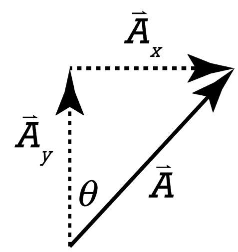
Flipping Physics Lecture Notes:
AP Physics 1 Review of *Kinematics*
https://www.flippingphysics.com/ap1-kinematics-review.html

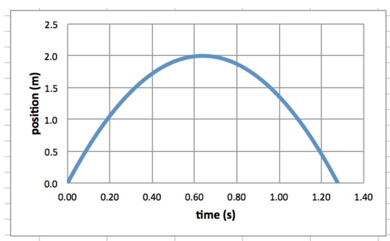
Introductory Concepts:

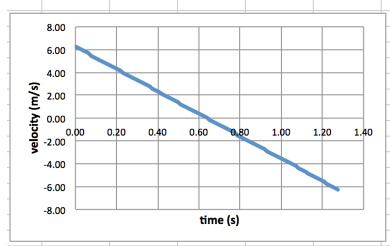
- Vector: Magnitude and Direction
  - Magnitude means the "amount" of the vector or the value of the vector without direction.
- Scalar: Magnitude only, no direction
- Component Vectors
  - Theta won't always be with the horizontal, so the component in the x direction won't always use cosine.
  - $\sin\theta = \frac{O}{H} = \frac{\vec{A}_x}{\vec{A}} \Rightarrow \vec{A}_x = \vec{A}\sin\theta$

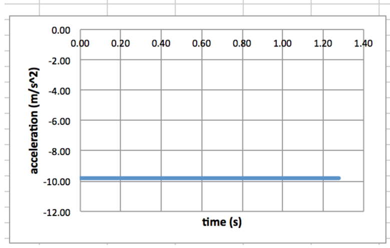


Kinematics:

- Distance vs. Displacement
  - Distance is how far something moves and it includes the path travelled.
    - Distance is a scalar.
  - Displacement is the straight-line distance from where the object started to where it ended.
    - Displacement is a vector.
    - Displacement is the change in position of an object. $\Delta\vec{x} = x_f - x_i$
- $Speed = \frac{Distance}{Time}$, is a scalar.
- Velocity, $\vec{v} = \frac{\Delta\vec{x}}{\Delta t}$, is a vector.
- Acceleration, $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$, is a vector.
- The slope of a position vs. time graph is velocity.
- The slope of a velocity vs. time graph is acceleration.
- On an acceleration vs. time graph, the area between the curve & the time axis is change in velocity.
- On a velocity vs. time graph, the area between the curve & the time axis is change in position which is also called displacement.
- In Free Fall, $a_y = -g = -9.81\frac{m}{s^2}$.
  - An object is in free fall if the only force acting on it is the force of gravity. In other words: the object is flying through the vacuum you can breathe♥ and not touching any other objects.







♥ Vacuum you can breathe = no air resistance.

- The Uniformly Accelerated Motion Equations (UAM Equations):

AP® Physics 1 Equation Sheet	*Flipping Physics®*
$v_x = v_{x0} + a_x t$	$v_f = v_i + a\Delta t$
$x = x_0 + v_{xo} t + \frac{1}{2} a_x t^2$	$\Delta x = v_i \Delta t + \frac{1}{2} a \Delta t^2$
$v_x^{\ 2} = v_{x0}^{\ 2} + 2a_x \left(x - x_0\right)$	$v_f^{\ 2} = v_i^{\ 2} + 2a\Delta x$
	$\Delta x = \frac{1}{2}\left(v_f + v_i\right)\Delta t$

- The AP Physics 1 UAM Equations assume $t_i = 0$; $\Delta t = t_f - t_i = t_f - 0 = t$
- Projectile Motion: An object flying through the vacuum you can breathe in at least two dimensions.

x direction	*y direction*
$a_x = 0$	Free-Fall
Constant Velocity	$a_y = -g = -9.81 \frac{m}{s^2}$
$v_x = \frac{\Delta x}{\Delta t}$	Uniformly Accelerated Motion
Δt is the same in both directions because it is a *scalar* and has magnitude only (no direction).	

  - Remember to break your initial velocity into its components if it is not directly in the x direction and if the initial velocity is directly in the x direction, then the initial velocity in the y direction equals zero.
- Relative Motion is Vector Addition.
  - Draw vector diagrams.
  - Break vectors into components using SOH CAH TOA.
  - Make a right triangle.
  - Use SOH CAH TOA and the Pythagorean theorem to determine the magnitude and direction of the resultant vector.
- Center of mass.
  - Only need to know center of mass qualitatively, in other words, without numbers.
  - For the purposes of translational motion, which is essentially non-rotational motion, the whole object or system of objects can be considered to be located at its center of mass. For example, an object or group of objects in projectile motion is described by only analyzing the motion of the center of mass not each individual part of the object or system.

