FORCES

A force is a physical quantity which when applied can bring about the following changes.

1) To make an object at rest to move.
2) To stop a moving object.
3) A force applied on a moving body can change the speed and direction of motion.
4) The force applied can deform the object [change the shape and size].

TYPES OF FORCES

Forces can be generally categorized into 2 major types.

- **Contact forces**
- **Non contact forces**

Physical causes and laws associated with FORCES:

Momentum: It is measured as the product of mass and velocity.

$$P = m \times v$$

SI unit of momentum is kg m/s
CGS unit of momentum is g cm/s

Newton's I law of motion [Law of inertia]:
"A body continues to be in the sate of rest or uniform motion until and unless an external force acts upon it".

Newton's II law of motion:
"Rate of change of momentum is directly proportional to the force applied and it takes place in the direction of force"

$$F = m \times a$$

Newton's III law of motion:

"Action and reaction forces are equal and opposite"

i.e., "For every action, there is an equal and opposite reaction"

Weight of a body is the force due to gravity on a given mass.

Therefore

$$\text{Weight} = F = mg$$

Where g is the acceleration due to gravity.

SI unit of force is newton [N]

$1N = 1kg\ m/s^2$

CGS unit of force is = dyne.

$1\ N = 10^5$ dyne

GRAVITATIONAL UNITS OF FORCE :

Kgf (kilogram force) and f (gram force) are the gravitational units of force.

$1\ kgf = 9.8\ N$ If $g = 9.8\ m/s^2$

$1\ kgf = 10\ N$ if $g = 10\ m/s^2$

Moment of a force (torque)

Moment of a force is that physical cause which brings about a turning effect on the body.

- **It is the turning effect of a force which is directly proportional to the magnitude of the force applied and**
- **distance of the point of application of force from the axis of rotation .**
- **Thus moment of a force or torque is measured as the product of the magnitude of force and perpendicular distance from the point of application of force to the axis of rotation.**

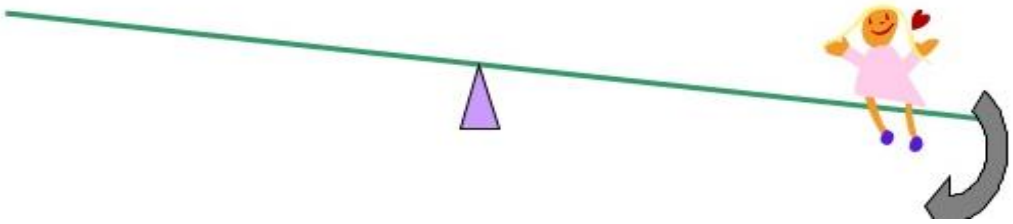
Moment of force or torque = Force X Perpendicular distance from point of application to axis of rotation.

moment of force or torque = F X d

SI unit of momennt of force = Nm (newton metre)
Other units are dyne cm, kgf m, gf cm.

A force can cause many things to move or stop. When a force causes an object to turn, this turning effect is called moments.

Example: A person sitting on a see-saw.



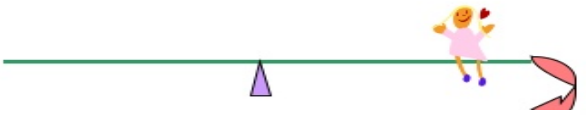
CLOCKWISE AND ANTICLOCKWISE MOMENTS:

A force applied on a body can turn the body either in clockwise or anticlockwise moments.

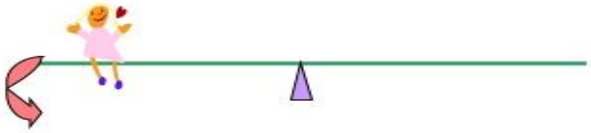
A force acting on a body can either produce clockwise moments or anticlockwise moments .

