A-Level Physics

Notes

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LGS (PARAGON)

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Title A-LEVEL PHYSICS NOTES

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Published by MS Books (042-35774780)

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AKBAR LAW CHAMBERS
39-40, 1st Floor, Sadiq Plaza, The Mall, Lahore.
0307-4299886, 042-36314839

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83-B Ghalib Market, Gulberg III Lahore
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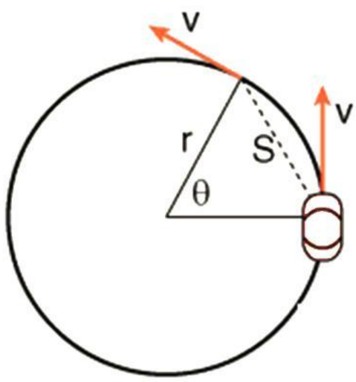
CIRCULAR MOTION

1. Consider an arc of a circle whose length (along the curve) is *s*, the circle is at radius *r*.



The angle measured, θ, measured in radians, is define by the following equation :

$$\theta = \frac{s}{r}$$

The equation shows that the radian is a dimensionless quantity since it is the ratio of two lengths.

Definitions: One radian is that angle supported by an arc length in a circle equal to the radius of the circle.

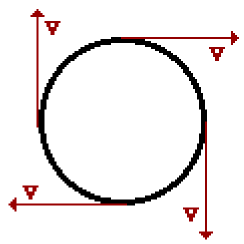
Rewriting the equation, $s = r\theta$

2. Differentiating with respect to time,

$$s = r\theta$$

$$\frac{\partial s}{\partial t} = r\frac{\partial \theta}{\partial t}$$

$$v = r\omega$$



The direction of the velocity vector at every instant is in a direction tangent to the circle.

Another way of looking into the above equation, when a body makes a complete circle:

i) it has travel a distance of 2πr

ii) the time taken is T, period

Therefore: $v = \frac{2\pi r}{T}$ or $v = 2\pi r f$

$v = r\omega$ where $\omega = 2\pi f$. angular speed

2π = angular displacement

v – tangential speed

ω – angular speed

Define ω :

Rate of change of angular displacement.

Ex:

1. Calculate the tangential speed and angular speed for a body on earth.
   (R_E = 6400 km, T= 24 hr)
2. A train is travelling on a track, which is part of a circle of radius 600 m, at a constant speed of 50 ms^{-1}. What is its angular velocity?

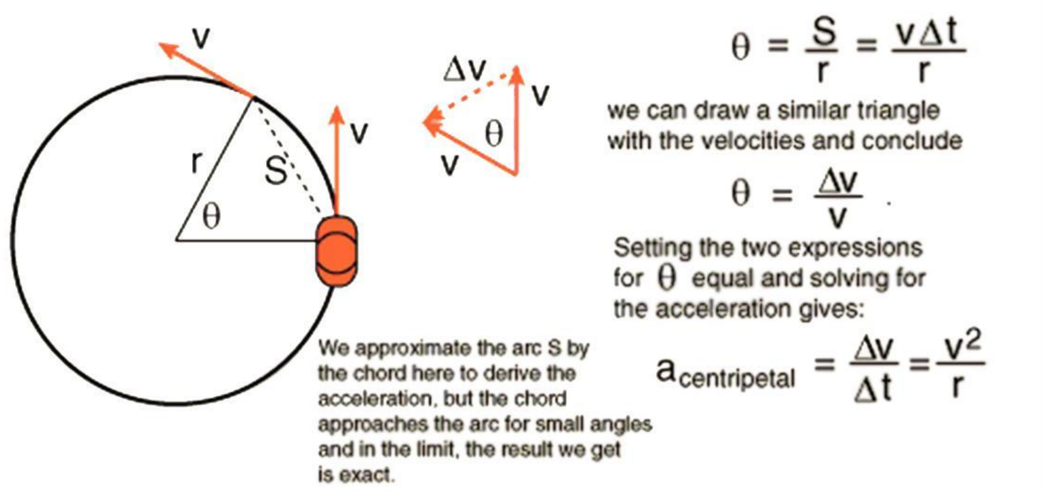
3. A washing machine spins its tub at a rate of 1200 revolutions perminute (rpm). If the diameter of the tub is 35 cm, find

a) the angular velocity of the tub.

b) the linear speed of the rim of the tub.

3. When a body is moving at constant speed, yet is said to accelerating. Explain this statement:

-- An object moving in a circle at a constant speed, its direction is constantly changing. Base on NFL, the body experiences a constantly changing velocity. Therefore the body must be accelerating.



This acceleration is directed towards a fix point - the center of the circle.

Since $v = r\omega$, then acceleration, $a_c = r\omega^2 = v\omega$.

Even if moving around the perimeter of the circle with a constant speed, there is still a change in velocity and subsequently an acceleration. This acceleration is directed towards the center of the circle.

And in accord with Newton's second law of motion, an object which experiences an acceleration must also be experiencing a net force; and the direction of the net force is in the same direction as the acceleration.

Therefore, $F_c = ma_c = mr\omega^2 = m\,v\omega$.

