3×10^{-12} N	A1

15 - (9702/42_Summer_2019_Q11) - Quantum Physics

(a)	packet/quantum of <u>energy</u>	M1
	of electromagnetic radiation	A1
(b)(i)	$E = hc / \lambda$	C1
	$1.18 \times 1.60 \times 10^{-13} = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / \lambda$ $\lambda = 1.05 \times 10^{-12}$ m	A1
(b)(ii)	$\lambda = h / p$ or $E = pc$	C1
	$p = (6.63 \times 10^{-34}) / (1.05 \times 10^{-12})$ or $p = (1.18 \times 1.60 \times 10^{-13}) / (3.00 \times 10^8)$ leading to $p = 6.3 \times 10^{-22}$ N s	B1
(c)	$6.3 \times 10^{-22} = 60 \times 1.66 \times 10^{-27} \times v$ $v = 6.3 \times 10^5$ m s ⁻¹	C1



16 - (9702/42_Winter_2019_Q10) - Electronics, Quantum Physics

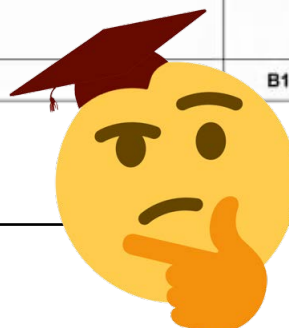
(a)	(as temperature rises) electrons in valence band gain energy	B1
	electrons jump to conduction band	B1
	holes are left in the valence band	B1
	increased <u>number</u> (density) of charge carriers causes lower resistance	B1
(b)(i)	$V^- = V^+$	C1
	$1.50 / 1.20 = R_T / 1.76$	C1
	$R_T = 2.2 \text{ (k}\Omega\text{)}$	C1
	temperature = 14°C	A1
(b)(ii)	(For LED to conduct,) V_{OUT} must be negative	B1
	$V^- > V^+$	B1
	R_T must be lower so temperature must be above (b)(i) value	B1

17 - (9702/41_Winter_2019_Q11) - Quantum Physics

(a)	energy (of photon) required to remove electron	M1
	from a surface	A1
	or reference to <u>minimum</u> energy	
	or reference to zero <u>kinetic</u> energy	
(b)(i)	1. photon energy = hc / λ	C1
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (280 \times 10^{-9})$	A1
	$= 7.1 \times 10^{-19} \text{ J}$	
	2. electron energy = $(7.1 - 5.5) \times 10^{-19} \text{ J}$	C1
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = (7.1 - 5.5) \times 10^{-19}$	C1
	$v = 5.9 \times 10^5 \text{ m s}^{-1}$	A1
(b)(ii)	energy is required to bring electron to the surface	B1
(c)	no change decreases	B4
	increases decreases	

18 - (9702/41_Summer_2020_Q10) - Quantum Physics

(a)	- photon gives energy to electron (in an inner shell) or electron (in an inner shell) absorbs a photon - electron moves (from lower) to higher energy level - energy (of photon) is equal to difference in energy levels - electron de-excites giving off photon (of same energy) - photons emitted in all directions Any four points, 1 mark each	B4
(b)	(in light) photons gives energy to electrons in VB or (in light) electrons in VB absorb photons	B1
	electron crosses FB/jumps to CB	B1
	(positive) holes left/created in VB	B1
	low intensity: few electrons in CB/most electrons in VB or high intensity: more photons so more electrons in CB or electron-hole pairs are charge carriers	B1
	more charge carriers results in lower resistance	B1



19 - (9702/41_Summer_2020_Q11) - Quantum Physics

(a)(i)	$E = mc^2$	C1
	$= 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2$	A1
	$= 8.2 \times 10^{-14} \text{ J}$	
(a)(ii)	$p = h / \lambda$ and $E = hc / \lambda$ or $E = pc$	C1
	$p = (8.2 \times 10^{-14}) / (3.0 \times 10^8)$	A1
	$= 2.7 \times 10^{-22} \text{ N s}$	
(b)	total momentum (before and after interaction) is zero or momentum must be conserved (in the interaction) or momentum of the photons must be equal and opposite	B1
	(photons emitted in) opposite directions	B1

20 - (9702/42_Summer_2020_Q11) - Quantum Physics

(a)	conduction band and valence band overlap	B1
	number (density) of charge carriers does not vary	B1
	increase in temperature gives rise to <u>increased</u> lattice vibrations	B1
	(lattice) vibrations hinder movement of charge carriers so resistance increases	B1
(b)	$mv = h / \lambda$	C1
	$v = (6.63 \times 10^{-34}) / [(2.6 \times 10^{-11}) \times (9.11 \times 10^{-31})]$ $(= 2.80 \times 10^7 \text{ m s}^{-1})$	C1
	$qV = \frac{1}{2}mv^2$	C1
	$V = [9.11 \times 10^{-31} \times (2.80 \times 10^7)^2] / [2 \times 1.60 \times 10^{-19}]$	A1
	$= 2.2 \times 10^3 \text{ V}$	

21 - (9702/41_Winter_2020_Q11) - Quantum Physics

(a)(i)	quantum of energy	M1
	of electromagnetic radiation	A1
(a)(ii)	arrow (on Fig. 11.1) pointing upwards and to the right	B1
(b)(i)	$\lambda = h / p$	C1
	$p = (6.63 \times 10^{-34}) / (544 \times 10^{-9})$	A1
	$= 1.22 \times 10^{-27} \text{ N s}$	
(b)(ii)	energy $= hc / \lambda$	C1
	$= 6.63 \times 10^{-34} \times 3.00 \times 10^8 \times (540^{-1} - 544^{-1}) \times 10^9$	A1
	$= 2.7 \times 10^{-21} \text{ J}$	
(c)	(smaller wavelength corresponds to) greater photon energy	B1
	any one point from: (deflected) photon loses energy (so not possible) (deflected) photon would need to gain energy (so not possible) - electron would need to lose energy (so not possible) - initially electron energy is zero (so not possible)	B1



22 – (9702/42_Winter_2020_Q11) – Quantum Physics

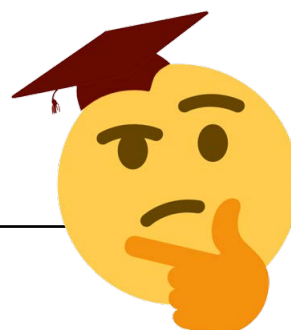
(a)	any two points from: • (maximum) kinetic energy of electrons is independent of intensity • maximum kinetic energy of electrons depends on frequency • no time delay (between illumination and emission)	B2
(b)(i)	(for $E_{\text{MAX}} = 0$) $1/\lambda_0 = 1.93 \times 10^6 \text{ (m}^{-1}\text{)}$ $f_0 = 3.00 \times 10^8 \times 1.93 \times 10^6$ $= 5.8 \times 10^{14} \text{ Hz}$	C1 A1
(b)(ii)	$hc/\lambda = \phi + E_{\text{MAX}}$	C1
	$hc = \text{gradient}$	C1
	gradient = e.g. $[(0.40 - 0.20) \times 1.60 \times 10^{-19}] / [(2.25 - 2.09) \times 10^9] \text{ (working needed)}$ $(= 2.0 \times 10^{-25})$	M1
	$h = (2.0 \times 10^{-25}) / (3.00 \times 10^8) = 6.7 \times 10^{-34} \text{ J s (both working and answer needed)}$	A1
(c)	straight line with same gradient as the original	B1
	straight line with x-axis intercept greater than $1.93 \times 10^6 \text{ m}^{-1}$	B1

23 – (9702/41_Summer_2021_Q6) – Electric Fields, Quantum Physics, Particle & Nuclear Physics