Dynamics

- Inertial Mass vs. Gravitational Mass
  - Inertial mass: the measure of an object's inertia or a measure of its resistance to acceleration.
  - Gravitational Mass: used to determine the force of gravity or weight of an object. $\vec{F}_g = m\vec{g}$
  - Inertial Mass and Gravitational Mass are experimentally identical.
- Newton's First Law: "An object at rest will remain at rest and an object in motion will remain at a constant velocity unless acted upon by a net external force."
  - Common mistake: "an object in motion will remain in *motion*" is wrong. It will remain at a constant velocity which means it will have a constant speed and a constant direction.
  - Common mistake: "unless acted upon by an external force." Do **not** leave out the word "*net*". It is the *sum of all the forces* that needs to be zero for an object to remain at rest or at a constant velocity.
- Newton's Second Law: $\sum \vec{F} = m\vec{a}$
  - It is arranged differently on the equation sheet: $\vec{a} = \frac{\sum \vec{F}}{m}$, but it is the same equation.
  - When you use Newton's Second Law, you must identify object(s) and direction.
  - Free Body Diagrams: always draw them to use Newton's Second Law.
    - On the AP Test, do ***NOT*** break forces in to components in your initial Free Body Diagram.
- The Force of Gravity or Weight of an object is always down. $\vec{F}_g = m\vec{g}$
- The Force Normal is caused by a surface, is normal or perpendicular to the surface and always a push.
- Dimensions for Force are Newtons, N: $\sum \vec{F} = m\vec{a} \Rightarrow N = \frac{kg \cdot m}{s^2}$
- The Force of Friction is parallel to the surface, opposes motion and independent of the direction of the force applied. On equation sheet: $\left|\vec{F}_f\right| \le \mu\left|\vec{F}_n\right|$, which works out to be three equations because we have two types of friction.
  - Static or non-moving friction: the two surfaces do *not* slide relative to one another. $\vec{F}_{sf} \le \mu_s\vec{F}_n$ and $\vec{F}_{sf_{max}} = \mu_s\vec{F}_n$
  - Kinetic or moving friction: the two surfaces *do* slide relative to one another. $\vec{F}_{kf} = \mu_k\vec{F}_n$
  - For two surfaces, the coefficient of kinetic friction is always less that the coefficient of static friction. $\mu_k < \mu_s$
- Newton's Third Law: $\vec{F}_{12} = -\vec{F}_{21}$, For every force from object one on object two there is an equal but opposite force from object two on object one where both forces are vectors.
- Newton's Third Law Force Pairs or Action-Reaction Pairs:
  - Act on two different objects and act simultaneously.
- Inclines: Break the Force of Gravity in to its components that are parallel and perpendicular to the incline. $F_{g_{\parallel}} = mg\sin\theta$ & $F_{g_{\perp}} = mg\cos\theta$
- Translational Equilibrium: $\sum \vec{F} = 0 = m\vec{a} \Rightarrow \vec{a} = 0$
  - The object is either at rest or moving with a constant velocity.

Work, Energy and Power

- $\Delta E = W = F_{\parallel} d = Fd\cos\theta$: In terms of an object or a group of objects which we call the system, the change in energy of the system equals the work done on the system which is equal to force times displacement times the angle between the force and the displacement. Work causes a change in energy of the system.
  - $F_{\parallel} = F\cos\theta$: The force parallel to the displacement is the force times the cosine of the angle between the force and the displacement of the object.
  - Identify which force you are using in the work equation.
  - Use the magnitude of the force and the displacement.
  - Dimensions for Work are Joules or Newtons times meters:
- Three types of mechanical energy:
  - *Kinetic Energy:* $KE = K = \frac{1}{2}mv^2$ (can't be negative)
  - Dimensions for energy are also Joules:

    $$KE = \frac{1}{2}mv^2 \Rightarrow (kg)\left(\frac{m}{s}\right)^2 = \frac{kg \cdot m^2}{s^2} = \left(\frac{kg \cdot m}{s^2}\right)(m) = N \cdot m = J$$
  - *Elastic Potential Energy:* $PE_e = U_s = \frac{1}{2}kx^2$ (can't be negative)
  - *Gravitational Potential Energy:* $PE_g = mgh$ or $\Delta U_g = mg\Delta y$
    - PE_g **Can** be negative. If the object is below the horizontal zero line, then h, the vertical height above the zero, is line negative.
- Work and Energy are Scalars!
- Conservation of Mechanical Energy: $ME_i = ME_f$
  - Valid when there is no energy converted to heat, light or sound due to friction.
  - Identify the initial and final points. Identify the horizontal zero line.
  - Substitute in mechanical energies that are present.
- If there is friction & you need to use energy: $W_f = \Delta ME$ (Does not work when there is a force applied.)
- Power, the rate at which work is done or energy is transferred into or out of the system.
  - $P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t} = \frac{Fd\cos\theta}{\Delta t} = Fv\cos\theta$
  - Dimensions for Power are Watts which are Joules per second:
    - $P = \frac{\Delta E}{\Delta t} \Rightarrow \frac{J}{s} = watts$ & $746\,watts = 1hp$
- Hooke's Law: $\left|\vec{F}_s\right| = k\left|\vec{x}\right|$: The force of a spring is linearly proportional to the displacement from equilibrium position.
  - The slope of a graph of Force of a Spring vs. displacement from equilibrium position is the spring constant. $slope = \frac{rise}{run} = \frac{F_s}{x} = k$
  - Typical dimensions for the spring constant are Newtons per meter: $\frac{F_s}{x} = k \Rightarrow \frac{N}{m}$