There are 2 types of moments:

- Clockwise moment



- Anticlockwise moment



If the moment of force turns the body in clockwise direction, then it is said to produce clockwise moments.

If the force acting on a body turns the body in anticlockwise direction , then it is said to have produced anticlockwise moments.

NOTE:

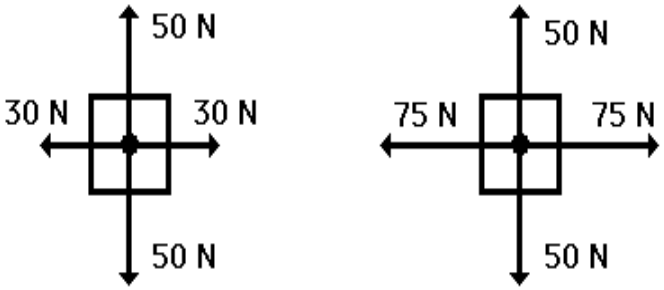
If the moment of a force is negative[-], then it is clockwise moment and on the other hand, if the moment of force is positive [+] then it is Anti-clockwise moment.

Equilibrium of bodies:

When all the forces acting at a point on a body keep Body either in the state of rest or of uniform motion,then the body is said to be in equilibrium.

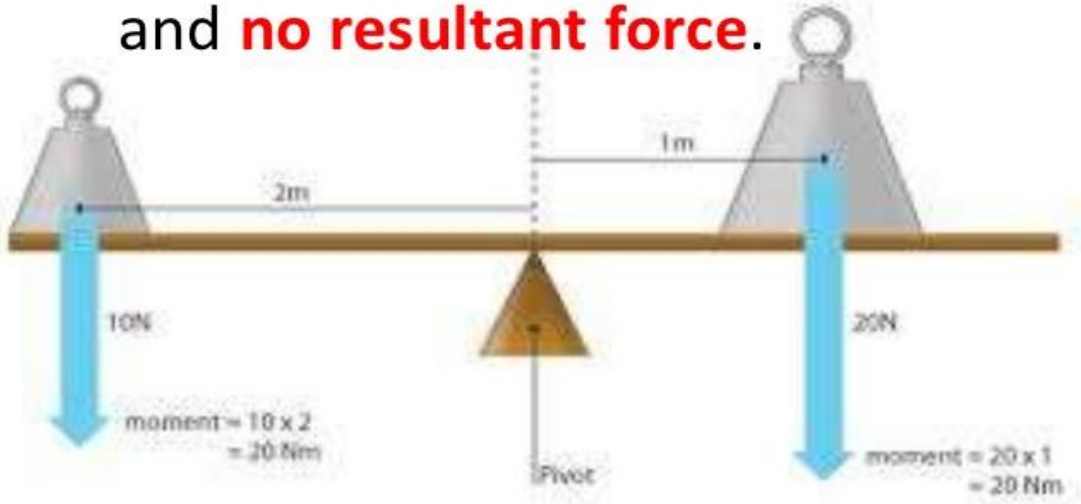
If all the forces acting on the body keep the body in the state of rest then it is said to be in STATIC EQUILIBRIUM.

If all the forces acting at a point on a body keep the body in The state of uniform motion, then it is said to be in DYNAMIC EQUILIBRIUM.



These two objects are at equilibrium since the forces are balanced. However, the forces are not equal.

If an object is in equilibrium there is **no resultant turning effect** and **no resultant force**.



