Circular Motion and Gravity

IB 11

Uniform Circular Motion: motion in a circle at a constant speed

Cycle: one complete revolution

Period: time for one cycle

Symbol: T

Formula for Period: $T = \frac{\text{time}}{\text{cycle}}$

Units: [s]

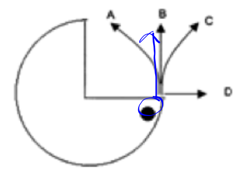
Average Speed

$\vec{V}_{avg} = 0$

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

Which path will the marble take? Why? Explain using one of Newton's Laws.

Newton's 1st law - object in motion (constant) stays in motion

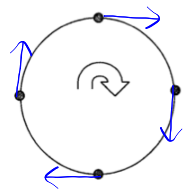


Instantaneous Velocity (linear velocity, tangential velocity)

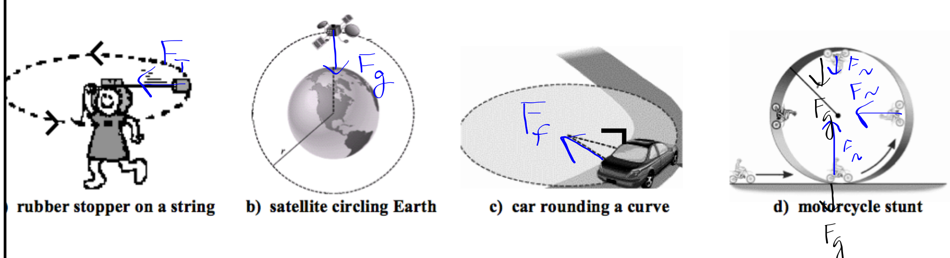
Magnitude: $\vec{V} = \frac{2\pi r}{T}$

Direction: tangent to circle, in direction of motion

Sketch the instantaneous velocity vectors for the marble at each location shown at right.



Draw and label the force causing the circular motion in each case below.



a) rubber stopper on a string b) satellite circling Earth c) car rounding a curve d) motorcycle stunt

1. In each case, what is the direction of the force causing the circular motion? in towards center
2. Are these objects accelerating, even if they are moving at a constant speed? yes
3. In which direction are they accelerating? in towards center
4. Are objects moving in circular motion ever in equilibrium? Explain.
   no, always accl

Centripetal Force and Acceleration

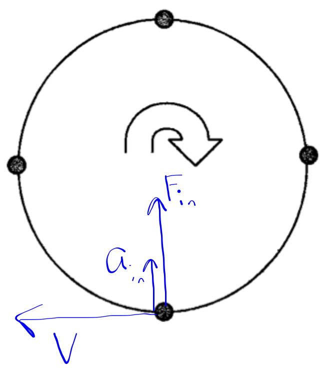
IB 11

Centripetal Force: a force acting toward the center of the circle

Symbol: $\Sigma \vec{F}_{in}$ ~~$(\vec{F}_c)$~~

Centripetal Acceleration: an acceleration toward the center of the circle

Symbol: $\vec{a}_{in}$ (a_c)



Sketch and label the instantaneous velocity, force, and acceleration for the marble at each location in the diagram.

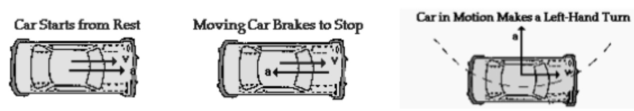
Compare the directions of the instantaneous velocity, force, and acceleration for an object in uniform circular motion.

NOTE: The phrase "centripetal force" does not denote a new and separate force of nature. The phrase is merely another name for the net force pointing toward the center of the circular path. The centripetal force always has another name, such as F_g, F_N, F_T, F_f, or any combination of these.

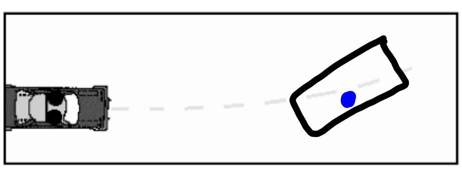
Centripetal force:

Centrifugal force: perception of outward force due to accl F.O.R.

How is the acceleration of a car related to the forces you feel as a rider in the car?



A car traveling down the road makes a quick left-hand turn. Explain, using Newton's laws and a different frame of reference, how any "centrifugal" force you feel can be explained as a centripetal force.



Centripetal Acceleration | **Centripetal Force**

$$a_{in} = \frac{\Sigma F_{in}}{m}$$

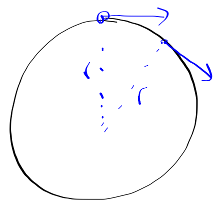
$$a_{in} = \frac{\Delta \vec{V}}{t} = \frac{V^2}{r}$$

$$\Sigma \vec{F}_{in} = m\left(\frac{V^2}{r}\right)$$

Centripetal Force is the Net Force!

$$\Sigma F_{in} = ma$$

$$F_T, F_g, F_N, F_f, = m\frac{V^2}{r}$$



1. A boy flies a 0.750-kg motorized plane on a 2.3 m string in a circular path. The plane goes around 8.0 times in 12.0 seconds. Determine the following:

a) the period of revolution

$$T = \frac{time}{cycle} = \frac{12\,s}{8.0} = \boxed{1.5\,s}$$

b) the speed of the plane

$$V = \frac{2\pi r}{T} = \frac{2\pi(2.3\,m)}{1.5\,s} = \boxed{9.6\,m/s}$$

c) the acceleration of the plane

$$a_{in} = \frac{V^2}{r} = \frac{(9.6\,m/s)^2}{2.3\,m} = \boxed{40.\,m/s^2}$$

d) the tension in the string (F_{in})

$$\Sigma F_{in} = mV^2/r$$

$$F_T = .75\,kg\,(40.\,m/s^2) = \boxed{30.\,N}$$

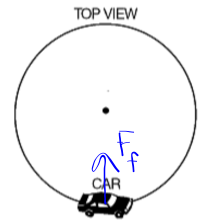
$T = time/cycle$

$V = 2\pi r/T$

$a_{in} = v^2/r$

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

2. A 1.5 kilogram toy car moves on a circular track of 1.3 meter radius at a constant speed of 2.0 meters per second. Determine the following:



a) the time it takes to go around the track once

$V = \frac{2\pi r}{T} \rightarrow T = \frac{2\pi r}{v} = \frac{2\pi\, 1.3m}{2m/s}$

$T = \boxed{4.1s}$

b) the centripetal acceleration of the cart

$a_{in} = v^2/r = \frac{(2m/s)^2}{1.3m} = \boxed{3.1 m/s^2}$

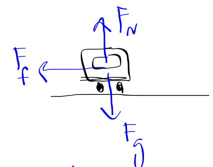
c) the centripetal force acting on the cart

$\Sigma F_{in} = \frac{mv^2}{r}$

$F_f = m(a_{in})$

$= 1.5kg \cdot 3.1 m/s^2$

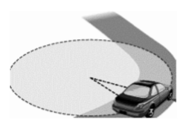
$= \boxed{4.6N}$



d) What is causing this force?

T = time/cycle
$V = 2\pi r/T$
$a_{in} = v^2/r$
$\Sigma F_{in} = m\frac{v^2}{r}$

3. A 2000. kg car attempts to turn a corner going at a speed of 25 m/s. The radius of the turn is 15 meters.



a) How much friction is needed to negotiate this turn successfully?

b) If the pavement is dry asphalt, will the car be able to safely turn? Justify your answer.

c) Derive an expression for the maximum speed with which a car of mass *m* can safely make a turn around a curve of radius *r*.