(a)	from $x = 0$ to $x = r$: $E = 0$	B1
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude passing through (r, E_0)	B1
	line passing through $(2r, E_0/4)$ and $(3r, E_0/9)$	B1
(b)	from $p = p_0/2$ to $p = p_0$: curve with negative gradient of decreasing magnitude passing through (p_0, λ_0)	B1
	line passing through $(\frac{1}{2}p_0, 2\lambda_0)$	B1
(c)	from $t = 0$ to $t = 45 \text{ s}$: curve with positive gradient of decreasing magnitude starting at $(0, 0)$	B1
	line passing through $(15, \frac{1}{2}N_0)$	B1
	line passing through $(30, 0.75N_0)$ and $(45, 0.88N_0)$	B1

24 – (9702/41_Summer_2021_Q11) – Quantum Physics

(a)	intensity: vary filament current/p.d. across filament	B1
	hardness: vary accelerating potential difference	B1
(b)(i)	$I = I_0 e^{-\mu x}$	C1
	$I_s = I_0 \exp(-0.92 \times 9.0)$ $= 2.5 \times 10^{-4} I_0$	A1
(b)(ii)	$I_c = [\exp(-0.92 \times 6.0) \times \exp(-2.9 \times 3.0)] I_0$	C1
	$= 6.7 \times 10^{-7} I_0$	A1
(c)	conclusion consistent with values in (b)(i) and (b)(ii) e.g. $I_s \gg I_c$ so good contrast	B1

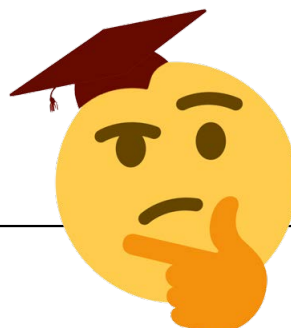


25 - (9702/41_Summer_2021_Q12) - Quantum Physics

(a)	- frequency determines energy of photon - intensity determines number of photons (per unit time) - intensity does not determine energy of a photon <i>Any two points, 1 mark each</i>	B2
	kinetic energy (of the electron) depends on the energy of one photon	B1
(b)(i)	$E = hc / \lambda$ or $E = hf$ and $c = f\lambda$	C1
	$E = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (250 \times 10^{-9})$	C1
	$(= 7.96 \times 10^{-19} \text{ J})$	A1
	$= 5.0 \text{ eV}$	
(b)(ii)	$E_{\text{MAX}} = \text{photon energy} - \text{work function}$	C1
	work function $= 5.0 - 1.4$ $= 3.6 \text{ eV}$	A1

26 - (9702/42_Summer_2021_Q12) - Quantum Physics

(a)	quantum of energy	M1
	of electromagnetic radiation	A1
(b)(i)	energy $= hc / \lambda$ or energy $= hf$ and $f = c / \lambda$	C1
	$0.57 \times 10^6 \times 1.60 \times 10^{-19} = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / \lambda$	A1
	$\lambda = 2.2 \times 10^{-12} \text{ m}$	
(b)(ii)	$p = h / \lambda$	C1
	$= (6.63 \times 10^{-34}) / (2.2 \times 10^{-12})$	A1
	$= 3.0 \times 10^{-22} \text{ N s}$	
	or	
	$p = E / c$	(C1)
	$= (0.57 \times 10^6 \times 1.60 \times 10^{-19}) / (3.00 \times 10^8)$	(A1)
	$= 3.0 \times 10^{-22} \text{ N s}$	
(c)(i)	mass (of Sm-157 nucleus) $= 157 \times 1.66 \times 10^{-27}$ or mass (of Sm-157 nucleus) $= 0.157 / (6.02 \times 10^{23})$	C1
	recoil speed $= (3.00 \times 10^{-22}) / (157 \times 1.66 \times 10^{-27})$	A1
	$= 1.2 \times 10^3 \text{ m s}^{-1}$	
(c)(ii)	$(1.2 \times) 10^3 \text{ m s}^{-1}$ is <u>much</u> less than $(3.0 \times) 10^8 \text{ m s}^{-1}$	B1



27 - (9702/41_Winter_2021_Q10) - Quantum Physics

(a)(i)	photoelectric effect	B1
(a)(ii)	electron diffraction	B1
(b)(i)	$\lambda = h / p$	M1
	h is the Planck constant	A1
(b)(ii)	de Broglie (wavelength)	B1
(c)(i)	$\frac{1}{2}mv^2 = eV$	C1
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 1.60 \times 10^{-19} \times 4800$ <u>so</u> $v = 4.1 \times 10^7 \text{ m s}^{-1}$	A1
(c)(ii)	$\lambda = h / mv$	C1
	$= 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 4.1 \times 10^7)$	
	$= 1.8 \times 10^{-11} \text{ m}$	A1

28 - (9702/41_Summer_2022_Q7) - Quantum Physics

(a)	quantum of energy	M1
	of electromagnetic radiation	A1
(b)(i)	photoelectric effect	B1
(b)(ii)	- there is a frequency below which no electrons are emitted or threshold frequency = $5.4 \times 10^{14} \text{ Hz}$ - work function of the metal = $3.6 \times 10^{-19} \text{ J}$ (or 2.2 eV) E_{MAX} increases (linearly) with (increasing) frequency - gradient of the line is the Planck constant or gradient of the line is $6.7 \times 10^{-34} \text{ J s}$ Any three bullet points, 1 mark each	B3
(c)(i)	different threshold frequency	B1
	(line has) same gradient but different intercept	B1
(c)(ii)	photons have same energy	B1
	line unchanged	B1

29 - (9702/42_Summer_2022_Q8) - Quantum Physics

(a)(i)	photoelectric effect	B1
(a)(ii)	electron diffraction	B1
(b)(i)	$\lambda = h / p$	C1
	$p = 4 \times 1.66 \times 10^{-27} \times 6.2 \times 10^7$	C1
	$(= 4.1 \times 10^{-19} \text{ N s})$	
	$\lambda = 6.63 \times 10^{-34} / 4.1 \times 10^{-19}$	A1
	$= 1.6 \times 10^{-15} \text{ m}$	
(b)(ii)	line with negative gradient throughout	B1
	curve asymptotic to both axes with non-zero λ at $v = 6.2 \times 10^7 \text{ m s}^{-1}$	B1
(c)	(de Broglie) wavelength negligible compared with width of doorway	B1

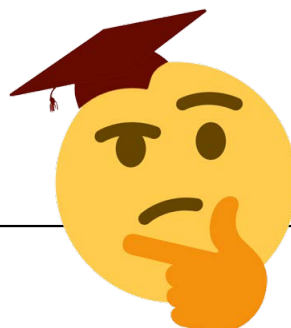


30 – (9702/41_Winter_2022_Q8) – Quantum Physics

(a)	photon energy (to remove electron)	B1
	minimum energy to remove electron or energy to remove electron from surface or energy to remove electron with zero kinetic energy	B1
	photon energy = hf	C1
	number per unit time = $8.36 \times 10^{-3} / (1.36 \times 10^{15} \times 6.63 \times 10^{-34})$ $= 9.27 \times 10^{15} \text{ s}^{-1}$	A1
(b)(ii)	$hf = \phi + E_{\text{MAX}}$	C1
	$\phi = (1.36 \times 10^{15} \times 6.63 \times 10^{-34}) - (3.09 \times 10^{-19})$	A1
	$= 5.93 \times 10^{-19} \text{ J}$	
(c)(i)	greater photon energy (and same work function)	M1
	so maximum kinetic energy is increased	A1
(c)(ii)	(greater photon energy and same power so) lower number of photons (per unit time)	M1
	(each electron absorbs one photon) so lower rate of emission	A1