Linear Momentum and Impulse

- Momentum: $\vec{p} = m\vec{v}$ (remember, momentum is a vector)
  - Dimensions for momentum have no special name: $\vec{p} = m\vec{v} \Rightarrow \frac{kg \cdot m}{s}$
- Conservation of momentum: $\sum \vec{p}_i = \sum \vec{p}_f$ (during all collisions and explosions)
  - Collisions in two dimensions: 2 different equations; $\sum \vec{p}_{xi} = \sum \vec{p}_{xf}$ & $\sum \vec{p}_{yi} = \sum \vec{p}_{yf}$
- Types of collisions:

Type of Collision	Is Momentum Conserved?	Is Kinetic Energy Conserved?
Elastic (bounce)	Yes	Yes
Perfectly Inelastic (stick)	Yes	No

  - Many collisions are in between Elastic and Perfectly Inelastic. They are called Inelastic collisions. During inelastic collisions the objects bounce off of one another, momentum is conserved however Kinetic Energy is not conserved. Elastic and Perfectly Inelastic collisions are the two ideal extremes.
- Rearranging Newton's Second Law in terms of momentum:
  - $\sum \vec{F} = m\vec{a} = m\left(\frac{\Delta\vec{v}}{\Delta t}\right) = m\left(\frac{\vec{v}_f - \vec{v}_i}{\Delta t}\right) = \frac{m\vec{v}_f - m\vec{v}_i}{\Delta t} = \frac{\vec{p}_f - \vec{p}_i}{\Delta t} = \frac{\Delta\vec{p}}{\Delta t} \Rightarrow \sum \vec{F} = \frac{\Delta\vec{p}}{\Delta t}$
  - Gives us the equation for impulse: $\Delta\vec{p} = \sum \vec{F}\Delta t = \vec{J} = Impulse$
  - The Impulse Approximation gives us the equation on the equation sheet: $\sum \vec{F} \approx \vec{F}_{impact} \Rightarrow \Delta\vec{p} = \vec{F}_{impact}\Delta t = \vec{J} = Impulse$
  - On a Force of Impact vs. time graph, the area between the curve & the time axis is impulse.
  - Dimensions for impulse: $\Delta\vec{p} = \vec{F}_{impact}\Delta t \Rightarrow N \cdot s = \frac{kg \cdot m}{s}$

Rotational Kinematics

- Angular Velocity: $\vec{\omega} = \frac{\Delta\vec{\theta}}{\Delta t}\left(\frac{rad}{s} \; or \; \frac{rev}{min} \right)$

$1 \; rev = 360^{\circ} = 2\pi \; radians$

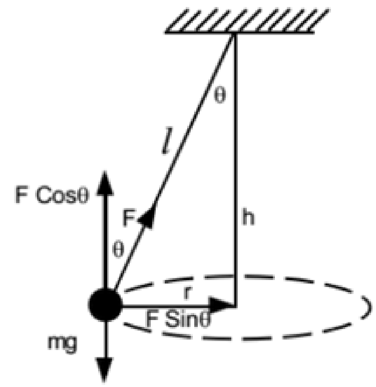
- Angular Acceleration: $\vec{\alpha} = \frac{\Delta\vec{\omega}}{\Delta t}\left(\frac{}{s^2} \right)$

Uniformly Accelerated Motion, UAM	Uniformly Angularly Accelerated Motion, UαM
$v_x = v_{x0} + a_x t$	$\omega = \omega_0 + \alpha t$
$x = x_0 + v_{xo} t + \frac{1}{2} a_x t^2$	$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$
$v_x{}^2 = v_{x0}{}^2 + 2a_x \left(x - x_0 \right)$	$\omega_f{}^2 = \omega_i{}^2 + 2\alpha\Delta\theta$
$\Delta x = \frac{1}{2}\left(v_f + v_i \right)\Delta t$	$\Delta\theta = \frac{1}{2}\left(\omega_f + \omega_i \right)\Delta t$

