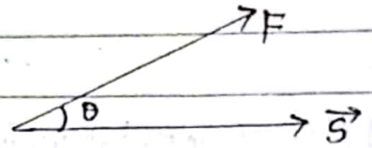
Work:

↳ Work is said to be done by force if body travell by certain distance.



Let S be the certain distance travell by a body by applying force F and also let θ be the angle between F & S. Then;

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

$\therefore \boxed{W = FS\cos\theta}$

★ Special cases

$\boxed{\text{Case I}}$:- When force is applied in the direction of displacement, i.e, $\theta = 0$

Now, $W = FS\cos 0° = FS$

i.e, there is maximum work done.

$\boxed{\text{Case II}}$:- When force is applied perpendicular to the displacement, i.e, $\theta = 90°$

Now, $W = FS\cos 90° = 0$

i.e, there is no workdone.

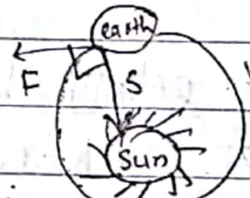


fig: example of no work done.

Work is an scalar quantity. It's SI unit is joule and CGS unit is erg.

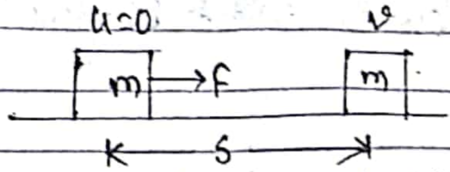
Energy:

↳ The capacity of doing work done is called energy. It is scalar quantity. It's unit is joule and CGS unit is erg.

Kinetic energy:

↳ The energy which is possessed by body at motion is called kinetic energy.

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



Let us consider a body of mass 'm' which is initially at rest. After applying force F its travells to distance S and final velocity becomes v. Then, work done on body;

$W = Fs$

Since, $F = ma$

$\therefore W = mas$ ---(i)

From eqn of motion,

$v^2 = u^2 + 2as$

$v^2 = 2as$ $[\because u = 0\ ms^{-1}]$

$\Rightarrow as = \frac{v^2}{2}$ ---(ii)

Using eqn (ii) in eqn (i)

$W = \frac{1}{2}mv^2$

This work done is stored in the form of K.E.

$\therefore \boxed{K.E. = \frac{1}{2}mv^2}$ #

Relation between K.E. & momentum:

We have,

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

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

Since, $p = mv$

$\therefore \boxed{K.E. = \frac{p^2}{2m}}$ This is required equation between K.E. and momentum.

SQ[1A] How does K.E. Change when momentum is double?

Soln:-

We have, $K.E._1 = \frac{p^2}{2m}$

If $p = 2p$

Then,

$K.E._2 = \frac{(2p)^2}{2m} = 4\frac{p^2}{2m} = 4\ K.E._1$

Thus, when p is double then K.E. is increase with 4 times.

SQ.[1B] How does K.E. change when momentum is half?

Soln:-

We have, $K.E._1 = \frac{p^2}{2m}$

If $p = p/2$

Then,

$K.E._2 = \frac{(p/2)^2}{2m} = \frac{p^2}{4} \times \frac{1}{2m} = \frac{1}{4}\frac{p^2}{2m} = \frac{1}{4} K.E._1$

Thus, When p is half then K.E. Increase with 1/4 times.

SQ.[1C] "The earth moving round the sun in an orbit is acted upon by a force, hence the work must be done on the earth by this force." Do you agree with this statement?

→ No, I'm not agree. When earth moving round the sun in an orbit, while upon by a force, there is angle between sun and distance (of sun to earth) and applied force is equal to zero or $\perp^r$ to each other. So ther is no work done.

LQ[2A] A bullet of mass 10 g is fired from a gun of mass 1 kg with a velocity of 100 ms^{-1}. Calculate the ratio of the kinetic energy of the bullet & the gun.

