

Lesson 1.8: Centripetal acceleration and centripetal force

Uniform circular motion: an object that is going around in a circle at a constant speed. However the velocity is continually changing as the direction of motion is always changing.

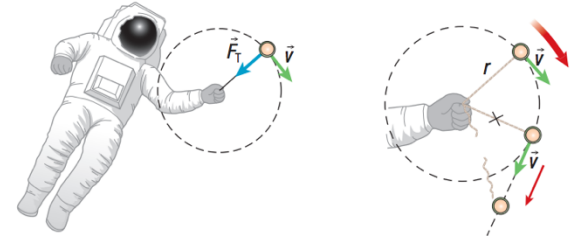
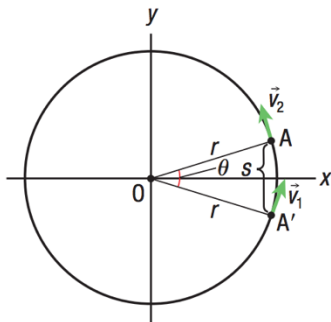
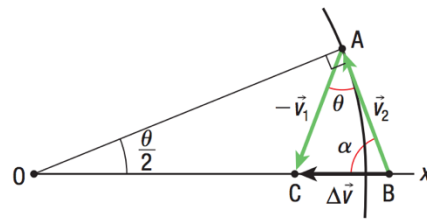


Figure 1 To give the hammer enough speed to travel a long distance down the field, the athlete must move it rapidly in a circular path.

By moving the ball in a circle, the instantaneous velocity is always tangential to the circular path, and the force that are always perpendicular to the direction of the velocity and that always pointing toward the center of the path is called the _____ force. The acceleration caused by this force (or we say caused by change of velocity) is called _____ acceleration, always going towards the centre.



(a)



(b)

$$\vec{a} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{\Delta t}$$

When $\Delta t \rightarrow 0$, arc length $s = v\Delta t$

Use similar triangle between OAA' and ABC: $\frac{\Delta v}{v} = \frac{v\Delta t}{r}$,

then rearrange: $\frac{\Delta v}{\Delta t} = \frac{v^2}{r}$

Hence: $\mathbf{a} = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2} = \mathbf{4\pi^2 r f^2}$

$$\mathbf{F} = \frac{mv^2}{r} = \frac{4\pi^2 rm}{T^2} = \mathbf{4\pi^2 r f^2}$$

$$\mathbf{v} = \frac{2\pi r}{T} \quad \mathbf{T} = \frac{1}{f}$$



Example 1: Calculating the Magnitude of Centripetal Acceleration

A child rides a carousel with a radius of 5.1 m that rotates with a constant speed of 2.2 m/s. Calculate the magnitude of the centripetal acceleration of the child.

Example 2: Calculating Frequency and Period of Rotation for a spinning object

The centripetal acceleration at the end of an electric fan blade has a magnitude of $1.75 \times 10^3 \text{ m/s}^2$. The distance between the tip of the fan blade and the centre is 12 cm. Calculate the frequency and the period of rotation of the fan.

Example 3: Calculating speed using apparent weight

A roller coaster car is at the lowest point on its circular track. The radius of curvature is 22 m. The apparent weight of one of the passengers in the roller coaster car is 3.0 times her true weight. Determine the speed of the roller coaster.

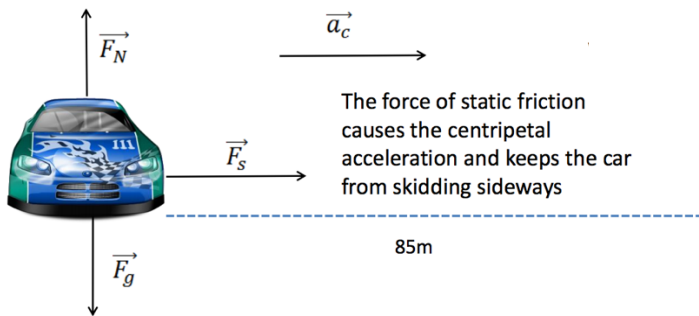


Example 4: Determining centripetal acceleration and identify the centripetal force

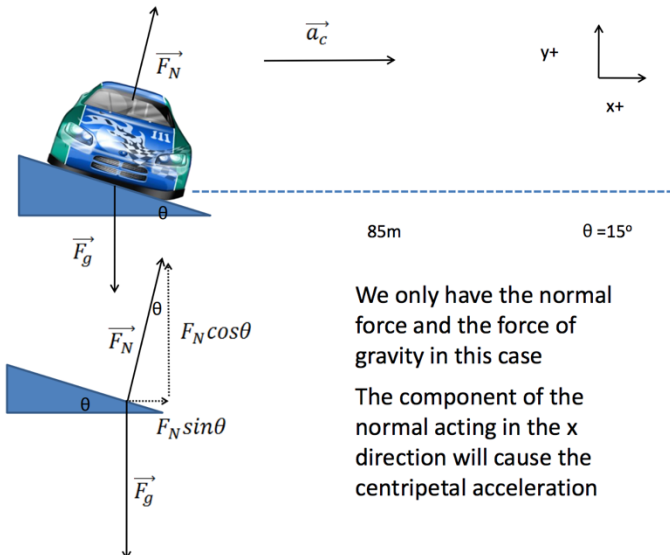
Suppose a bug is sitting on the edge of a horizontal DVD. The bug has a mass of 5.0 g, and the DVD has a radius of 6.0 cm. The DVD is spinning such that the bug travels around its circular path three times per second. Calculate the centripetal acceleration of the bug and the net force on the bug. Also Identify the force or forces responsible for the centripetal force.

Example 5: Real world application - Calculating speed on level surface and banked Turn

What force is causing the centripetal acceleration of a car of mass 1200 kg going around a level corner of radius 85 m with a constant speed of 20 m/s. What is the magnitude of this force?



Now consider the same car going around a **frictionless** banked curve of the same radius. The angle of the bank is 15° . What force is providing the centripetal acceleration? What **“ideal” speed** (i.e., Critical speed) must the car maintain to travel safely around the curve?



We only have the normal force and the force of gravity in this case

The component of the normal acting in the x direction will cause the centripetal acceleration

Continued: Now let's add static friction in!

A car making a turn on a dry, banked highway ramp is experiencing friction. The coefficient of static friction between the tires and the road is **0.60**. Determine the **maximum** speed at which the car can safely negotiate a turn of radius 85 m with a banking angle of 15° .