WORK POWER AND ENERGY

Work

(i) Whenever a force acting on a body displaces it, work is said to be done by the force.

(ii) The product of force and displacement in the direction of force is known as the work done.

(iii) If a force 'F' acting on the body displaces it by a distance 'S' in the direction of force, then work done is given by

$$W = F.S.$$

(iv) If the force and displacement are in different directions and θ is the angle between them, then the work done is given by

$$W = F.S.\cos\theta$$

(v) If the force and displacement are at right angles to each other, then the work done is zero i.e.,

$$W = F.S.\cos 90° = 0.$$

(vi) If the displacement is zero, then the work done is zero.

(vii) Work done is positive if $\theta < 90°$ and negative if $\theta > 90°$.

(viii) Work done is a scalar quantity therefore it is the dot product of force $\vec{F}$ and displacement $\vec{S}$, i.e.,

$$W = \vec{F}.\vec{S}$$

(ix) If force and displacement both are variable quantities, then the work done is represented by the area under force-displacement graph added with sign.

(x) Work done does not depend on the path followed and time taken.

(xi) Dimensional formula for work is ML^2T^{-2}.

(xii) In SI system unit of work is **Joule**, and in C G S system the units of work is **erg**.

$$1 \text{ joule} = 10^7 \text{ erg}.$$

Joule (J) : It is SI unit of work. If a force of 1 N produces a displacement of 1 m in the direction of force, then the work done is 1 J. i.e.,

$$1 \text{ joule} = 1 \text{ newton} \times 1 \text{ metre}$$

$$1 \text{ J} = 1 \text{ N} \times 1 \text{ m} = 1 \text{ Nm}$$

Also $1 \text{ J} = 10^7$ erg, when erg is the unit of work in C G S system.

Power

(i) Power is defined as the rate of doing work.

(ii) $P = \frac{W}{t} = \frac{FS}{t} = F.v$

(iii) Power is a scalar quantity. It is equal to the dot product of force vector $\vec{F}$ and velocity vector $\vec{v}$. i.e.,

$$P = \vec{F}.\vec{v}$$

(iv) S I unit of power is watt.

Watt (W): It is S I unit of power. If one joule work is done in one second by any agent, then its power is said to be one watt. Hence,

$$1 \text{ watt} = \frac{1 \text{ joule}}{1 \text{ second}}.$$

$$\text{or } 1 \text{ W} = 1 \text{ Js}^{-1}$$

$$\text{Also, } 1 \text{ kilowatt (kW)} = 10^3 \text{ W}$$

$$1 \text{ megawatt (MW)} = 10^6 \text{ W}$$

$$1 \text{ horsepower (HP)} = 746 \text{ W}.$$

Energy

Energy of an object is defined as its capacity for doing work and is measured by the amount of work it can do.

It is a scalar quantity. Its SI unit is joule (J).

Kinetic energy : It is defined as the energy possessed by the object by virtue of its motion and is measured by the amount of work done by the object against an opposing impressed force before it comes to rest.

$$\text{K.E.} = E_K = \frac{1}{2}mv^2$$

where, m = mass of the object

v = velocity of the object.

Potential energy : It is defined as the energy possessed by the object by virtue of its position or condition and is measured by the amount of work done by the object in passing from the present position or condition to some standard position or condition.

$$\text{P.E.} = E_P = mgh$$

where, m = mass of the object

g = acceleration due to gravity

h = height of the object from the surface of the earth

Potential energy may be positive or negative. It is positive if the forces are repulsive in nature and negative if the forces are attractive in nature.

Law of conservation of energy : It states that energy can neither be created nor destroyed but can be transformed from one form to another.

Variation of mass with velocity : Mass of an object moving with a velocity v relative to the observer is given by,

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where, m_0 = mass of the object when it is at rest w.r.t. the observer.

c = speed of the light in vacuum

= $3 \times 10^8\ \text{ms}^{-1}$

Mass-Energy equivalence : According to Einstein's relation, energy associated with a mass 'm' is given by,

$$E = mc^2$$

where, c = speed of light

= $3 \times 10^8\ \text{ms}^{-1}$

Conservative forces : If the amount of work done against a force depends only on the initial and final positions of the body moved, such a force known as conservative force. Gravitational force and electrostatic force are conservative forces, while frictional forces are non-conservative forces.

Collisions

Collision is exchange of energy when two bodies interact each other. A collision also occurs if the path of motion of a particle or a system is affected by the influence of a neighbouring system.