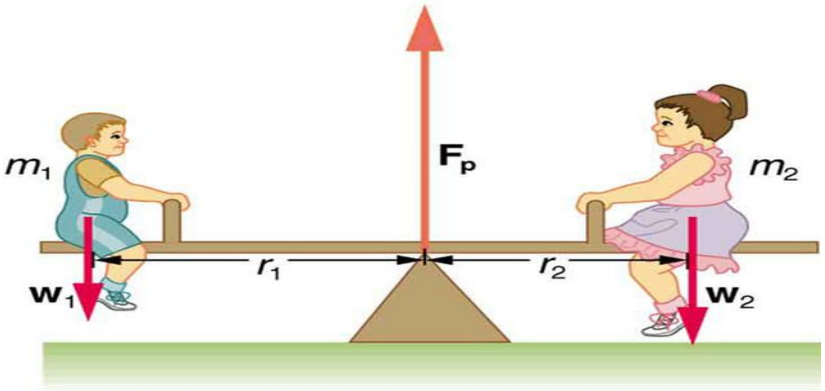
PRINCIPLE [LAW] OF MOMENTS:

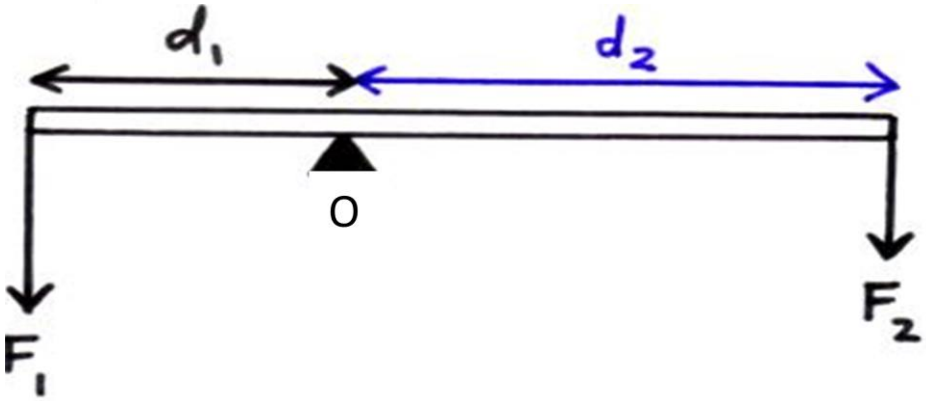
" In equilibrium ,algebraic sum of all anticlockwise moments is equal to the algebraic sum of all clockwise moments. This is called as the principle of moments or law of moments."

In the figure ,

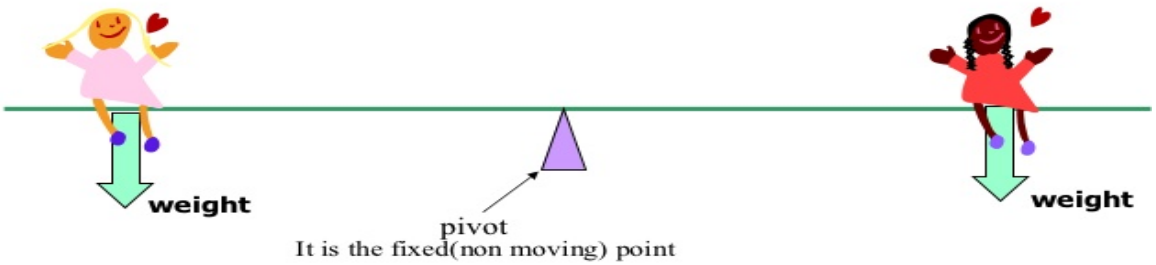
Moment of force due to F_1 about 'O' = Moment of force due to F_2 about 'O'

$$F_1 \times d_1 = F_2 \times d_2$$





For an object to be in equilibrium(stable/not moving), the total clockwise moment must be equal to the anticlockwise moment about the same pivot point.



COUPLE :

Two equal, parallel and opposite forces not acting on the same line constitute a couple.