- Equations are valid when $\vec{\alpha} = constant$

- Tangential velocity is the linear velocity of an object moving along a circular path. $\vec{v}_t = r\vec{\omega}$
  - The direction of tangential velocity is tangent to the circle and normal to the radius.
  - Tangential velocity is a linear velocity so it has the same dimensions as linear velocity: $\frac{m}{s}$
- Centripetal Force and Centripetal Acceleration:
  - Centripetal force is the net force in the in direction or the "center seeking" force which causes the acceleration of the object in toward the center of the circle.
  - Centripetal Force, $\sum F_{in} = m\vec{a}_c$:
    - Not a new force.
    - Never in a Free Body Diagram.
    - The direction "in" is positive and the direction "out" is negative.
  - Centripetal Acceleration, $a_c = \frac{v_t{}^2}{r} = r\omega^2$
- The Period, T, is the time for one full cycle or revolution.
  - Dimensions for period: seconds or seconds per cycle.
- The Frequency, f, is the number of cycles or revolutions per second.
  - Dimensions for frequency are cycles per second which are called Hertz, Hz: $f \Rightarrow \frac{cyc}{\text{sec}} = Hz$
  - Frequency and Period are inversely related: $T = \frac{1}{f}$
- We can use the equation for angular acceleration to derive an equation on the equation sheet:
  - $\vec{\omega} = \frac{\Delta\vec{\theta}}{\Delta t} = \frac{2\pi \; rad}{T} \Rightarrow T = \frac{2\pi}{\omega} = \frac{1}{f}$

The Conical Pendulum Example:



- $F_T \cos\theta = mg \Rightarrow F_T = \dfrac{mg}{\cos\theta}$
- $\vec{F}_T \sin\theta = m\left(\dfrac{v_t^2}{r}\right) \Rightarrow \left(\dfrac{mg}{\cos\theta}\right)\sin\theta = m\left(\dfrac{\left(\dfrac{2\pi r}{T}\right)^2}{r}\right) \Rightarrow g\tan\theta = \dfrac{4\pi^2 r^2}{T^2 r} = \dfrac{4\pi^2 r}{T^2}$

And solve for the radius in terms of the length of the string.

$$\sin\theta = \frac{O}{H} = \frac{r}{L} \Rightarrow r = L\sin\theta$$

$$g\tan\theta = \frac{4\pi^2 r}{T^2} \Rightarrow g\frac{\sin\theta}{\cos\theta} = \frac{4\pi^2 L\sin\theta}{T^2} \Rightarrow \frac{g}{\cos\theta} = \frac{4\pi^2 L}{T^2} \Rightarrow \boxed{T^2 = \frac{4\pi^2 L\cos\theta}{g}}$$

And we end with an expression for the period of the circular motion.

Rotational Dynamics

- Torque, the ability to cause an angular acceleration of an object: $\vec{\tau} = \vec{r}_{\perp}\vec{F} = \vec{r}\vec{F}\sin\theta$
    - The moment arm or lever arm is: $\vec{r}_{\perp} = \vec{r}\sin\theta$
    - A larger moment arm will cause a larger torque.
        - Maximize torque by maximizing r, the distance from axis of rotation to the force.
        - Maximize torque by using an angle of 90° because $\left(\sin\theta\right)_{\max} = \sin\left(90°\right) = 1$
    - Dimensions for Torque are Newtons meters, N·m, not to be confused with Joules for energy:
    - Torque is a vector.
        - For direction use clockwise and counterclockwise. (sadly, not the right hand rule)
- Rotational form of Newton's Second Law: $\sum \vec{\tau} = I\vec{\alpha}$
- Moment of Inertia or Rotational Mass:
    - For a system of particles: $I = \sum_i m_i r_i^2$
    - Dimensions for Moment of Inertia: $I = \sum_i m_i r_i^2 \Rightarrow kg \cdot m^2$
    - For a rigid object with shape the value or the equation will be given to you. For example: $I_{solid\ cylinder} = \frac{1}{2}MR^2$; $I_{thin\ hoop} = MR^2$; $I_{solid\ sphere} = \frac{2}{5}MR^2$; $I_{thin\ spherical\ shell} = \frac{2}{3}MR^2$; $I_{rod} = \frac{1}{12}ML^2$; $I_{rod\ about\ end} = \frac{1}{3}ML^2$
        - With the exception of $I_{rod\ about\ end}$, these are all about the center of mass of the object.
- Rotational Kinetic Energy: $KE_{rot} = \frac{1}{2}I\omega^2$
    - KE_{rot}, like translational energy, is in Joules, J.
    - Rolling without slipping: When an object rolls down a hill, it will gain not only translational kinetic energy but also rotational kinetic energy. Which means, the higher the moment of inertia, the higher the rotational kinetic energy of the object and therefore the lower amount of energy that will be left over for translational kinetic energy and therefore a lower final linear velocity.
        - Using Conservation of Mechanical Energy: $ME_i = ME_f \Rightarrow PE_{gi} = KE_{rot\ f} + KE_{t\ f}$
        - Also need the equation for the velocity of the center of mass of a rigid object rolling without slipping: $v_{cm} = R\omega$
- Angular Momentum: $\vec{L} = I\vec{\omega}$
    - Dimensions for Angular Momentum: $\vec{L} = I\vec{\omega} \Rightarrow \left(kg \cdot m^2\right)\left(\frac{rad}{s}\right) = \frac{kg \cdot m^2}{s}$
- Angular Impulse: $\Delta\vec{L} = \vec{\tau}_{impact}\Delta t = Angular\ Impulse$
    - Dimensions for Angular Impulse: $\Delta\vec{L} = \vec{\tau}_{impact}\Delta t \Rightarrow N \cdot m \cdot s$

