Today's Objectives
Rotational Motion

After today, you should be able to:

- Recognize uniform circular motion
- Identify force that causes curved motion
- Determine both tangential and centripetal acceleration
- Relate to gravity (if time)

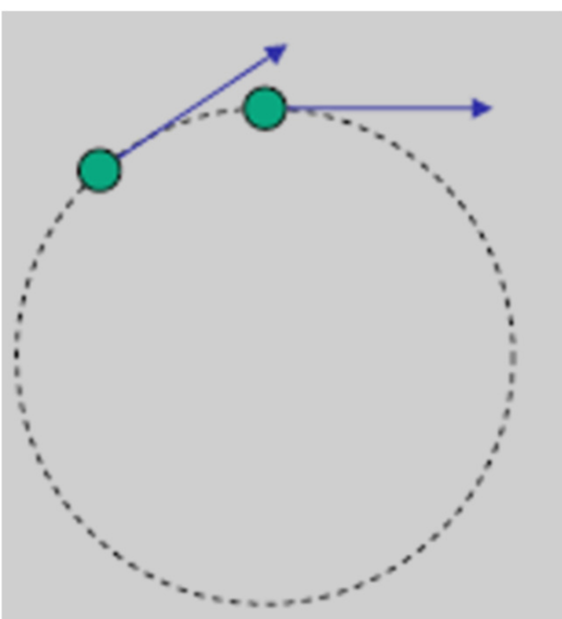
Practice: 7.15, 7.17, 7.21, 7.23, 7.25, 7.29, 7.31

What is Uniform Circular Motion?

Uniform circular motion is when an object moves in a circle at a constant speed.

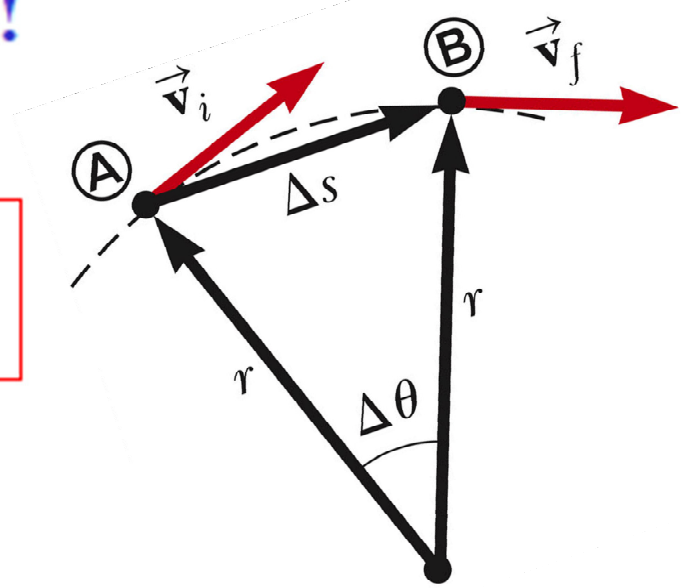
- For Uniform Circular Motion, speed is constant .. not velocity!

- Since the direction is changing, so is the velocity ..



There is acceleration!

Different Directions = Different Velocities!



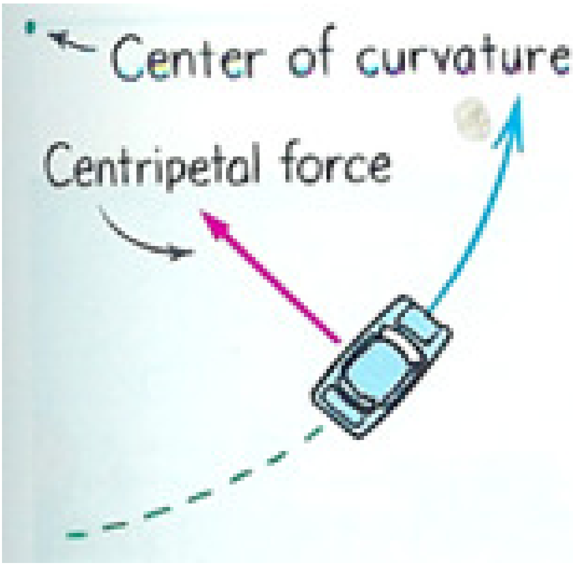
Centripetal Force

Newton's 1st Law: An object in motion will stay in motion with constant speed and direction unless acted on by an external force.

A **centripetal force** is the force that makes an object move in a curved path.

The can moves in a circle because of the tension in the rope

The force exerted radially inward by friction on the tires makes the car move in a circle.