31 – (9702/42_Winter_2022_Q9) – Quantum Physics

(a)(i)	- energy of photon has a corresponding frequency - change in electron energy level emits a single photon - photon energy = difference in energy levels - discrete frequencies must have come from discrete energy gaps - discrete energy changes imply discrete energy levels <i>Any three points, 1 mark each</i>	B3
(a)(ii)	transition (to -3.400 eV) from X corresponds to 658 nm line	C1
	$E_1 - E_2 = hc / \lambda$	C1
	$E_1 - (-3.400) = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (658 \times 10^{-9} \times 1.60 \times 10^{-19})$	A1
	and so $E_1 = -1.51 \text{ eV}$ (full substitution and answer needed)	
(b)(i)	redshift	B1
(b)(ii)	moving away (from observer)	B1
(b)(iii)	$\Delta\lambda / \lambda = v / c$	C1
	e.g. for 658 nm line: $\Delta\lambda = 686 - 658$ $(= 28 \text{ nm})$ (other lines may be used)	
	$28 / 658 = v / (3.00 \times 10^8)$ (other lines may be used)	C1
	$v = 1.3 \times 10^7 \text{ m s}^{-1}$	A1
(c)	$v = H_0 d$	C1
	$H_0 = (1.3 \times 10^7) / (5.7 \times 10^{24})$	A1
	$= 2.3 \times 10^{-18} \text{ s}^{-1}$	



32 – (9702/42_Summer_2023_Q8) – Quantum Physics

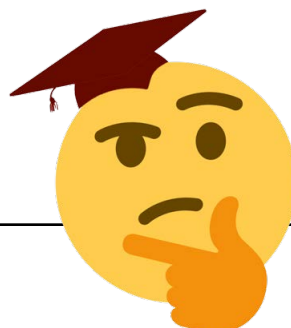
(a)	transition (emits) (one) photon with energy equal to the difference in energy between the two levels	B1
	frequency of radiation corresponds to energy of photon	B1
(b)(i)	line to the left of the pair in Fig. 8.2, labelled A	B1
	larger gap between line A and the nearest of the pair in Fig. 8.2 than between the lines in the pair	B1
(b)(ii)	line to the left of both the pair in Fig. 8.2 and line A, labelled B	B1
	larger gap between line B and line A than between line A and the nearest one of the pair in Fig. 8.2	B1
(c)	$E = hf$	C1
	$E_3 = E_1 + h(f_A + f_B)$	A1

33 – (9702/41_Winter_2023_Q8) – Quantum Physics

(a)(i)	$p = E / c$	M1
	$E = hc / \lambda$ and completion of algebra leading to $p = h / \lambda$	A1
(a)(ii)	wavelength = $(6.63 \times 10^{-34}) / (9.5 \times 10^{-28}) = 700 \times 10^{-9} \text{ m}$ so red	B1
(b)(i)	power = intensity $\times$ area	C1
	number per unit time = $(160 \times 2.5 \times 10^{-6}) / (9.5 \times 10^{-28} \times 3.00 \times 10^8) = 1.4 \times 10^{15} \text{ s}^{-1}$	A1
(b)(ii)	pressure = force / area	C1
	force = rate of change of momentum	C1
	$= 2 \times 9.5 \times 10^{-28} \times 1.4 \times 10^{15}$	
	pressure = $(2 \times 9.5 \times 10^{-28} \times 1.4 \times 10^{15}) / (2.5 \times 10^{-6})$ $= 1.1 \times 10^{-6} \text{ Pa}$	A1
(c)	photons have greater momentum or fewer photons per unit time	B1
	greater photon momentum but smaller number of photons (per unit time) so pressure is the same	B1

34 – (9702/42_Winter_2023_Q8) – Quantum Physics

(a)	packet / quantum of <u>energy</u>	M1
	of electromagnetic radiation	A1
(b)(i)	photoelectric effect	B1
(b)(ii)	- electron needs a minimum energy to escape or electron emitted if energy in packet is enough - energy must be absorbed in packets that are related to frequency - intensity relates to number of packets (not to energy in packet) - electron absorbs only a single whole packet Any three points, 1 mark each	B3
(c)(i)	Planck constant	B1
(c)(ii)	– work function (energy)	B1

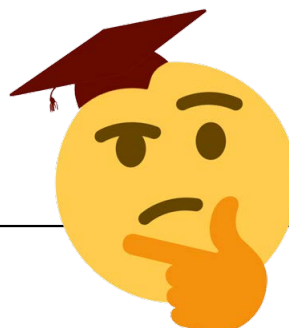


1 - (9702/41_Summer_2017_Q12) - Particle & Nuclear Physics

(a)	$x = 7$
(b)(i)	$E = mc^2$
	$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$
	$= 1.494 \times 10^{-10} \text{ J}$
	division by 1.6×10^{-13} clear to give 934 MeV
(b)(ii)	$\Delta m = (235.123 + 1.00863) - (94.945 + 138.955 + 2 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$ or $\Delta m = 235.123 - (94.945 + 138.955 + 1 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$
	$= 0.21053 \text{ u}$
	energy $= 0.21053 \times 934$
	$= 197 \text{ MeV}$
(c)	kinetic energy of nuclei/particles/products/fragments
	γ -ray photon energy

2 - (9702/42_Summer_2017_Q12) - Particle & Nuclear Physics

(a)	$7 \text{ }^0_{-1}\text{e}$
(b)(i)	$E = mc^2$
	$= 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$
	$= 1.494 \times 10^{-10} \text{ J}$
	division by 1.60×10^{-13} clear to give 934 MeV
(b)(ii)	$\Delta m = (82 \times 1.00863\text{u}) + (57 \times 1.00728\text{u}) - 138.955\text{u}$
	$= (-) 1.16762 \text{ (u)}$
	energy $= 1.16762 \times 934$
	energy per nucleon $= (1.16762 \times 934) / 139$ $= 7.85 \text{ MeV}$
(c)	above $A = 56$, binding energy per nucleon decreases as A increases
	U-235 has larger nucleon number
	so less (binding energy per nucleon)
	or
	fission takes place with uranium
	fission reaction releases energy
	binding energy per nucleon less (for uranium than for products)

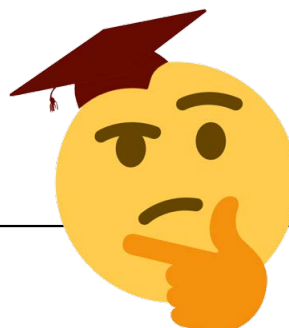


3 - (9702/41_Winter_2017_Q9) - Particle & Nuclear Physics

(a)	image of one slice/section	(B1)			
	images (of one slice) taken from different angles	(M1)			
	to give 2D image (of one slice)	(A1)			
	(repeated for) many slices	(M1)			
	to build up 3D image (of whole body/structure)	(A1)			
	Max. 4 marks total	4			
(b)	evidence of subtraction of background (–26)	C1			
	evidence of division by three	C1			
	<table border="1"><tr><td>7</td><td>11</td></tr><tr><td>6</td><td>2</td></tr></table>	7	11	6	2
7	11				
6	2				

4 - (9702/41_Winter_2017_Q12) - Particle & Nuclear Physics

(a)	• emission from radioactive daughter products • self-absorption in source • absorption in air before reaching detector • detector not sensitive to all radiations • window of detector may absorb some radiation • dead-time of counter • background radiation <i>Any two points.</i>	B2
(b)(i)	curve is not smooth or curve fluctuates/curve is jagged	B1
(b)(ii)	clear evidence of allowance for background	B1
	half-life determined at least twice	B1
	half-life = 1.5 hours (1 mark if in range 1.7–2.0; 2 marks if in range 1.4–1.6)	A2
(c)	1. half-life: no change	M1
	because decay is spontaneous/independent of environment	A1
	2. count rate (likely to be or could be) different/is random/cannot be predicted	B1

