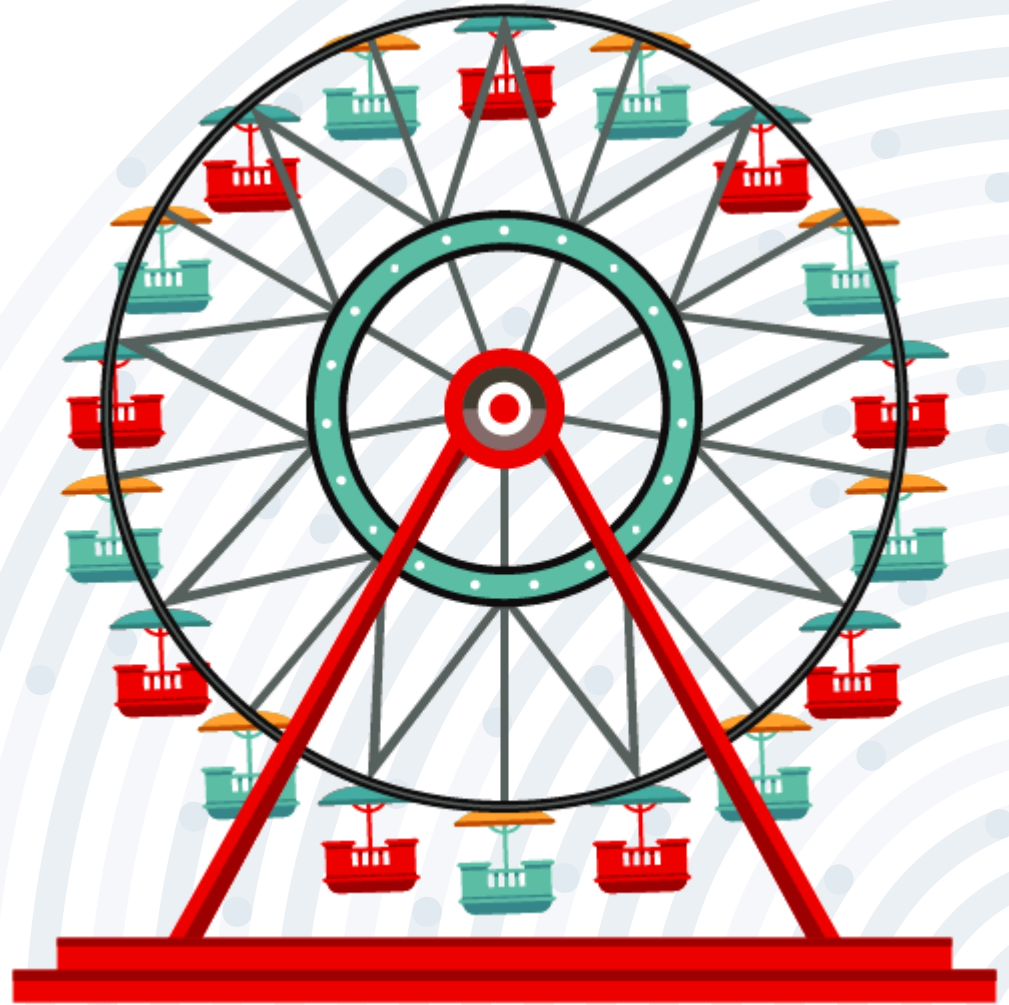


Circular Motion



Uniform circular motion can be described as the motion of an object in a circle at a constant speed. As an object moves in a circle, it is constantly changing its direction. At all instances, the object is moving tangent to the circle.



