Central Force Model

Uniform Circular Motion

Unit Learning Expectations – We are learning to:

-graph and state the relationships between velocity and mass, velocity and radius, and velocity and period for an object undergoing uniform circular motion.

-apply the mathematical expression that describes the relationship between force, mass, radius and velocity.

-distinguish between centripetal (Fnet-c) and previously described forces.

- construct force diagrams that display the forces acting on an object undergoing uniform circular motion.

Uniform Circular Motion

- Essential Questions
  - What is necessary to keep an object moving in a circular path?
  - How did you make your sphere in the introductory activity travel in a circular path?
  - Did you use a new force that we have not yet described?
    - i.e. something other than Fg, Fn, Ff, Fpush, Fpull, etc…

Uniform Circular Motion

- Essential Questions
  - What direction does the force act to keep the sphere moving in a circular path?
  - What happens to the sphere if you remove the force? How does it travel?
  - If the sphere travels with constant speed around the circle, is velocity also constant?

Uniform Circular Motion

- Essential Questions
  - If the direction the sphere travels is always changing, does it fit our constant velocity or uniform acceleration model?
  - What factors contribute to how much force is required to maintain circular motion?

Uniform Circular Motion

- Essential Questions
  - What is necessary to keep an object moving in a circular path?
  - How did you make your sphere in the introductory activity travel in a circular path?
  - Did you use a new force that we have not yet described?
    - i.e. something other than Fg, Fn, Ff, Fpush, Fpull, etc…

Uniform Circular Motion

- Essential Questions
  - What is necessary to keep an object moving in a circular path?
    - A force was required
  - How did you make your sphere in the introductory activity travel in a circular path?
    - Pushed it toward the center
  - Did you use a new force that we have not yet described?
    - i.e. something other than Fg, Fn, Ff, Fpush, Fpull, etc…
      - No, nothing new just same contact forces we have already studied

Uniform Circular Motion

- Conceptual Responses
  - What direction does the force act to keep the sphere moving in a circular path?
    - Always directed toward center of circle
  - What happens to the sphere if you remove the force? How does it travel?
    - Continues moving in straight path, at a tangent to circle
  - If the sphere travels with constant speed around the circle, is velocity also constant?
    - Because direction is always changing, it moves with constant speed but velocity changes.

Uniform Circular Motion

- Key Questions
  - If the direction the sphere travels is always changing, does it fit our constant velocity or uniform acceleration model?
    - The particle force model holds that an unbalanced force is required to cause a change in velocity; therefore this is uniform acceleration.
  - What factors contribute to how much force is required to maintain circular motion?
    - Mass, velocity, & radius of circle

Uniform Circular Motion

Uniform Circular Motion

The Centripetal Force and Direction Change

- Any object moving in a circle (or along a circular path) experiences a **centripetal force**. That is, there is some physical force pushing or pulling the object towards the center of the circle. This is the centripetal force requirement. The word *centripetal* is merely an adjective used to describe the direction of the force. “Centri-“ means center and “-petal” means towards. **We are not introducing a new *type* of force but rather describing the direction of the net force acting upon the object that moves in the circle.** Whatever the object, if it moves in a circle, there is some force acting upon it to cause it to deviate from its straight-line path, accelerate inwards and move along a circular path.

Uniform Circular Motion

- Net forces
  - Fnet-x = sum of all horizontal forces
    - Generally define right as positive & left as negative.
  - Fnet-y = sum of all vertical forces
    - Generally define up as positive & down as negative.
  - Fnet-c = (centripetal force) sum of all forces directed toward or away from the center of a circular path
    - Generally define toward center as positive & away from center as negative.

Uniform Circular Motion

- Circular Motion Situations
  - Horizontal
    - Fnet-c is positive toward center.
      - Example: Fnet-c = Ft + Fn ≠ 0N
    - Fg acts vertically so it neither acts toward or away from the center of the circular path and therefore is not considered when analyzing Fnet-c in this case
  - Vertical
    - Fnet-c is positive toward center.
      - Example: Fnet-c = Fg + Fn ≠ 0N
    - Fg can act either toward or away from the center of the circular path
    - Fg does not change magnitude, but can change from positive to negative

Note: in all cases of circular motion Fnet-c never equals 0N.

Uniform Circular Motion

- Vertical Circular Motion – 4 key locations
- Example of stopper on string:

$\mathbf{F_{net\text{-}c}} = F_T + F_g$

- – note on diagrams that black $\mathbf{F_{net\text{-}c}}$ is the sum of F_T and F_g and should not be considered a separate force.
- – $\mathbf{F_{net\text{-}c}}$ is shown next to forces; however it is the sum of the forces and is addition of F_T and F_g.