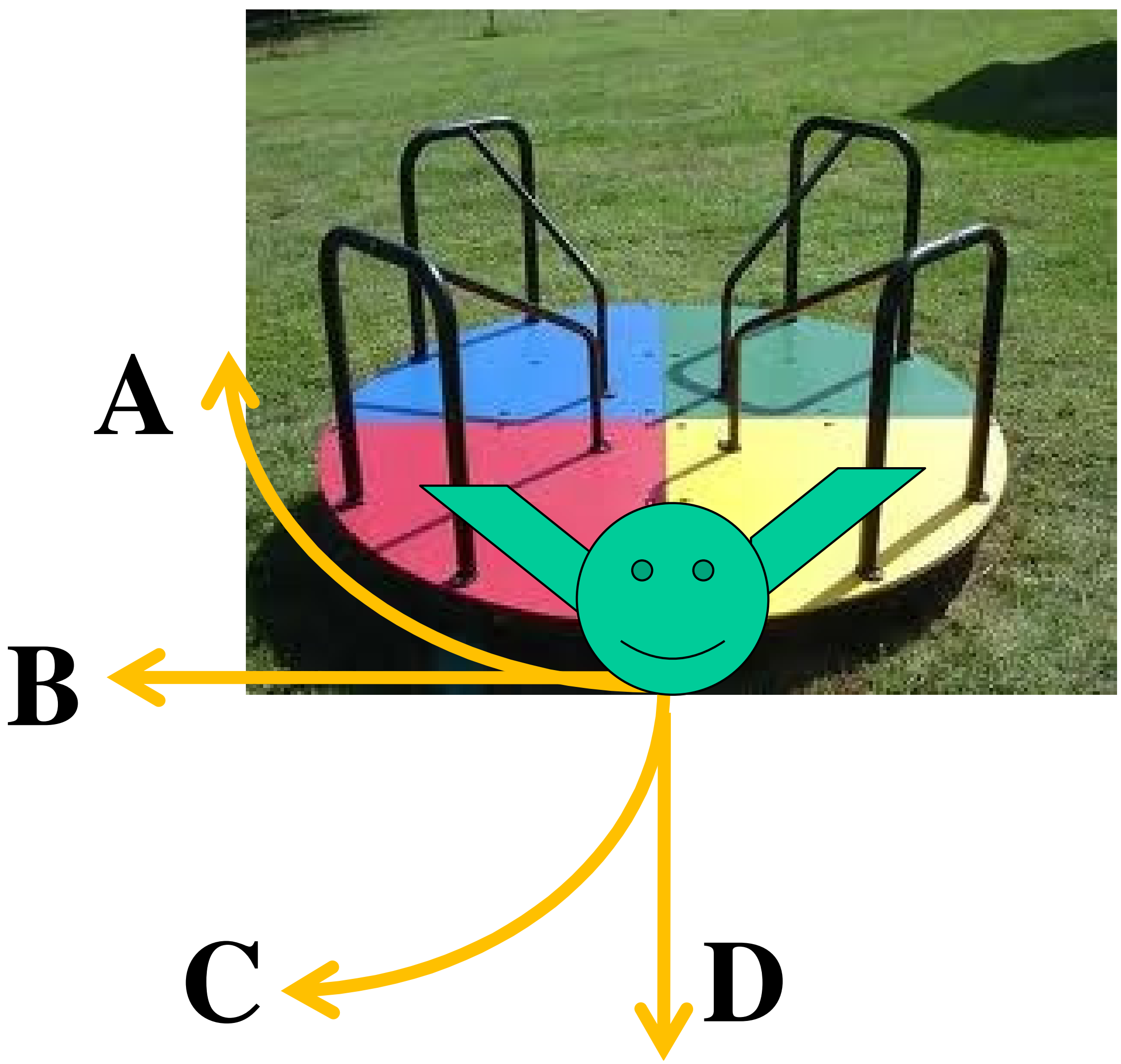


Contrast with Centrifugal Force (A Fictitious Force)

Centrifugal: The faster you go, it feels like there is an increasing force pushing you away from the center of the merry-go-round.

Centripetal: In reality, your body is trying to follow Newton's first law, but the merry-go-round is applying a force to go in a circle.

The merry go round is turning **clockwise** as viewed from the top, as shown. If you are standing on the bottom edge (boundary between red and yellow), what direction would you go if you let go?



Q93

Fictitious Forces
(Centrifugal Force)

According to Newton's 1st Law, your body wants to continue to move in a straight line of constant velocity and if you don't hold on or hold yourself against a bar (adding a centripetal force), you will move in a straight line off the merry-go-round.

Circular Motion in Merry Go Rounds

- Don’t believe me?
- What’s going on here?

Newton's Laws Appear Like They Don't Work From An Accelerating Reference Frame

(with respect to the ground, they do)

Boy and girl are in a noninertial (accelerating) reference frame so Newton's laws don't apply

Centripetal vs Tangential Forces

The Net Force (and therefore acceleration) can always be broken into two parts: $(\Sigma F = ma)$

1. **Centripetal** -- perpendicular to the direction of motion. Forces perpendicular to the velocity only change the direction of motion, not the speed!

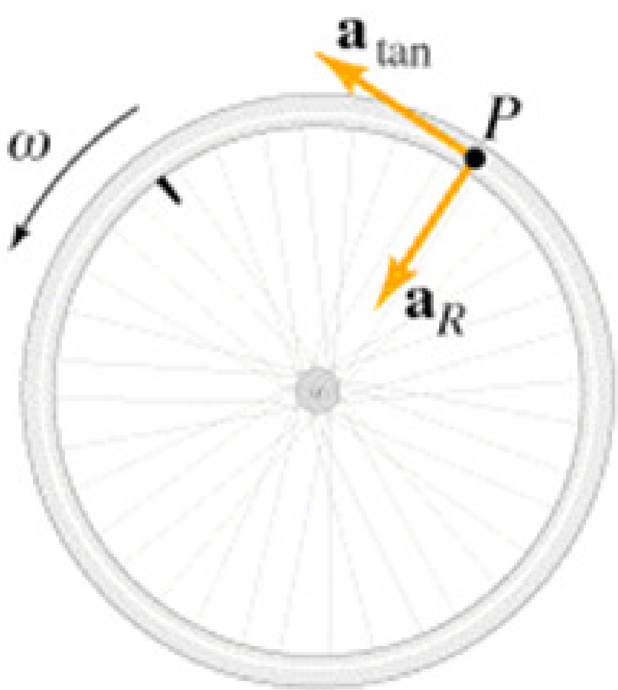
2. **Tangential** -- parallel to the direction of motion. Forces parallel to the motion only change the speed -- not the direction!