Rotational vs. Linear Review

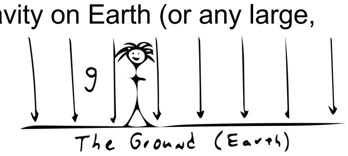
Name:	Linear:	Rotational:
Displacement	$\Delta\vec{x} = x_f - x_i$	$\Delta\vec{\theta} = \theta_f - \theta_i$
Velocity	$\vec{v}_{avg} = \frac{\Delta\vec{x}}{\Delta t}$	$\vec{\omega}_{avg} = \frac{\Delta\vec{\theta}}{\Delta t}$
Acceleration	$\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t}$	$\vec{\alpha}_{avg} = \frac{\Delta\vec{\omega}}{\Delta t}$
Uniformly Accelerated Motion (UAM) or Uniformly Angularly Accelerated Motion (UαM)	$v_f = v_i + at$ $x_f = x_i + v_i t + \frac{1}{2}at^2$ $v_f^2 = v_i^2 + 2a(x_f - x_i)$ $x_f - x_i = \frac{1}{2}(v_f + v_i)t$	$\omega_f = \omega_i + \alpha t$ $\theta_f = \theta_i + \omega_i t + \frac{1}{2}\alpha t^2$ $\omega_f = \omega_i + 2\alpha(\theta_f - \theta_i)$ $\theta_f - \theta_i = \frac{1}{2}(\omega_f + \omega_i)t$
Mass	Mass	$I_{particles} = \sum_i m_i r_i^2$
Kinetic Energy	$KE_{translational} = \frac{1}{2}mv^2$	$KE_{rotational} = \frac{1}{2}I\omega^2$
Newton's Second Law	$\sum \vec{F} = m\vec{a}$	$\sum \vec{\tau} = I\vec{\alpha}$
Force / Torque	Force	$\vec{\tau} = \vec{r} \times \vec{F}$
Power	$P_{translational} = \vec{F} \bullet \vec{v}$	$P_{rotational} = \vec{\tau} \bullet \vec{\omega}$
Momentum	$\vec{p} = m\vec{v}$	$\vec{L}_{particle} = \vec{r} \times \vec{p}$ $\vec{L}_{object\ with\ shape} = I\vec{\omega}$
Work (constant force)	$W = \vec{F} \cdot \Delta\vec{r} = F\Delta r\cos\theta$	$W = \vec{\tau} \cdot \Delta\vec{\theta}$
Net Work-Kinetic Energy Theorem	$W_{net} = \Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$	$W_{net} = \Delta KE = \frac{1}{2}I\omega_f^2 - \frac{1}{2}I\omega_i^2$

A little bonus: Look what happens when we combine a couple of the above formulas:

$$W_{net} = \vec{\tau}_{net} \cdot \Delta\vec{\theta} = I\alpha\Delta\theta = \frac{1}{2}I\omega_f^2 - \frac{1}{2}I\omega_i^2 \Rightarrow 2\alpha\Delta\theta = \omega_f^2 - \omega_i^2 \Rightarrow \omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta \text{ (UαM!)}$$

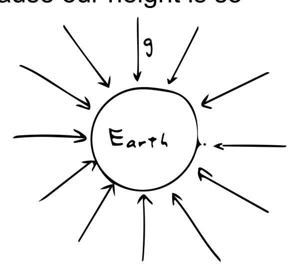
Universal Gravitation

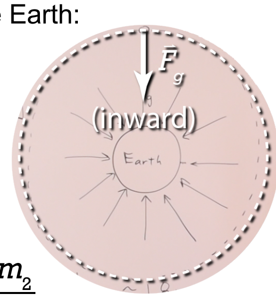
- Newton's Universal Law of Gravitation: $F_g = \frac{Gm_1m_2}{r^2}$
    - Universal Gravitational Constant: $G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$
    - r is not defined as the radius, it is defined as the distance between the centers of mass of the two objects which can be confusing because sometimes it does work out to be the radius. ☺
    - $\vec{F}_g = m\vec{g}$ is planet specific.
    - $F_g = \frac{Gm_1m_2}{r^2}$ is universally true.
    - We can combine the two to solve for the acceleration due to gravity on Earth (or any large, celestial body): $F_g = m_o g = \frac{Gm_o m_E}{(R_E + alt)^2} \Rightarrow g = \frac{Gm_E}{(R_E + alt)^2}$