Soln

Let, mass of bullet $(m_b) = 10\ g = \frac{10}{1000}\ kg = 0.01\ kg$

" " gun $(m_g) = 1\ kg$

Velocity of bullet $(V_b) = 100\ ms^{-1}$, velocity of gun $(V_g) = ?$

K.E. of " $(K.E_1) = ?$

" of gun $(K.E._2) = ?$ And ratio between KE_1 & $KE_2 = ?$

Now, we have, $m_g u_g + m_b u_b = m_g V_g + m_b V_b$

or, $0 = 1 \times V_g + 0.01 \times 100$

$\Rightarrow V_g = -1\ ms^{-1}$

Now,

$$\frac{K.E._1}{K.E_2} = \frac{\frac{1}{2} m_b V_b^2}{\frac{1}{2} m_g V_g^2} = \frac{0.01 (100)^2}{1 (-1)^2} = \frac{100}{1} = 100 : 1$$

Thus, ratio of the K.E. of bullet and gun is 100 : 1. #

LQ[2B] A stationary mass explodes into two parts of mass 4 units and 40 units respectively. If the larger mass has an initial K.E. = 100 J. What is the initial K.E. of the smaller mass?

Let, mass of big part $(m_2) = 4$ unit and smaller part $(m_1) = 40$ unit.

and K.E. of smaller part $(K.E_1) = ?$ and bigger part $(K.E._2) = 100\ J$.

Now, we have,

$$\frac{K.E._1}{K.E_2} = \frac{P^2/2m_1}{P^2/2m_2} = \frac{m_2}{m_1}$$

or, $\frac{K.E_1}{100} = \frac{40}{4} = 10$

$\Rightarrow K.E._1 = 1000$ Joule

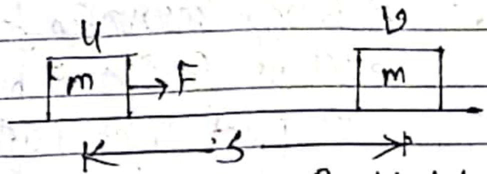
Thus, K.E. of smaller mass = 1000 Joule #

Work energy Theorem — (Work done by constant force)

↳ It State that, "Workdone on a body is equal to change in Kinetic energy".

i.e, Work done = Change in K.E.

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



Let us consider a body of mass is moving with initial velocity 'u'. When force 'F' is applied then the body travell distance 'S' with final velocity 'v' then work done on body is given by;

$W = Fs$

Since, $F = ma$

$\therefore W = mas$

From eqn of motion

$v^2 = u^2 + 2as$

$$as = \frac{v^2 - u^2}{2} \quad \text{——(ii)}$$

Using eqn(ii) in eqn(i)

$$W = m\left[\frac{v^2 - u^2}{2}\right]$$

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

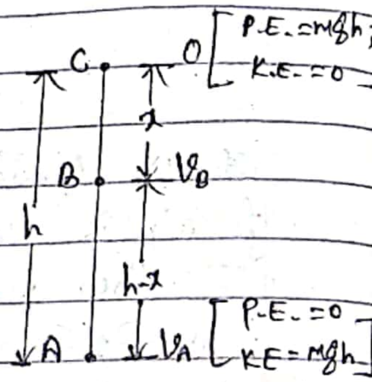
i.e, Work done = Change in K.E. which proves work energy theorem.

Principle of Conservation of energy:-

↳ It state that, "Energy can be neither created nor destroyed but it can be change one form to another form."

☆ Energy Conservation for a freely falling body:-

↳ Let us Consider a body having mass 'm' is at rest at point C at height 'h' from the ground. Suppose body falls down and B be the any point at depth 'x' from C and A be any point on the ground.