$$\vec{a} = \vec{a}_{\tan} + \vec{a}_R$$

Relations Between Angular and Linear Quantities

- Anything rotating has a centripetal acceleration
- If the angular velocity ω is increasing or decreasing, there is a tangential acceleration in addition to the centripetal acceleration

$$v = r\omega$$



$$a_{tan} = \frac{\Delta v}{\Delta t} = \frac{\Delta(r\omega)}{\Delta t} = \frac{r\Delta\omega}{\Delta t}$$

$$a_{tan} = r\alpha$$

$$a_R = \frac{v^2}{r} = \frac{(\omega r)^2}{r}$$

$$a_R = \omega^2 r$$

Note that **net** acceleration is $\vec{a} = \vec{a}_{tan} + \vec{a}_R$

What is the acceleration of a person at the equator of Earth due to Earth's rotation about its axis?

(Radius at equator is 6400 km)

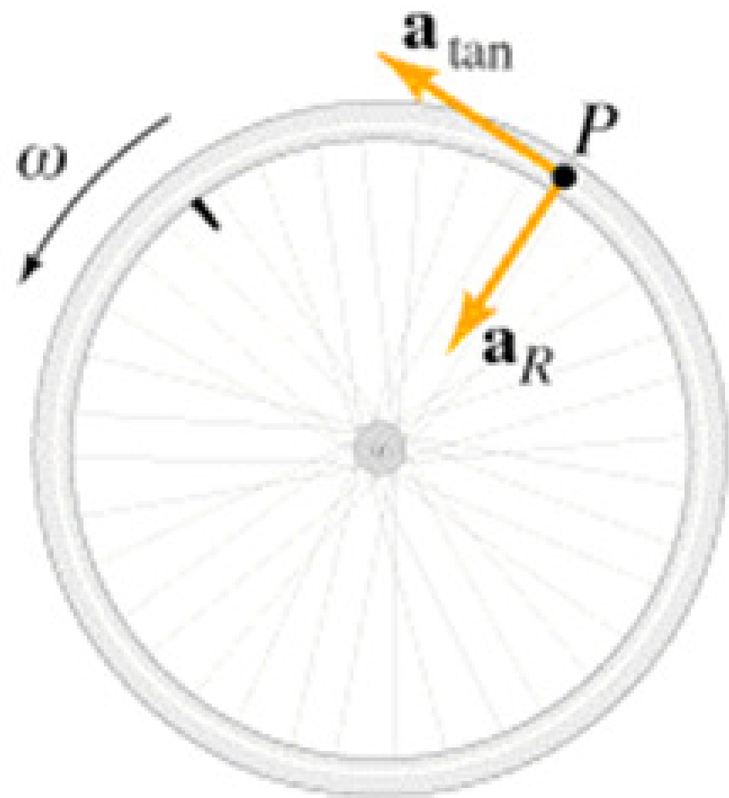
What kind of acceleration is it?