- The gravitational field is approximately constant on the surface of the Earth because our height is so small compared to the radius of the Earth. $h_{mr.p} \approx 1.8$ m, $R_E \approx 6{,}370{,}000$ m
- The gravitational field is not constant from a global perspective and decreases as altitude increases, this can be shown using a vector field diagram.
- Solving for the speed of the satellite in orbit around the Earth:
    - $\sum F_{in} = F_g = m_s a_c = \frac{Gm_s m_E}{r^2} = m_s \frac{v_t^2}{r}$

      $\Rightarrow v_t = \sqrt{\frac{Gm_E}{r}} = \sqrt{\frac{Gm_E}{(R_E + alt)}}$

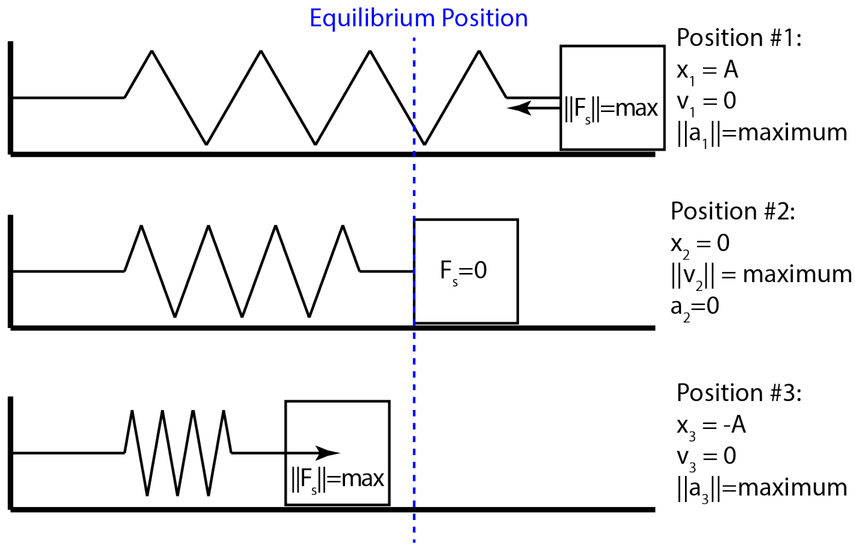




- Universal Gravitational Potential Energy: $U_g = -\frac{Gm_1m_2}{r}$
    - The equation used to find gravitational potential energy in a non-uniform gravitational field.
    - $U_g \leq 0$: The zero line is infinitely far away. $U_{g_\infty} = -\frac{Gm_1m_2}{\infty} \approx 0$
    - A single object can *not* have Universal Gravitational Potential Energy. Universal Gravitational Potential Energy is defined as the Gravitational Potential Energy that exists between *two* objects.
        - Technically Gravitational Potential Energy in a constant gravitational field: $PE_g = mgh$, is the gravitational potential energy that exists between the object and the Earth. So even PE_g requires two objects.

Simple Harmonic Motion

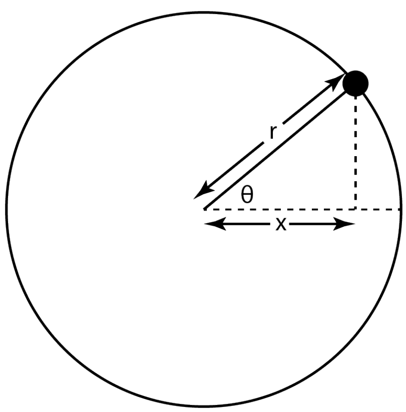
The mass-spring system shown at right is in simple harmonic motion. The mass moves through the following positions: 1, 2, 3, 2, 1, 2, 3, 2, 1, 2, 3, 2, 1, 2, 3, 2, 1, 2, 3, 2, etc.



Simple Harmonic Motion (SHM) is caused by a Restoring Force:

- A Restoring Force is always:
  - Towards the equilibrium position.
  - Magnitude is proportional to distance from equilibrium position.

To derive the equation for position in SHM, we start by comparing simple harmonic motion to circular motion.