At point C:

K.E.=0, P.E.=mgh

Total energy = K.E.+PE
$= mgh$ —(i)

At point B:

Let V_B be the velocity of body,
then, $KE = \frac{1}{2} m V_B^2$

Using eqn of motion along CB;

$V_B^2 = 0 + 2gx = 2gx$

$\therefore KE = \frac{1}{2} m \cdot 2gx = mgx$

& $P.E. = mg(h-x)$

Total energy = K.E.+P.E.
$= mgx + mg(h-x)$
$= mgx + mgh - mgx$
$= mgh$ —(ii)

At point A:

Let V_A be the velocity of body.
Then, $KE = \frac{1}{2} m V_A^2$

Using eqn of motion along CA

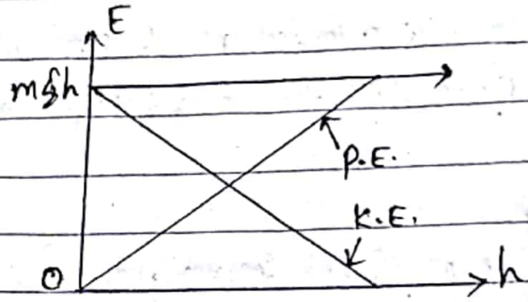
$V_A^2 = 0 + 2gh = 2gh$

$\therefore KE = \frac{1}{2} m \cdot 2gh = mgh$

P.E.=0

Total energy = K.E.+P.E. = mgh

eqn (i), (ii), (iii) shows that total energy remains constant at every point when body fall freely gravity. which verifies principle of conservation of gravity.



[fig: Variation of K.E. and P.E. at different point in the path.]

Conservative & non-Conservative force:-

↳ A force is said to be conservative if work done by it doesn't depends upon distance but depends upon displacement.

↳ A force is said to be non-conservative if work done by it doesn't depend upon displacement but depends upon distance.

[e.g.] Here gravitational force, electrostatic force, Magnetic force are conservative forces. and frictional force, mechanical force are non-conservative forces etc.

power:

↳ the rate of doing work is called power.

i.e, $\text{power} = \dfrac{\text{work}}{\text{time}} = \dfrac{W}{t}$

or, $P = \dfrac{\vec{F}.\vec{S}}{t}$

$\therefore P = \vec{F}.\vec{v} \quad [\because v = \dfrac{\vec{S}}{t}]$

If θ be the angle between $\vec{F}$ & $\vec{v}$, Then;

$P = FV\cos\theta$

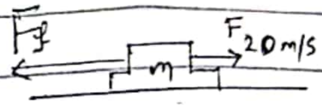
If $\vec{F}$ & $\vec{v}$ are in same direction (i.e, $\theta = 0°$)

$\therefore \boxed{P = F.V}$

Tips: 1 KW = 1000 W

Q.3[A] A car of mass 1000 kg moves at a constant speed of $20\ ms^{-1}$ along a horizontal road where frictional force is 200 N. Calculate the power developed by the engine.

★ We have,



$F = ma + F_f$

Since, $a = 0$ i.e, moving with constant speed;

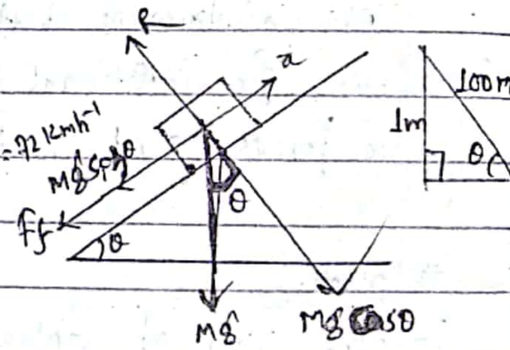
$\therefore F = F_f = 200\ N$

And, $P = F \cdot v = 200 \times 20 = 4000\ W$

Thus, the power developed by the engine is 4000 W. #

Q.3[B] A train of mass 2×10^5 kg moves at a constant speed of $72\ kmh^{-1}$ up a straight inclined against a frictional force of 1.28×10^4 N. The incline is such that the train rises vertically 1.0 m for every 100 m travelled along the incline. Calculate the necessary power developed by the ~~engine~~ train.

