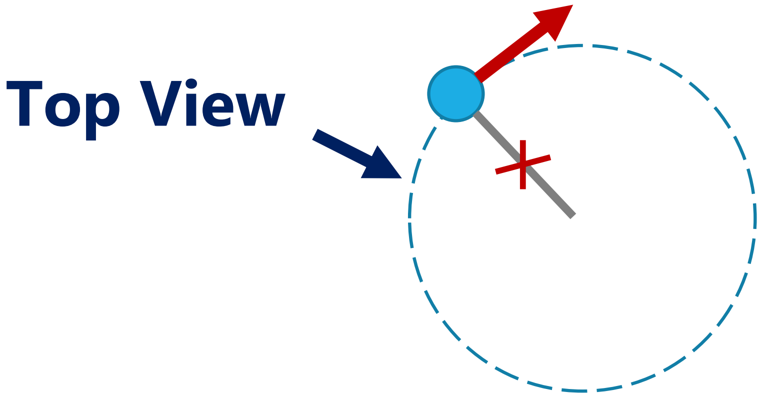
Vertical Circular Motion with Tension

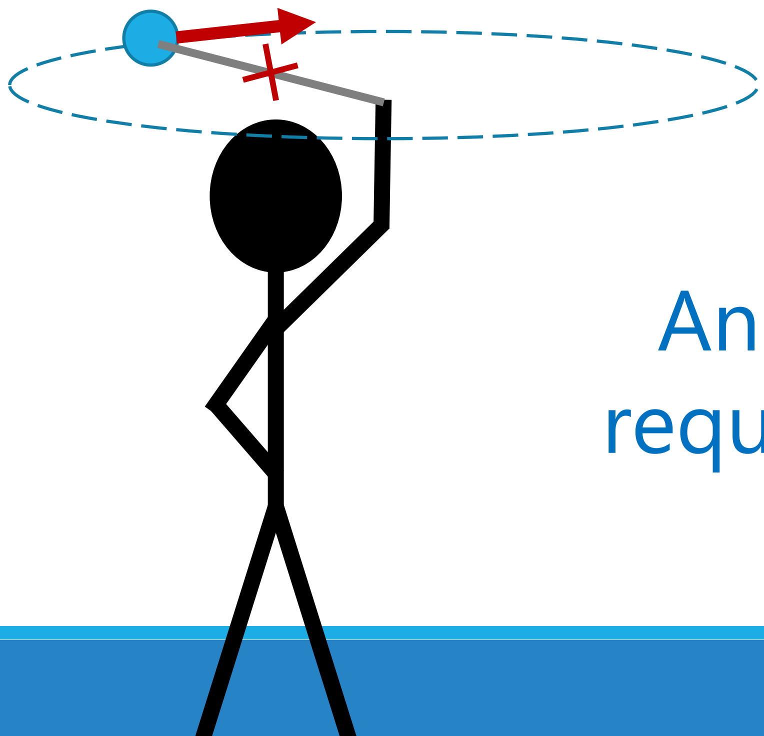
IB PHYSICS | CIRCULAR MOTION

IB Physics Data Booklet

Sub-topic 6.1 – Circular motion	
$v = \omega r$ $a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$ $F = \frac{mv^2}{r} = m\omega^2 r$	v – linear velocity (m s^{-1}) ω – angular velocity (rad s^{-1}) r – radius (m) T – period (s) a – centripetal acceleration (m s^{-2}) F – centripetal force (N)

Try This…





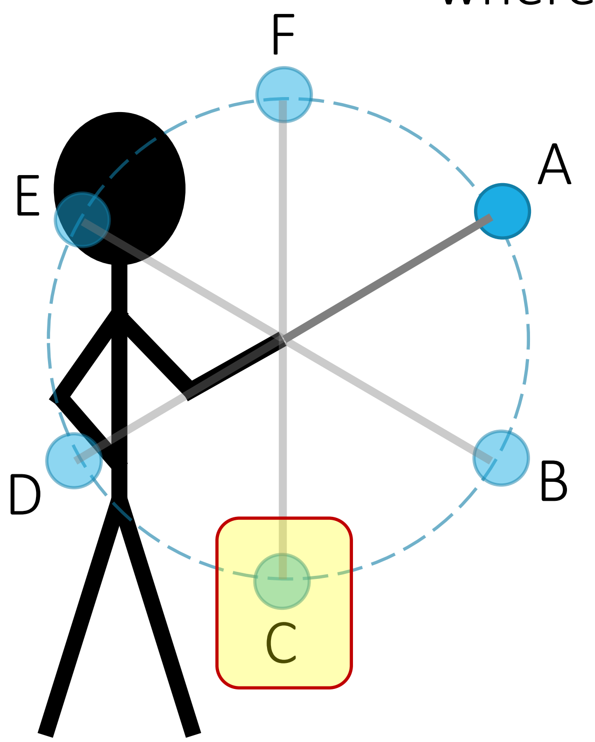
If you swing a ball on a string above your head, and the string breaks, what happens?