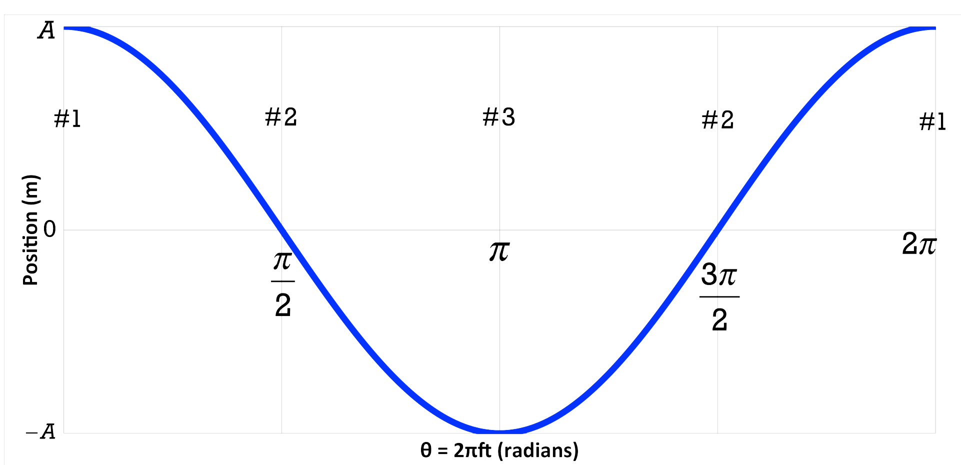
$$\cos\theta = \frac{A}{H} = \frac{x}{r} \Rightarrow x = r\cos\theta \;\; \& \;\; T = \frac{2\pi}{\omega} = \frac{1}{f} \Rightarrow \omega = 2\pi f$$

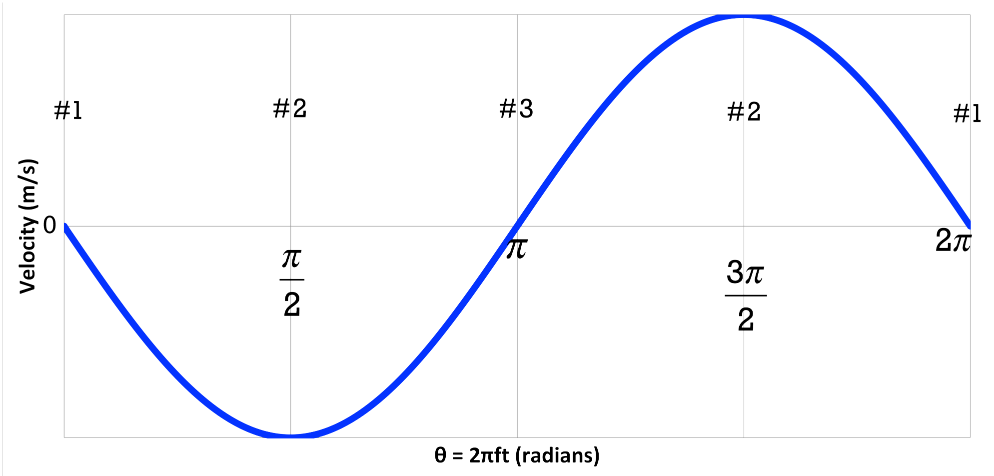
$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{\theta_f - \theta_i}{t_f - t_i} = \frac{\theta_f - 0}{t_f - 0} = \frac{\theta}{t} \Rightarrow \theta = \omega t$$

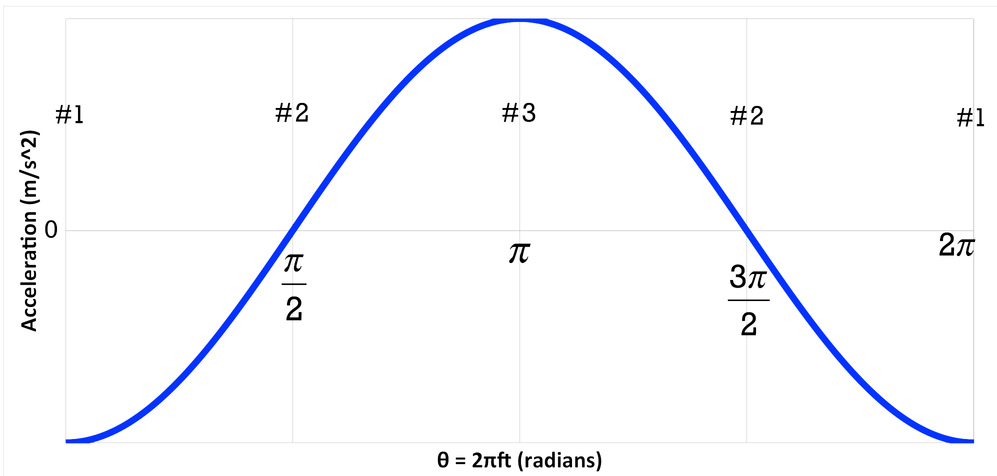
$$x = r\cos\theta = r\cos(\omega t) = r\cos\left[(2\pi f)(t)\right] = A\cos\left[(2\pi f)(t)\right]$$

