Section 10.2

- Centripetal Acceleration
- Centripetal Force

Centripetal Acceleration

Uniform Circular Motion

The motion of an object in a circular path at a constant speed is known as uniform circular motion (UCM).

An object in UCM is constantly changing direction, and since velocity is a vector and has direction, you could say that an object undergoing UCM has a constantly changing *velocity,* even if its *speed* remains constant.

If the velocity of an object is changing, it must be accelerating. Therefore, an object undergoing UCM is constantly accelerating.

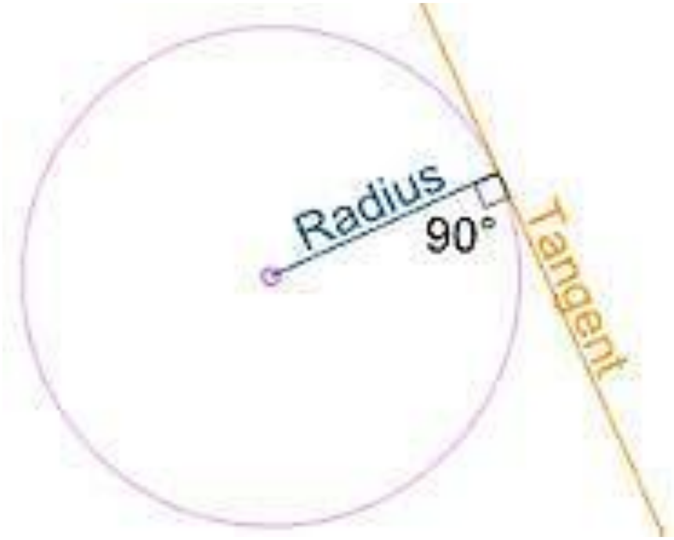
This type of acceleration is known as centripetal acceleration.

Acceleration in a Circle

- Acceleration is define as the rate of change of velocity
- Object moving in uniform circular motion has an acceleration
- Centripetal acceleration ("center pointing acceleration")

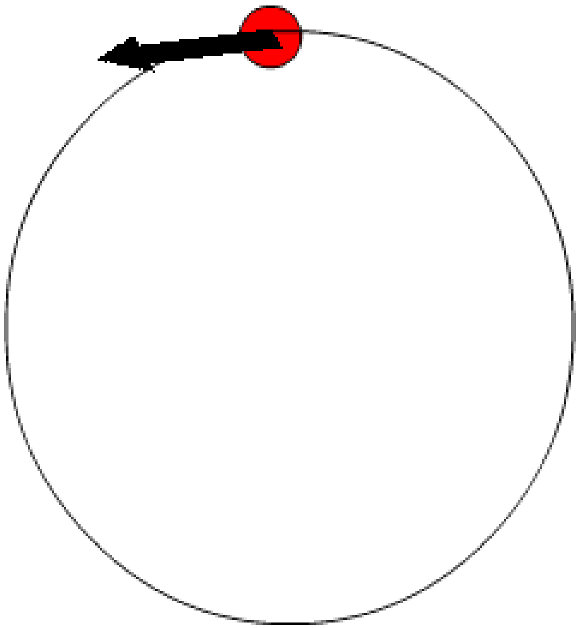
What is a Tangent Line ??

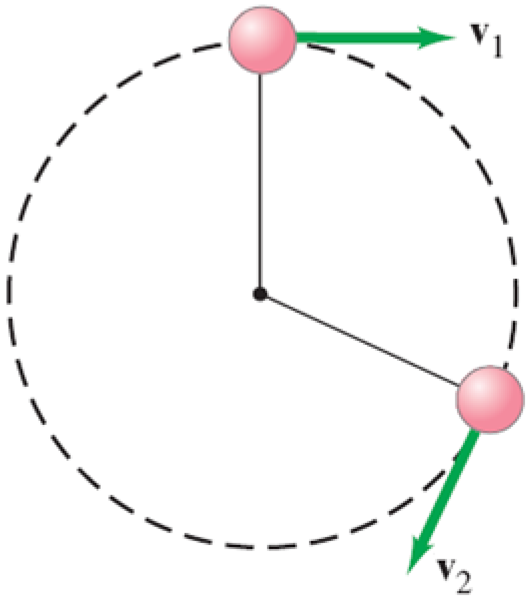
In geometry, the tangent line (or simply tangent) to a curve at a given point is the straight line that "just touches" the curve at that point.