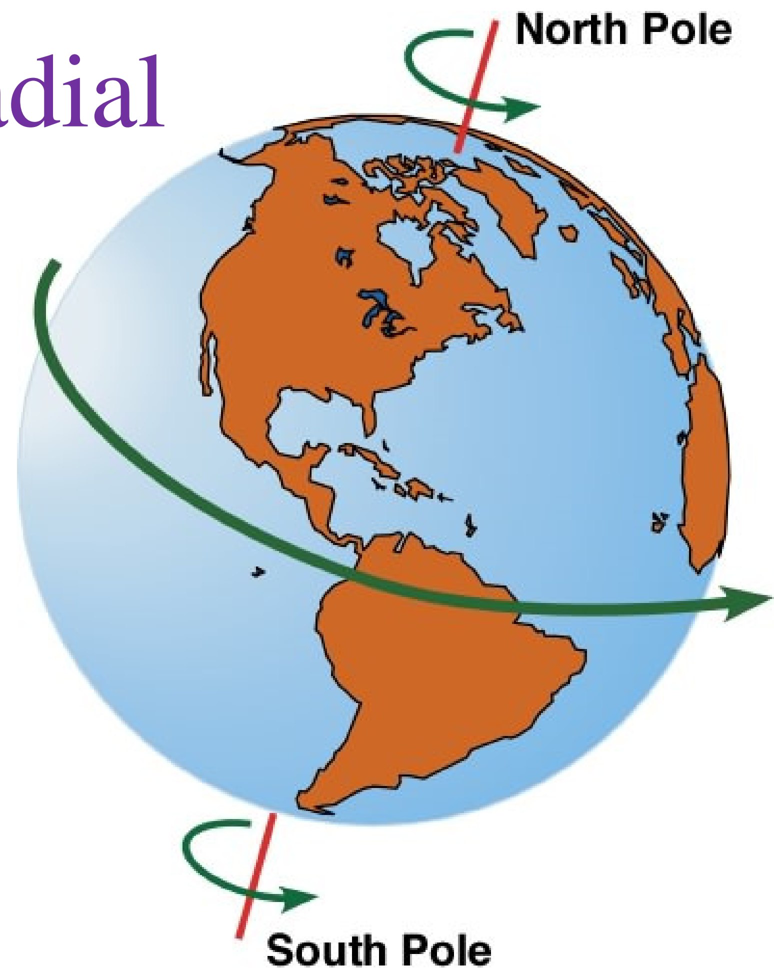
A. Tangential/Angular

B. Centripetal/Radial

C. Neither

D. Both





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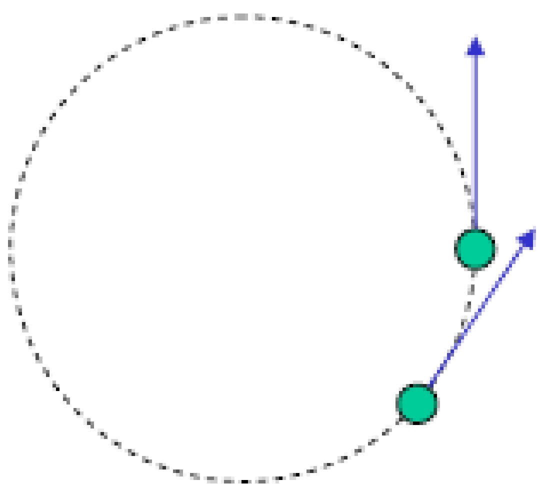
Uniform Circular Motion

Uniform circular motion is when an object moves in a circle at a constant speed.

The Earth is not speeding up, so the tangential acceleration $a_{tan}=0=r\alpha$

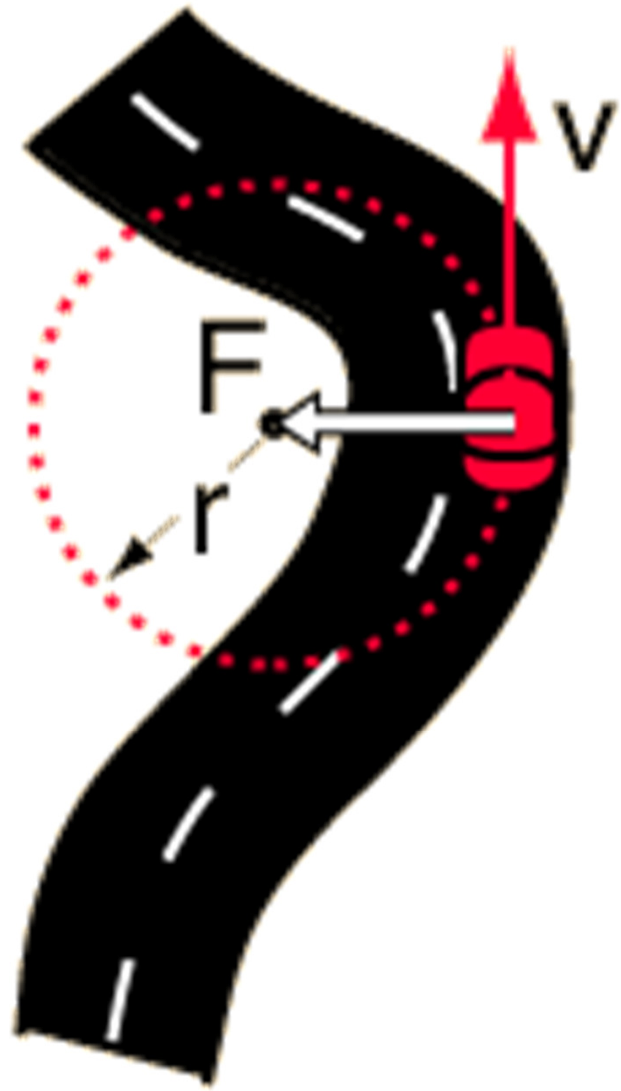
The radial acceleration $a_{radial}=v^2/R$



Car Going Around a Curve

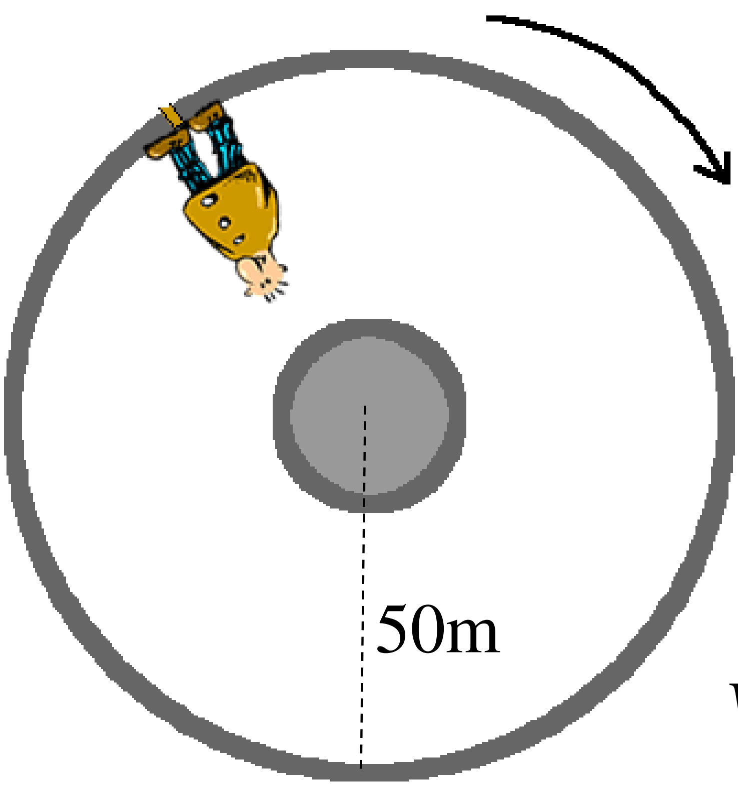
$$F_{centripetal} = m\frac{v^2}{r}$$

$\frac{v^2}{r}$ is the centripetal acceleration



Problem similar to homework: Artificial gravity

Astronauts spending lengthy periods of time in space experience negative effects due to weightlessness, such as weakening of muscle tissue. In order to simulate gravity, how many revolutions per minute would be required to create a normal force equal in magnitude to the astronaut's weight?



