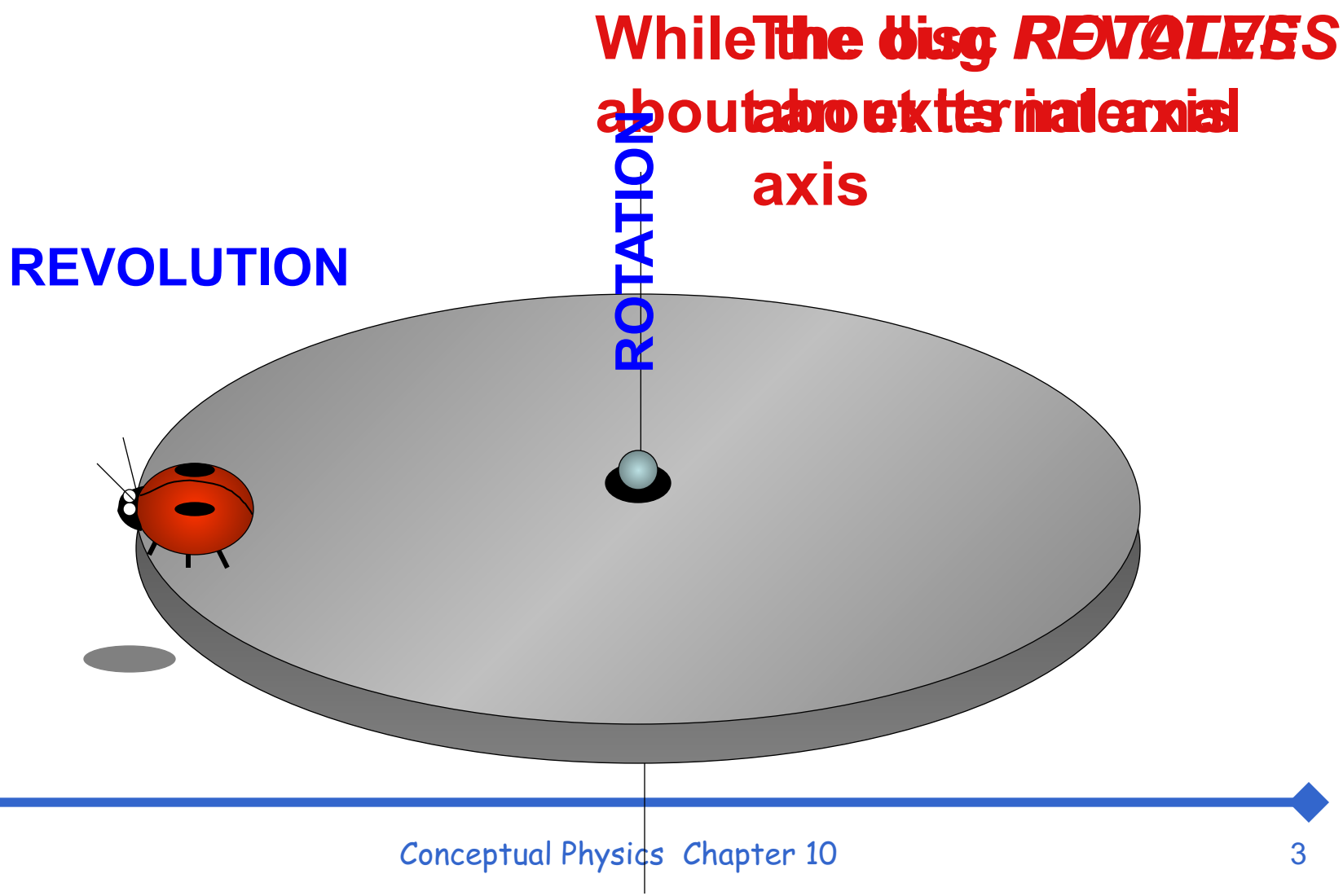
Circular Motion

Rotation and Revolution

- Any object that is turning does so about an imaginary straight line called the *axis*.
- If the axis is located within the turning body (internal), the motion is called a *rotation*.
- If the axis is located outside of the turning body (external), the motion is called a *revolution*.