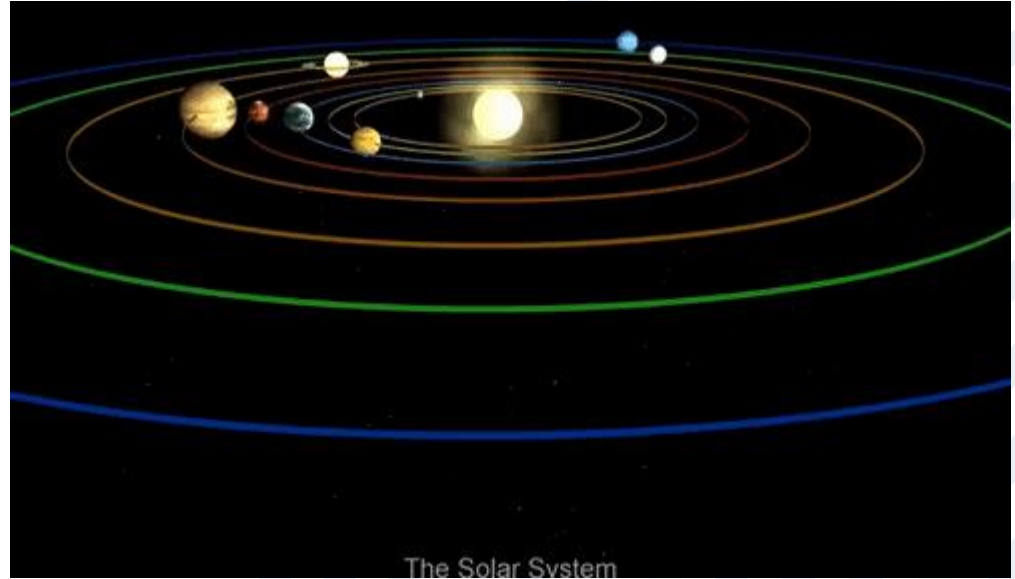
There are two types of circular motion. Both types involve an axis.

Rotation or Spin – an object turns about an **internal** axis. That means the axis of rotation is located within the body of the object in motion.

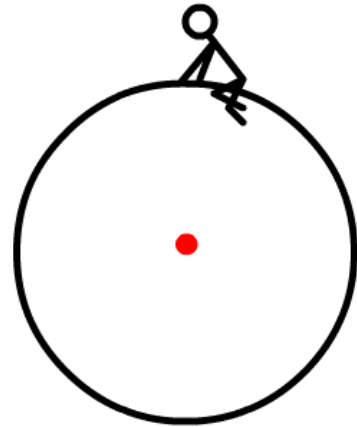
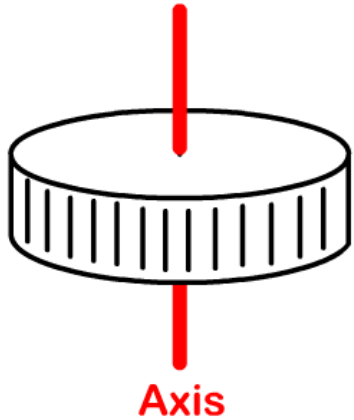


There are two types of circular motion. Both types involve an axis.

Revolution – an object turns about an **external** axis. That means the axis of rotation is located outside and at some distance away from the object in motion.



Rotation



Revolution

The difference between rotation and revolution is the location of the axis of rotation.

The Ferris wheel turns about an axis.

The Ferris wheel rotates, while the riders revolve about its axis.



Question:

Who is moving faster?

Which moves faster on a merry-go-round, a horse near the outside rail or one near the inside rail?



To answer the question, we have to know which “speed” we are talking about.

The horses both have two type of circular motion speed,
tangential or *linear speed*
and
rotational or *angular speed*.



Every part of the record is spinning at the same rate. This is known as **rotational speed or angular speed**, or simply how fast something is spinning.

It is measured in **RPM** or **revolutions per minute**.

Think of it as if how many times something goes around in a given period of time.

Interesting fact:

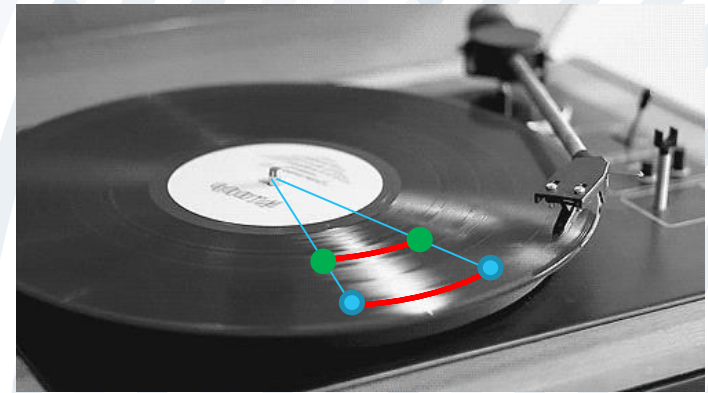
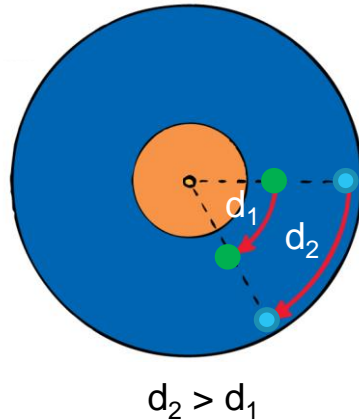
Vinyl is pressed in one of 3 speeds: $33 \frac{1}{3}$ Rotations Per Minute (RPM), 45 RPM, and 78 RPMs. The majority of 12-inch long play (LPs) are $33 \frac{1}{3}$ RPMs, and most 7-inch extended play (EPs) or singles are 45 RPMs.



