BIG PICTURE IDEAS

#1) Newton's Law of Universal Gravitation can be used to determine the gravitational force between any two masses.

#2) An ideal spring force is proportional to its displacement from equilibrium position.

#3) The net force in the in-direction acting an object moving along a circular path is called centripetal force.

Topic 2.6b – Universal Gravitation and Gravitational Field

1) The equation for the magnitude of the gravitational force using Newton's Law of Universal Gravitation is: $F_g = \frac{Gmm}{r^2}$

   a) G is the Gravitational Constant and has a value of $6.67x10^{-11}\frac{N \cdot m^2}{kg^2}$

      i) However, I do not have to memorize this number because it is on the equation sheet!

   b) m represents the gravitational masses of the two objects which are interacting via the gravitational force.

   c) r is not the radius. r is the distance between the centers of mass of the two objects.

      i) This could be confusing, because sometimes r is the radius.

   d) The gravitational force is always directed along a line connecting the centers of mass of the two objects.

      i) The gravitational force on each of the two masses is always directed toward the other mass.

   e) The gravitational forces acting on both masses have the same magnitude.

2) In the narrow band of altitudes which humans live on this planet*, the local gravitational field, g, is nearly constant and can be treated as constant with negligible error and the local gravitational field is directed downward.

   a) The equation for the gravitational force in that gravitational field is $F_g = mg$, however, a subscript is missing on the mass. The subscript missing on the mass is the mass of the object.

      i) This gravitational force equation describes the interaction between 2 masses; mass of the object and mass of the Earth.

   b) On the surface of a planet, gravitational force is also called weight.

   c) The gravitational field can be determined by dividing the gravitational force exerted by the field on a test mass by the mass of the test mass.

      i) This is easy to remember because it is a rearrangement of the gravitational force equation.

      Like this: $F_g = mg \Rightarrow g = \frac{F_g}{m}$

3) The equation for the gravitational field on the surface of any planet, g, can be derived using Newton's Law of Universal Gravitation.

   Like this: $F_g = m_{object}g = \frac{Gm_{object}m_{planet}}{r^2} \Rightarrow g = \frac{Gm_{planet}}{\left(R_{planet}\right)^2}$

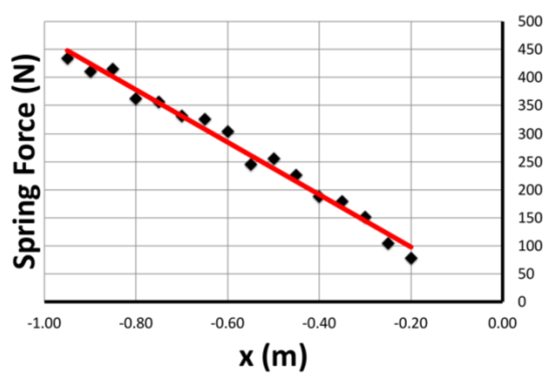
* If this does not apply to you, and you are currently working on this Study Guide, please contact me. I have some questions.

Topic 2.6b – Universal Gravitation and Gravitational Field (continued)

4) If the only force acting on the object is the gravitational force, then the object is in free fall, and the acceleration of the object has the same magnitude as the gravitational field, g.
   a) The units of the free fall acceleration are $\frac{m}{s^2}$ and the units of the gravitational field are $\frac{N}{kg}$.
   b) I can show these two units are equivalent. Look! See! → $\frac{N}{kg} = \frac{(kg \cdot m)/s^2}{kg} = \frac{m}{s^2}$
   c) On the AP Physics 1 exam, we can approximate g near the surface of planet Earth to be: $10\frac{m}{s^2}$ or $10\frac{N}{kg}$
5) The gravitational force is a field force. Field forces occur when two objects interact without touching each other.
   a) Other examples of field forces are the electric force and the magnetic force which are not discussed in AP Physics 1.

Topic 2.8 – Spring Force

1) An ideal spring force is proportional to its displacement from equilibrium position.
2) The direction of the spring force is always toward equilibrium or rest position.
3) The equation for the spring force is called Hooke's law and it is: $\vec{F}_s = -k\Delta\vec{x}$
   a) k is the spring constant and is a measure of how much force it takes to compress or expand a spring per meter. In other words, a larger spring constant will have more resistance to changes in distance from equilibrium position.
      i) Typical units for k are $\frac{N}{m}$ and k is always positive.
   b) Δx is the displacement of the system/object from equilibrium or rest position.
   c) The magnitude of the slope of a graph of spring force vs. displacement from equilibrium position is the spring constant.
4) The negative in Hooke's law represents that the spring force and the displacement of the object from rest position are opposite in direction.
5) An ideal spring has negligible mass.
6) Using the graph to the right, determine the spring constant of the spring:



$$F_s = -kx \;\&\; y = (\text{slope})\,x + b$$

Draw a best fit line and pick two points on that line to determine slope.