Travels in a straight line tangent to the circle

An inward facing force is required for circular motion

Think about it…

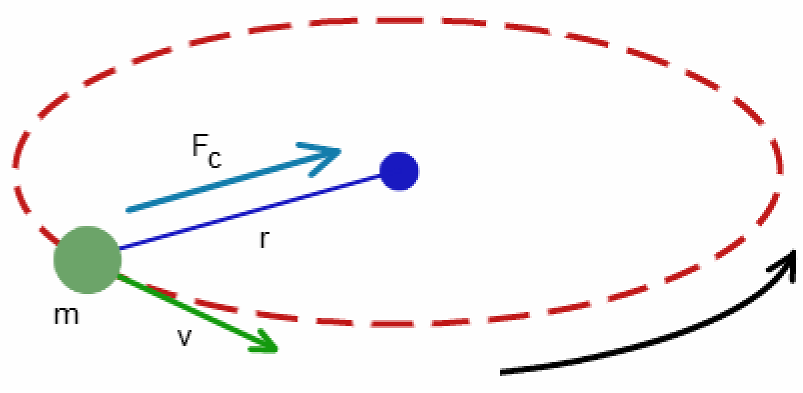
If you swing a ball on a string in a vertical circle, where is the string most likely to break? Why?



Because gravity is pulling against the string at this point

Centripetal Force

Remember, for an object to follow a curved path, there must be an inward pointing centripetal force (F_c)



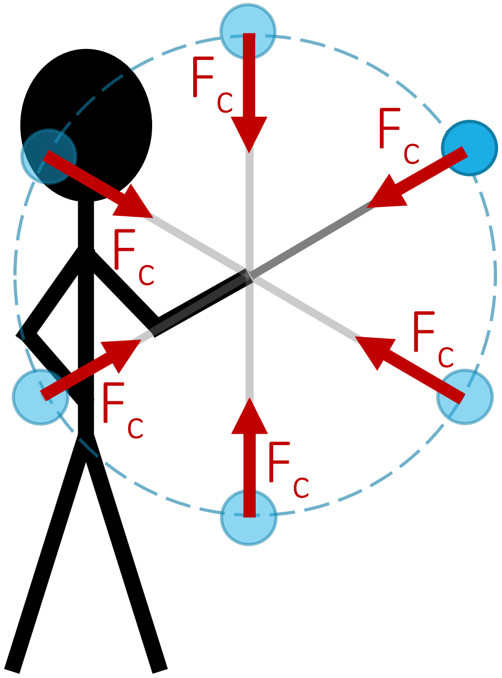
This is not really a force that shows up on a free body diagram like F_g, R, F_f, and F_T.

Rather, it is more like the net force that is required to create that circular motion

If an object is in circular motion: $F_{net} = F_c$

Vertical Circle

When you make a vertical circle the net force at all points must equal the centripetal force (F_c)

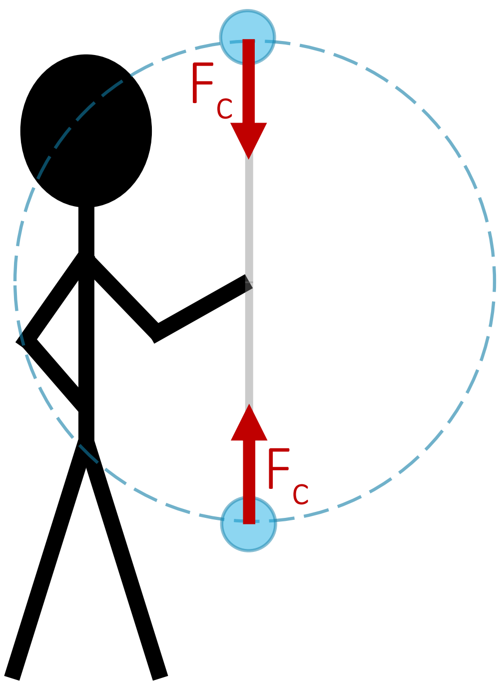


This is the case for horizontal circles too! The main difference is that now the weight is a factor…