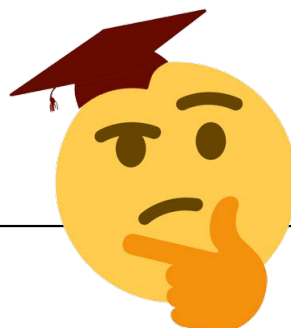


5 - (9702/42_Winter_2017_Q12) - Particle & Nuclear Physics

(a)(i)	<u>nucleus</u> emits particles/EM radiation/ionising radiation	B1
	emission/release from unstable <u>nucleus</u> or emission from <u>nucleus</u> is random and/or spontaneous	B1
(a)(ii)	probability of decay (of a nucleus) or fraction of (number of undecayed) nuclei that will decay	M1
	per unit time	A1
(b)	energy is shared with another particle	B1
	mention of antineutrino	B1
(c)(i)	number = $[(1.2 \times 10^{-9}) / 131] \times 6.02 \times 10^{23}$ or number = $(1.2 \times 10^{-3} \times 10^{-9}) / (131 \times 1.66 \times 10^{-27})$ (= 5.51×10^{12})	C1
	$A = \lambda N$	C1
	= $[0.086 / (24 \times 3600)] \times 5.51 \times 10^{12}$	A1
	= 5.5×10^6 Bq	
(c)(ii)	$1/50 = \exp(-0.086t)$ or $1/50 = 0.5^n$	C1
	$t = 45$ days	A1

6 - (9702/42_Summer_2018_Q12) - Particle & Nuclear Physics

(a)	emission of particles/radiation by <u>unstable nucleus</u>	B1
	spontaneous emission	B1
(b)(i)	P – the curve that starts with a high number D – the curve with the peak S – the curve that increases from zero throughout (one correct 1 mark, all three correct 2 marks)	B2
(b)(ii)	$\lambda t_{1/2} = 0.693$	C1
	$\lambda = 0.693 / (60.0 \times 60)$	
	= $1.93 \times 10^{-4} \text{ s}^{-1}$	A1
(c)	half-life of F is much shorter than half-life of E	B1
	<u>nuclei</u> of F decay (almost) as soon as they are produced	B1

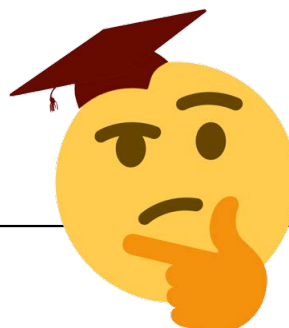


7 - (9702/41_Summer_2018_Q13) - Particle & Nuclear Physics

(a)	emission of particles/radiation by unstable nucleus	B1
	spontaneous emission	B1
(b)(i)	use of graph to determine half-life = 14 minutes	B1
	hence $\lambda = \ln 2 / (14 \times 60) \text{ (s}^{-1}\text{)}$	C1
	N at 14 minutes = 4.4×10^7 and $A = \lambda N$	C1
	activity = $4.4 \times 10^7 \times \ln 2 / (14 \times 60)$ = $3.6 \times 10^4 \text{ Bq}$	A1
	or	
	correct tangent drawn at time $t = 14$ minutes	(B1)
	magnitude of gradient of tangent identified as activity	(C1)
	correct working for gradient leading to activity	(C1)
	activity = $3.6 \times 10^4 \text{ Bq}$	(A1)
(b)(ii)	$3.6 \times 10^4 = \lambda \times 4.4 \times 10^7$ or $\lambda = \ln 2 / (14.0 \times 60)$	C1
	$\lambda = 8.2 \times 10^{-4} \text{ s}^{-1}$	A1

8 - (9702/41_Winter_2018_Q12) - Particle & Nuclear Physics

(a)	unstable nucleus	B1
	emission of particles/photons	B1
	emission is spontaneous or (particles/radiation) are ionising	B1
(b)(i)	tangent drawn and gradient calculation attempted	B1
	activity = $1.3 \times 10^6 \text{ Bq}$ (1 mark for answer within $\pm 0.2 \times 10^6 \text{ Bq}$, 2 marks for answer within $\pm 0.1 \times 10^6 \text{ Bq}$)	A2
(b)(ii)	$A = \lambda N$	C1
	$\lambda = (1.3 \times 10^6) / (3.05 \times 10^{10}) = 4.3 \times 10^{-5} \text{ s}^{-1} (\approx 4 \times 10^{-5} \text{ s}^{-1})$	A1
(c)	$A = A_0 e^{-\lambda t}$	C1
	$1.0 \times 10^3 = 4.6 \times 10^3 \exp(-5.5 \times 10^{-7} \times t)$	
	$\ln(4.6) = 5.5 \times 10^{-7} \times t$	C1
	$t = 2.78 \times 10^6 \text{ s}$ = 32 days	A1

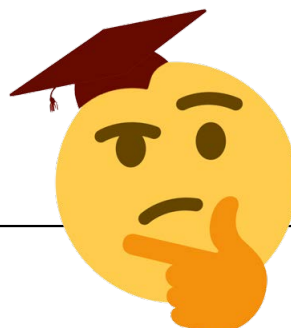


9 - (9702/42_Winter_2018_Q12) - Particle & Nuclear Physics

(a)	fusion: two nuclei <u>combine</u> to form a (single) nucleus	B1
	fission: a (single) large nucleus <u>divides</u> to form (smaller) nuclei	B1
	Any one from: - fusion is initiated by (very) high temperatures - fission is initiated by neutron bombardment - resulting nuclei in fission are of similar size (both processes) release energy - binding energy per nucleon increases - total binding energy increases - fission involves release of neutrons	B1
(b)(i)	neutron	B1
(b)(ii)	1. zero	A1
	2. $(4 \times 11.3290 \times 10^{-13}) - (2 \times 1.7813 \times 10^{-13}) - (3 \times 4.5285 \times 10^{-13})$	C1
	energy change = $45.316 \times 10^{-13} - 17.148 \times 10^{-13}$ = $2.82 \times 10^{-12} \text{ J}$	A1
(b)(iii)	1.0 mol or N_A nuclei of each energy = $2.817 \times 10^{-12} \times 6.02 \times 10^{23}$ = $1.7 \times 10^{12} \text{ J}$	A1

10 - (9702/41_Summer_2019_Q12) - Particle & Nuclear Physics

(a)(i)	$\Delta N / \Delta T$	B1
(a)(ii)	$\Delta N / N$	B1
(a)(iii)	$\Delta N / (N \Delta T)$	B1
(b)(i)	1. mass change = $5.60 \times 10^{-3} \text{ u}$	A1
	2. energy = $(\Delta)m c^2$	C1
	= $5.6 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ (= $8.36 \times 10^{-13} \text{ J}$)	C1
	= 0.84 pJ	A1
(b)(ii)	kinetic energy (of recoil) of lead (nucleus)	B1
	energy of γ -ray photon	B1

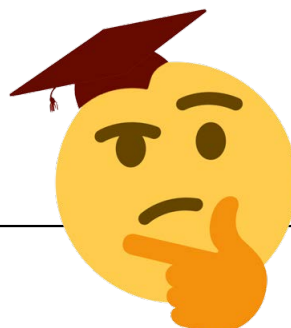


11 - (9702/42_Summer_2019_Q12) - Particle & Nuclear Physics

(a)	energy required to separate the nucleons (in a nucleus)	M1
	to infinity	A1
	or	
	energy released when nucleons come together (to form nucleus)	(M1)
	from infinity	(A1)
(b)	mass defect = $140.911 - (57 \times 1.007) - (84 \times 1.009)$	C1
	= $140.911 - 142.155$	C1
	= (-1.244 u)	
	energy = $c^2(\Delta)m$	C1
	= $(3.00 \times 10^8)^2 \times 1.244 \times 1.66 \times 10^{-27}$	A1
	= $1.9 \times 10^{-10} \text{ J}$	
(c)(i)	$A = A_0 e^{-\lambda t}$ and $\ln 2 = \lambda t_{1/2}$	C1
	$0.40 = \exp(-\ln 2 \times t / 3.9)$	C1
	or	
	$(0.5)^n = 0.40$	(C1)
	$n = 1.32$ and $t = 1.32 \times 3.9$	(C1)
	$t = 5.2 \text{ hours}$	A1
(c)(ii)	daughter product may be radioactive or random nature of decay	B1

