PHYS 1441 – Section 002
Lecture #11

Wednesday, Oct. 13, 2010

Dr. Jaehoon Yu

- Force of Friction Review
  - Example for Motion with friction
- Uniform Circular Motion
- Centripetal Acceleration
- Newton's Law & Uniform Circular Motion
- Unbanked and Banked highways
- Newton's Law of Universal Gravitation

Announcements

- Reading Assignments
  - CH5.4, 5.5, 5.9 and 6.2
- Quiz next Monday, Oct. 18
  - Beginning of the class
  - Covers CH4.5 to CH5.3
- Colloquium today
  - Our own Dr. Q. Zhang

Physics Department
The University of Texas at Arlington
COLLOQUIUM

Modeling and Simulations of Materials

Dr. Qiming Zhang

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The University of Texas at Arlington
4:00 pm Wednesday October13, 2010 room 101 SH

Abstract:

First-principles computational studies are widely used in modeling and simulations of the electronic and magnetic properties of materials. In this talk, I will briefly review the theoretical methodology and present several applications conducted recently in our group. They include searching for low-cost solar-cell materials, studying on the exchanged-coupled nanocomposite permanent magnet materials, and fundamental study on carbon adsorption on transition metal surfaces.

Refreshments will be served in the Physics Lounge at 3:30 p.m.

Forces of Friction Summary

Resistive force exerted on a moving object due to viscosity or other types frictional property of the medium in or surface on which the object moves.

These forces are either proportional to the velocity or the normal force.

Force of static friction, f_s: *The resistive force exerted on the object until just before the beginning of its movement*

Empirical Formula

$$\left|\vec{f}_s\right| \leq \mu_s \left|\vec{F}_N\right|$$

What does this formula tell you?

Frictional force increases till it reaches the limit!!

Beyond the limit, the object moves, and there is **NO MORE** static friction but kinetic friction takes it over.

Force of kinetic friction, f_k

$$\left|\vec{f}_k\right| = \mu_k \left|\vec{F}_N\right|$$

The resistive force exerted on the object during its movement

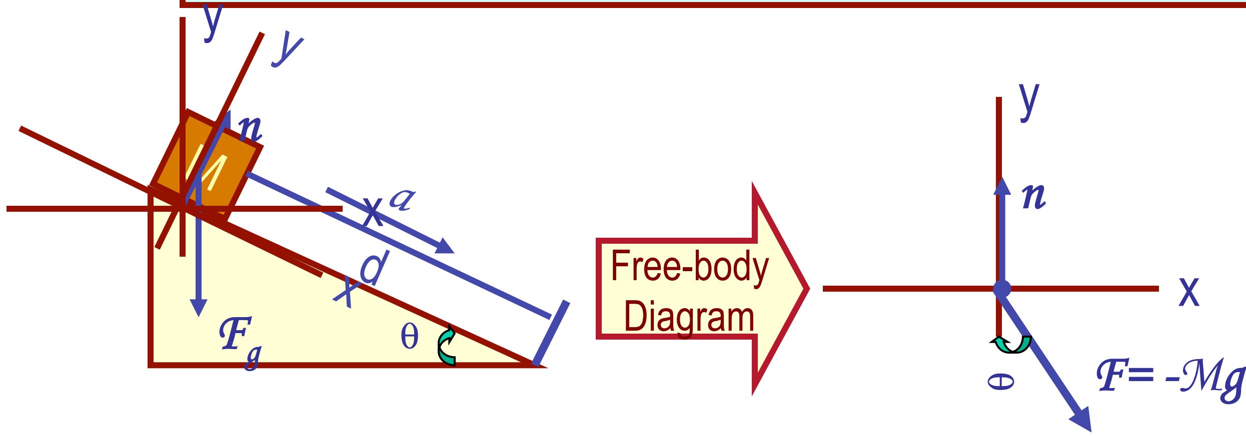
Which direction does kinetic friction apply?

Opposite to the motion!