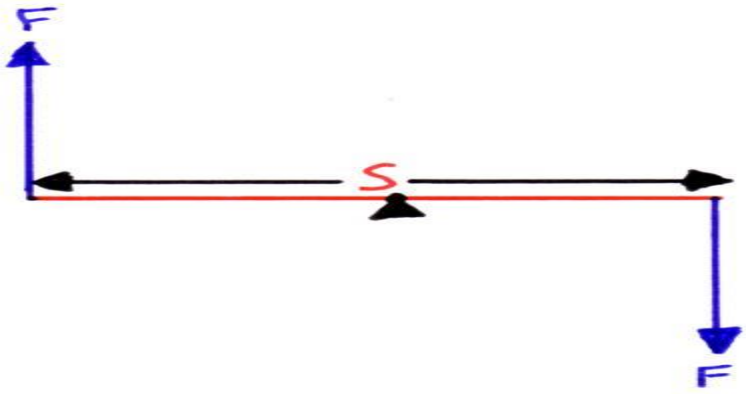
eg: turning of a tap
turning of steering wheel of the car
turning of a key to open/ close the lock.

Moment of a couple:

It is the measure of couple action.

Moment of a couple is defined as the product of either of the two forces and the perpendicular distance from the line of action of the two forces.

Moment of a couple = Either of the two forces X distance between the two forces

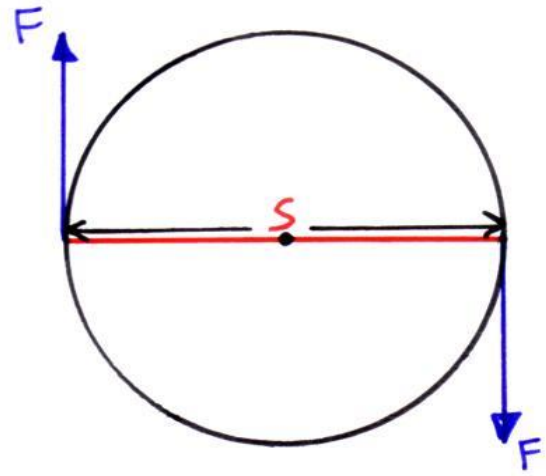


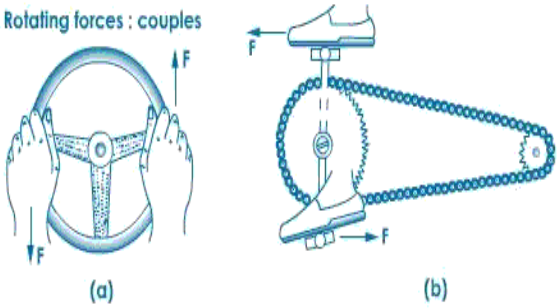
Moment of a couple = F X d

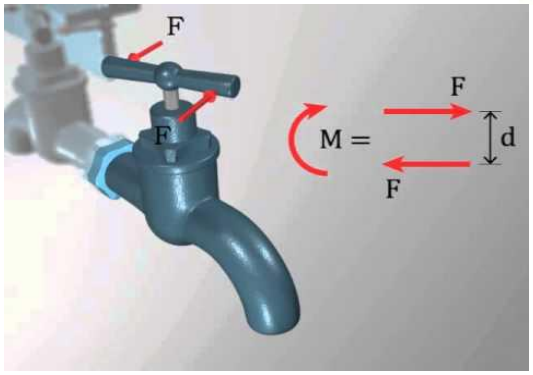
The SI unit of moment of a couple is Nm
CGS unit is dyne cm
Other units are Kgf m and gf cm.

Examples of couple action

Turning of a tap, turning of the cap of a bottle,Turning of key while opening of the door.