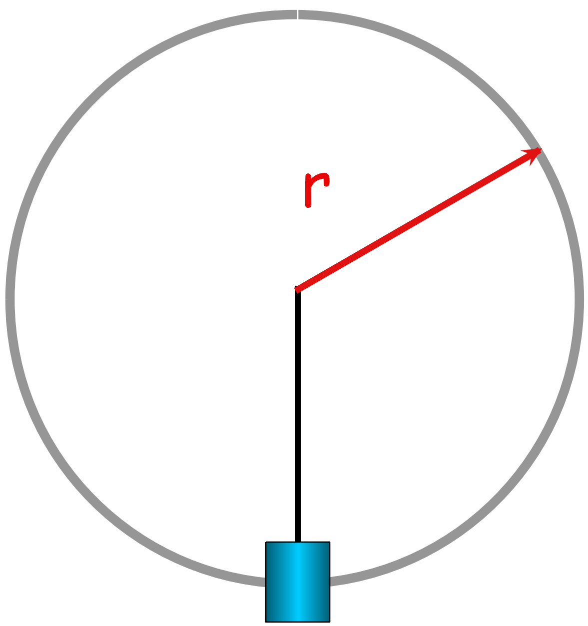
Rotation and Revolution



Tangential Speed

- *Linear speed* is the distance traveled per unit time.

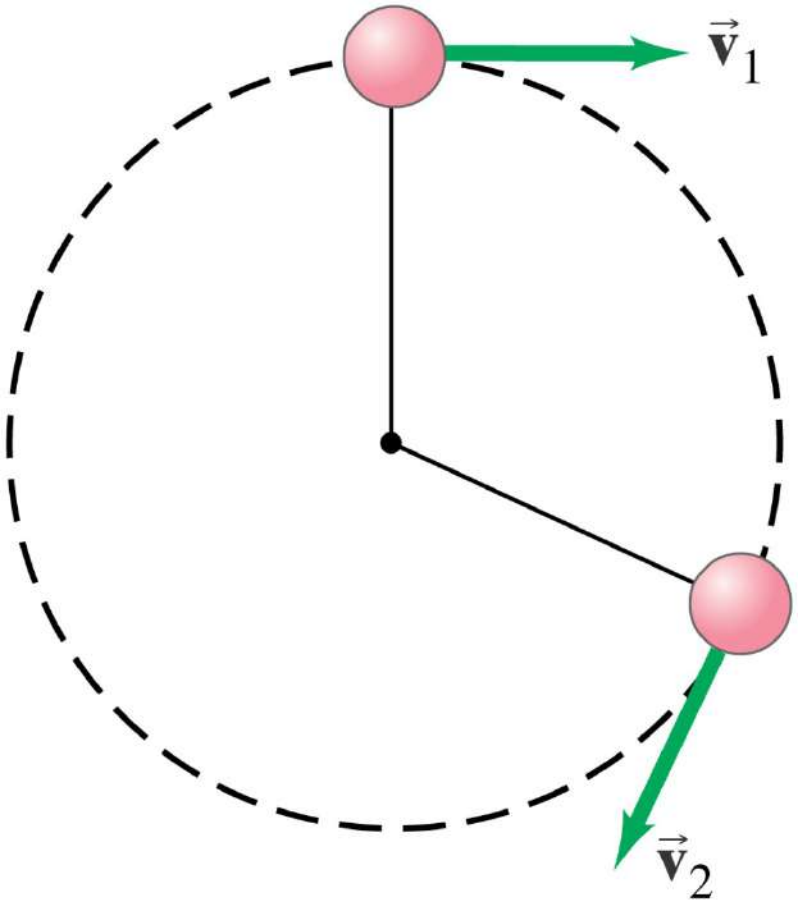
$$s = \frac{d}{t} = \frac{2\pi r}{T}$$



[illegible] ence of [illegible] represented by T.

Tangential Speed

The linear speed of the ball at any given instant is always directed *tangent* to the circular path.