Example w/o Friction

A crate of mass M is placed on a frictionless inclined plane of angle θ.

a) Determine the acceleration of the crate after it is released.



$$\vec{F} = \vec{F}_g + \vec{n} = m\vec{a}$$

$$F_x = Ma_x = F_{gx} = Mg\sin\theta$$

$$\boxed{a_x = g\sin\theta}$$

$$F_y = Ma_y = n - F_{gy} = n - mg\cos\theta = 0$$

Supposed the crate was released at the top of the incline, and the length of the incline is d. How long does it take for the crate to reach the bottom and what is its speed at the bottom?

$$d = v_{ix}t + \frac{1}{2}a_x t^2 = \frac{1}{2}g\sin\theta\, t^2$$

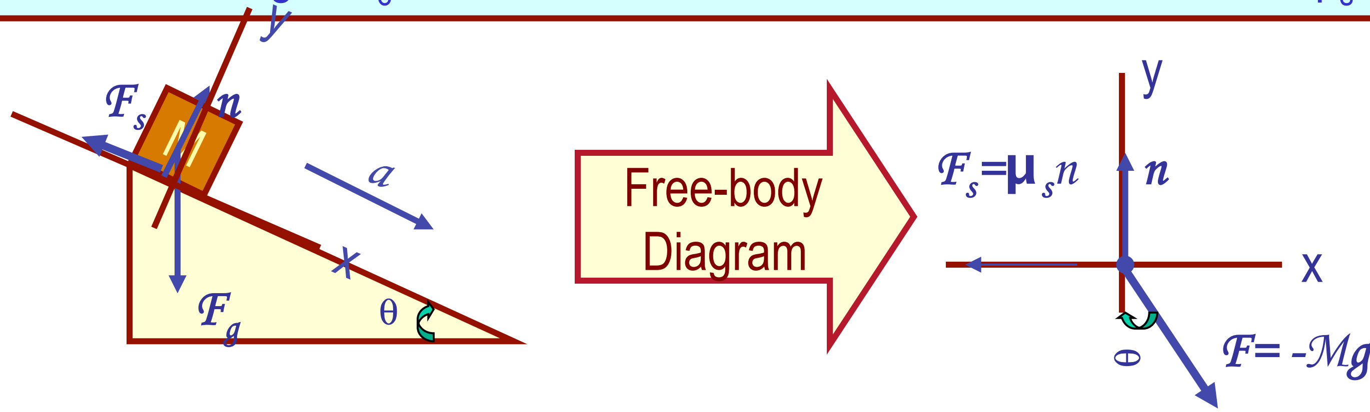
$$\boxed{\therefore t = \sqrt{\frac{2d}{g\sin\theta}}}$$

$$v_{xf} = v_{ix} + a_x t = g\sin\theta\sqrt{\frac{2d}{g\sin\theta}} = \sqrt{2dg\sin\theta}$$

$$\boxed{\therefore v_{xf} = \sqrt{2dg\sin\theta}}$$

Example w/ Friction

Suppose a block is placed on a rough surface inclined relative to the horizontal. The inclination angle is increased till the block starts to move. Show that by measuring this critical angle, θ_c, one can determine coefficient of static friction, μ_s.