12 - (9702/41_Winter_2019_Q12) - Particle & Nuclear Physics

(a)	$E = (3.0 \times 10^8)^2 \times 1.66 \times 10^{-27} (= 1.49 \times 10^{-10} \text{ J})$	M1
	= $(1.49 \times 10^{-10}) / (1.60 \times 10^{-19}) = 9.34 \times 10^8 = 934 \text{ MeV}$	A1
	or	
	binding energy = 8.443×95 [or equivalent using La-139 nucleus]	(M1)
	binding energy / mass defect = $(8.443 \times 95) / 0.859 = 934 \text{ MeV}$	(A1)
(b)(i)	binding energy = $1.865 \times 934 (= 1741.91 \text{ MeV})$	C1
	binding energy per nucleon = $1741.91 / 235$	A1
	= 7.41 (MeV)	
(b)(ii)	less (than)	B1
(c)	energy = $\{(1.219 + 0.859) - 1.865\} \times 934$	C1
	or energy = $(95 \times 8.443) + (139 \times 8.189) - (235 \times 7.412)$	
	= 199 MeV	A1
(d)	number of reactions = $1.2 \times 10^{-7} \times 6.02 \times 10^{23}$	C1
	= 7.22×10^{16}	
	energy release (for one reaction) = $199 \times 1.60 \times 10^{-13} (= 3.18 \times 10^{-11} \text{ J})$	C1
	power = $(7.22 \times 10^{16} \times 3.18 \times 10^{-11}) / (25 \times 10^{-3})$	A1
	= $9.2 \times 10^7 \text{ W}$	



13 - (9702/42_Winter_2019_Q12) - Particle & Nuclear Physics

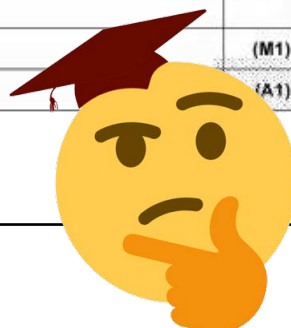
(a)(i)	(decay is) unpredictable/cannot be predicted	B1
(a)(ii)	probability of decay (of a nucleus)	M1
	per unit time	A1
(b)	$A = \lambda N$	C1
	(for 1.00 m^3) $A = 0.600 / 4.80 \times 10^{-3}$ (= 125 Bq)	C1
	$N = 125 / ([7.55 \times 10^{-3}] / 3600)$ (= 5.96×10^7)	C1
	so ratio = $(2.52 \times 10^{25}) / (5.96 \times 10^7)$	C1
	or	
	(for $4.80 \times 10^{-3} \text{ m}^3$) N for air = $2.52 \times 10^{25} \times 4.80 \times 10^{-3}$ (= 1.21×10^{23})	(C1)
	N for radon = $0.600 / ([7.55 \times 10^{-3}] / 3600)$ (= 2.86×10^5)	(C1)
	so ratio = $(1.21 \times 10^{23}) / (2.86 \times 10^5)$	(C1)
	ratio = 4.2×10^{17}	A1

14 - (9702/41_Summer_2020_Q12) - Particle & Nuclear Physics

(a)(i)	time at which a nucleus will decay cannot be predicted or constant probability of decay of a nucleus	B1
(a)(ii)	decay (of a nucleus) not affected by environmental factors	B1
(b)	$A = A_0 e^{-\lambda t}$ and $\lambda = \ln 2 / t_{1/2}$	C1
	$= 3.6 \times 10^5 \times \exp [-(2 \times \ln 2) / 1.4]$	C1
	or	
	$A = A_0 \times 0.5^N$	(C1)
	$= 3.6 \times 10^5 \times 0.5^N$ where $N = 2 / 1.4$	(C1)
	$A = 1.3 \times 10^5 \text{ Bq}$	A1
(c)(i)	smooth curve, starting at (0, 3.6×10^5) and passing through (1.4, 1.8×10^5) and (2.0, 1.3×10^5)	B1
(c)(ii)	(activity of sample is greater than activity of X so) there must be an additional source of activity	C1
	the decay product (of isotope X) is radioactive	A1

15 - (9702/42_Summer_2020_Q12) - Particle & Nuclear Physics

(a)	difference between mass of nucleus and mass of (constituent) nucleons	M1
	where nucleons are separated to infinity	A1
(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2 / (1.60 \times 10^{-13}) = 934 \text{ MeV}$	A1
(b)(ii)	mass defect = $2 \times (1.007276 + 1.008665) - 4.001506$ (= 0.030376)	B1
	binding energy per nucleon = $(0.030376 \times 934) / 4 = 7.09 \text{ MeV}$	A1
(c)	binding energy per nucleon is much greater	M1
	so would require a large amount of energy to separate the nucleons in helium	A1
	or	
	amount of energy released in forming hydrogen isotopes	(M1)
	is less than energy required to break apart helium nucleus	(A1)



16 - (9702/41_Winter_2020_Q12) - Particle & Nuclear Physics

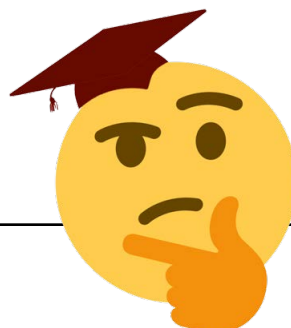
(a)(i)	unstable nucleus	B1
	emits ionising radiation or decays spontaneously	B1
(a)(ii)	probability of decay (of a nucleus)	M1
	per unit time	A1
(b)	$A = \lambda N$	C1
	$560 = 9.9 \times 10^{-7} \times N$	A1
	$N = 5.7 \times 10^8$	
(c)	$A = A_0 e^{-\lambda t}$	C1
	$170 = 560 \exp(-9.9 \times 10^{-7} \times t)$	
	$t = 1.2 \times 10^6 \text{ s}$	C1
	$= 14 \text{ days}$	A1

17 - (9702/42_Winter_2020_Q12) - Particle & Nuclear Physics

(a)(i)	energy required to separate nucleons (of nucleus)	M1
	to infinity	A1
(a)(ii)	a (single) large nucleus <u>divides</u> to form (smaller) nuclei	B1
	any one point from: - initiated by neutron bombardment - resulting nuclei are of similar size - binding energy per nucleon increases - total binding energy increases - neutrons released - combined mass of smaller nuclei is less than mass of large nucleus	B1
(b)	binding energy per nucleon is a maximum at around $A = 56$	B1
	products of splitting a ^{56}Fe nucleus must have a lower total binding energy	B1
	(reaction would require) a net input of energy	B1

18 - (9702/41_Summer_2021_Q6) - Electric Fields, Quantum Physics, Particle & Nuclear Physics

(a)	from $x = 0$ to $x = r$: $E = 0$	B1
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude passing through (r, E_0)	B1
	line passing through $(2r, E_0/4)$ and $(3r, E_0/9)$	B1
(b)	from $p = p_0/2$ to $p = p_0$: curve with negative gradient of decreasing magnitude passing through (p_0, λ_0)	B1
	line passing through $(\frac{1}{2}p_0, 2\lambda_0)$	B1
(c)	from $t = 0$ to $t = 45 \text{ s}$: curve with positive gradient of decreasing magnitude starting at $(0, 0)$	B1
	line passing through $(15, \frac{1}{2}N_0)$	B1
	line passing through $(30, 0.75N_0)$ <u>and</u> $(45, 0.88N_0)$	B1

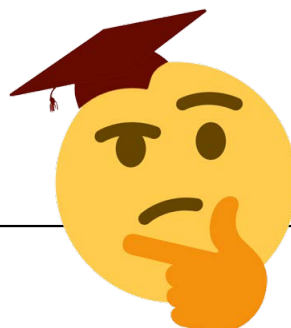


19 - (9702/41_Winter_2021_Q12) - Particle & Nuclear Physics

(a)	probability of decay (of a nucleus)	M1
	per unit time	A1
(b)	$A = \lambda N$	C1
	$N = \text{mass} / (\text{nucleon number} \times u)$	C1
	$2.92 \times 10^9 = (\lambda \times 5.87 \times 10^{-10}) / (131 \times 1.66 \times 10^{-27})$	A1
	$\lambda = 1.08 \times 10^{-6} \text{ s}^{-1}$	
(c)	- sample emits radiation in all directions - some radiation is absorbed by air/detector window - self-absorption within the source - dead time/inefficiency of detector Any two points, 1 mark each	B2