Circular Motion with Velocity Vector

The velocity vector is always tangent to the circular path

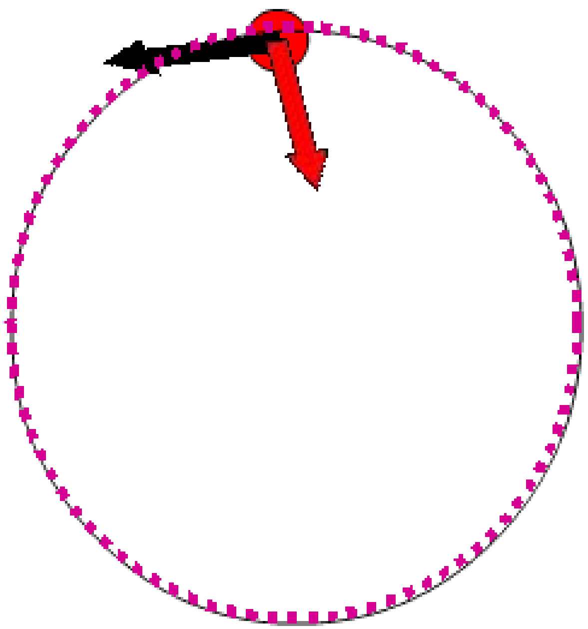


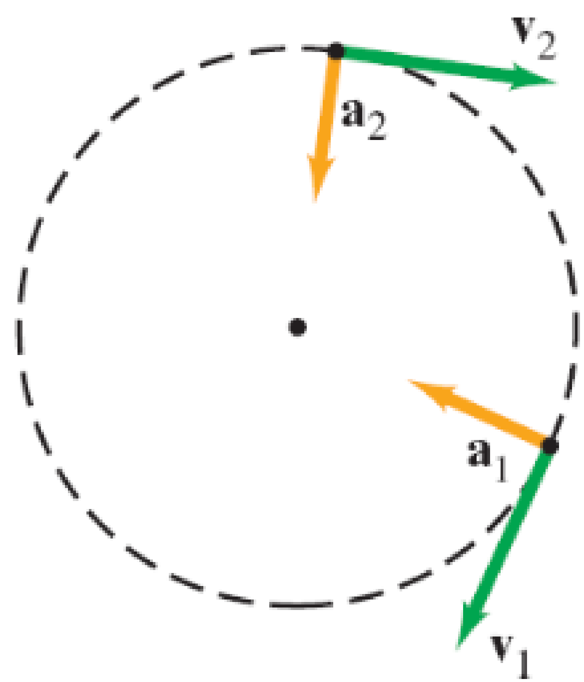


The above example is for an object that is moving counter-clockwise

Circular Motion with Velocity and Acceleration Vectors

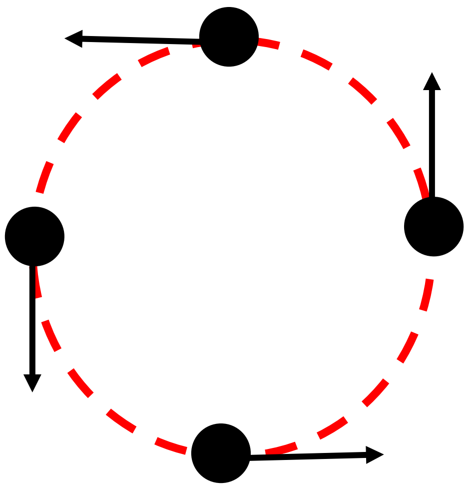
The acceleration vector is always towards the center of the circular path