Net force $$\vec{F} = M\vec{a} = \vec{F}_g + \vec{n} + \vec{f}_s$$

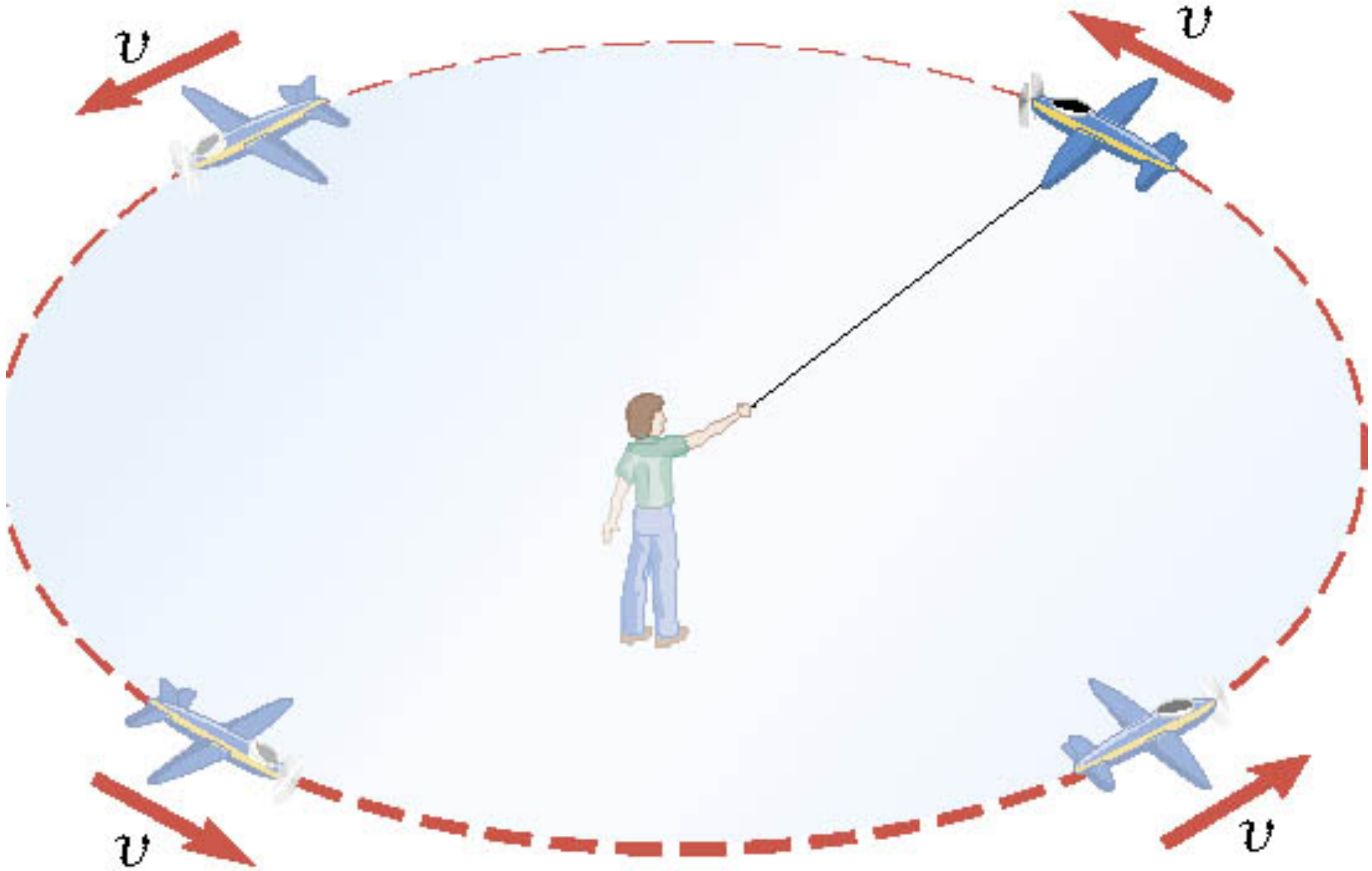
x comp. $$F_x = F_{gx} - f_s = Mg\sin\theta - f_s = 0 \quad f_s = \mu_s n = Mg\sin\theta_c$$

y comp. $$F_y = n - F_{gy} = n - Mg\cos\theta_c = Ma_y = 0 \quad n = F_{gy} = Mg\cos\theta_c$$

$$\mu_s = \frac{Mg\sin\theta_c}{n} = \frac{Mg\sin\theta_c}{Mg\cos\theta_c} = \tan\theta_c$$