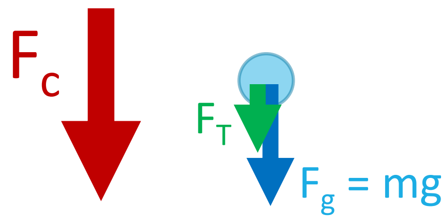
Again, this isn't some magical new force but rather a combination of all forces resulting in…

$$F_{net} = F_c$$

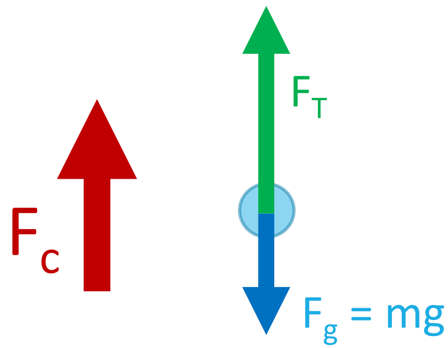
Let’s focus on the top and bottom…



At the Top:



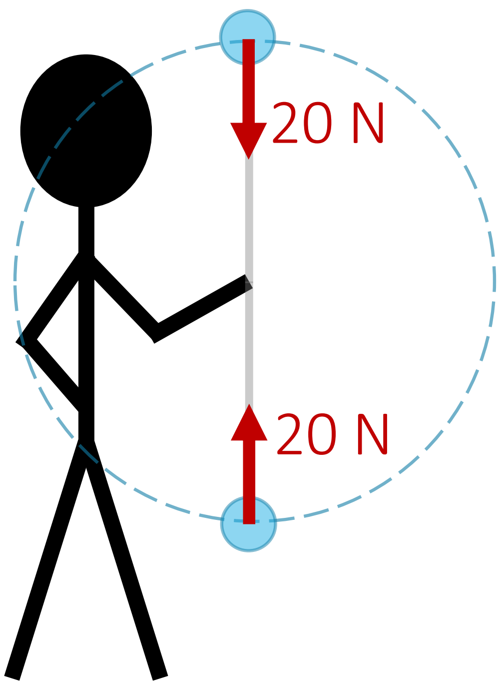
At the Bottom:



Now with numbers!

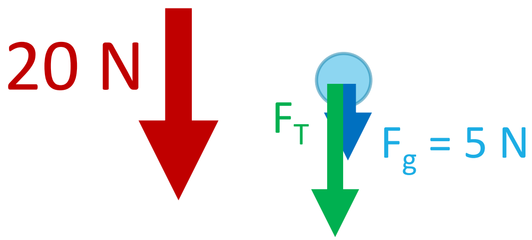
F_c required is 20 N

F_g of object is 5 N



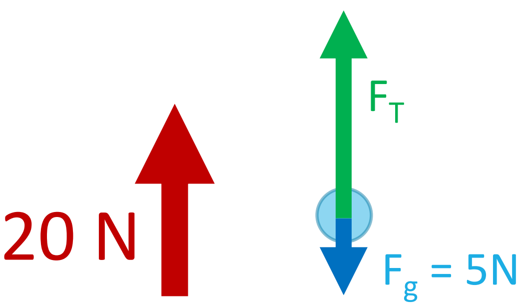
At the Top:

*F_T is determined by comparing the known forces (F_g) to the net force (F_c) and finding the difference



