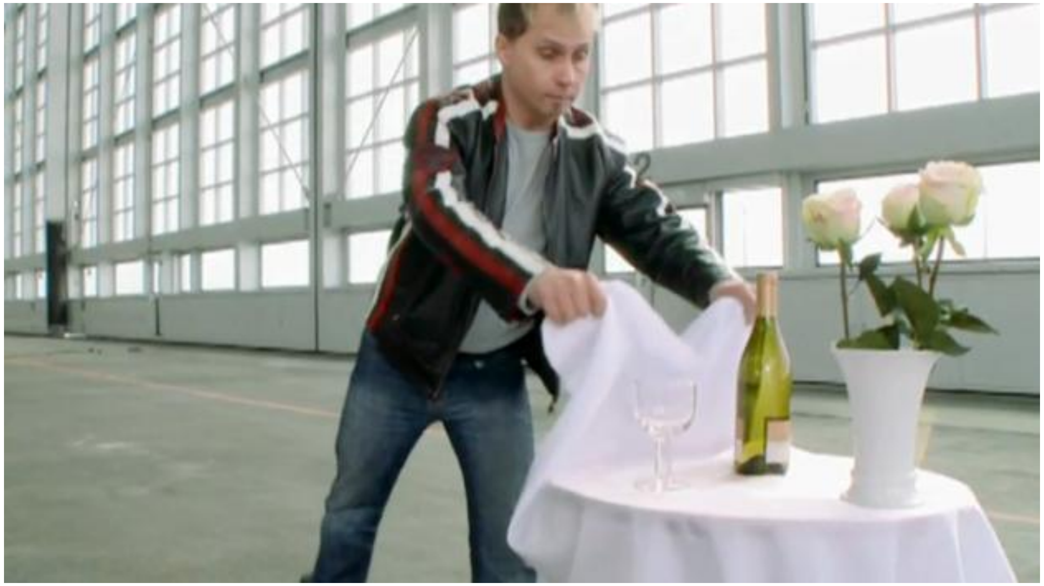
Centripetal Force and Acceleration

IB PHYSICS | CIRCULAR MOTION

Remember Newton's 1st?

A body will remain at rest or moving with constant velocity unless acted upon by an unbalanced force

"Law of Inertia"



Remember back…

There are 3 ways that an object can be experiencing acceleration?

Speeding Up

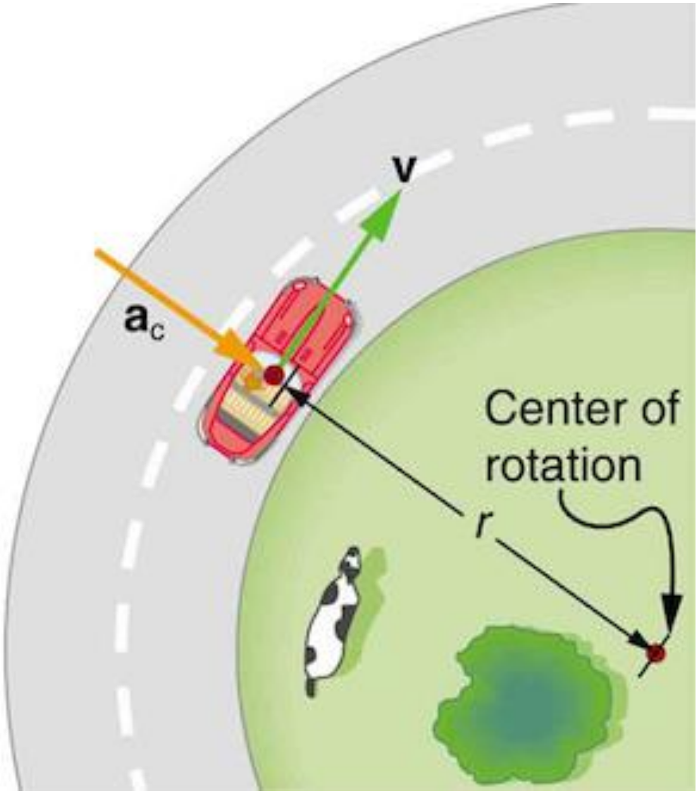
Slowing Down

Changing Direction

Centripetal Acceleration

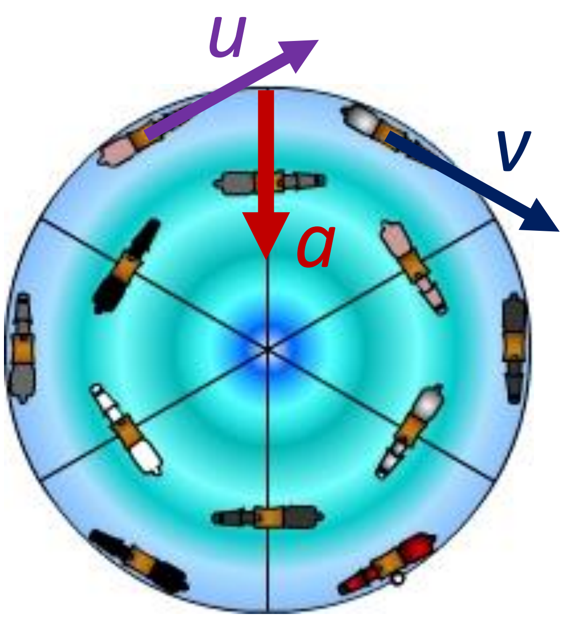
Centripetal acceleration represents the rate of change of velocity and its direction