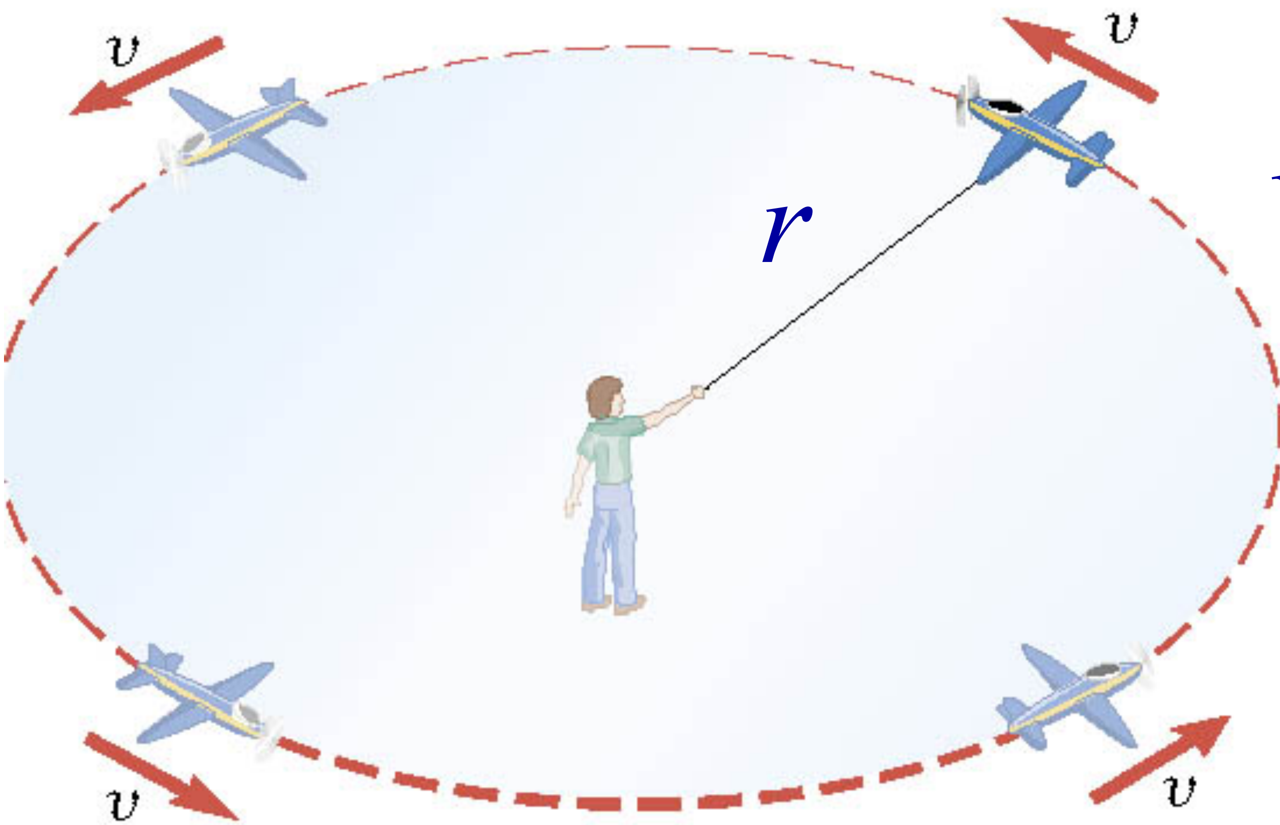
Definition of the Uniform Circular Motion

Uniform circular motion is the motion of an object traveling at a constant speed on a circular path.



Speed of a uniform circular motion?

Let *T* be the period of this motion, the time it takes for the object to travel once around the complete circle whose radius is r.



$$v = \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{T}$$

Ex. : A Tire-Balancing Machine

The wheel of a car has a radius of 0.29m and is being rotated at 830 revolutions per minute on a tire-balancing machine. Determine the speed at which the outer edge of the wheel is moving.