(i) **Elastic collisions :** In these collisions, both kinetic energy and linear momentum of colliding particles are conserved.

(ii) **Inelastic collisions :** In these collisions, kinetic energy of the colliding particles is not conserved, while their linear momentum is conserved. However, total energy of the system is conserved.

Elastic collision in one dimension : Let a particle of mass m_1 moving with velocity u_1 collides with another particle of mass m_2 at rest, then there velocities after collision, in the line of motion of the first particle, are given by,

$$v_1 = \frac{m_1 - m_2}{m_1 + m_2} u_1$$

and $$v_2 = \frac{2m_1}{m_1 + m_2} u_1$$

Special cases

(i) If $m_2 >> m_1$, then $v_1 = -u_1$ and $v_2 = 0$

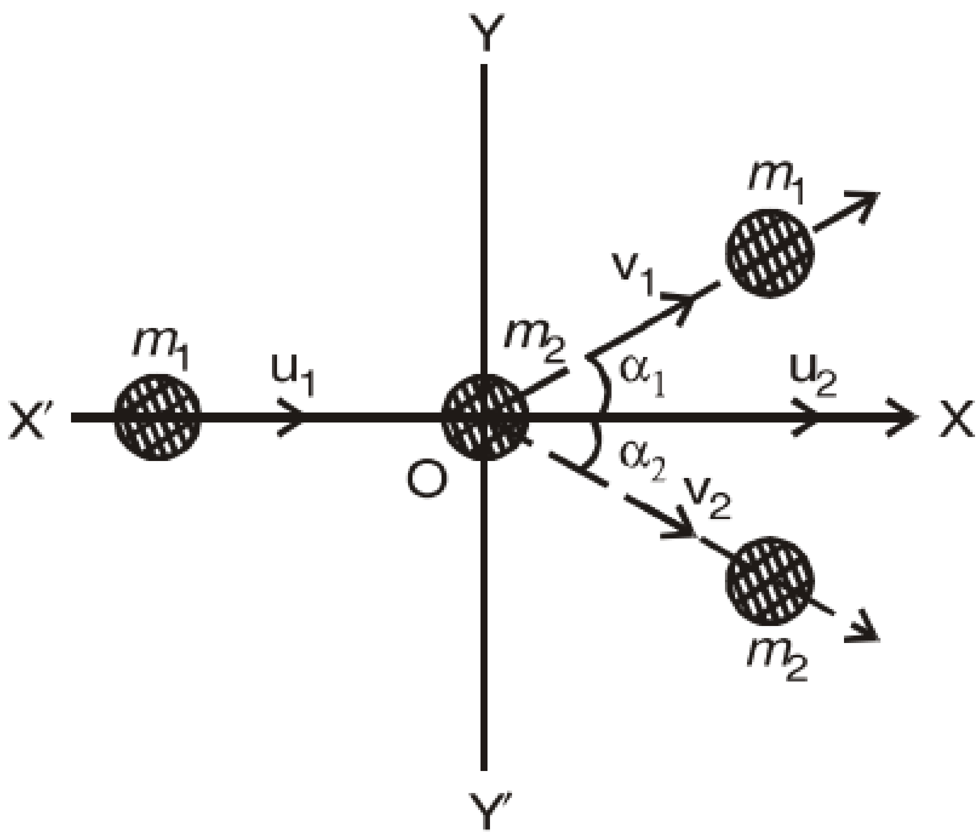
(ii) If $m_1 >> m_2$, then $v_1 = u_1$ and $v_2 = 2u_1$

(iii) If $m_1 = m_2$, then $v_1 = 0$ and $v_2 = u_1$

i.e., if the two particles of nearly comparable masses collide each other, after collision their velocities get interchanged. This principle is made use in collision of elementary particles.

Elastic collision in two dimensions : Let particles of masses m_1 and m_2 moves along x-axis with velocities u_1 and u_2. They are inclined at an angle α_1 and α_2 with x-axis after collision. They move with velocities v_1 and v_2 respectively in these directions. Then

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$



Also momentum along x-axis before collision = momentum along x-axis after collision.

i.e., $m_1u_1 + m_2u_2 = m_1v_1 \cos \alpha_1 + m_2v_2 \cos \alpha_2$

Similarly,

Momentum along y-axis before collision = Momentum after collision along y-axis.

i.e., $0 = m_1v_1 \sin \alpha_1 - m_2v_2 \sin \alpha_2$.