★ Soln: Given;



$m = 2 \times 10^5$ kg, $\sin\theta = \frac{1}{100} = 10^{-2}$, $g = 10\ ms^{-2}$;

$F_f = 1.28 \times 10^4\ N$

velocity (v) $= 72\ kmh^{-1} = \frac{72 \times 1000}{60 \times 60} = 20\ ms^{-1}$

Now, we have, $F = mg\sin\theta + F_f$

$= 2 \times 10^6 \times 10^{-2} + 1.28 \times 10^4$

$= 2 \times 10^4 + 1.28 \times 10^4$

$\therefore F = 3.28 \times 10^4\ N$

Again; $P = F \cdot v$

$= 3.28 \times 10^4 \times 20$

$= 65.6 \times 10^4$

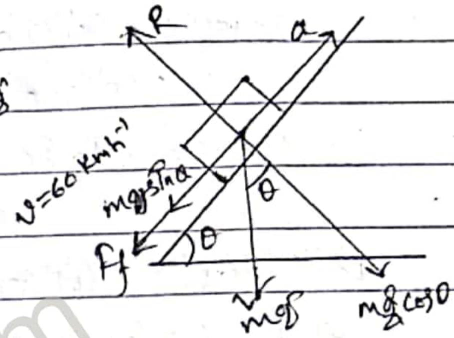
$= 656 \times 10^3\ W$

$= 656\ kW$

Thus, 656 kW power is developed by the train.

Q.3[c] Find the power of an engine in kilowatts which pulls a train of mass 600 tonnes up an incline of 1 in 100 at the rate of 60 kmh^{-1}. The weight of the engine is 200 tonnes and the resistance due to friction is 50 Newton's per tonne.

☆ Soln:- Given



$m = 6000$ tonnes $+ 200$ tonnes $= 800$ tonnes $= 800 \times 1000\ kg = 800000\ kg$

$F_f = (800 \times 50)N = 40000N$

$\sin\theta = \frac{1}{100}$, $g = 10\ ms^{-2}$

$V = 60\ kmh^{-1} = \frac{60 \times 1000}{60 \times 60} = \frac{100}{6}\ ms^{-1}$

Now, we have, $F = mg\sin\theta + F_f$

$= 800000 \times 10 \times \frac{1}{100} + 40000N$

$= 120000\ N$

Now, $P = F.V$

$= 120000 \times \frac{100}{6}$

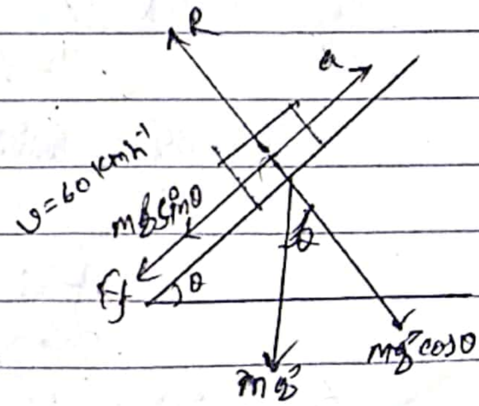
$= 2000000\ W$

$\therefore P = 2000\ KW$

Hence, the power of the engine is 2000 KW. #

Q.3[D] A 650 KW power engine of a vechile of mass $1.5 \times 10^5\ Kg$ is rising on an inclined plane of inclination 1 in 100 with a constant speed of 60 kmh^{-1}. Find the frictional force between the wheels of the vechile and the plane.

☆ Soln: Given;



$P = 650\ KW = 650000\ W$, $\sin\theta = \frac{1}{100}$, $m = 1.5 \times 10^5\ kg$

$V = 60\ kmh^{-1} = \frac{60 \times 1000}{60 \times 60} = \frac{100}{6}\ ms^{-1}$, $g = 10\ ms^{-2}$

Now; we have, $F = mg\sin\theta + F_f$

or, $F = 1.5 \times 10^5 \times 10 \times \frac{1}{100} + F_f$

Since, $F = \frac{P}{v} = \frac{650000}{\frac{100}{6}} = 39000\ N$

$\therefore 39000 = 1.5 \times 10^4 + F_f$

$\Rightarrow F_f = 24000\ N$ #

Hence, the frictional force between plane is 24000 N.

Collision:-

[1] Elastic Collision:

↳ A collision is said to be elastic if momentum and K.E. are conserved during collision.

Example: Collision between atomic or sub-automic particles
Collision between gas molecules etc.

