Uniform Circular Motion

An object undergoes uniform circular motion when the object moves in a circular path at constant speed.

The velocity vector for the object is tangent

velocity

velocity

velocity

to the circular path at each point around

the circle.

Since the direction of the velocity changes,

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the object has acceleration. The acceleration

vector is directed along a radius toward the

acceleration

center of the circle. “Directed toward the

center” is called “centripetal” in physics.

The acceleration of the object is the

centripetal acceleration.

Since the acceleration is perpendicular to the velocity, there is no component of acceleration along the line of velocity. With no component along the line of velocity, the acceleration cannot change the speed. The centripetal acceleration only changes the direction of the object.

NET force

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According to Newton’s second law, if there is

acceleration, there must be a NET force on

the object. The NET force on an object must

be in the same direction as the acceleration.

The NET force on an object moving with uniform

circular motion is directed toward the center of

the circle, and is called the “centripetal force.”

For uniform circular motion, the speed of the object, the acceleration, and the NET force will have the same sizes at all times.

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The centripetal force keeps the object moving in a circle. If the centripetal force is removed the object will move in a straight line, tangent to the circle at the point where the object was when the force was removed.

Examples of uniform circular motion:

 swinging ball on the end of a string

 a car rounding a circular curve at constant speed

 the Ferris wheel turning at constant speed

 a satellite moving in a circular orbit around a planet

The centripetal acceleration of an object depends upon two factors:

 1. the speed of the object

 2. the radius of the circular path

The faster the object moves, the larger is its acceleration. A smaller acceleration is needed for an object to move in a larger circle. In math terms, the acceleration of the object is directly proportional to the square of the speed and inversely proportional to the radius of the circle.

 

ac – centripetal acceleration in m/s2

v – speed in meters/second

r – radius of the circle in meters

To double the speed of the object, the object must have 4 times the acceleration. To double the radius, the object must reduce its acceleration by half.

According to Newton’s second law, NET F = ma, the NET force on the object must be mac. The NET force on an object with uniform circular motion is the centripetal force, Fc. Since ac = v2/r, then

 

Fc – centripetal force in newtons

m – mass of object in kilograms

v – speed in meters/second2

r – radius of the circle in meters

Twice as much force is needed to move an object that is twice as massive.

To double the speed, the force must be 4 times larger.

Half as much force is needed to move the object in a circle that is twice as large.

For the examples given earlier:

The tension in the string provides the centripetal force for the ball.

Friction provided the centripetal force for the car.

The wheel beams and struts provided the centripetal for the seats.

Gravity provided the centripetal force for the satellite.

The two equations above apply to an object moving in a circular path at ANY point in its path.

IF the object has uniform circular motion THEN the equations produce the same values at ALL points.

IF the object has nonuniform circular motion THEN the equations produce different values at different points because the speed will not be the same at all points.