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THE PERFECT GUIDE

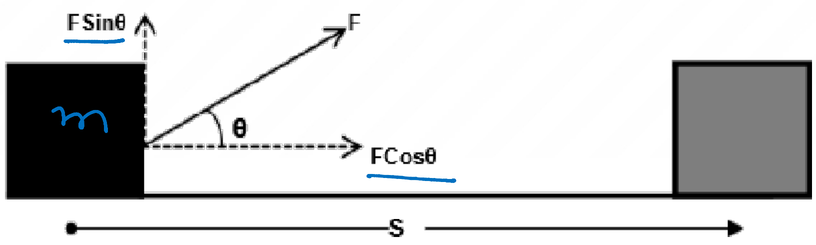
PHYSICS

WORK, ENERGY AND POWER

1) Develop the notions of work and kinetic energy and show that it leads to work – energy theorem.?

A) Work : Work done by the force is the product of component of force in the direction of the displacement and the magnitude of the displacement.

Suppose a constant force $\vec{F}$ acting on a body produces a displacement $\vec{S}$ in the body along the positive x – direction as show in fig.



$W = (F\cos\theta)s$, $\vec{W} = \vec{F}\cdot\vec{S}$

Thus, work done is the dot product of force and displacement. Work is scalar quantity.

$W=0$ $F=0$ $W=0$

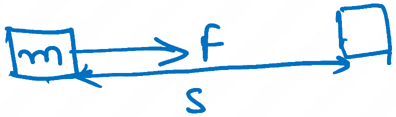
Conditions : Work done is zero if displacement is zero (or) forces is zero (or) force and displacement are mutually perpendicular. $F \perp S$, $W=0$

Kinetic energy : The energy possessed by a body by virtue of its motion is called kinetic energy. $K.E = \frac{1}{2}mv^2$

Work energy theorem : The work done by the resultant force acting on a body is equal to the change in kinetic energy.

$\boxed{W = K_f - K_i}$ (or) $\boxed{W = \Delta K}$

proof



acceleration is constant 'a'

From $v^2 - u^2 = 2as$ ——— (1)

equation (1) Dividing with $\left(\frac{m}{2}\right)$ both sides.

$$\frac{m}{2}(v^2 - u^2) = \left(\frac{m}{2}\right) 2as$$

$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mas$$

$$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = F \cdot s$$ (According Newton II^{nd} $F = ma$)

$K_f - K_i = W$ ($W = F \cdot s$) by work definition)

$\Rightarrow \boxed{W = \Delta K}$

2) State and prove law of conservation of energy in case of a freely falling body.?

A) Statement : " Energy can neither be created nor destroyed. But it can be converted from one form to another form. The total energy of a closed system always remains constant".

This law is called law of conservation of energy.

Proof : In case of freely falling body :

A body of mass 'm' is freely falling at a height 'H' from the ground.

The total mechanical energy of the body E = K.E + P.E

Where K.E = kinetic energy; P.E = Potential energy.

Suppose A, B and C are the points at heights H, h and ground respectively.

(i) At point 'A'

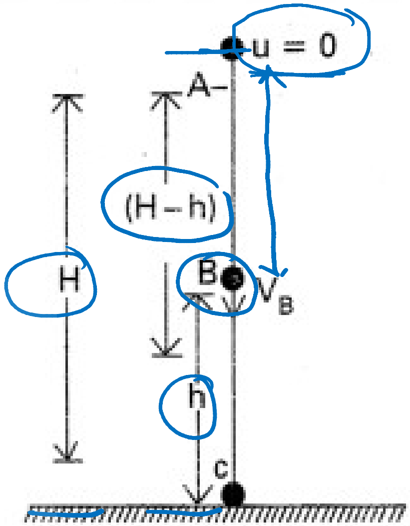
Total Energy at point A, $E_A = K.E + P.E$

$K.E = \frac{1}{2}mu^2$, $u = 0$, $K.E = 0$

$P.E = mgH$

$E_A = 0 + mgH$

$\boxed{\therefore E_A = mgH}$



(ii) At point 'B'

Total Energy B: $E_B = K.E + P.E$

$K.E = \frac{1}{2}mV_B^2$

$V_B^2 - u^2 = 2g(H-h)$

$V_B^2 = 2g(H-h)$

$K.E = \frac{1}{2}m\,2g(H-h)$

$K.E = mg(H-h)$, $P.E = mgh$

$E_B = mg(H-h) + mgh$

$E_B = mgH - \cancel{mgh} + \cancel{mgh}$

$$\boxed{E_B = mgH} \text{ ——— } (2)$$

(ii) At point 'c'

Total Energy at point 'c' $E_c = K.E + P.E$

$$K.E = mgH, \quad P.E = 0$$

$$\therefore E_c = mgH + 0$$

$$\boxed{\therefore E_c = mgH} \text{ ——— } (3)$$

From equation (1), (2) and (3), Total Energy At point A, B and 'c' conserved.

$\therefore$ Hence proved

3) What are collisions ? Explain the possible types of collisions. Develop the theory of one dimensional elastic collision ?

A) Collision : A strong interaction between two bodies which involves exchange of moment is called collision.

Collision are of two types.

