Circular Motion - FR

- Any object that revolves about a single point or axis undergoes circular motion.
- The speed of an object in a circular motion points *along the tangent* with the circle.
- The speed can be found using the formula $v = \frac{d}{t} = \frac{2\pi r}{T}$, where $r$ is the radius of the circle and $T$ is the time, called *period*, needed for the object to complete one rotation.
- Centripetal acceleration is always directed toward the center and it is due to a change in direction, and can be found using the formula $a_c = \frac{v^2}{r}$.
- Tangential acceleration is due to a change in speed.
- A uniform circular motion has a *constant speed*, therefore it has centripetal acceleration only but not a tangential acceleration.
- The net force that is directed toward the center of the circle is called *centripetal force*; There is no such thing as a *centrifugal force*.
- Using the *Newton’s second law* for the centripetal force we can write $F_c = ma_c$.
- The formula for the centripetal force is $F_c = \frac{mv^2}{r}$.
- Centripetal force is simply the name given to the net force on an object in uniform circular motion; it is not some special extra force that has to be there.
- *Friction* between a race car’s tires and a circular track is a centripetal force that keeps the car in a circular path.
- *Gravitational force* is a centripetal force that keeps Moon in its orbit around Earth.
- Inertia in circular motion is often *misinterpreted* as a force; In other words, centrifugal force does not exist.
1. Identify the forces that contribute to the centripetal force on the object in each of the following examples:

   a. a *bicyclist* moving around a flat, circular track  \[ \text{gravity, normal} \]
   b. a *bicycle* moving around a flat, circular track  \[ \text{gravity, normal, friction (s & k)} \]
   c. a *satellite* in the orbit around the Earth  \[ \text{gravity} \]
   d. a *race car* turning a corner on a steeply banked curve  \[ \text{gravity, normal, friction (s & k)} \]

2. Explain what makes a passenger in a turning car slide toward the door of the car.

   inertia
   inertial force
   centrifugal force
   (which is a *fake* force, *not* real)

3. Pizza makers traditionally form the crust by throwing the dough up in the air and spinning it. Why does this make the pizza crust bigger?

   (same picture as above; instead of the circle being a person, it would be a piece of dough)
   The inertial force is bigger than the tension between two pieces of dough next to each other, that is why the crust gets bigger.

4. Give an example of a situation in which an automobile driver can have a centripetal acceleration but no tangential acceleration.

   If the driver is driving an automobile w/ constant speed while turning. Turning means some curve, therefore we have \[ \Delta \text{change of direction} \] 2
   Constant speed means \[ a_t = 0 \ m/s^2 \] (\( a_t = \Delta V \))
5. Why does mud fly off a rapidly turning wheel?

Because of inertia. Trucks have mud flaps above the wheels to collect the mud escaping the wheels.

6. A rope attaches a tire to an overhanging tree limb. A girl swinging on the tire has a centripetal acceleration of 3.0 \( \text{m/s}^2 \). If the length of the rope is 2.1 m, what is the girl's tangential speed?

\[
a_c = \frac{v^2}{r}
\]

\[
v^2 = a_c \cdot r
\]

\[
v = \sqrt{a_c \cdot r} = \sqrt{(3.0 \text{ m/s}^2)(2.1 \text{ m})}
\]

\[
v \approx 2.5 \text{ m/s}
\]

7. A bicyclist is riding at a tangential speed of 13.2 m/s around a circular track. The magnitude of the centripetal force is 377 N, and the combined mass of the bicycle and the rider is 86.5 kg. What is the track's radius?

\[
F_c = \frac{mv^2}{r}
\]

\[
r = \frac{mv^2}{F_c} = \frac{(86.5 \text{ kg})(13.2 \text{ m/s})^2}{377 \text{ N}}
\]

\[
r \approx 40.0 \text{ m}
\]

8. A dog sits 1.5 m from the center of a merry-go-round. The merry-go-round is set in motion, and the dog's tangential speed is 1.5 m/s. What is the dog's centripetal acceleration?

\[
a_c = \frac{v^2}{r} = \frac{(1.5 \text{ m/s})^2}{1.5 \text{ m}}
\]

\[
a_c = 1.5 \text{ m/s}^2
\]
9. At amusement parks, there is a popular ride where the floor of a rotating cylindrical room falls away, leaving the backs of the riders "plastered" against the walls. Suppose the radius of the room is 3.30 m and the speed of the wall is 10.0 m/s when the floor falls away.

a) What is the source of the centripetal force acting on the riders?

Centripetal force is the normal force the wall exerts on the rider. Riders wanted to fly away due to the centripetal force; they don't so they push on the wall.

b) How much centripetal force acts on a 55.0 kg rider?

\[ F_c = \frac{m v^2}{R} = \frac{(55.0 \text{ kg})(10.0 \text{ m/s})^2}{3.30 \text{ m}} \]

\[ F_c = 1670 \text{ N} \]

c) What is the minimum coefficient of static friction that must exist between a rider's back and the wall, if the rider is to remain in place when the floor drops away?

FBD for the rider.  \[ F_c = F_N = \frac{m v^2}{R} \]

Along \( y \)-direction:

\[ \mu_s F_N = mg \]

\[ \mu_s \left(\frac{m v^2}{R}\right) = \mu_s mg \]

\[ \mu_s = \frac{gr}{v^2} = \frac{(9.81 \text{ m/s}^2)(3.30 \text{ m})}{(10.0 \text{ m/s})^2} \]

\[ \mu_s = 0.324 \]