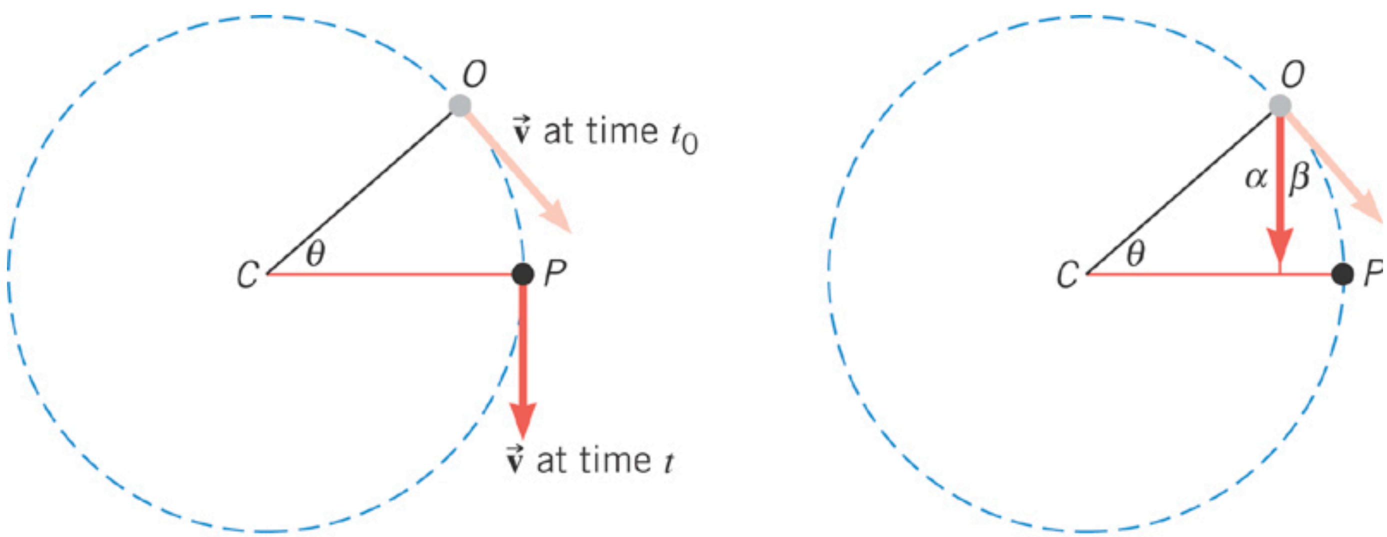
$$\frac{1}{830\,\text{revolutions}/\text{min}} = 1.2\times10^{-3}\,\text{min}/\text{revolution}$$

$$T = 1.2\times10^{-3}\ \text{min} = 0.072\ \text{s}$$

$$v = \frac{2\pi r}{T} = \frac{2\pi(0.29\ \text{m})}{0.072\ \text{s}} = 25\,\text{m}/\text{s}$$

Centripetal Acceleration

In uniform circular motion, the speed is constant, but the direction of the velocity vector is *not constant.*



(a) (b)