The other type of speed is called **tangential** or **linear speed**. This is a measure of distance traveled per unit of time, m/s.

This is a measure of how fast an object is moving with respect to distance and time.

In our example below, the blue dot traveled a greater distance than the green dot in the same amount of time. That means the blue dot is faster.



Question:

Who is moving faster?

Which moves faster on a merry-go-round, a horse near the outside rail or one near the inside rail?

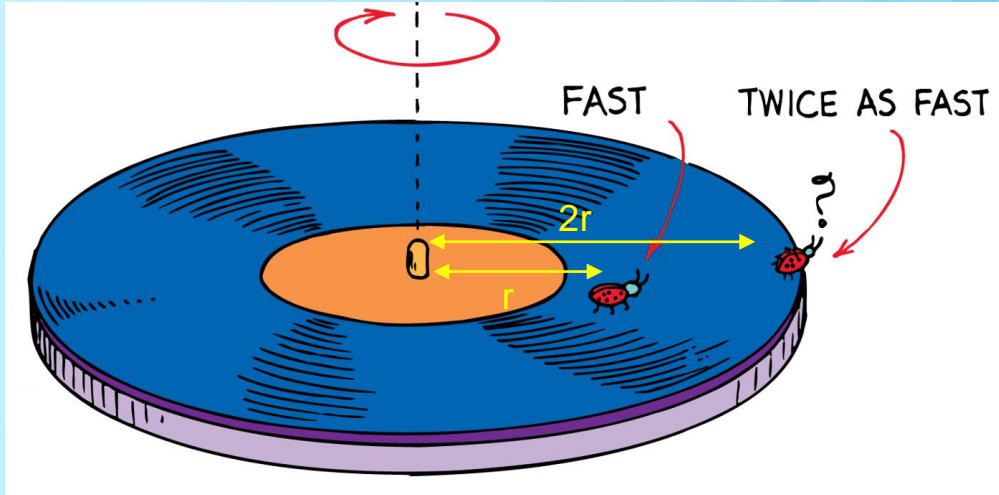
The outside rail horses are faster.



The relationship between tangential speed and rotational speed.

Tangential speed = radial distance x rotational speed

$$v = r\omega$$



Warning:

Do not do this at home or any where.

Where should you sit to reduce the effect of being flung outward?



Minimum linear speed

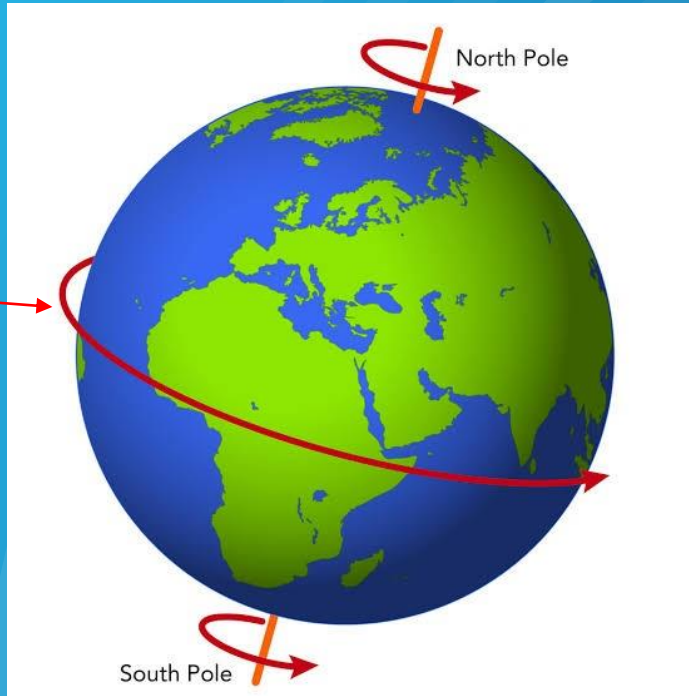
Maximum linear speed

The further from the center, the greater the linear speed (tangential).