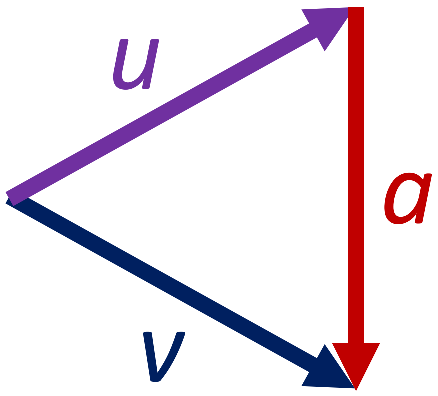
$$a = \frac{v^2}{r}$$



Centripetal Acceleration

Centripetal acceleration can be seen when finding the change between velocity vectors





Centripetal acceleration will always point to the **center**

Calculating Centripetal Acceleration

$$a = \frac{v^2}{r}$$

$$v = \omega r$$

$$\omega = \frac{2\pi}{T}$$

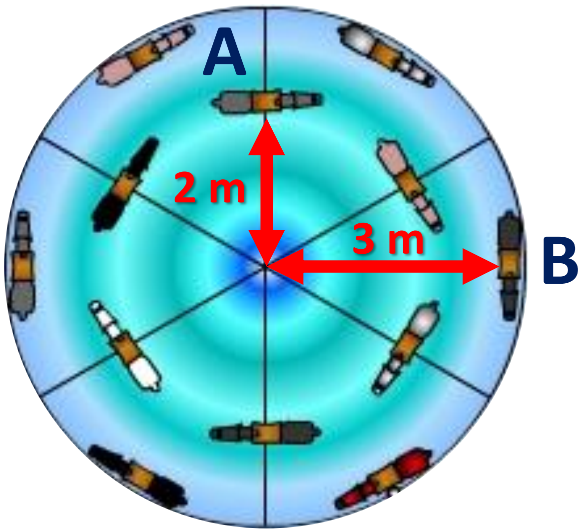
$$v = \frac{2\pi r}{T}$$

$$a = \frac{\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{\frac{4\pi^2 r^2}{T^2}}{r} = \frac{4\pi^2 r^{\not 2}}{T^2 \not r} = \frac{\mathbf{4\pi^2 r}}{\mathbf{T^2}}$$

IB Physics Data Booklet

Sub-topic 6.1 – Circular motion
$v = \omega r$ $a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$ $F = \frac{mv^2}{r} = m\omega^2 r$

Try this....



$$a = \frac{v^2}{r}$$

If the carousel spins at 1 complete rotation every 10 seconds, what is the centripetal acceleration for each row?

A	ω = 0.63 rad s^{-1} | v = 1.3 m s^{-1} $a = \frac{1.3^2}{2} = 0.843 \text{ m s}^{-2}$
B	ω = 0.63 rad s^{-1} | v = 1.9 m s^{-1} $a = \frac{1.9^2}{3} = 1.20 \text{ m s}^{-2}$

Wait… Where's the Force?

We know from Newton's 2nd Law that every time that we have acceleration, there must be a force causing that change in velocity

$$F = ma$$

$$a = \frac{v^2}{r}$$

$$F = \frac{mv^2}{r}$$

Calculating Centripetal Force

$$F = \frac{mv^2}{r}$$

$$v = \omega r$$

$$F = \frac{m(\omega r)^2}{r} = \boldsymbol{m\omega^2 r}$$

IB Physics Data Booklet

Sub-topic 6.1 – Circular motion
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F = ma

Try This...

A **3 kg** rock swings in a circle of radius **5 m**. If its constant speed is **8 m s^{-1}**, what is the centripetal acceleration and force?

$$v = \omega r$$

$$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$$

$$F = \frac{mv^2}{r} = m\omega^2 r$$

m = 3 kg r = 5 m v = 8 m s^{-1}

$$a = \frac{v^2}{r} = \frac{8^2}{5} = \mathbf{12.8\ m\ s^{-2}}$$

$$F = ma = (3)(12.8) = \mathbf{38.4\ N}$$

Try This...

A pilot is flying a small plane at 30.0 m s^{-1} with a radius of 100.0 m. If a force of 635 N is needed to maintain the pilot's circular motion, what is the pilot's mass?

$$v = \omega r$$

$$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$$

$$F = \frac{mv^2}{r} = m\omega^2 r$$

v	30 m s^{-1}
r	100 m
F	635 N
m	?

$$F = \frac{mv^2}{r}$$

$$635 = \frac{m(30)^2}{100}$$

$$m = 70.56 \text{ kg}$$

Equation Summary

Sub-topic 6.1 – Circular motion
$v = \omega r$
$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$
$F = \frac{mv^2}{r} = m\omega^2 r$

Velocity

Linear: $v \rightarrow$ m s^{-1}

Angular: $\omega \rightarrow$ rad s^{-1}

Centripetal Acceleration

changes direction toward center

$a_c \rightarrow$ m s^{-2}

Centripetal Force

directed toward center

$F = ma$

See derived equations

Lesson Takeaways

- ❑ I can determine the direction and magnitude of centripetal acceleration and centripetal force
- ❑ I can identify circular motion properties in a description and choose an appropriate equation to relate them