20 - (9702/42_Winter_2021_Q12) - Particle & Nuclear Physics

(a)(i)	cannot predict when a particular nucleus will decay or cannot predict which nucleus will decay next	B1
(a)(ii)	(decay is) not affected by external (environmental) factors	B1
(b)(i)	$A = A_0 \exp(-\lambda t)$ and so $\ln A = \ln A_0 - \lambda t$	C1
	gradient of line = $(-\lambda)$	
	$\lambda = (36.4 - 35.0) / (20 - 0)$	C1
	$(= 0.07(0) \text{ min}^{-1})$	
	half-life = $\ln 2 / \lambda$	A1
	$= \ln 2 / 0.070$	
	$= 10 \text{ min}$	
	or	
	$A_0 = \exp(-36.4) = 6.43 \times 10^{15} \text{ (Bq)}$	(C1)
	$A_0 / 2 = 3.21 \times 10^{15} \text{ (Bq)}, \text{ so } \ln(A_0 / 2) = 35.7$	(C1)
(b)(ii)	read off half-life = 10 min	(A1)
	or	
	(at one half-life,) $\ln A = 36.4 - \ln 2$	(C1)
	$= 35.7$	(C1)
	read off half-life = 10 min	(A1)
(b)(ii)	$A = \lambda N$	C1
	$N = \text{mass} / (\text{nucleon number} \times u)$	C1
	or	
	$N = (\text{mass} / \text{nucleon number}) \times N_A$	
	$\exp(36.4) = (1.17 \times 10^{-3} \times 5.66 \times 10^{-7}) / (\text{nucleon number} \times 1.66 \times 10^{-27})$ or $\exp(36.4) = (1.17 \times 10^{-3} \times 5.66 \times 10^{-4} \times 6.02 \times 10^{23}) / \text{nucleon number}$ nucleon number = 62	A1

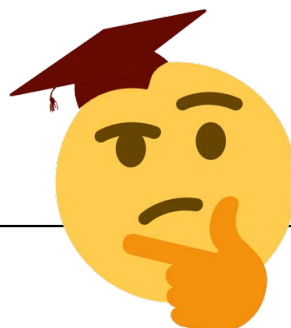


21 – (9702/41_Summer_2022_Q8) – Particle & Nuclear Physics

(a)(i)	energy required to separate the nucleons (in the nucleus)	M1
	to infinity	A1
(a)(ii)	curve starting close to the origin and forming a single peak	B1
	peak shown to left of centre, with steep line on LHS of peak and shallow line on RHS of peak	B1
(b)(i)	fusion	B1
(b)(ii)	both particles have low A values or both particles are at left-hand end of graph	B1
	He-3 has higher binding energy (per nucleon) than H-2	B1
(c)	$\Delta m = [(2 \times 2.014102) - (3.016029 + 1.008665)] \text{ u}$ (= 0.00351 u)	C1
	$E = \Delta mc^2$	C1
	= $0.00351 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$	C1
	(= $5.24 \times 10^{-13} \text{ J}$)	
	1.00 mol of deuterium forms 0.500 mol of helium-3	C1
	total energy = $0.500 \times 6.02 \times 10^{23} \times 5.24 \times 10^{-13}$	A1
	= $1.58 \times 10^{11} \text{ J}$	

22 – (9702/42_Summer_2022_Q10) – Particle & Nuclear Physics

(a)	spontaneous emission of (ionising) radiation	B1
	emission from unstable nucleus	B1
(b)(i)	curve with decreasing negative gradient passing through (0, N_0)	B1
	curve passing through (T , $0.5N_0$)	B1
	curve passing through ($2T$, $0.25N_0$) and ($3T$, $0.125N_0$)	B1
(b)(ii)	line through origin with positive gradient	B1
	straight line passing through (N_0 , A_0)	B1
(c)(i)	activity	B1
(c)(ii)	decay constant	B1
(d)	$N = N_0 \exp(-\ln 2 \times 1.70T / T)$	C1
	$N / N_0 = 0.31$	A1

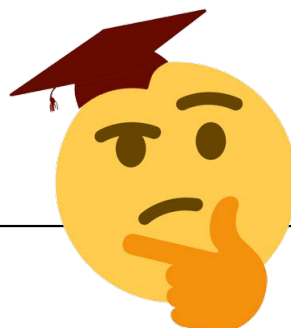


23 - (9702/41_Winter_2022_Q10) - Particle & Nuclear Physics

(a)(i)	cannot predict when a (particular) nucleus will decay or cannot predict which nucleus will decay next	B1
(a)(ii)	not affected by external / environmental factors	B1
(b)(i)	line fluctuates or trend is a straight line	B1
(b)(ii)	straight line of best fit drawn on Fig. 10.1	B1
(b)(iii)	$M = M_0 \exp(-\lambda t)$ so $\ln M = \ln M_0 - \lambda t$ so gradient = $-\lambda$ (and magnitude of gradient = λ)	B1
(b)(iv)	gradient = $(-)(8.0 - 4.8) / (11.6 - 0)$ (allow any correct pair of values from Fig. 10.1)	C1
	$\lambda = 0.28 \text{ s}^{-1}$	A1
(b)(v)	half-life = $0.693 / \lambda$	A1
	= $0.693 / 0.28$	
	= 2.5 s	
(c)	(for reaction to occur,) energy is released	B1
	energy release comes from fall in mass so total mass of products must be less (than mass of carbon-15)	B1

24 - (9702/41_Summer_2023_Q9) - Particle & Nuclear Physics

(a)	time for activity (of sample) to halve	B1
(b)	sketch: line with positive gradient starting at (0,0) and extending to $t = 80$ min	B1
	exponential curve, extending from $t = 0$ to $t = 80$ min, with gradient of steadily decreasing magnitude	B1
	line passing through (0,0), (20, $0.5N_0$) and (40, $0.75 N_0$)	B1
(c)(i)	every (undecayed) nucleus has the same probability of decay	M1
	fewer (undecayed) nuclei remaining (with time), so fewer will decay (in a given time interval)	A1
(c)(ii)	- sample emits in all directions but detector only captures emissions in one direction - some emissions are absorbed before reaching detector - some emissions are scattered within the sample - simultaneous arrival of multiple particles only registers once - some particles may reach detector but not cause ionisation Any two points, 1 mark each	B2
	measured count rate is less than the activity	B1

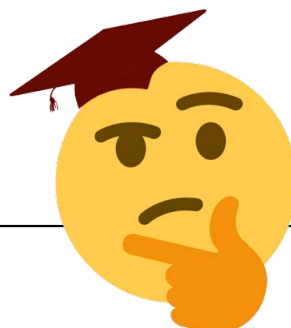


25 - (9702/42_Summer_2023_Q9) - Particle & Nuclear Physics

(a)	difference between mass of nucleus and (total) mass of nucleons	M1
	when infinitely separated	A1
(b)(i)	neutron	B1
(b)(ii)	$E = \Delta m c^2$	C1
	$\Delta m = (0.030377 - 0.002388 - 0.009105)u$ (= 0.018884u)	C1
	energy release = $(0.030377 - 0.002388 - 0.009105) \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2 = 2.8 \times 10^{-12} \text{ J}$	A1
(c)(i)	number of atoms per unit time = $(1.4 \times 10^{28}) / (2.8 \times 10^{-12})$ (= $5.0 \times 10^{39} \text{ s}^{-1}$)	C1
	mass of one atom = $4 \times 1.66 \times 10^{-27}$ or $(4 \times 10^{-3}) / (6.02 \times 10^{23})$ (= $6.64 \times 10^{-27} \text{ kg}$)	C1
	mass per unit time = $6.64 \times 10^{-27} \times 5.0 \times 10^{39}$ = $3.3 \times 10^{13} \text{ kg s}^{-1}$	A1
(c)(ii)	$L = 4\pi\sigma T^4$	C1
	$1.4 \times 10^{28} = 4\pi \times 5.67 \times 10^{-8} \times (2.3 \times 10^9)^2 \times T^4$	
	$T = 7800 \text{ K}$	A1