Zero linear speed

Maximum linear speed



Rotational speed is the same everywhere.

Cause of circular motion:

The cause of any motion is a force, but for circular motion, it's a special force. The name for a force that keeps an object moving in a circular motion is called **Centripetal** (center seeking) force.

The centripetal force on an object depends on the object's tangential speed, its mass, and the radius of its circular path.

High speed barrel roll demonstrating centripetal force



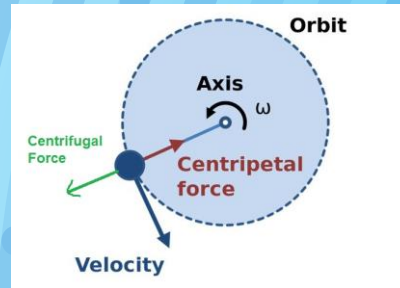
Newton's First Law of Motion:

Object in motion tends to travel in a straight line path unless acted on by an outside force.

In order to make something change its inertia, a force is needed.

To make an object move in a circular path, the force must be directed to the center of the circle.

The force in this case is the tension on the string being pulled inward by the person.

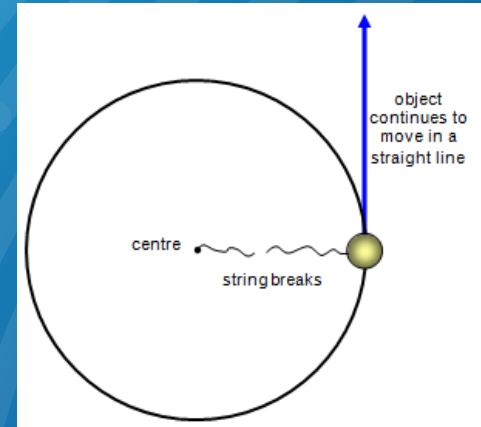


What would happen if the string broke?

Because of the object's inertia, the ball would fly off in a straight line path.



The blue path is also known as the **tangent** line of the circle, and that's why the speed in that direction is called the **tangential speed**.

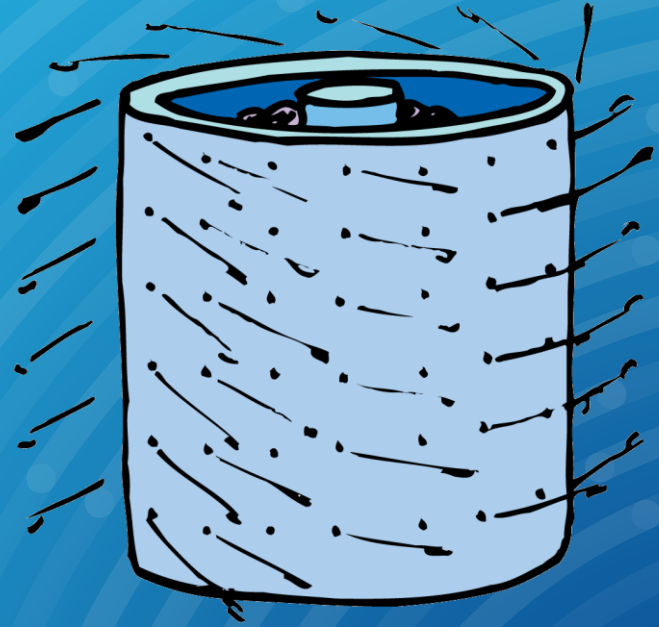


Application of circular motion.

A **centrifuge** is **used** to separate particles suspended in a liquid according to particle size and density, viscosity of the medium, and rotor speed. Within a solution, gravitational force will cause particles of higher density than the solvent to sink, and those less dense than the solvent to float to the top.