Goal: $\Sigma F_{radial} = ma_c = N = mg$

$ma_c = \mathrm{m}v^2/\mathrm{r} = mr\omega^2 = mg$ **or** $\omega^2 = g/r$

$$\omega = sqrt(9.8m/s^2 / 50m)$$
$$= 0.44\ rad/s\ (1rev/2\pi\ rad)$$
$$(60s/1min)$$
$$= 4.23\ rev/min$$
$$V = sqrt(9.8m/s^2 * 50m) = 22m/s(50mph)$$

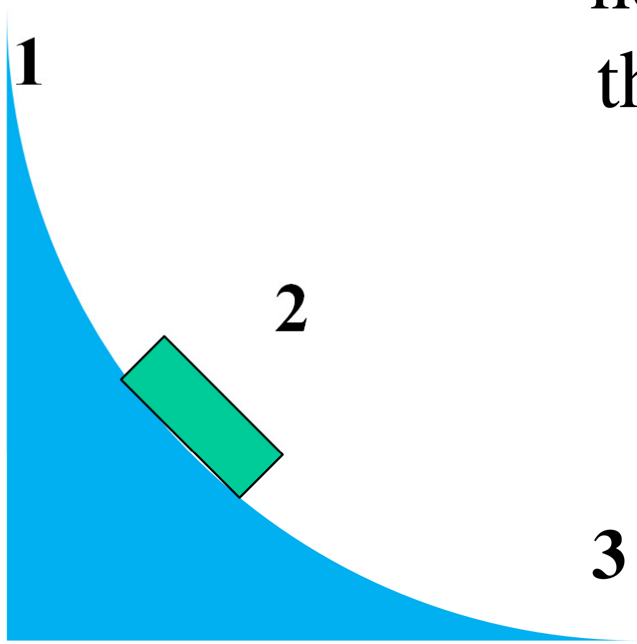
Same Idea for a Centrifuge

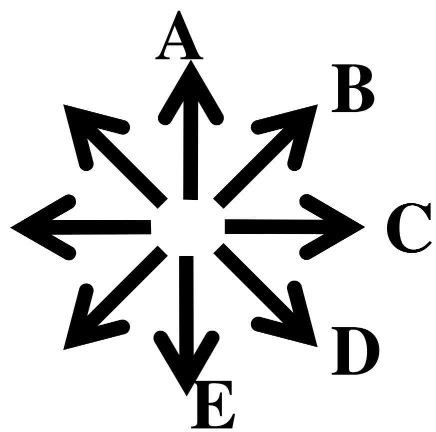
A sample of blood is placed in a centrifuge of radius 16.0 cm. The mass of a red blood cell is $3.0\ 10^{-16}$ kg, and the magnitude of the force acting on it as it settles out of the plasma is $4.0\ 10^{-11}$ N. At how many revolutions per second should the centrifuge be operated?

Physics of the Halfpipe

A snowboarder slides from rest at position 1 and goes down a halfpipe.

When the snowboarder reaches position 2, which of the arrows most nearly corresponds to the direction of the **normal force** on the snowboard?



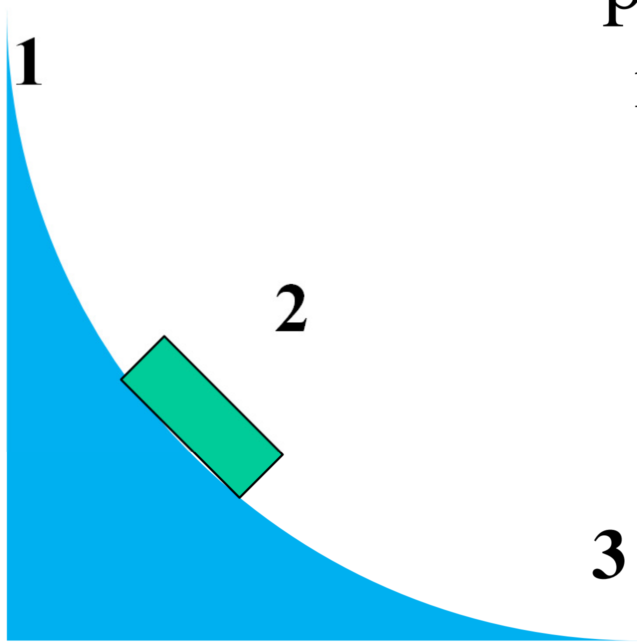


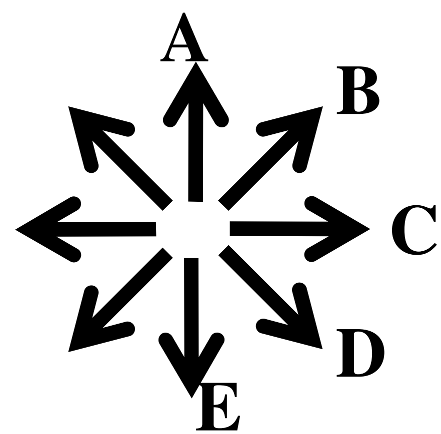
Q95

Physics of the Halfpipe

A snowboarder slides from rest at position 1 and goes down a halfpipe under the influence of gravity.