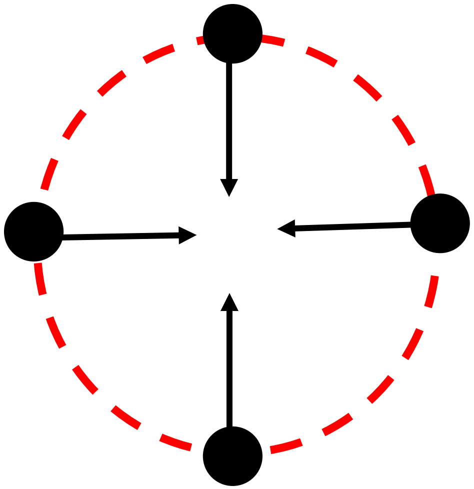


The above example is for an object that is moving counter-clockwise

Vectors on a Circular Path (summary)



Velocity Vector
(Tangent to the path)



Acceleration Vector
(Towards the center)

The Centripetal Acceleration Equation

An object moving in a circle of radius (r) at constant speed (v) has an acceleration whose direction is toward the center of the circle and whose magnitude is:

$$a_C = \frac{v^2}{r}$$

Example #1

An ice skater skates in a circular path of radius 7 m with a speed of 6 m/s.

a. **What is the period (T) of the ice skater (in seconds)?**
b. **What is the ice skater's centripetal acceleration (a_c)?**

a. **7.33 seconds**

b. **5.14 m/s^2**

Example #2

A mass moves in a circular path with a velocity of 1.5 m/s and a centripetal acceleration of 3.6 m/s^2. What is the radius, in meters, of the circular motion of the mass?

0.625 m

Example #3

The Moon's nearly circular orbit about the Earth has a radius of about 384,000 km and a period of 27.3 days. Determine the centripetal acceleration (a_c) of the Moon.

0.0027 m/s^2

Example #4

Mr. Holbrook's favorite ride at the Clark County Fair is the rotor. The ride has a radius of 4 meters and a frequency of 0.5 hertz.

a. **What is Mr. Holbrook's speed (V) on the rotor?**
b. **What is Mr. Holbrook's centripetal acceleration (a_c) on the rotor?**

a. **12.57 m/s**

b. **39.5 m/s^2**

Centripetal Force / Centrifugal Force

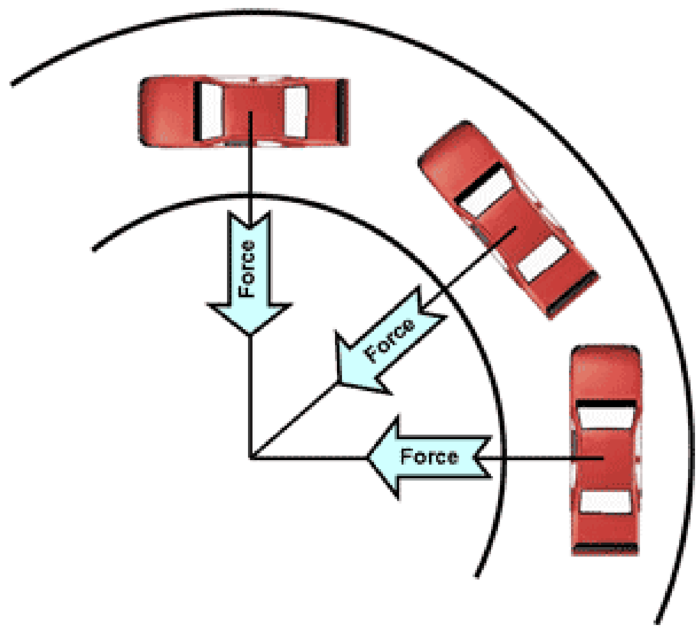
Centripetal Force

- We should remember from earlier work that motion is always caused by some kind of force.
- The same is true for circular motion
- Centripetal Force is any force that causes an object to follow a circular path.

Centripetal Force

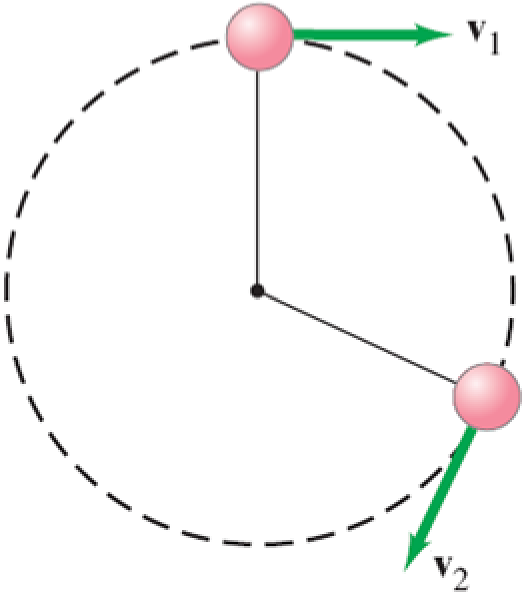
- Centripetal force can be thought of as a "center seeking" force.