CENTRE OF GRAVITY:

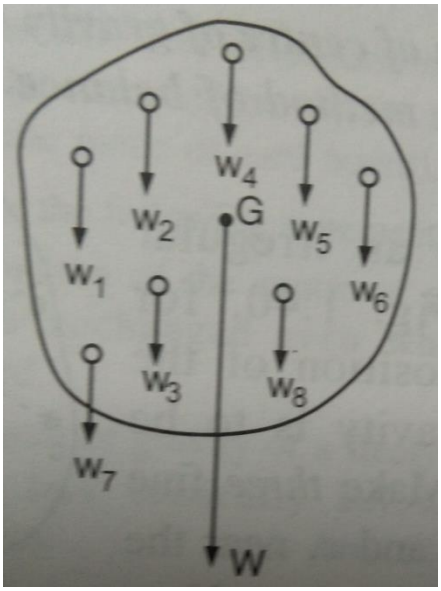
Center of gravity is the place in a system or body where the weight is evenly dispersed and all sides are in balance.
You know that every body is made up of molecules and each molecule has it mass and therefore weight of each of the molecule acts in the downward direction.

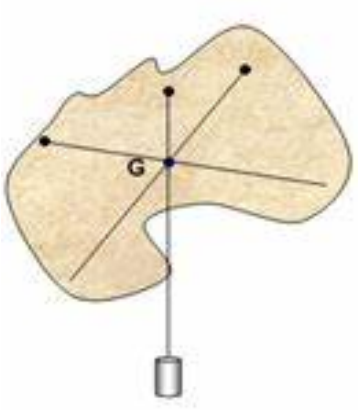
Hence centre of gravity of a body is the point about which the algebraic sum of moments of weights of all the particles Constituting the body is zero.

The entire weight of the body is said to be acting at this point howsoever the body is placed.

Note:

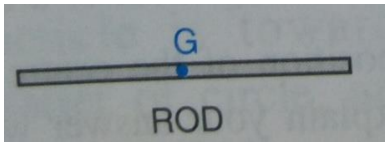
1. **The position of centre of gravity depends upon the shape of the body**
2. **It is not necessary that the centre of gravity always be within the material of the body.**
3. **The centre of gravity does not change with the orientation of the body. i.e., it does not matter how the body is placed.**