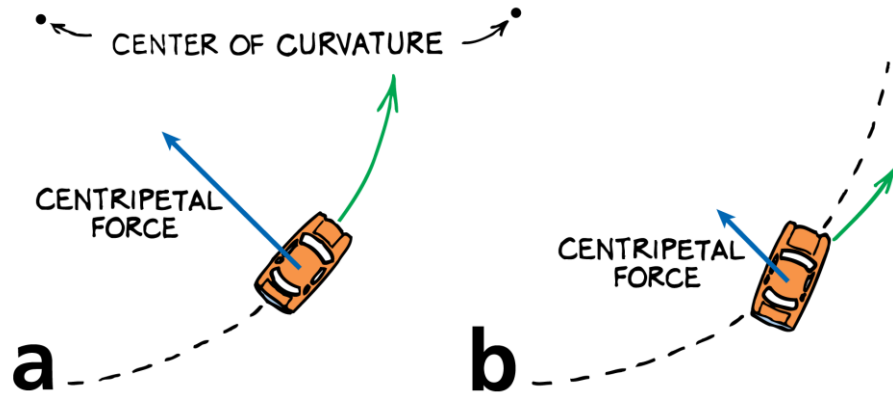
Application of circular motion.



During the rinse cycle of a washing machine, the water is separated from the clothes by spinning the drum really fast and the clothes are forced to move in a circular path while the water is allowed to go in a straight line path through the holes in the drum.

The centripetal force may come in different form.
As in the example of the tether ball and the hammer
throw, it is the tension on the string or chain.

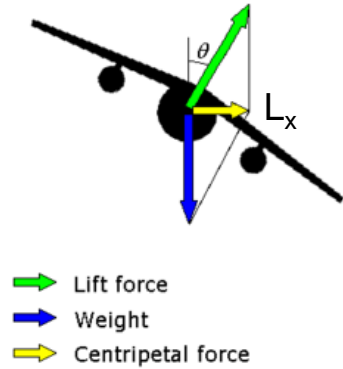
For a car turning, it would be the friction force
between the tires and the road.



- The right amount of friction for the car to follow the curve.
- Not enough friction to hold the curve, and the car skidded off the road.

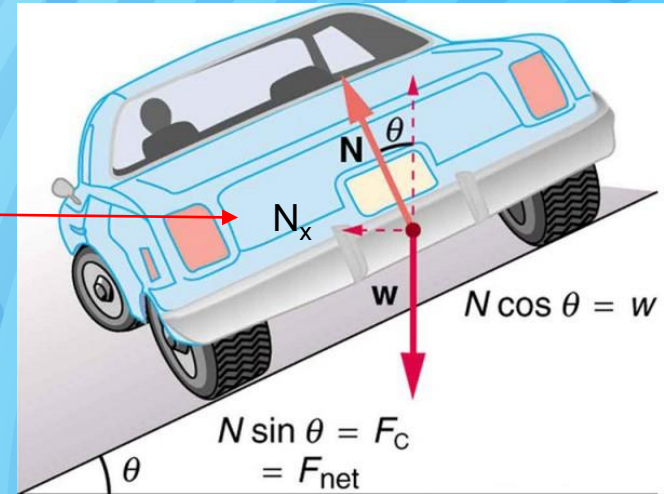


For an airplane banking in the air, it is the horizontal component of the lift force of the airplane.



Using the concept of centripetal force and applying it to car traveling on the road is extremely important.

The angle of the bank help protect cars from sliding off the road. Because of the angle, the normal force of the car is no longer vertical and the horizontal component of it acts as the centripetal force pushing the car inward and helping it turn.





Daytona track has a 31° angle and a possible speed of 170 mph around the turn.

The banking of the road allows drivers to take a curve at higher speed.

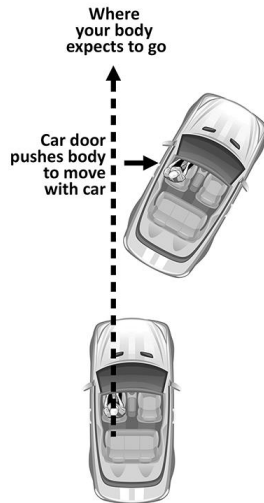


Centripetal vs Centrifugal Force

Centripetal force is a real force that pushes an object towards a center of rotation.

Centrifugal force (center fleeing) is a fictitious feeling of being push outward in circular motion. It is an effect of rotation. It is not part of an interaction and therefore it cannot be a true force. This is caused by the inertia of the object or its nature to move is a straight line path.