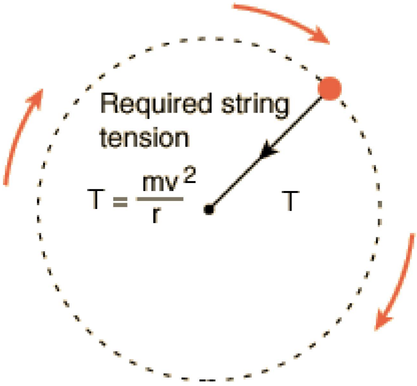
Question: Since there is a force acting on the body, explain whether there is a work done on the body?

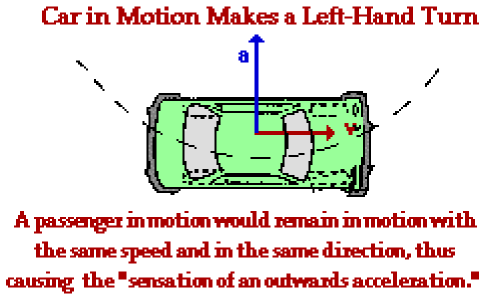
1. Find the acceleration of the moon if it travels at a constant speed of 1020 ms^{-1} and takes 27.3 days for a complete revolution of the Earth.

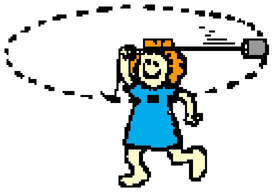
2. A car is negotiating a circular track of radius 120 m at 75 kmh^{-1}, calculate its centripetal acceleration.

3. From question 5, say the mass of the driver is 70 kg and the car's mass is 1500 kg. Calculate the force acting on the driver and the car.

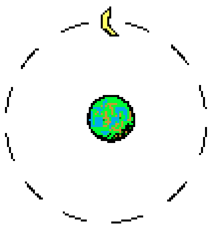
4. Examples of Centripetal forces:





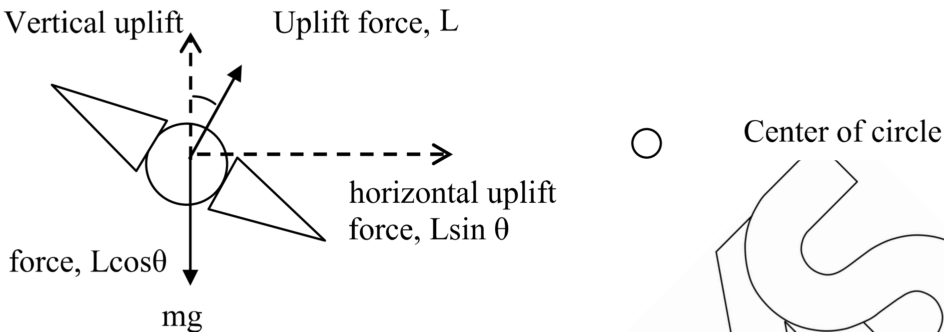


As a bucket of water is tied to a string and spun in a circle, the force of tension acting upon the bucket provides the centripetal force required for circular motion.
**Explain why water in the bucket does not spill out of the bucket?



As the moon orbits the Earth, the force of gravity acting upon the moon provides the centripetal force required for circular motion.

If there is a centripetal force acting on the moon, explain why the moon does not fall down towards earth?



When a body moves in a circular path,

$$L\cos\theta = mg$$

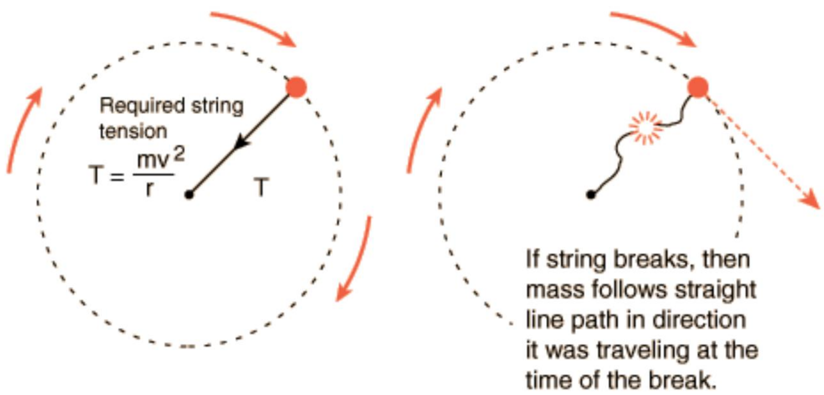
Required centripetal force, $L\sin\theta = \frac{mv^2}{r}$

$$\tan\theta = \frac{v^2}{rg}$$

I. With constant radius, *r* the angle it should tilt increases with increasing speed of the body moving.

II. By increasing the radius, a body can travel with a higher speed.

Question: In all the examples above, explain what will happen to rotating bodies if there is no centripetal force?



The string must provide the necessary centripetal force to move the ball in a circle. If the string breaks, the ball will move off in a **straight line with constant speed**.

The straight line motion in the absence of the constraining force is an example of Newton's first law. The example here presumes that **no other net forces** are acting, such as horizontal motion on a frictionless surface.

If there is gravitational force then the body will have a parabolic path.

An audio CD rotates 500 rpm when reading an inside track. The inside track of the CD is 50 mm out from the center. Find

i) the period of the rotation of the CD

ii) the linear speed and the angular speed

iii) the centripetal acceleration of the point on the inside track.