Rotational Speed

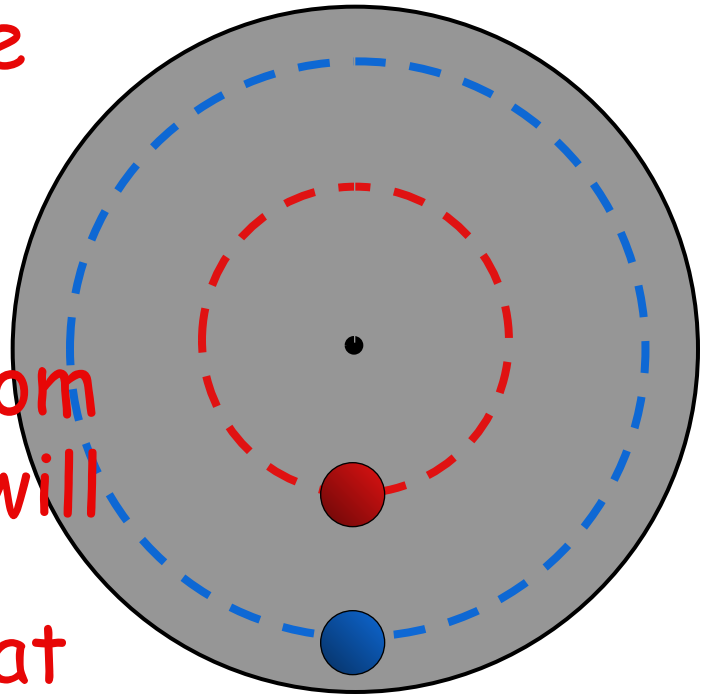
- The *rotational speed* or *angular speed* is the number of rotations per unit time.
- Rotational speed is commonly measured in RPM (rotations/revolutions per minute).
- We use the Greek letter omega (ω) to represent rotational speed.
- Example: ω = 30 RPM

Rotational Speed

Two objects on a rotating platform will have the same rotational speed.

$v = r \cdot w$

The object furthest from the center of rotation will have the greatest tangential speed.

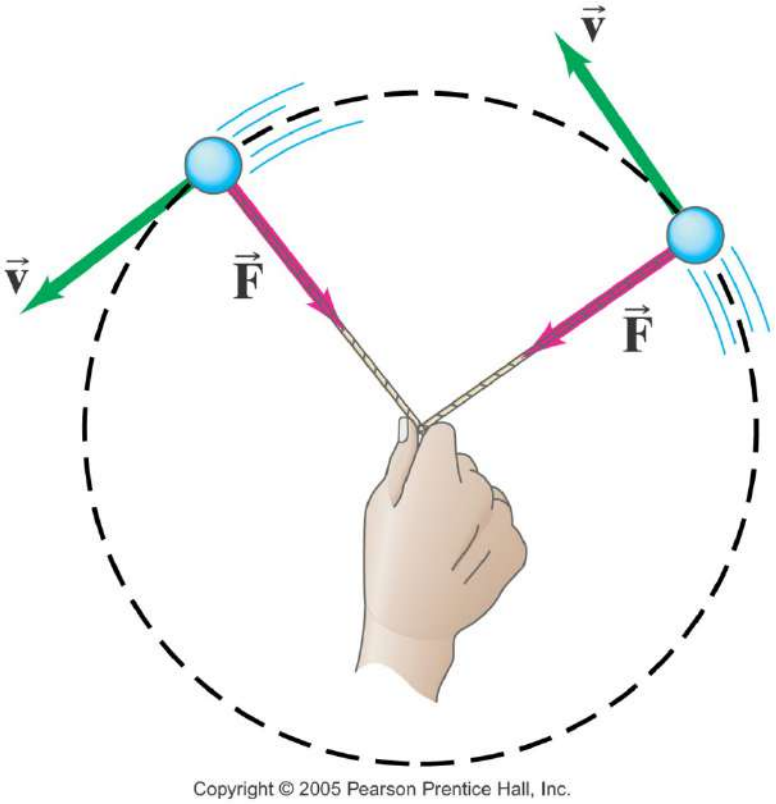


Question

On a merry-go-round, the horses along the outer rail are located three times farther from the axis of rotation than the horses along the inner rail. If a boy sitting on one of the inner horses has a rotational speed of 4 RPM and a tangential speed of 2 m/s, what will be the tangential speed and rotational speed of his sister sitting on one of the outer horses?