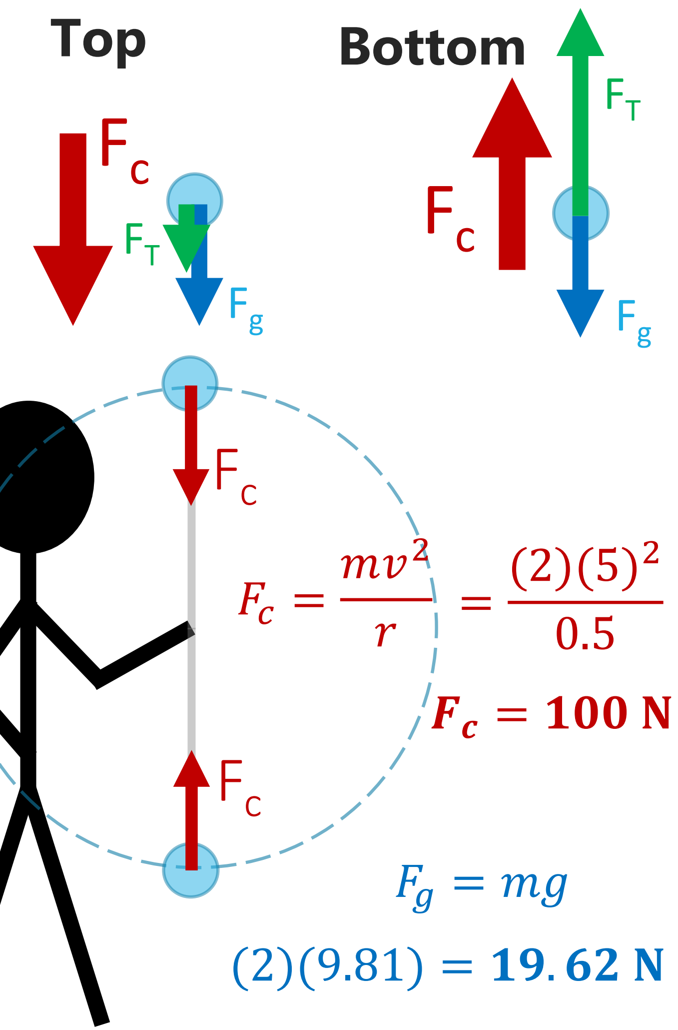
$F_T = 15$ N

At the Bottom:



$F_T = 25$ N

What is the tension?



Top

m	2 kg
v_t	5 m/s
r	0.5 m
F_c	100 N
F_{net}	100 N
F_g	19.62 N
F_T	80.38 N

Bottom

m	2 kg
v_t	5 m/s
r	0.5 m
F_c	100 N
F_{net}	100 N
F_g	19.62 N
F_T	119.62 N

What is the tension?

What is the angular velocity in rad s^{-1} at the bottom of a vertical circle created when a 0.2-kg phone charger is swung with a 0.8 m cord and a tension of 6 N at the lowest point?

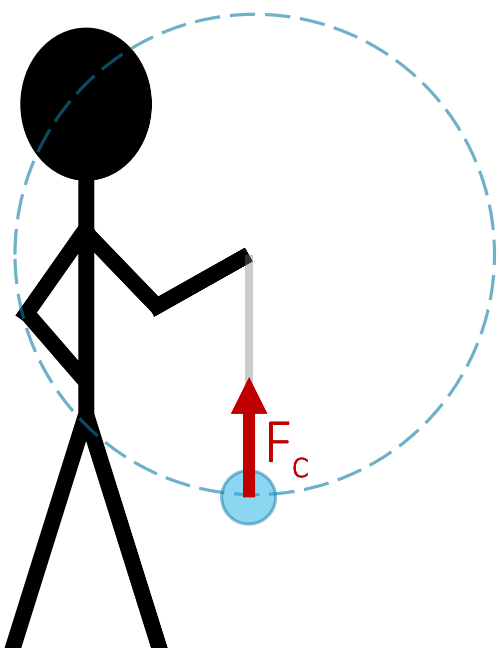
$$F_c = \frac{mv^2}{r} = m\omega^2 r$$

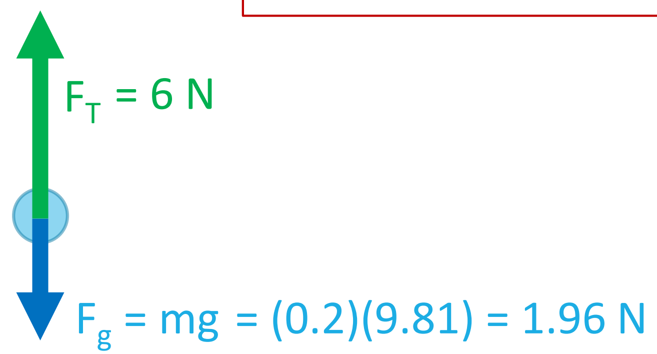
$$F_c = m\omega^2 r$$

$$4.04 = (0.2)\omega^2(0.8)$$

$$\omega^2 = 25.25$$

$$\boldsymbol{\omega = 5.02\ \mathrm{rad\ s^{-1}}}$$





$F_c = 6 - 1.96 = 4.04$ N

Lesson Takeaways

- ❑ I can compare the forces on an object at different positions in vertical circular motion
- ❑ I can determine the magnitude and direction of the forces needed for the overall centripetal force
- ❑ I can qualitatively describe how tension changes in a vertical circle