Effects of a force acting on an object

(Note: a body = an object)

(i) A force can set a body in motion. For example, if a ball at rest on the floor is pushed, it rolls on the floor.

(ii) A force can stop a moving body. For example, a moving bicycle can be brought to rest by application of brakes.

(iii) A force acting on a body can change the speed of the body. For example, when brakes are applied to a moving bicycle, its speed decreases due to the friction between the brake shoes and the rim of the tyre.

(iv) A force can change the direction of motion of the body. For example, in uniform circular motion of a body, the direction of motion of the body keeps on changing due to the applied force.

(v) A force can change the speed as well as the direction of motion of the body. For example. when a. ball bowled by 4 bowler is hit by a batsman, there occurs a Change in the speed as well as direction of motion of the ball.

(vi) A force can change the shape and size of the body on which it acts. For example, when a rubber ball is pressed, it gets deformed and hence no longer remains spherical. Also that can be a decrease in volume.

Types of forces :

Gravitational force: The gravitational force between the earth and the moon. The gravitational force is a universal force, i.e., it acts between any two objects in the universe.

Electromagnetic force: The force between two charged particles in motion.

Nuclear force: The force between a proton and a neutron in the nucleus of an atom.

Newton's laws of motion:

(1) Newton's first law of motion: An object continues to remain at rest or in a state of uniform motion along a straight line unless an external unbalanced force acts on it.

(2) Newton's second law of motion : The rate of change of momentum is proportional to the applied force and the change of momentum occurs in the direction of the force.

(3) Newton's third law of motion: Every action force has an equal and opposite reaction force which acts simultaneously.

[Note : Equal in magnitude and opposite in direction.]

Thus, a force acts on any object moving along a circle and it is directed towards the centre of the circle, tType equation here.his is called the centripetal force. 'Centripetal' means centre seeking, i.e., the object tries to go towards the centre of the circle because of this force.

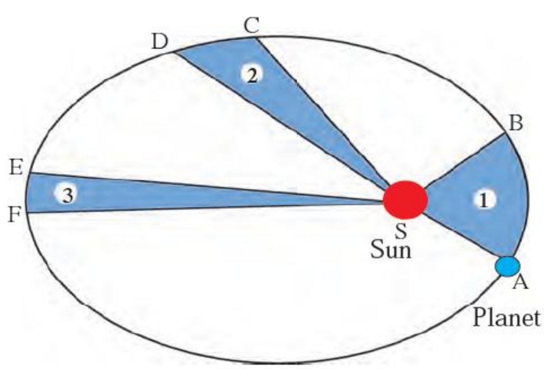
2. Kepler's laws of planetary motion –

(1) The orbit of a planet is an ellipse with the Sun at one of the foci.

(2) The line joining the planet and the Sun sweeps equal areas in equal intervals of time.

(3) The square of the period of revolution of a planet around the Sun is directly proportional to the cube of the mean distance of the planet from the Sun.

$$(period\ of\ revolution)^2 \propto \left(\frac{ab}{2}\right)^3$$



The orbit of a planet moving around the Sun.

3. Newton's universal law of gravitation : Every object in the Universe attracts every other object with a definite force. This force is directly proportional to the product of the masses of the two objects and inversely proportional to the square of the distance between them.

4. The earth's gravitational force: The gravitational force on any object due to the earth is always directed towards the centre of the earth. If the object is on the earth's surface, in the usual notation

$$F = \frac{Gm_1m_2}{r^2}$$

5. The earth's gravitational acceleration : The acceleration produced in a body due to the earth's gravitational force is called the acceleration due to gravity or the earth's gravitational acceleration and its magnitude is denoted by g. It is directed towards the earth's centre.

$$g = \frac{GM}{r^2} \quad \text{for} \quad r \geq R \text{ (radius of the earth).}$$

It depends on the location of the body.

6. Mass : The mass of an object is the amount of matter present in it. Its SI unit is kg.

7. Weight : The weight of an object is defined as the force with which the earth attracts the object. Its magnitude is mg and SI unit is the newton (N).

8. Free fall : Whenever an object moves under the influence of gravity alone, it is said to be falling freely.

For a freely falling object, with u =0 and a =g,

we have $v = gt,\ s = \frac{1}{2}gt^2\ and\ v^2 = 2gs$ (in the usual notation).

For an object thrown upward, as the object moves upward, the direction of acceleration is opposite to that of the velocity. Hence, the acceleration is negative, with a= —g.

9. Gravitational potential energy : The gravitational potential energy of an object at a height h from the earth's surface = $-\frac{GMm}{R+H} = -\frac{mgR^2}{R+h}$

10. Escape velocity - $v_{esc} = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$.

For $u = v_{esc}$ (from the earth's surface), the body overcomes the earth's gravitational attraction. It will then move to infinity and come to rest there.

11. The total energy of a body revolving around the earth =kinetic energy + potential energy

$$= \frac{1}{2}(mv^2) + \left(-\frac{GMm}{R+h}\right)$$

12. Uniform circular motion of a planet around the Sun:

(1) Centripetal force acting on the planet, $\frac{mv^2}{r} =$ gravitational force exerted by the Sun on the planet, $\frac{GMm}{r^2}$

(2) Centripetal acceleration of the planet,

$$a = \frac{v^2}{r} = \frac{\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{4\pi^2\, r}{T^2}$$

(3) The period of revolution of the planet,

$$T = \frac{2\pi r}{v} = \frac{2\pi}{\sqrt{GM}}\, r^{\frac{3}{2}} = \frac{2\pi}{\sqrt{gR^2}}\, r^{\frac{3}{2}}$$

Important Formulae

Newton's first equation of motion is
$v = u + a\,t;$

According to Newton's law

$$F = \frac{G\,m_1 m_2}{r^2}$$

$$\therefore \text{Weight, } W = F = m\,g \quad .... \quad \left(g = \frac{G\,M}{R^2} \right)$$

$$v = g\,t$$

$$s = \frac{1}{2} g\,t^2$$

$$v^2 = 2\,g\,s$$

Newton's second equation of motion gives

$$s = u\,t + \frac{1}{2} a\,t^2$$

Newton's third equation of motion
$v^2 = u^2 + 2\,a\,s$

For an object of mass m

on the surface of earth

A. Kinetic energy $= \frac{1}{2} mv^2_{esc}$

B. Potential energy $= -\frac{GMm}{R}$

C. Total energy $= E_1 =$ Kinetic energy + Potential energy

$$= \frac{1}{2} mv^2_{esc} - \frac{GMm}{R}$$

at infinite distance from the earth

A. Kinetic energy = 0

B. Potential energy $= -\frac{GMm}{\infty} = 0$

C. Total energy $= E_2 =$ Kinetic energy + potential energy
= 0

Escape velocity = $v_{esc} = \sqrt{\frac{2\,GM}{R}}$