When the snowboarder reaches position 2, which of the arrows most nearly corresponds to the direction of the board's **net acceleration**?





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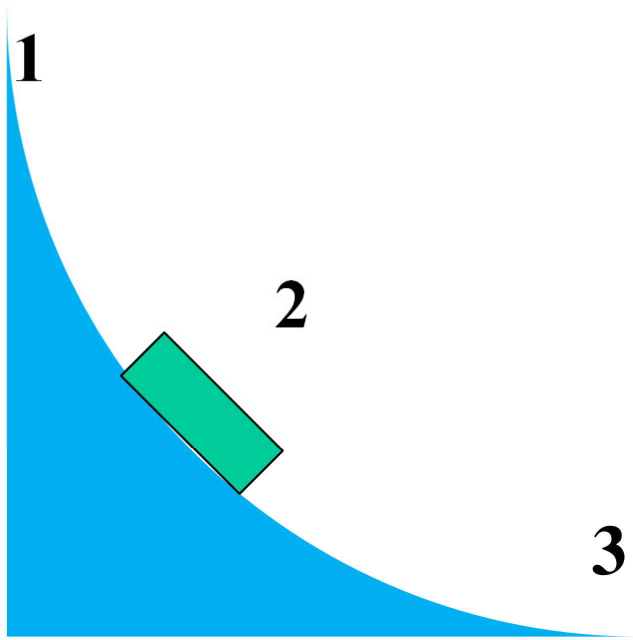
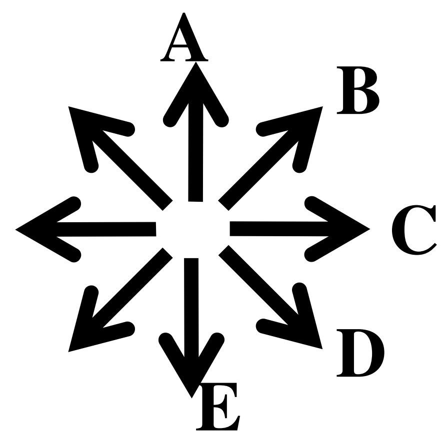
Physics of the Halfpipe

Let’s now consider just a snowboard sliding down the halfpipe.

When the wheel reaches position 2, which of the arrows most nearly corresponds to the direction of the **net forces** on the board?





Q97

Why does the Moon Orbit the Earth?

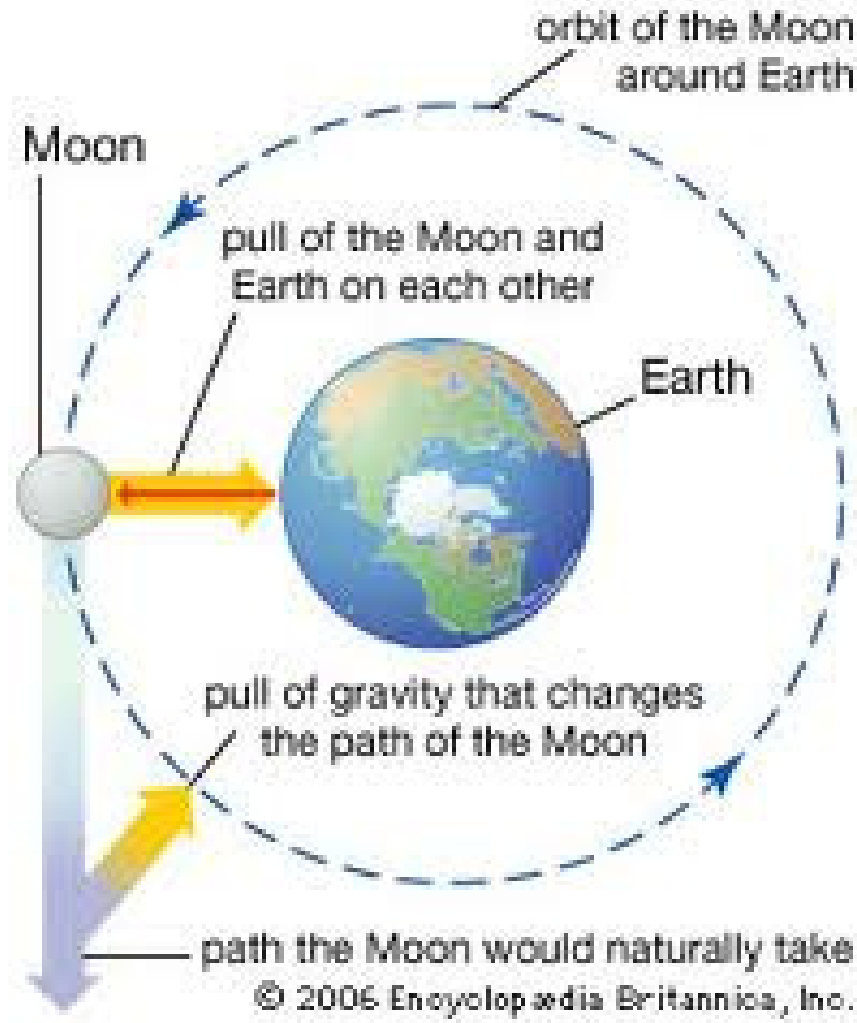
All objects that have mass attract each other

Magnitude of gravitational attractive force between two objects is related to the masses and distance between them.