26 - (9702/41_Winter_2023_Q9) - Particle & Nuclear Physics

(a)	(two small) nuclei join together	M1
	to form one larger nucleus	A1
(b)	line with a peak at $A \approx 56$	B1
	line with steep initial positive gradient on the left of peak and shallower negative gradient at all points to the right of peak and line does not return to 0 binding energy	B1
(c)(i)	X shown at value of A to the right of the peak	B1
(c)(ii)	Y shown at value of A close to 1	B1
(d)	energy from 1 nucleus = $(1.77 \times 10^{13}) / (6.02 \times 10^{23})$ (= $2.94 \times 10^{-11} \text{ J}$)	C1
	binding energy of Z = $[(1.25 + 1.81) \times 10^{-10}] - 2.94 \times 10^{-11}$ (= $2.77 \times 10^{-10} \text{ J}$)	C1
	nucleon number of Z = $93 + 139 + 2 - 1$ (= 233)	C1
	binding energy per nucleon = $(2.77 \times 10^{-10}) / (233 \times 1.60 \times 10^{-13})$ = 7.43 MeV	A1



27 - (9702/42_Winter_2023_Q9) - Particle & Nuclear Physics

(a)(i)	material introduced into the body and (position in body) can be detected or absorbed by the tissue (being studied)	B1
(a)(ii)	$X = \beta^+$ or e^+ and $P = 1$	B1
	$Q = 0$ and $R = 18$	B1
(b)(i)	positrons (emitted in the decay) and electrons annihilate	B1
	mass of particles becomes energy of gamma photons	B1
(b)(ii)	arrival times of photons are processed	B1
	image built up of tracer concentration in the tissue	B1
(c)(i)	$A = \lambda N$ and $\lambda = \ln 2 / T$	C1
	$N = n \times N_A$	C1
	2 photons produced from each decay, so $R_0 = 2 \times \lambda \times n \times N_A$	A1
	$R_0 = (2 \ln 2) n N_A / T$ (allow 0.693 for $\ln 2$)	
(c)(ii)	sketch: exponential decay curve from $t = 0$ to $t = 2T$, starting at $(0, R_0)$ and with a negative gradient of continuously decreasing magnitude	B1
	line with negative gradient passing through $(T, R_0/2)$ and $(2T, R_0/4)$	B1



1 – (9702/41_Winter_2020_Q10) – *Medical Imaging*

(a)	X-rays are used	B1
	section (of object) is scanned	B1
	scans/images taken at many angles/directions or images of each section are 2-dimensional	B1
	(images of (many)) sections are combined	B1
	(to give) 3-dimensional image of (whole) structure	B1
(b)	K = 6	B3
	L = 7	
	M = 2	
	N = 9	
	3 marks: all four correct 2 marks: three correct and one incorrect or all correct with two numbers transposed 1 mark: two correct and two incorrect	

2 – (9702/41_Summer_2021_Q4) – *Medical Imaging*

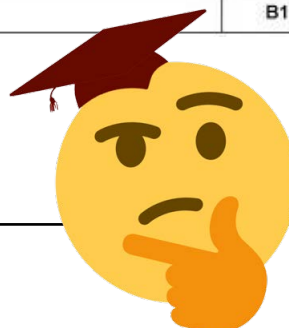
	(ultrasound) pulse	B1
	reflected at boundaries	B1
	gel is used to minimise reflection at skin or generated and detected by quartz crystal	B1
	time delay between generation and detection gives information about depth	B1
	intensity (of reflected wave) gives information about nature of boundary	B1

3 – (9702/42_Summer_2021_Q11) – *Medical Imaging*

(a)	to produce a 3-dimensional image of structure/body	B1
(b)	X-rays (are used)	B1
	scanning in sections	B1
	scanning from many angles	B1
	image of each section is 2-dimensional	B1
	scanning repeated for many sections or images of many sections combined together	B1

4 – (9702/41_Winter_2021_Q11) – *Medical Imaging*

(a)(i)	ease with which edges can be distinguished	B1
(a)(ii)	difference in degrees of blackening	B1
(b)	$I = I_0 \exp(-\mu x)$	C1
	$0.12 = \exp(-\mu \times 2.3)$	C1
	$\ln 0.12 = -2.3 \times \mu$	
	$\mu = 0.92 \text{ cm}^{-1}$	A1
(c)	advantage: produces 3-dimensional image	B1
	disadvantage: (much) greater exposure to radiation	B1



5 - (9702/42_Winter_2021_Q11) – Medical Imaging

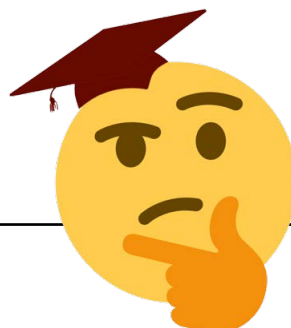
(a)	generates <u>ultrasound</u>	B1
	detects <u>reflected</u> ultrasound	B1
	applied p.d. causes crystal to vibrate or vibrations cause crystal to generate an e.m.f.	B1
(b)(i)	product of density and speed	M1
	speed of ultrasound in medium	A1
(b)(ii)	difference between (the specific acoustic impedances)	C1
	- if similar/same then reflection coefficient is zero/very low - if very different then reflection coefficient is (nearly) 1 - the lower the difference means lower the reflection coefficient (any one point)	A1

6 - (9702/41_Summer_2022_Q9) – Medical Imaging

(a)(i)	electrons are accelerated (by an applied p.d.)	B1
	electrons hit target	B1
	X-rays produced when electrons decelerate	B1
(a)(ii)	images of the multiple sections are combined to create a 3-D image	B1
(b)(i)	$I = I_0 \exp(-\mu x)$	C1
	$= I_0 \exp(-0.89 \times 5.6)$	A1
	$= 0.0068 I_0$	
(b)(ii)	$I = I_0 \exp(-2.4 \times 3.4) \times \exp(-0.89 \times 3.2)$	C1
	$= 1.7 \times 10^{-5} I_0$	A1
(c)	comparison of intensities or values in (b) leading to conclusion consistent with these values	B1

7 - (9702/42_Winter_2022_Q10) – Medical Imaging

(a)(i)	introduction of tracer (into the body)	M1
	containing a β^+ emitter	A1
(a)(ii)	positron interacts with electron	B1
	(pair) annihilation occurs	B1
	mass of particles converted into gamma photons	B1
(b)	(annihilation of electron and positron) produces two photons	B1
	$E = (\Delta)mc^2$	B1
	$E = hf$ and $f = c/\lambda$ or $E = hc/\lambda$	B1
	$\lambda = \{[2 \times] 6.63 \times 10^{-34} \times 3.00 \times 10^8\} / \{[2 \times] 9.11 \times 10^{-31} \times (3.00 \times 10^8)^2\}$	B1
	$= 2.4(3) \times 10^{-12} \text{ m or } 2.4(3) \text{ pm (full substitution and answer with unit needed)}$	



8 - (9702/42_Summer_2023_Q10) - *Medical Imaging*

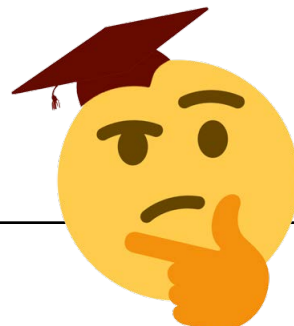
(a)(i)	electrons	B1
(a)(ii)	electrons are decelerated / stopped on impact with the target	B1
	(kinetic) energy lost by electrons emitted as (X-ray) photons	B1
(a)(iii)	$eV = hc / \lambda$	C1
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (1.60 \times 10^{-19} \times 5800)$	C1
	$= 2.14 \times 10^{-10} \text{ m}$	A1
(b)	$I = I_0 \exp(-\mu x)$	C1
	$I_T / I_0 = \exp(-(1.4 \times 2.8))$	C1
	$= 0.020$	
	% absorbed $= (1.000 - 0.0198) \times 100$ $= 98\%$	A1