Centripetal Force

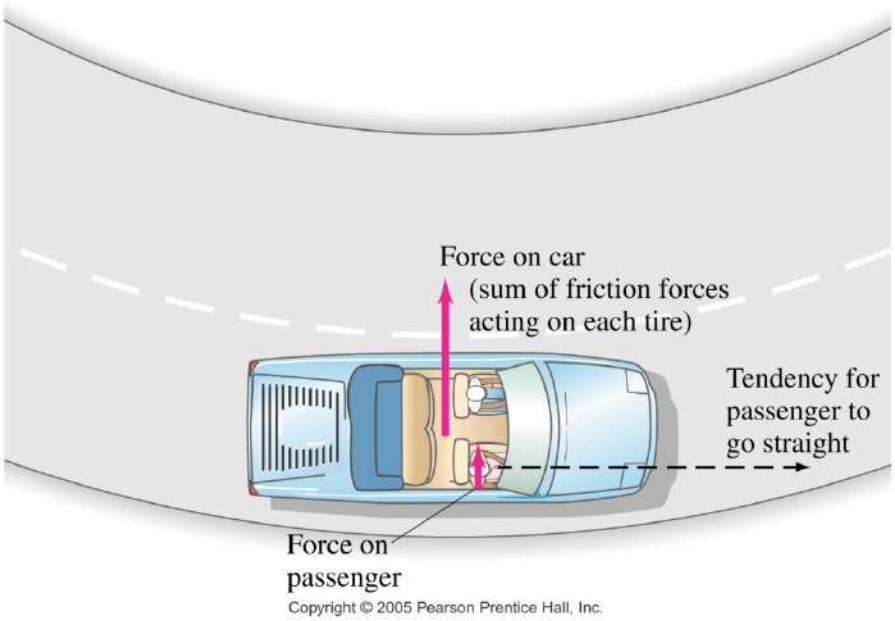
- This is the force that must act on an object to move it in a circular path.
- The direction of the force is toward the center of the circle.
- Without this force, the object would travel in a straight line (tangent to the circle).
- Centripetal means "directed toward the center."



Centripetal Force

- The sideways acting friction between the tires of a car and the road keeps the car moving safely along a circular curve.

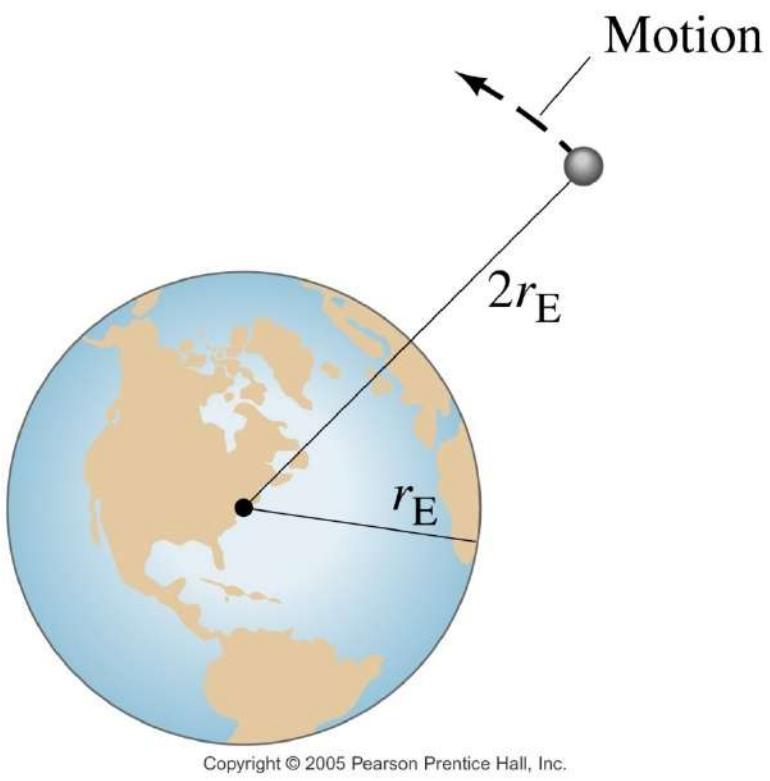
The car door exerts an inward normal force on the passenger in a vehicle that is rounding a left-hand turn.