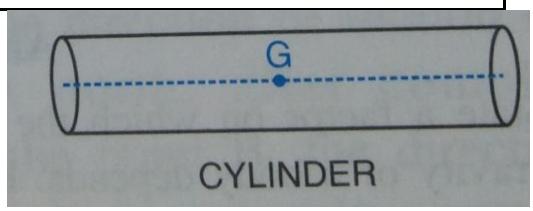


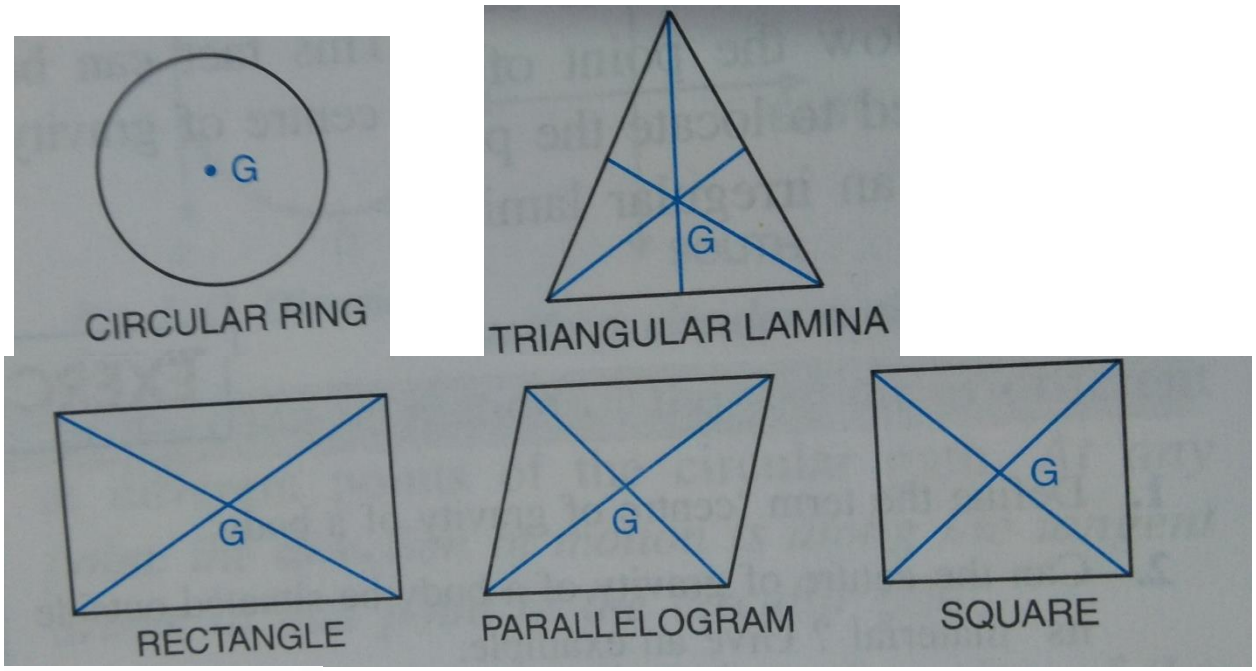


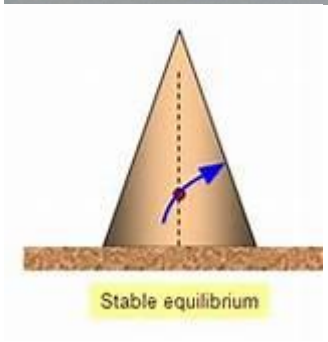
Centre of gravity for an Irregularly shaped body

Object	Position of centre of gravity
1) Rod	mid point of rod
2) Circular disc	Geometric centre
3) Solid or hollow sphere	Geometric centre of the sphere
4) Cylinder	mid –point on the axis of cylinder
5) Solid cone	At a height h/4 from the base ,on its axis (h = height of cone)
6) Hollow cone	At a height h/3 from the base on its axis
7) Circular ring	Centre of ring
8) Triangular lamina	The point of intersection of medians
9) Parallelogram or rectangular lamina or square or a rhombus	The point of intersection of the diagonals.









Stable,unstable and neutral equilibrium state of bodies :

For a body to be in stable equilibrium, the centre of gravity should be as low as possible.

If the position of centre of gravity is raised, i.e if the body is kept in such a position such that the centre of gravity is raised ,then the body loses its balance. Hence it is said to be in unstable equilibrium.

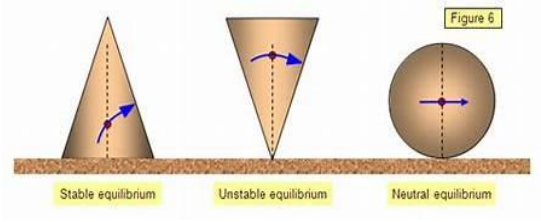
When a body is in its state of stable equilibrium ,smaller forces acting on a body do not destabilize the body.

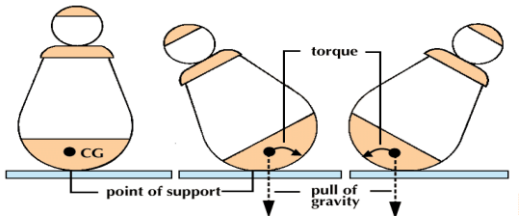
For a body to be in stable equilibrium, the centre of gravity should be as low as possible.

NOTE:

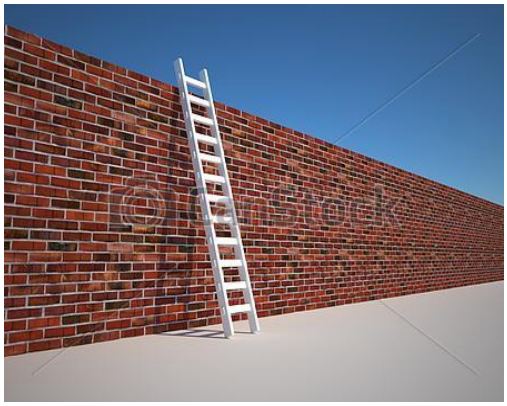
1. **Smaller forces acting on bodes in its sate of neutral equilibrium destabilize the body but they regain the normal position by stabilizing themselves.**