- Centripetal force is always directed toward the center



Centripetal Force

All Circular motion requires a Centripetal Force otherwise the body continues in a straight line path (Inertia…baby!!!)



Centripetal Force – Newton's 1st Law

"Objects in motion tend to remain in motion, and objects at rest want to stay at rest, unless acted on by an outside force"

Newton's First Law tells us that only a force can cause a body to move out of a straight line path.

In circular motion the direction of the body is continually changing at every instant. Therefore a force must be acting.

That force is called centripetal (central) force since it acts toward the circle of the circular path.

Centripetal Force – Newton's 2^{nd} Law

All circular motion requires a centripetal force. Newton's Second Law of Motion tells us that force equal mass times acceleration.

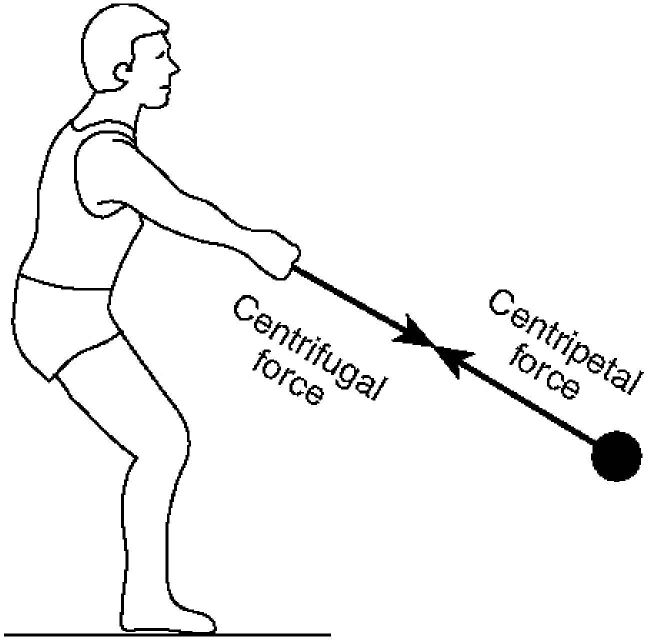
Therefore, centripetal force must produce an acceleration (centripetal acceleration). Since the force acts towards the center of the circular path, the acceleration must also be towards the center !

- ***All circular motion is accelerated motion.***
- ***The acceleration is always circular motion.***
- ***The acceleration is always towards the center of the circular path.***

Centrifugal Force

- **Just like we have an inward seeking force with circular motion, we can also have an outward seeking motion.**