In the elastic collision the nature of force is conserved.

[2] Inelastic Collision

↳ A collision is said to be inelastic if K.E. is non-conserved but momentum is conserved during collision.

example:- Collision between cars
mud thrown in wall etc

In the inelastic collision the nature of force is non conserved.

Elastic Collision in one dimension :-

Imp

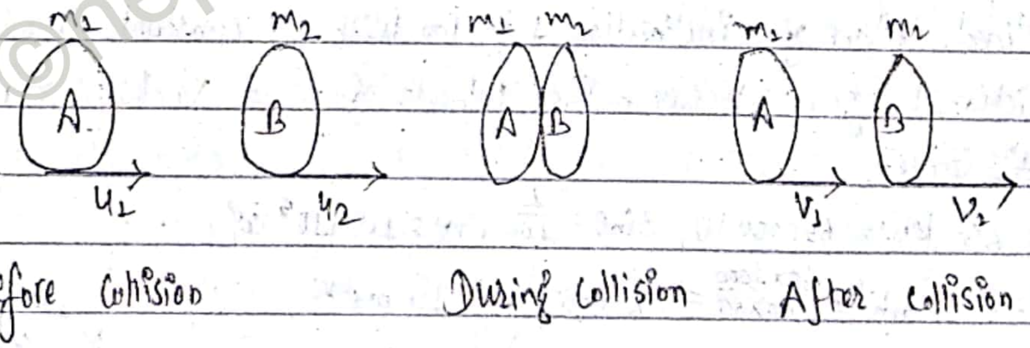


fig: Elastic collision between two bodies.

Since, in elastic collision momentum is conserved;

i.e., $m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$ —— eqn (i)

or, $m_1 (u_1 - v_1) = m_2 (v_2 - u_2)$ —— eqn (ii)

Also, In elastic Collision K.E. is Conserved;

$$\frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$$

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

Dividing eqn (iii) by eqn (ii), we get;

$$u_1 + v_1 = v_2 + u_2$$

Or, $u_1 - u_2 = v_2 - v_1$ ——— (iv)

equation (iv) shows that relative velocity of approach $(u_1 - u_2)$ before collision is equal to relative velocity of separation $(v_2 - v_1)$ after collision.

From eqn (iv),

$$v_2 = u_1 - u_2 + v_1$$

Using value of v_2 in eqn (i)

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

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

Or, $(m_1 - m_2) u_1 + 2 m_2 u_2 = (m_1 + m_2) v_1$

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

Also, from eqn (iv), $v_1 = v_2 - u_1 + u_2$

Using value of v_1 in eqn (i);

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

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

Or, $2 m_1 u_1 + (m_2 - m_1) u_2 = (m_1 + m_2) v_2$

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

Special cases:

$\boxed{\text{Case A}}$: When, $m_1 = m_2$ then, eqn (v) & (vi) becomes,

$$v_1 = u_2 \quad \& \quad v_2 = u_1$$

i.e, If two bodies of equal masses suffers elastic collision then after the collision they will interchange their velocities.

$\boxed{\text{Case B}}$: When, $u_2 = 0$ [i.e, 2nd body at rest]

Then eqn (v) & (vi) becomes;

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) u_1 \quad \text{—— (vii)}$$

$$v_2 = \frac{2m_1u_1}{m_1 + m_2} \quad \text{—— (viii)}$$

(i) When, $m_1 >> m_2$, then eqn (vii) & (viii) becomes,

$$v_1 = u_1 \ \& \ v_2 = 2u_1$$

i.e, velocity of heavier body is same of its initial velocity but after lighter body aquireds a velocity which is double the initial velocity of heavier body.

(ii) When, $m_1 << m_2$ then eqn (vii) & (viii) becomes,

$$v_1 = -u_1 \quad \& \quad v_2 = 0$$

i.e, the velocity of lighter body is reversed & velocity of heavier body is zero.