Uniform Circular Motion

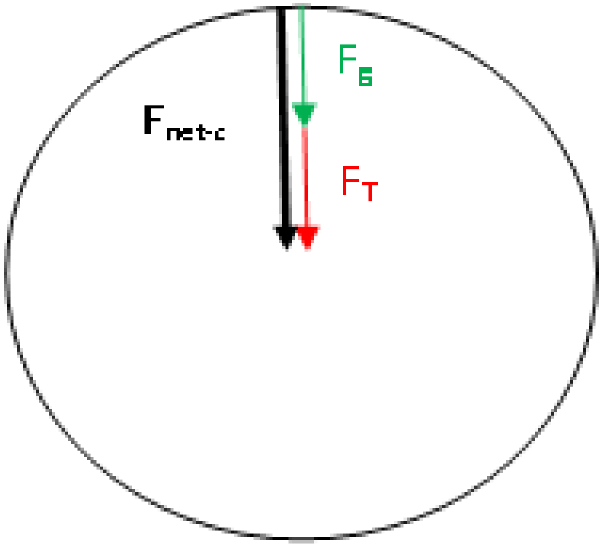
- <u>Vertical Circular Motion – 12 o'clock</u>

$\mathbf{F_{net\text{-}c}}$ = F_T + F_g , assume $\mathbf{F_{net\text{-}c}}$ **= +20N** and mass is 1kg.

+20N = F_T + (+10N)

(positive b/c directed toward center of circle or positive direction)

F_T = +10N



Uniform Circular Motion

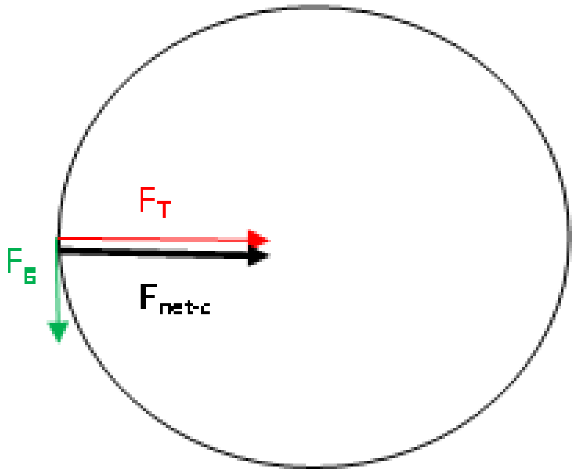
- <u>Vertical Circular Motion – 3 & 9 o'clock</u>

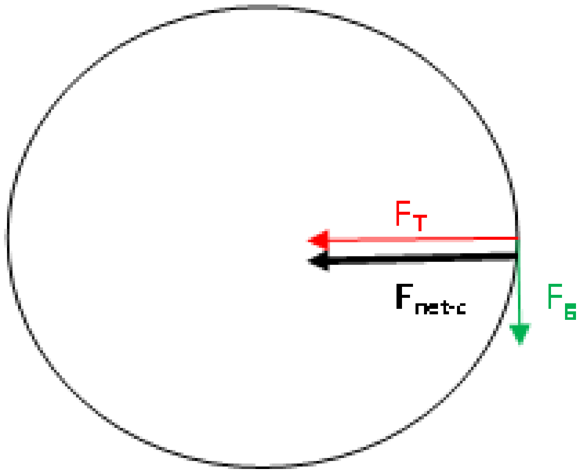
$F_{net\text{-}c}$ = $F_T + F_g$, assume **$F_{net\text{-}c}$ = +20N** and mass is 1kg.

(in this case F_g is not part of the **$F_{net\text{-}c}$** equation because it does not act in a direction toward or away from the center of the circular path.

+20N = F_T (positive b/c directed toward center of circle or positive direction)

F_T = +20N **9 o'clock3 o'clock**





Uniform Circular Motion

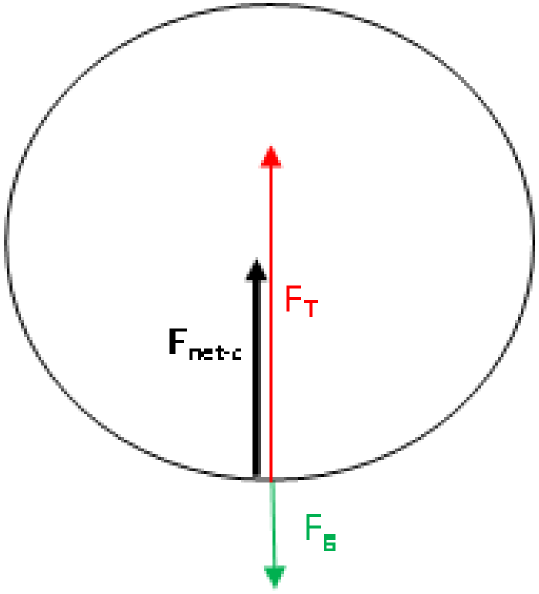
- <u>Vertical Circular Motion – 6 o'clock</u>

$\mathbf{F_{net\text{-}c}}$ = F_T + F_g , assume $\mathbf{F_{net\text{-}c}}$ **= +20N** and mass is 1kg.