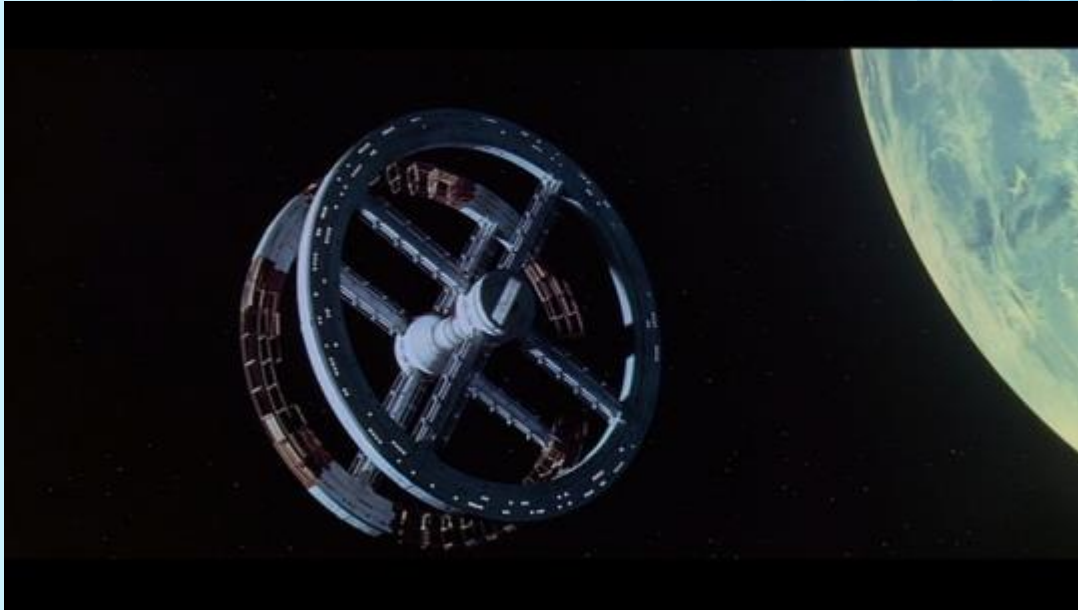
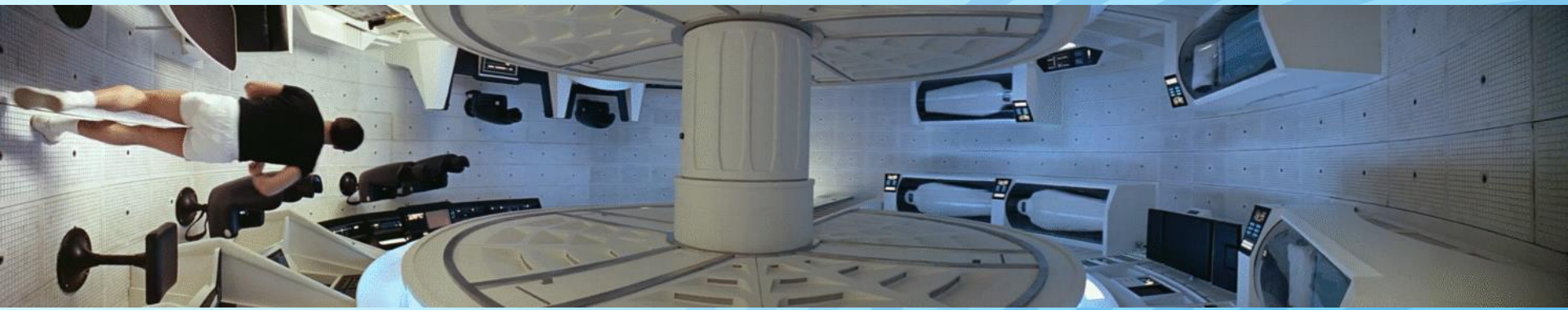
Without the door and seatbelt, you would still go forward as the car turns away from you.



When you are sitting in a car and it turns, you feel like flying out of the car.

As the merry-go-round moves faster, the person's linear velocity increases to the point centripetal force is greater than the person's ability to hold on and the person's inertia took over.





Using the concept of inertia and circular motion, we can create an artificial gravity on a space station.

Based on the same concept as the door of a turning car pushes on you to keep you going in a circle inside the car, the side wall of the spinning station pushes on you. Your reaction to being pushed translate into artificial gravity as your feet pushes back on the walls.

A Space Odyssey 2001



From the movie, *Passengers*, the spacecraft spins to create the gravity on the ship.

Summary Questions:

1. What is circular motion?
2. Explain the difference between rotation and revolution as it relates to circular motion.
3. Explain the difference between linear speed and rotational speed.
4. Where on a merry-go-round is the linear speed zero?
5. What is centripetal force?
6. What is centrifugal force?
7. How can we artificial gravity?