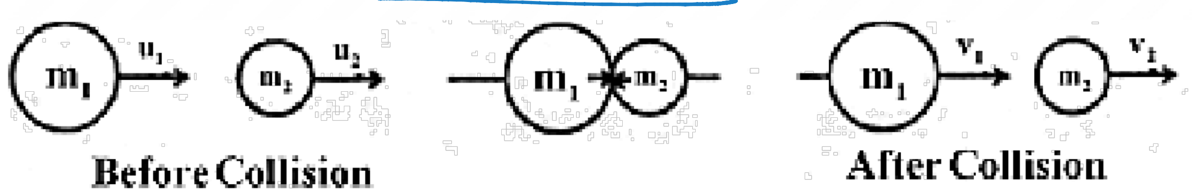
They are (i) Elastic collision and (ii) Inelastic collision.

Elastic Collision : The collision in which both the momentum and kinetic energy of the system remain conserved is called elastic collision.

Inelastic Collision : The collision in which only momentum of the system is conserved but kinetic energy is not conserved is called inelastic collision.

Ex : Collision between cricket bat and ball.

Elastic collision in one dimension : Consider two bodies of masses m_1 and m_2 moving along the same direction with initial velocities u_1 and u_2 respectively. Let $u_1 > u_2$. Let v_1 and v_2 be their final velocities respectively after the collision along their initial direction of motion. Let us assume that it is perfectly elastic collision. So, both momentum and kinetic energy of the system are conserved.



before collision momentum = After collision momentum.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$m_1(u_1 - v_1) = m_2(v_2 - u_2) \quad \text{— (1)}$$

Law of conservation kinetic energy

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

$$\Rightarrow m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2) \quad \text{— (2)}$$

equation (2) Dividing with (1)

$$\frac{\cancel{m_1}(u_1^2 - v_1^2)}{\cancel{m_1}(u_1 - v_1)} = \frac{\cancel{m_2}(v_2^2 - u_2^2)}{\cancel{m_2}(v_2 - u_2)}$$

$$\frac{(u_1 + v_1)\cancel{(u_1 - v_1)}}{\cancel{(u_1 - v_1)}} = \frac{(v_2 + u_2)\cancel{(v_2 - u_2)}}{\cancel{(v_2 - u_2)}}$$

$$u_1 + v_1 = v_2 + u_2$$

$$\Rightarrow (u_1 - u_2) = (v_2 - v_1) \text{ --- } (3)$$

From equation $v_2 = u_1 + v_1 - u_2$ — (4)

equation (4) sub. in equation (1)

$$m_1(u_1 - v_1) = m_2(u_1 + v_1 - u_2 - u_2)$$

$$m_1 u_1 - m_1 v_1 = m_2 u_1 + m_2 v_1 - 2 m_2 u_2$$

$$\Rightarrow v_1(m_1 + m_2) = (m_1 - m_2) u_1 + 2 m_2 u_2$$

$$\boxed{v_1 = \frac{(m_1 - m_2)}{(m_1 + m_2)} u_1 + \frac{(2 m_2)}{(m_1 + m)} u_2}$$

From equation (3) $v_1 = v_2 + u_2 - u_1$ — (5)

equation (5) sub in equation (1)

$$m_1(u_1 - (v_2 + u_2 - u_1)) = m_2(v_2 - u_2)$$

$$\Rightarrow m_1 u_1 - m_1 v_2 - m_1 u_2 + m_1 u_1 = m_2 v_2 - m_2 u_2$$

$$\Rightarrow v_2(m_1 + m_2) = (m_2 - m_1) u_2 + 2 m_1 u_1$$

$$\Rightarrow \boxed{v_2 = \frac{(m_2 - m_1) u_2}{m_1 + m_2} + \frac{2 m_1 u_1}{m_1 + m_2}}$$

4) A machine gun fires 360 bullets per minute and each bullet travels with a velocity of 600 ms^{-1}. If the mass of each bullet is 5 gm, find the power of the machine gun ?

Sol : No. of bullets is (N) = 360, Velocity (V) = 600m/sec

mass (m) = 5gm ⇒ $m = 5 \times 10^{-3}$ kg

$\boxed{P = \frac{W}{t}}$, $P = \frac{N \frac{1}{2} m v^2}{t}$

$P = \frac{\cancel{360}^{36} \times \frac{1}{\cancel{2}} \times 5 \times 10^{-3} \times 600 \times 600}{\cancel{60}}$

$P = 540 \times 10^{-3} \times 10^{4}$

$P = 5400$ watt (or) 5.4kW

$\boxed{P = 5.4\,kW}$

5) A pump is required to lift 600 kg of water per minute from a well 25 m deep and to eject it with a speed of $50\ \mathrm{ms^{-1}}$. Calculate the power required to perform the above task ?

Sol :

mass (m) = 600 kg, h = 25 m, v = 50 m/sec

$$\boxed{P = \frac{mgh + \frac{1}{2}mv^2}{t}}$$

$$P = \frac{600 \times 10 \times 25 + \frac{1}{\cancel{2}} \times \cancel{600}^{300} \times 50 \times 50}{60}$$

$$P = \frac{1,50,000 + 7,50,000}{60} = \frac{\cancel{900000}^{15000}}{\cancel{60}} = 15000\ \text{Watt}$$

or. = 15 kWatt

THANK YOU