Centripetal Force

If the road is slick or friction is not great enough, the car will have a tendency to skid off tangent to the curve.

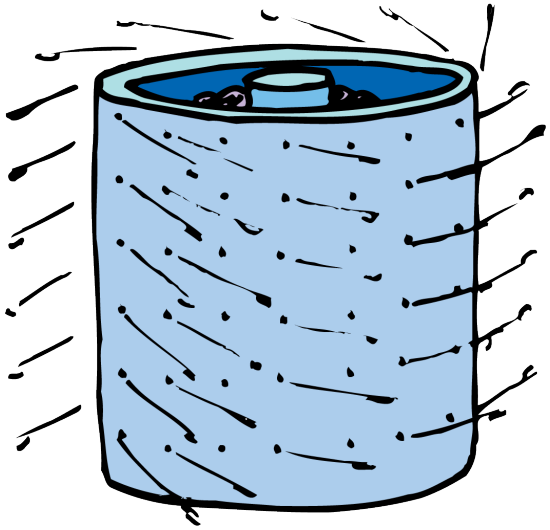
Centripetal Force



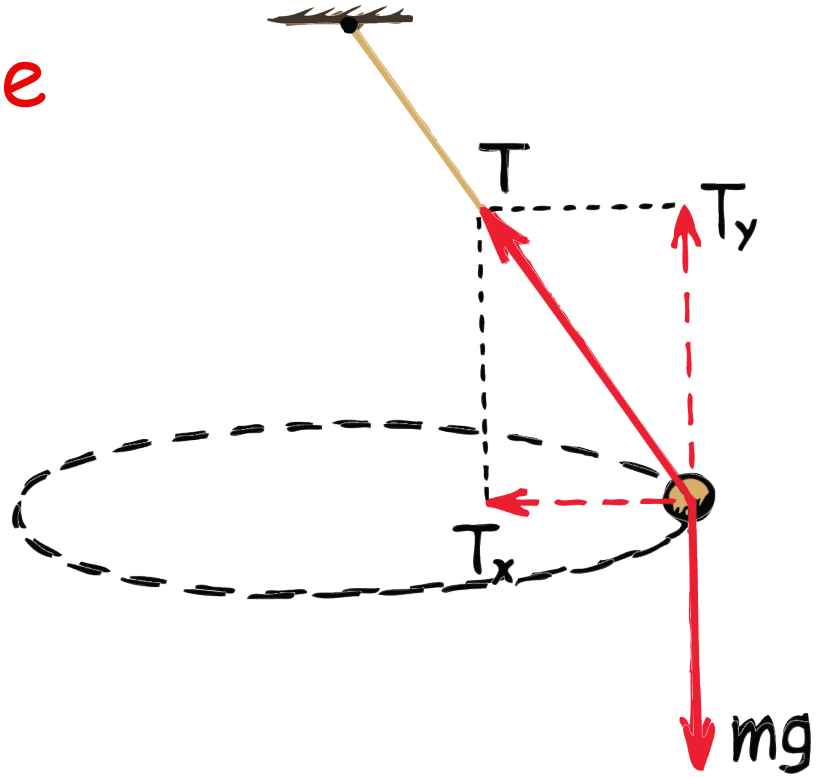
The earth exerts an inward gravitational force on the moon as it travels along its circular orbit about the earth.