$$\alpha + \beta = 90^\circ$$

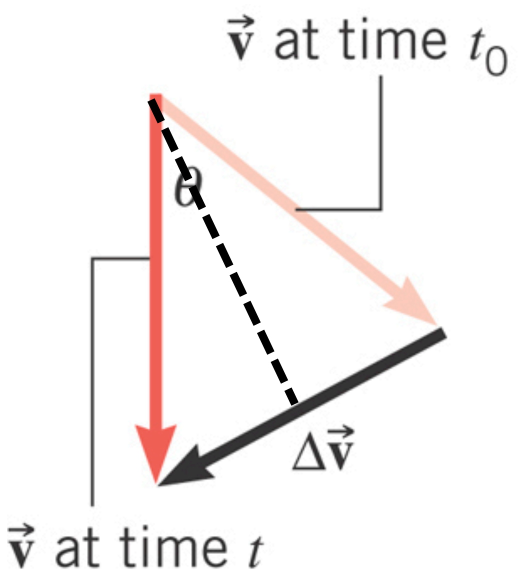
$$\alpha + \theta = 90^\circ$$

$$\beta - \theta = 0$$

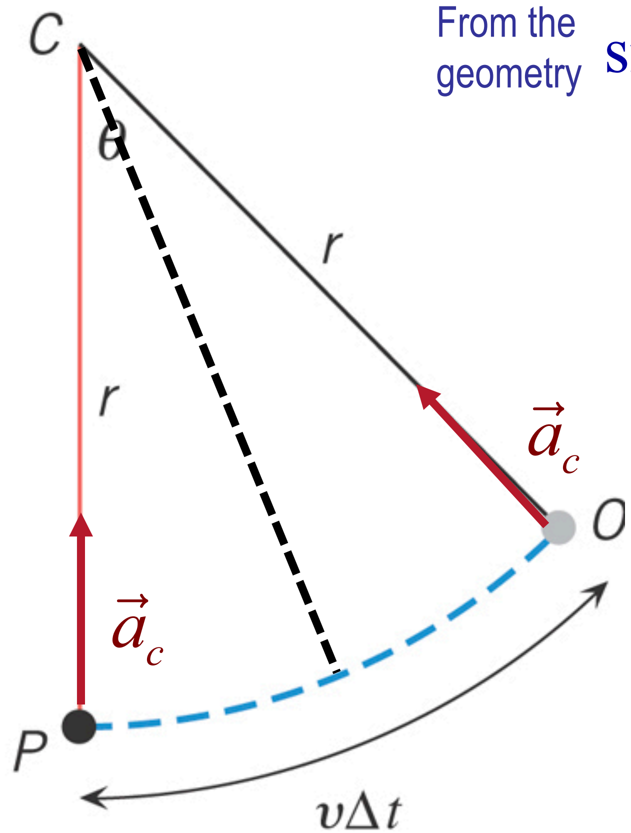
$$\beta = \theta$$

The change of direction of the velocity is the same as the change of the angle in the circular motion!

Centripetal Acceleration



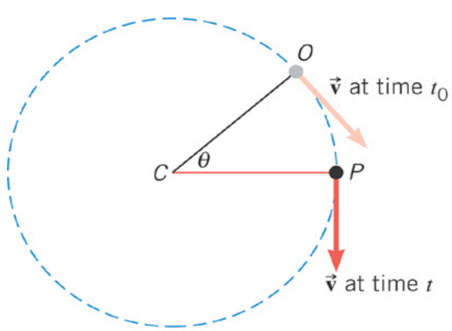
(a)



From the geometry $\sin\theta/2 = \dfrac{\Delta v}{\cancel{2}v} = \dfrac{v\Delta t}{\cancel{2}r}$

$$\frac{\Delta v}{\Delta t} = \frac{v^2}{r}$$

$$\boxed{a_c = \frac{v^2}{r}}$$



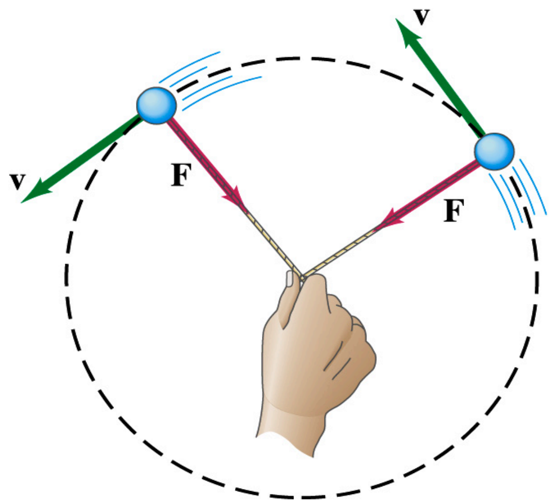
(a) (b)

What is the direction of a_c?

Always toward the center of circle!

Centripetal Acceleration

Newton's Second Law & Uniform Circular Motion



*The **centripetal*** acceleration is always perpendicular to the velocity vector, **v**, and points to the center of the rotational axis (radial direction) in a uniform circular motion.*

$$\boxed{a_c = \frac{v^2}{r}}$$

Are there forces in this motion? If so, what do they do?