- **This outward seeking motion is called Centrifugal force.**

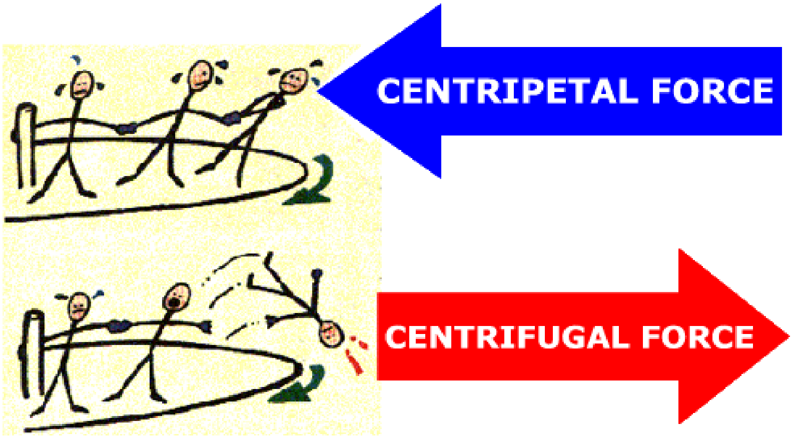


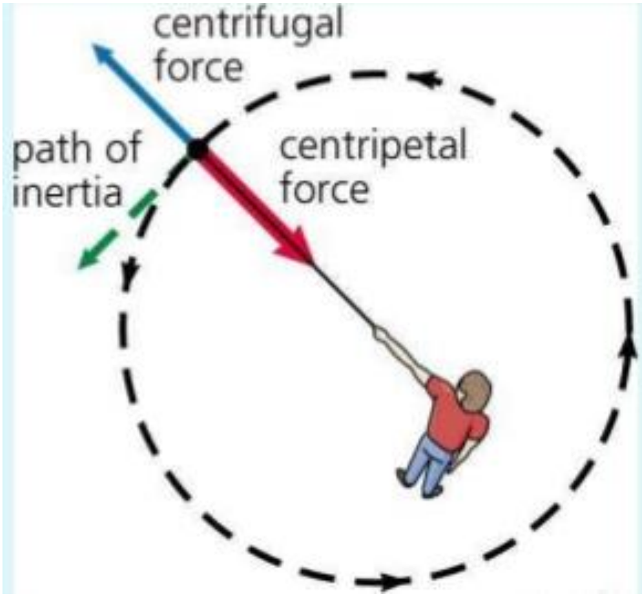
Note: A centrifugal force will never appear on a free-body diagram and never be included in Newton's laws.

Centrifugal Force

- Centrifugal force can be seen if we tie a string to a bucket and fill the bucket with water.
- The force holding the water in the bucket and keeping it from falling out is Centrifugal Force.
- Centrifugal force is measured the same way we measure centripetal force
- The only difference is the fact that our direction is outward and not inward.

Forces


CENTRIPETAL FORCE
CENTRIFUGAL FORCE


centrifugal force
path of inertia
centripetal force

Centripetal Force Equation

$$F = ma$$

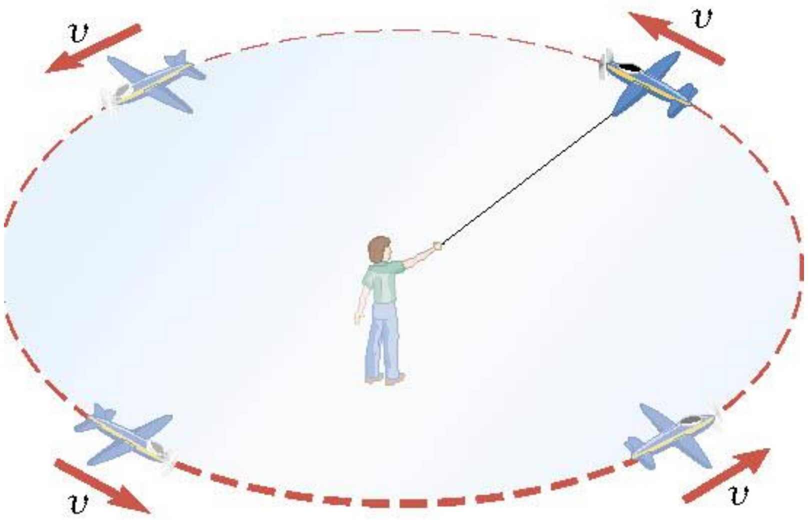
$$a_C = \frac{v^2}{r}$$

$$F_C = m\frac{v^2}{r}$$

Example 5:

A model airplane is swung by a rope in a circle with constant speed. The plane has a mass of 0.90 kg. Find the tension force (F_C) in the 17 meter rope for a speed of 19 m/s.

19.11 N



Example #6:

A rubber stopper of mass 0.013 kg is swung at the end of a cord 0.85 m long with a period of 0.65 s. Find the centripetal force (F_C) that is exerted on the stopper.

1.03 N

Example 7:

A 35 kg boy sits on a merry-go-round with a period of 3.78 seconds at a distance of 1.75 meters from the center of rotation. Find:

a. The boy's circular speed (V)
b. The centripetal acceleration (a_c)
c. The centripetal force (F_c)

a. 2.91 m/s

b. 4.84 m/s^2

c. 169.4 N