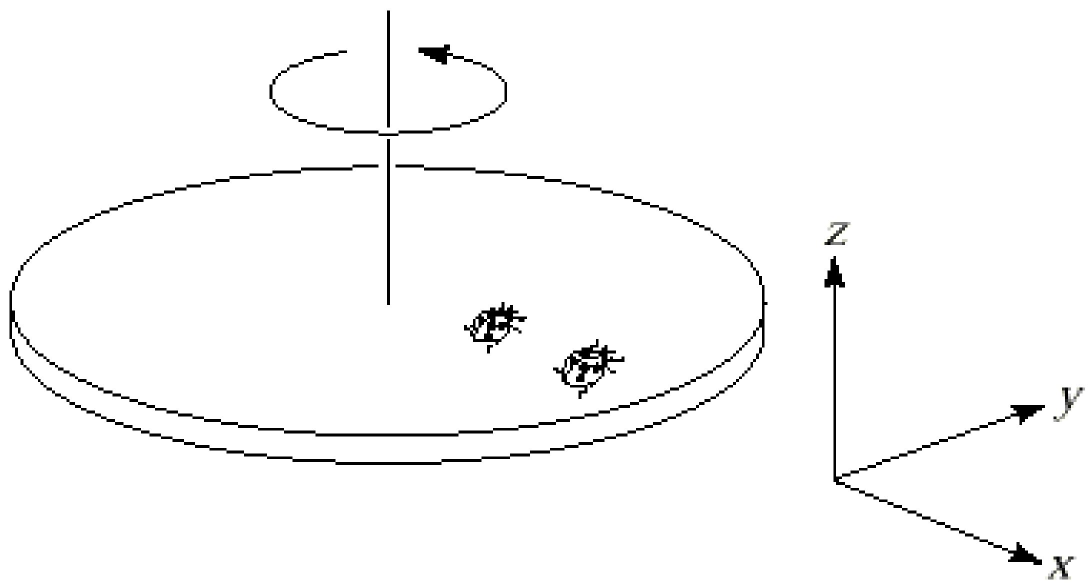
$$F_G = G\frac{m_1 m_2}{r^2}$$

r = distance between centers of two objects

$G = 6.67 \times 10^{-11}$ N m^2 / kg^2 (Gravitational Constant)



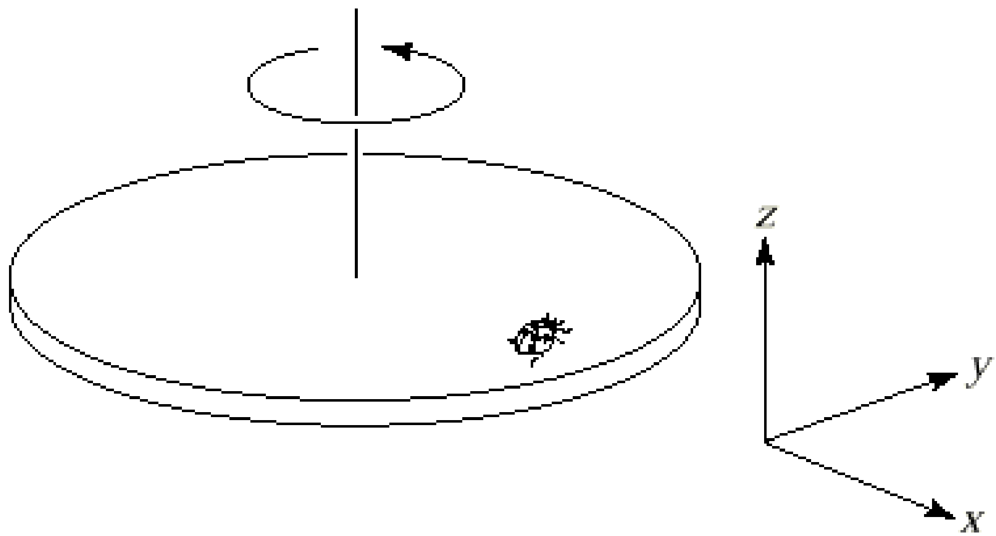
A ladybug sits at the outer edge of a merry-go-round, and a gentleman bug sits halfway between her and the axis of rotation. The merry-go-round makes a complete revolution once each second. The gentleman bug's angular speed is



1. half the ladybug's.
2. the same as the ladybug's.
3. twice the ladybug's.
4. impossible to determine