The force that causes the centripetal acceleration acts toward the center of the circular path and causes the change in the direction of the velocity vector. This force is called the **centripetal force.**

$$\sum F_c = ma_c = m\frac{v^2}{r}$$

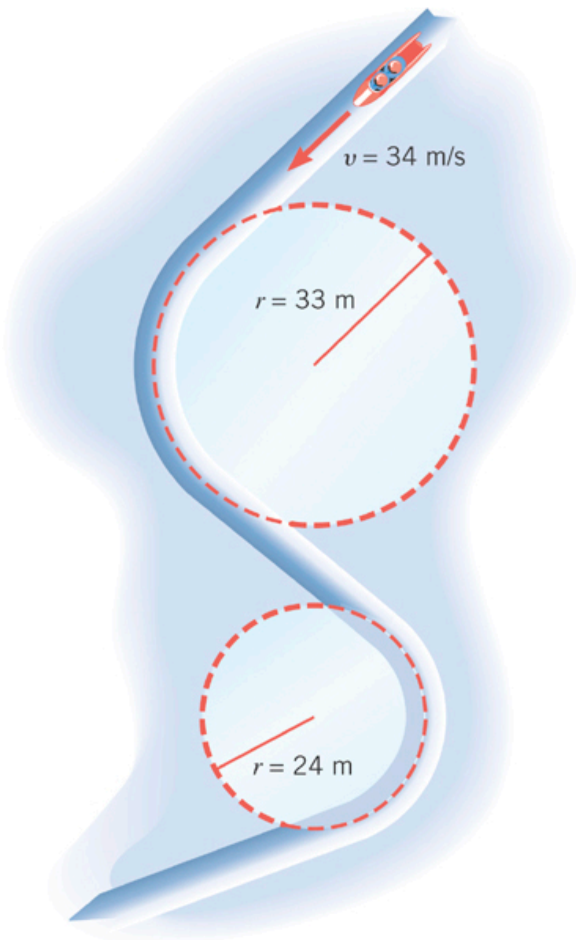
What do you think will happen to the ball if the string that holds the ball breaks?

The external force no longer exist. Therefore, based on Newton's 1st law, the ball will continue its motion without changing its velocity and will fly away following the tangential direction to the circle.

***Mirriam Webster: Proceeding or acting in the direction toward the center or rotational axis**

Ex. Effect of Radius on Centripetal Acceleration

The bobsled track at the 1994 Olympics in Lillehammer, Norway, contained turns with radii of 33m and 23m. Find the centripetal acceleration at each turn for a speed of 34m/s, a speed that was achieved in the two –man event. Express answers as multiples of $g=9.8m/s^2$.



Centripetal acceleration:

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

R=33m

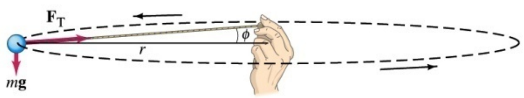
$$a_{r=33m} = \frac{(34)^2}{33} = 35\,m/s^2 = 3.6g$$

R=24m

$$a_{r=24m} = \frac{(34)^2}{24} = 48\,m/s^2 = 4.9g$$

Example of Uniform Circular Motion

A ball of mass 0.500kg is attached to the end of a 1.50m long cord. The ball is moving in a horizontal circle. If the string can withstand maximum tension of 50.0 N, what is the maximum speed the ball can attain before the cord breaks?



Centripetal acceleration:

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

When does the string break?

$$\sum F_r = ma_r = m\frac{v^2}{r} > T$$

when the required centripetal force is greater than the sustainable tension.

$$m\frac{v^2}{r} = T \qquad v = \sqrt{\frac{Tr}{m}} = \sqrt{\frac{50.0 \times 1.5}{0.500}} = 12.2\left(m/s\right)$$

Calculate the tension of the cord when speed of the ball is 5.00m/s.

$$T = m\frac{v^2}{r} = 0.500 \times \frac{\left(5.00\right)^2}{1.5} = 8.33\left(N\right)$$