Q. [4(A)] A 0.15 kg glider is moving to the right on a frictionless horizontal air track with a speed of 0.80 ms^{-1}. It has a head on Collision with a 0.300 kg glider that is moving to the left with a speed of 2.2 ms^{-1}. Find the final velocity [magnitude & direction] of each glider if the Collision is elastic.

Soln:- Given;

$m_1 = 0.15$ kg $u_1 = 0.8\ ms^{-1}$ $v_1 = ?$

$m_2 = 0.3$ kg $u_2 = -2.2\ ms^{-1}$ $v_2 = ?$

We have,

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

or, $(0.15)(0.8) + (0.3)(-2.2) = (0.15)v_1 + (0.3)v_2$

or, $(0.15)v_1 + (0.3)v_2 = -0.54$ ---- eqn (i)

here, Also, $u_1 - u_2 = v_2 - v_1$

Or, $0.8 + 2.2 = v_2 - v_1$

Or, $v_2 = 3 + v_1$ —— (ii)

putting the value of v_2 in eqn (i)

Or, $(0.15)v_1 + (0.3)(3 + v_1) = -0.54$

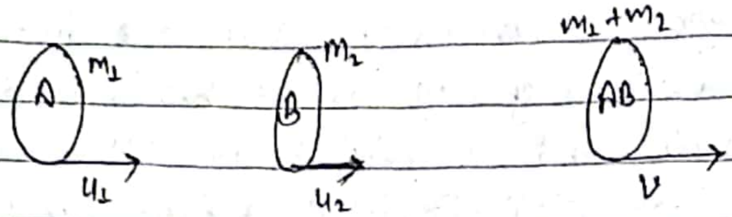
Or, $0.45 v_1 + 0.9 = -0.54$

or, $v_1 = \frac{-1.44}{0.45} = -3.2\ ms^{-1}$

$\therefore \boxed{v_1 = 3.2\ ms^{-1}}$ #

& $\boxed{v_2 = 3 + 3.2 = 0.2\ ms^{-1}}$ #

Inelastic Collision in one dimension:-



Before collision   After Collision

fig: Inelastic Collision between two bodies

Since, In inelastic Collision momentum is Conserved,

$m_1u_1 + m_2u_2 = (m_1+m_2)v$ —— (i) which is known as momentum eqⁿ.

If 2nd body is at rest (i.e., $u_2 = 0$)

$m_1u_1 = (m_1+m_2)v$

$v = \left(\frac{m_1}{m_1+m_2}\right)u_1$ —— (ii)

Also, K.E. before Collision be,

$E_1 = \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2$

$\therefore E_1 = \frac{1}{2}m_1u_1^2$ —— (iii) $[\because u_2 = 0]$

And, K.E. ~~before~~ after Collision,

$E_2 = \frac{1}{2}(m_1+m_2)v^2$

$= \frac{1}{2}(m_1+m_2)\left(\frac{m_1}{m_1+m_2}\right)^2 u_1^2$ [∵ using

$\therefore E_2 = \frac{1}{2}\cdot\frac{m_1^2 \times u_1^2}{m_1+m_2}$ —— (iv)

Dividing eqⁿ (iv) by (iii)

$\frac{E_2}{E_1} = \frac{1}{\cancel{2}} \times \frac{m_1^2 \times u_1^2}{m_1+m_2} \times \frac{\cancel{2}}{m_1u_1^2} = \frac{m_1}{m_1+m_2}$ —— (v) which is known as energy eqⁿ.

or, $(m_1+m_2)E_2 = m_1E_1$

$\Rightarrow E_1 > E_2$

$\Rightarrow$ Initial K.E. > Final K.E.

Hence, there is loss of energy during inelastic collision.

Q.5[A] A ball of mass 4 kg moving with a velocity 10 ms^{-1} Collides with another body of mass 16 kg moving with 4 ms^{-1} from the opposite direction and then Coalesces into a single body. Compute the loss of energy on impact.

Soln: $m_1 = 4$ kg, $u_1 = 10\ ms^{-1}$, Common velocity (v) = ?
$m_2 = 16$ kg, $u_2 = -4\ ms^{-1}$, loss of energy $(E_1 - E_2)$ = ?