+20N = F_T + (-10N)

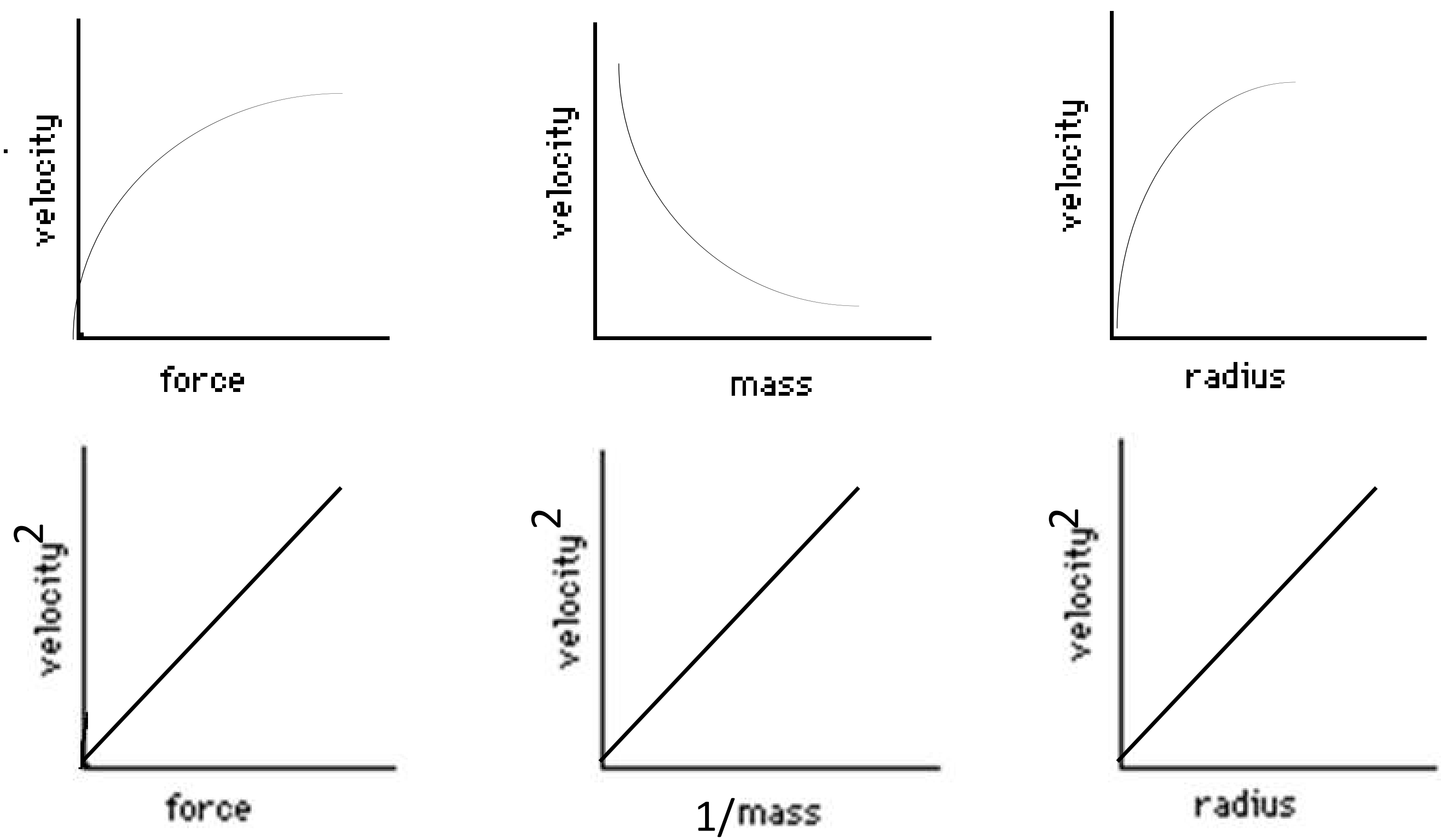
(negative b/c directed away from center of circle or negative direction)

F_T = +30N



Uniform Circular Motion

Lab Data



Uniform Circular Motion

- Using slopes of linear graphs and qualitative comparisons of variables, the mathematical representation for Fnet-c is:

Fnet-c = $mv^2/r$and $a_c = v^2/r$

- Note – see geometric proof in reading

References & Resources

- Texts
  - CP
  - Honors
- Links
  - Rutgers Physics
  - Phet : University of Colorado
  - The Physics Classroom