Q98

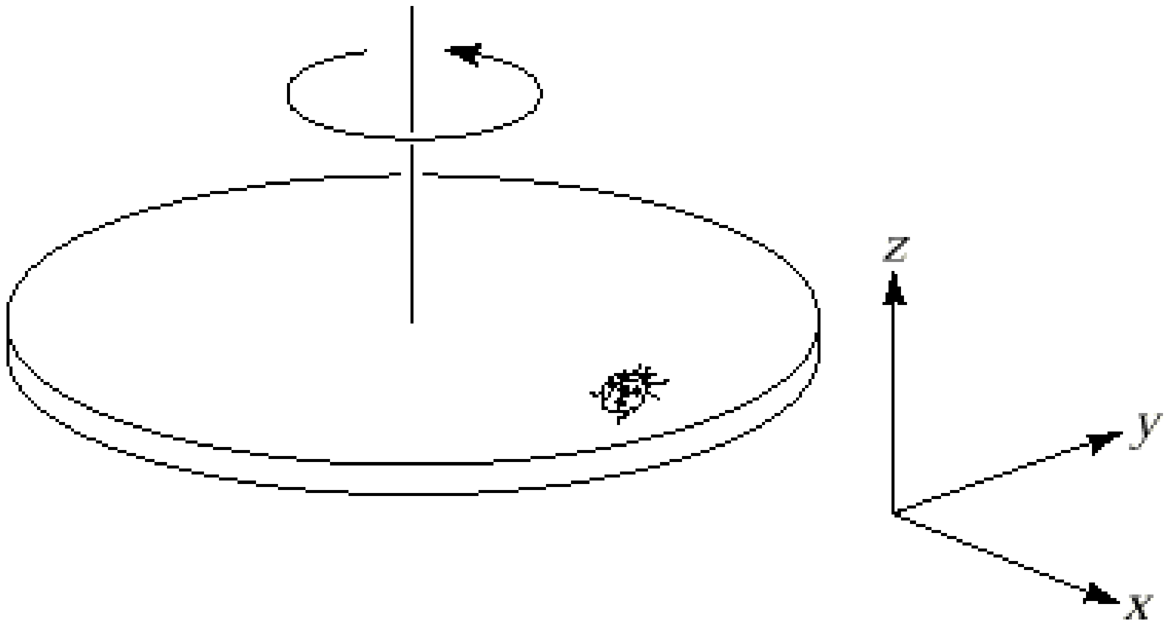
A ladybug sits at the outer edge of a merry-go-round, that is turning and slowing down. At the instant shown in the figure, the radial component of the ladybug's (Cartesian) acceleration is



1. in the $+x$ direction.
2. in the $-x$ direction.
3. in the $+y$ direction.
4. in the $-y$ direction.
5. in the $+z$ direction.
6. in the $-z$ direction.
7. zero.

Q99

A ladybug sits at the outer edge of a merry-go-round that is turning and slowing down. The tangential component of the ladybug's (Cartesian) acceleration is



A. in the $+x$ direction.

B. in the $-x$ direction.

C. in the $+y$ direction.

D. in the $-y$ direction.

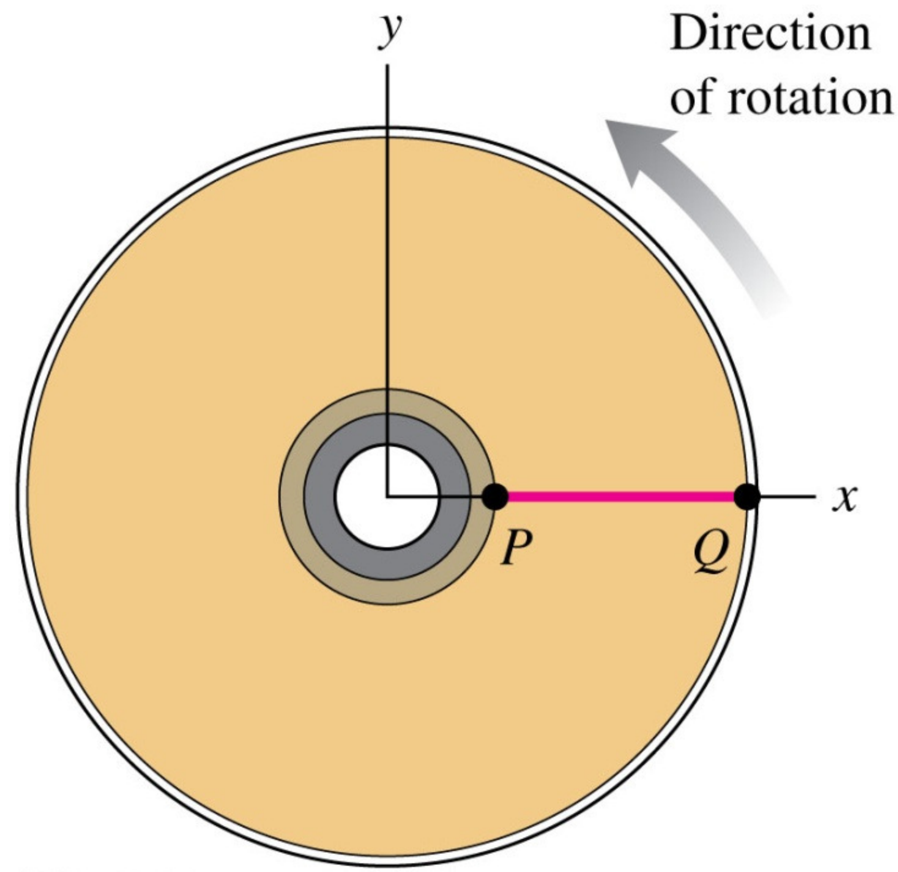
E. in the $+z$ direction.

Q100

Good Summary

- http://www.youtube.com/watch?v=-G7tjiMNVlc

A DVD is rotating with an ever-increasing speed. How does the centripetal acceleration a_{rad} compare at points P and Q?



A. P and Q have the same a_{rad}

B. Q has a greater a_{rad} than P.

C. Q has a smaller a_{rad} than P.

Q101

Clicker Answers

93=B, 94=B, 95=B, 96=C, 97=C,
98=2, 99=2, 100=D, 101=B