Centripetal Force

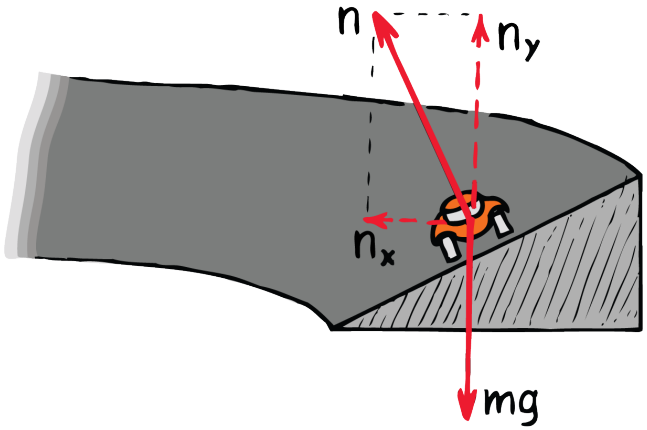
- The spinning drum in a washing machine exerts an inward force on the clothes inside of it.
- The holes in the spinning drum prevent it from exerting an inward force on the water and the water will consequently fly off tangent to the drum wall.



Centripetal Force



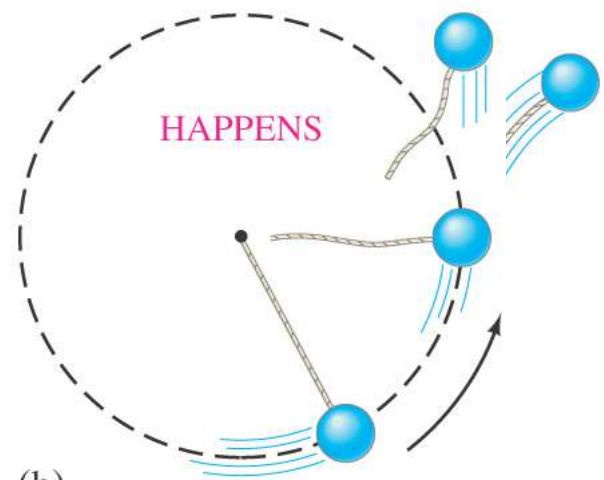
Centripetal Force



Centripetal Force

The centripetal force prevents an object from continuing along a straight line. When the centripetal force vanishes or is reduced, the object will fly off tangent to the circular path.

- There is no centrifugal (outward) force!



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Centripetal Force

- Centripetal force is not a new type of force. It is *any* force that happens to cause an object to move along a circular path. It can be provided by gravity, friction, tension, normal force, electrical force or any combination of these.

Centripetal Acceleration

- Since a body undergoing uniform circular motion maintains a constant speed, we must find the acceleration of this body using

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

This is called the *centripetal acceleration.*

Centripetal Acceleration

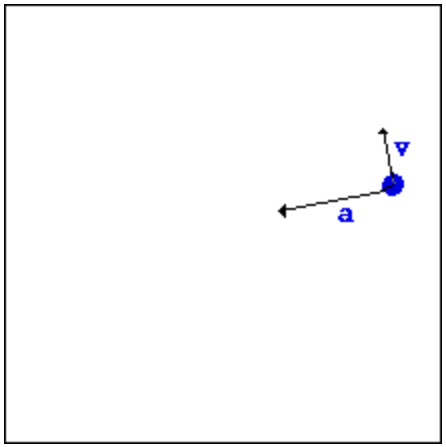
- The centripetal acceleration and the centripetal force are related by Newton's second law:

$$F_c = ma_c$$

Both the force that causes circular motion and the acceleration that results will *always* be directed *inward*.

Centripetal Acceleration

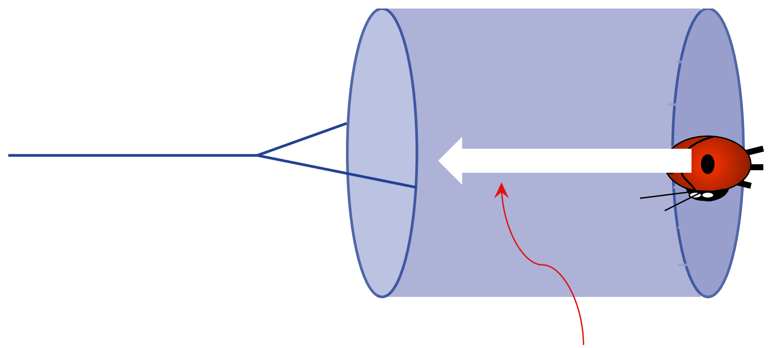
Although the speed of an object undergoing uniform circular motion remains constant, the body accelerates.