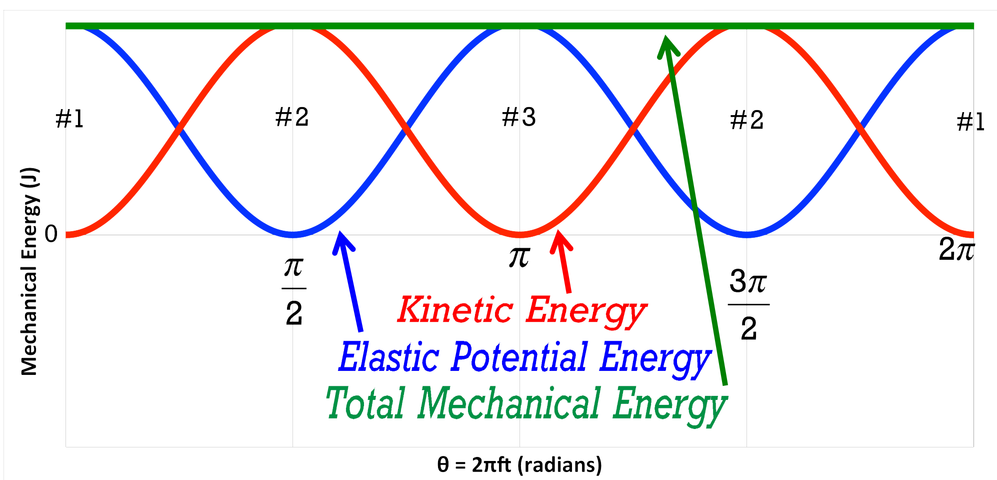
(letting r = A)

Looking at the graphs …









The period of a mass-spring system: $T_s = 2\pi\sqrt{\frac{m}{k}}$ Is independent of amplitude and acceleration due to gravity.

The period of a pendulum: $T_p = 2\pi\sqrt{\frac{L}{g}}$ Is independent of amplitude and mass.

*ALL *Equations to Memorize**

Let me be clear about what I mean by "memorize": I mean you should have the equation memorized, know what it means and know when you can use it. This is a lot more than just being able to write down the equation.

The following equations are *not* on the Equation Sheet provided by the AP College Board for the AP Physics 1 exam:

- $speed = \frac{distance}{time}$; $\vec{v} = \frac{\Delta\vec{x}}{\Delta t}$; $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$
  - Please make sure you understand the differences between vectors and scalars, please.♥
- $\Delta x = \frac{1}{2}\left(v_f + v_i\right)\Delta t$
  - This is another Uniformly Accelerated Motion (UAM) equation you should know.
- $F_{g_\parallel} = mg\sin\theta$ & $F_{g_\perp} = mg\cos\theta$
  - When an object is on an incline, we often need to sum the forces in the parallel and perpendicular directions, which necessitates resolving the force of gravity into its components in the parallel and perpendicular directions.
  - Note: theta in this equation is the incline angle.
- Equations having to do with Mechanical Energy:
  - $ME_i = ME_f$: Conservation of Mechanical Energy can be used when there is no work done by the force of friction or the force applied.
  - $W_f = \Delta ME$: Can be used when there is no work done by the force applied.
  - $W_{net} = \Delta KE$: Is always true.
- $P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t} = \frac{Fd\cos\theta}{\Delta t} = Fv\cos\theta$
  - This is useful because you have power in terms of velocity.
- $\sum \vec{p}_i = \sum \vec{p}_f$
  - Conservation of linear momentum is valid when the net force acting on the system is zero, which is true during all collisions and explosions.
- $\vec{\omega} = \frac{\Delta\vec{\theta}}{\Delta t}$ & $\vec{\alpha} = \frac{\Delta\vec{\omega}}{\Delta t}$
  - Angular velocity and angular acceleration were, sadly, left off the equation sheet.

- $\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$ & $\Delta\theta = \frac{1}{2}\left(\omega_f + \omega_i\right)\Delta t$
    - These two Uniformly Angularly Accelerated Motion (UαM) equations were also, sadly, left off the equation sheet.
- $\vec{v}_t = r\vec{\omega}$
    - The tangential velocity of an object.
- $v_{cm} = R\omega$
    - The velocity of the center of mass of an object rolling without slipping.
- $\sum \vec{F}_{in} = m\vec{a}_c$
    - The equation for the centripetal force acting on an object to keep it moving in a circle.
- $I = \sum_i m_i r_i^2$
    - The moment of inertia or "rotational mass" of a system of particles.
- $\sum \vec{L}_i = \sum \vec{L}_f$
    - Conservation of Angular Momentum, valid when the net external torque acting on the system is zero. $\sum \tau_{external} = 0$