9 - (9702/43_Summer_2023_Q8) - *Medical Imaging*

(a)(i)	specific acoustic impedance $= 1200 \times 1400 = 1.68 \times 10^6 \text{ kg m}^{-2} \text{ s}^{-1}$	A1
(a)(ii)	density of air shown in table as 1.29	A1
	speed of sound in tissue shown in table as 1540	A1
(b)(i)	intensity reflection coefficient $= (Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$	C1
	$= (1680000 - 440)^2 / (1680000 + 440)^2$	
	$= 0.999$	A1
(b)(ii)	intensity reflection coefficient $= (Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$	A1
	$= (1680000 - 1680000)^2 / (1680000 + 1680000)^2$	
	$= 0$	
(c)	without gel, (almost) all of the (incident) ultrasound is reflected (from skin)	B1
	with gel, (almost) all of the (incident) ultrasound is transmitted (into the body)	B1

10 - (9702/41_Winter_2023_Q10) - *Medical Imaging*

(a)	ultrasound production: vibrating quartz crystal	B1
	X-ray production: electrons hitting metal target	B1
	ultrasound detected wave: reflected	B1
	X-ray detected wave: transmitted	B1
(b)(i)	$I = I_0 \exp(-\mu x)$	C1
	$\ln(0.72) = -6.2\mu$	A1
	$\mu = 0.053 \text{ cm}^{-1}$	
(b)(ii)	$I / I_0 = \exp(-9.3 \times 0.053)$	C1
	$(= 0.61)$	
	percentage attenuated $= 100 \times (1.00 - 0.61)$ $= 39\%$	A1



1 - (9702/42_Summer_2022_Q9) - *Astronomy & Cosmology*

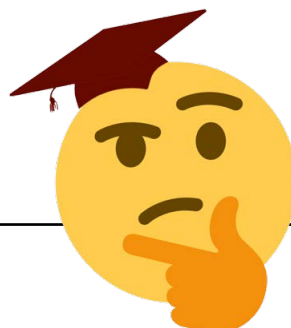
(a)(i)	speed is (directly) proportional to distance	M1
	where speed is speed of recession of galaxy (from observer) and distance is distance of galaxy away from observer	A1
(a)(ii)	wavelengths (of spectral lines) are greater (than their known values)	B1
	redshift shows stars (in distant galaxies) moving away from Earth	B1
(b)	(all) parts of Universe moving away from each other	B1
	more distant objects are moving away faster	B1
	matter must have been close together / very dense in the past	B1

2 - (9702/41_Summer_2022_Q10) - *Astronomy & Cosmology*

(a)	wavelength of maximum intensity is inversely proportional to (thermodynamic) temperature	B1
(b)(i)	$\lambda_{\text{MAX}} = 0.50 \mu\text{m}$ for A and $0.65 \mu\text{m}$ for B	C1
	$T = 5800 \times (0.50 / 0.65)$	A1
	$= 4500 \text{ K}$	
(b)(ii)	(star B has) greater peak / average wavelength	B1
	(star B looks) redder	B1
(c)(i)	apparent wavelength is greater or wavelength is greater than known value	B1
	(due to) movement of star away (from observer)	B1
(c)(ii)	by examining the (lines in the) spectrum (of light from the star)	B1
	and comparing with known spectrum	B1

3 - (9702/41_Winter_2022_Q9) - *Astronomy & Cosmology*

(a)	total power of radiation emitted (by the star)	B1
(b)(i)	$F = L / (4\pi d^2)$	C1
	$= 9.86 \times 10^{27} / [4\pi \times (8.14 \times 10^{16})^2]$	A1
	$= 1.18 \times 10^{-7} \text{ W m}^{-2}$	
(b)(ii)	$L = 4\pi\sigma r^2 T^4$	C1
	$9.86 \times 10^{27} = 4 \times \pi \times 5.67 \times 10^{-8} \times r^2 \times 9830^4$	
	radius $= 1.22 \times 10^9 \text{ m}$	A1
(c)	wavelength of peak intensity determined (from spectrum of star)	B1
	wavelength of peak intensity from object of known temperature determined	B1
	Wien's displacement law used or wavelength of peak intensity inversely proportional to temperature	B1

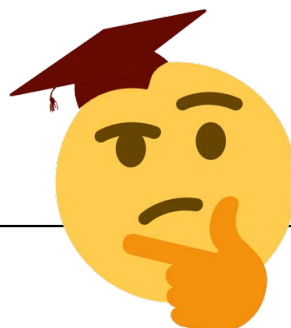


4 - (9702/41_Summer_2023_Q10) - Astronomy & Cosmology

(a)	speed is (directly) proportional to distance	M1
	speed is speed of recession of galaxy from an observer, and distance is the distance of the galaxy from the observer	A1
(b)	$F = L / (4\pi d^2)$	C1
	$= (3.8 \times 10^{31}) / [4\pi \times (1.8 \times 10^{24})^2]$	A1
	$= 9.3 \times 10^{-19} \text{ W m}^{-2}$	
(c)(i)	galaxy is moving away (from the Earth)	B1
	wavelength (of light from the galaxy) increased by the Doppler effect / due to redshift	B1
(c)(ii)	$\Delta\lambda / \lambda = v / c$	C1
	$v = [(492 - 486) \times 3.00 \times 10^8] / 486$	
	$(v = 3.7 \times 10^6 \text{ m s}^{-1})$	
	$H_0 = v / d$	C1
	$= (3.7 \times 10^6) / (1.8 \times 10^{24})$	A1
	$= 2.1 \times 10^{-18} \text{ s}^{-1}$	

5 - (9702/41_Winter_2023_Q3) - Ideal Gases, Astronomy & Cosmology

(a)(i)	N : number of molecules (of the gas)	B1
	m : mass of one molecule (of the gas)	B1
	$\langle c^2 \rangle$: mean square speed (of molecules)	B1
(a)(ii)	$pV = NkT$	M1
	$NkT = \frac{1}{2}Nm\langle c^2 \rangle$ and $E_k = \frac{1}{2}m\langle c^2 \rangle$ leading to $E_k = (3/2)kT$	A1
(b)	$\frac{1}{2} \times 3.34 \times 10^{-27} \times 9300^2 = (3/2) \times 1.38 \times 10^{-23} \times T$	C1
	$T = 6980 \text{ K}$	A1
(c)(i)	$L = F \times 4\pi d^2$	C1
	$L = 2.52 \times 10^{-8} \times 4\pi \times (4.16 \times 10^{16})^2$	A1
	$= 5.48 \times 10^{26} \text{ W}$	
(c)(ii)	$L = 4\pi\sigma r^2 T^4$	C1
	$5.48 \times 10^{26} = 4\pi \times 5.67 \times 10^{-8} \times r^2 \times 6980^4$	
	$r = 5.69 \times 10^5 \text{ m}$	A1
(d)	(very high pressure so) molecules are (very) close together (<i>not just 'nearer'</i>)	B1
	forces between molecules are not negligible or volume of molecules not negligible compared with gas volume	B1



6 - (9702/42_Winter_2023_Q10) – Astronomy & Cosmology

(a)	temperature inversely proportional to wavelength	M1
	temperature is thermodynamic temperature of surface, and wavelength is the wavelength at which maximum emission rate occurs	A1
(b)(i)	(astronomical) object of known luminosity	B1
(b)(ii)	star / galaxy is moving away from the student	B1
(b)(iii)	one tick placed in correct column in each row:	B1
	wavelength: too high	
	surface temperature: too low	B1
	distance: unchanged	B1
	radius: too high	B1