The velocity and acceleration vectors are always perpendicular to each other.

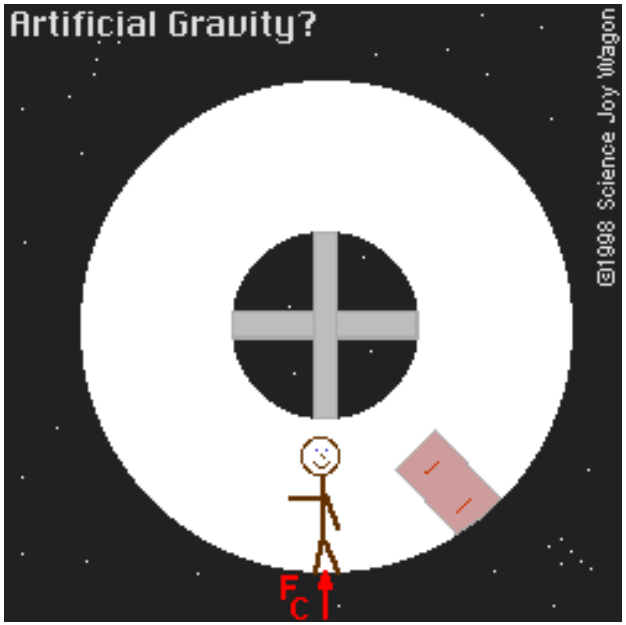
Centripetal Force

[illegible] feet of the ladybug.



Simulated Gravity

Even though a space station may be in free fall, the occupants of the space station feel a simulated gravity from the spinning motion.



At the correct rotational speed this *microgravity* will feel identical to the gravitational pull on earth.

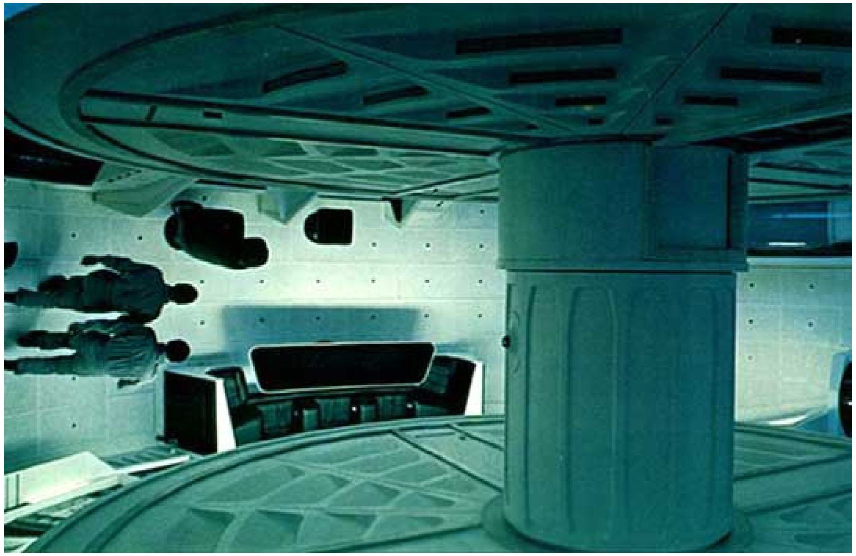
Simulated Gravity

Space stations can either be of a modest radius with a rather large rotational speed or could be larger to allow for a reduced rotational speed.

Simulated Gravity

The effect of the simulated gravity varies directly with the distance from the axis and with the rotational speed of the space station.

To produce a rotational speed that would be acclimated to by most humans, the space station would have to be about 2 km in diameter.



Question

How would one's weight be affected if the earth were to begin spinning faster on its axis?