2. **If a body is placed on a surface such that its centre of gravity is neither raised nor lowered, then the body is said to be in neutral equilibrium.**



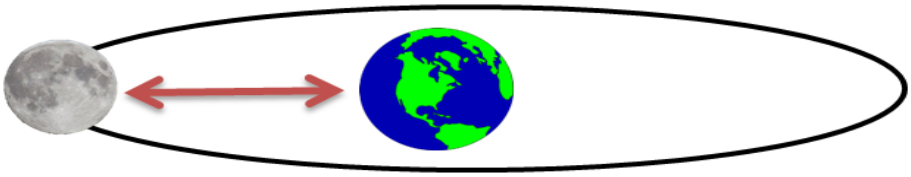


3. **while the smaller forces acting on a body which is in its position of unstable equilibrium destabilizes the body. Hence it loses its balance.**



UNIFORM CIRCULAR MOTION:

When a body moves with a constant speed in a circular path, the motion is said to be Uniform circular motion.



What is Uniform Circular Motion?

When a body or object moves in a circle, it is said to be in a circular motion i.e., we can say that motion in a circle is a circular motion.

When a body or object moves along a circular path, then its direction of motion or direction of speed keeps changing continuously.

Eg:
So, if an athlete moves with a constant speed along a circular path, then the velocity of the athlete will not be constant because velocity is the speed in a specified direction and here the direction of speed changes continuously. Since, the velocity changes with the continuous change in direction, the motion along a circular path is said to be accelerated.

Some more examples of Uniform Circular Motion are:

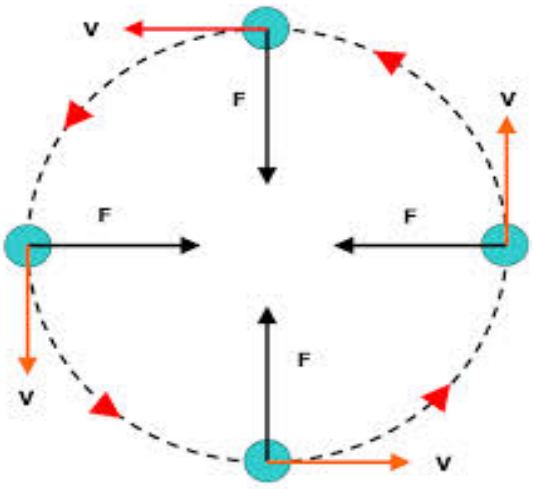
1. Artificial satellites move in uniform motion around the earth. Therefore, the motion of a satellite around the earth is accelerated.

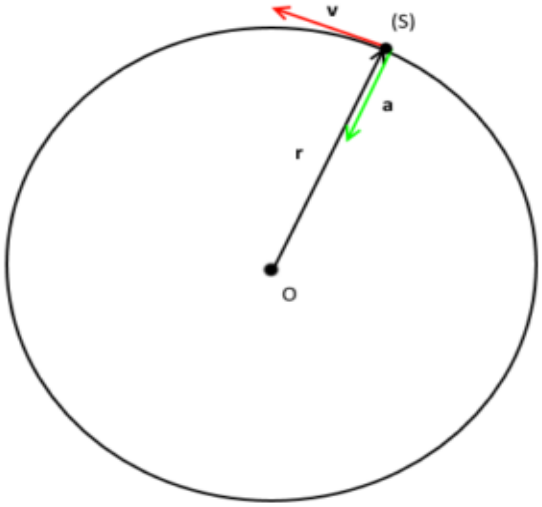
2. The moon moves in a uniform circular motion around the earth. We know that moon is a natural satellite of the earth.