$$\Rightarrow k = -\text{slope} = -\frac{F_{s_2} - F_{s_1}}{x_2 - x_1} = -\frac{445N - 100N}{-0.95m - (-.2m)} \approx 460\frac{N}{m}$$

Topic 2.9 – Circular Motion

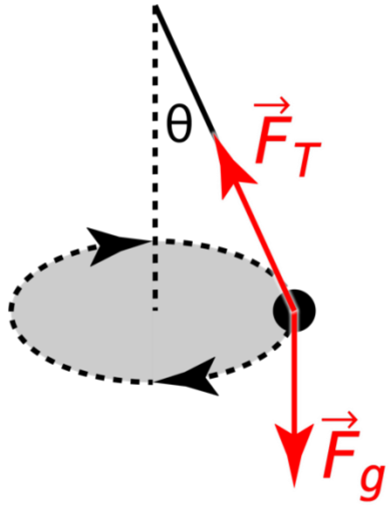
1) The linear velocity of an object moving along a circular path is called tangential velocity which is always directed perpendicular to the radius describing the path and parallel to the path itself.
2) An object, moving along a circular path, must have a centripetal acceleration which is always directed inward toward the center of the circle.
   a) Acceleration equals change in velocity over change in time. And velocity is vector, which means it has both magnitude and direction.
   b) The reason an object moving along a circular path must have a centripetal acceleration is because the direction of the tangential velocity of the object is always changing.
      i) This centripetal acceleration equals the square of tangential speed divided by radius. $a_c = \frac{{v_t}^2}{r}$
3) An object, moving along a circular path at a constant speed, can be defined using the following terms:
   a) The time it takes the object to complete one circle is defined as the period the symbol for which is T.
   b) The number of revolutions completed by the object per second is defined as frequency. The symbol for which is f.
      i) These two terms are inversely related to one another to using the following equation: $T = \frac{1}{f}$
   c) Starting with the equation for speed, I can derive the equation for the period of an object traveling at a constant speed in a circular path in terms of radius, r, and tangential speed, v. And yes, I recognize that, for speed here mr.p is using "v_t" and I can let that go. Circle → Yes, I can *let it go*.

$$\text{speed} = \frac{\text{distance}}{\text{time}} \Rightarrow v_t = \frac{\text{Circumference}}{T} = \frac{2\pi r}{T} \Rightarrow T = \frac{2\pi r}{v_t}$$

4) Centripetal force is the net force in the in direction or the "center seeking" force which causes the centripetal acceleration of the object in toward the center of the circle.
   a) The equation for centripetal force is: $\sum \vec{F}_{in} = m\vec{a}_c$
   b) The centripetal force is not a new force
   c) The centripetal force is never in a free body diagram.
   d) When summing the forces in the "in" direction, the direction "in" is positive and the direction "out" is negative.

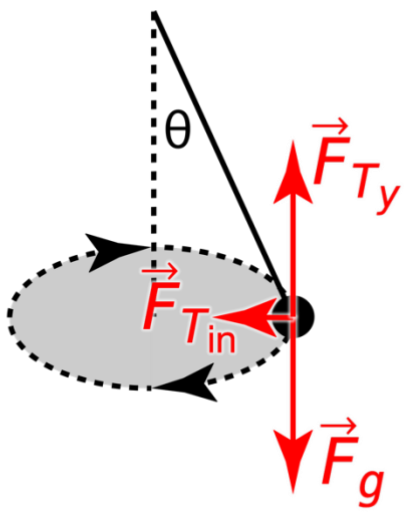
Topic 2.9 – Circular Motion (continued)

5) A simple pendulum is rotating in a horizontal circle where the rope makes an angle θ with the vertical as shown. To clarify, the shaded area is in a horizontal plane and the pendulum bob is moving along that horizontal circle.



a) Draw the free body diagram of all the forces acting on the pendulum bob.

b) What force(s), or force component(s), is(are) the centripetal force acting on the pendulum bob?



The centripetal force is the net force in the in-direction. To determine that force, we need to break the force of tension into its components in the y and in-directions. Looking at the free body diagram, the only force acting in the in-direction is the component of the force of tension in the in-direction.

$$\sum F_{in} = F_{T_{in}}$$

Answer: The component of the force of tension in the in-direction.