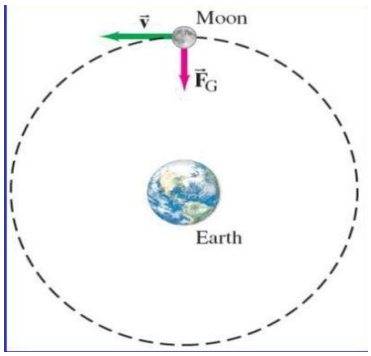
3. Similarly, we can say that movement of earth around the sun is also a uniform circular motion. So, the motion of earth around the sun is accelerated.

4. The tip of a second's hand of a watch exhibits uniform circular motion on the circular dial of the watch.

So, we understood that Force is required to make body move in a circle. And a body or object moves in a circular path with constant speed is uniform circular motion.



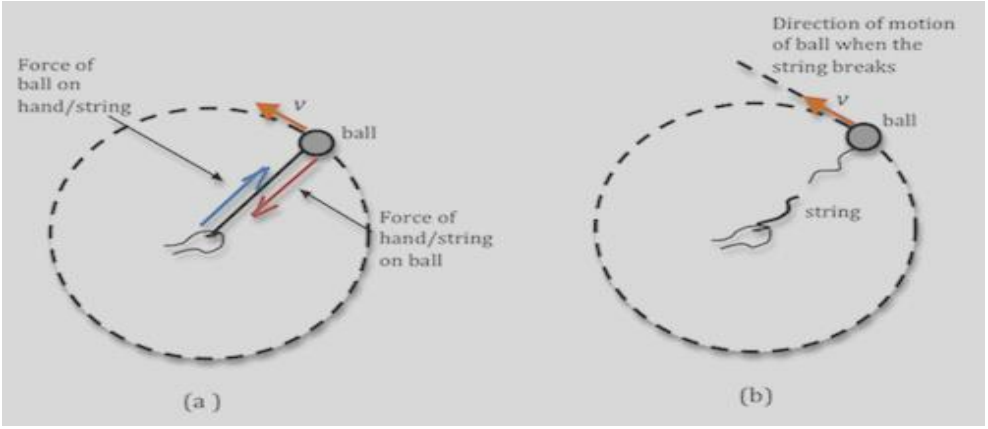




CENTRIPETAL AND CENTRIFUGAL FORCES:

A centripetal force is that by which bodies moving with a uniform speed along a circular path and is directed along the radius towards the centre.

This force is also variable because its direction changes at each point of the circular path. Therefore, for a body moving in a circular path, there must be a force which provides the Centripetal force required for the circular motion.



Eg:

1. **In an atom, an electron moves around the nucleus in a circular path for which the required centripetal force is provided by the electrostatic force of attraction on the negatively charged electrons by the positively charged nucleus.**

2. **A planet moves around the sun in a circular path for which the gravitational force of attraction on the planet by sun provides the necessary centripetal force.**

3. **When a stone tied at the end of a string is whirled in a circular path by holding the free end in the hand, the tension in the string provides the necessary centripetal force.**

CENTRIFUGAL FORCE:

A force assumed to be acting on a body in a direction away from the centre of the circular Path is called as centrifugal force.
The direction of the centrifugal force is opposite to the direction of centripetal force.

In magnitude, centripetal and centrifugal forces are equal.
But centrifugal force is not the reaction force to the centripetal force though both the Forces are equal to each other and act in opposite directions as they are not on the same Body.

CENTRIPETAL FORCE	CENTRIFUGAL FORCE
1.It is always directed radially towards the centre of the circular path.	It is directed radially away from the centre of the circular path.
2. It is associated with external agent.	It is not associated with agent
3. It is a real force in an inertial frame of reference	It is a fictitious force in an internal frame of reference.
4. It is necessary to make a body move in a circular path.	It comes into play in a rotating frame of reference.