Now, We have,
$$m_1u_1 + m_2u_2 = (m_1+m_2)v$$
or, $$4(10) + 16(-4) = (4+16)v$$
$$\Rightarrow v = -1.2\ ms^{-1}$$

Here,
$$E_1 = \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2$$
$$= \frac{1}{2}4(10)^2 + \frac{1}{2}(16)(-4)^2$$
$$\Rightarrow E_1 = 328\ J$$

And, $$E_2 = \frac{1}{2}(m_1+m_2)v^2$$
$$= \frac{1}{2}(4+16)(-1.2)^2$$
$$\Rightarrow E_2 = 14.4\ J$$

Again,
$\therefore$ Loss of energy during Collision = $E_1 - E_2 = (328 - 14.4)J = 313.6\ J$ #

Q.5[B] A ball A of mass 0.1 kg moving with a velocity of 6 ms^{-1} Collides directly with a ball B of mass 0.2 kg at rest. Calculate their common velocity if both balls move off together. If ball A had rebounded with a velocity of 2 ms^{-1} in the opposite direction after Collision, What would be the new velocity of B?

Soln: $m_1 = 0.1$ kg, $u_1 = 6\ ms^{-1}$, $m_2 = 0.2$ kg, $u_2 = 0\ ms^{-1}$, $v = ?$, $v_1 = -2\ ms^{-1}$, $v_2 = ?$

Now, We have, $m_1u_1 + m_2u_2 = (m_1+m_2)v$
or, $(0.1)(6) + (0.2)(0) = (0.1+0.2)v$
$\Rightarrow v = 2\ ms^{-1}$

Again, $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
or, $(0.1)(6) + (0.2)(0) = (0.1)(-2) + (0.2)v_2$
$\Rightarrow v_2 = 4\ ms^{-1}$

Thus Common Velocity is 2 ms^{-1} and new Velocity of B is 4 ms^{-1} #

[Imp]

Q. 6[A] A bullet of mass 20g. travelling horizontally at $100\,ms^{-1}$ embends itself in the centre of a block of wood mass 1 kg. which is suspended by light vertical string 1 m. in length. Calculate the maximum inclination of the string to the vertical.

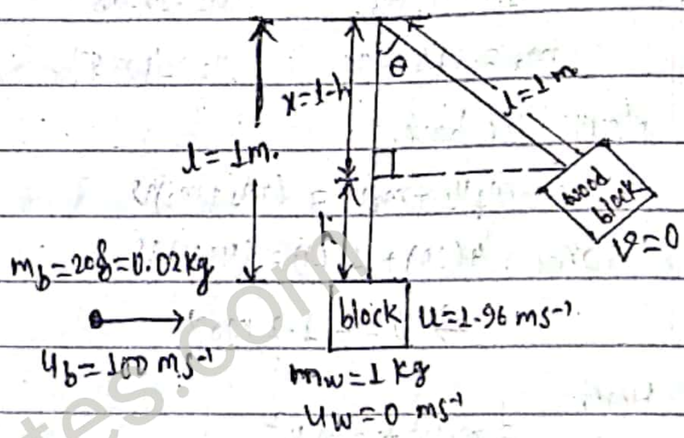
☆ Solution:- Let, bullet = b & wooden block = W &,

We have,

$m_b u_b + m_w u_w = (m_b + m_w)u$

or, $(0.02)(100) + (1)(0) = (0.02+1)u$

$\Rightarrow u = 1.96\ ms^{-1}$



Here,

$v^2 = u^2 - 2gh$

or, $0^2 = (1.96)^2 - 2(10)h$

$\Rightarrow h = 0.19\ m$

and $x = l - h = (1 - 0.19)m = 0.81\,m$

Again, $\cos\theta = \frac{x}{l} = \frac{0.81}{1} = 0.81$

$\Rightarrow \boxed{\theta = 35.9°}$ Thus, maximum inclination of the string is 35.9°.#

Q. 7[A] A water reservoir tank of capacity $250\,m^3$ is situated at a height of 20m from the water level. What will be the power of an electric motor to be used to fill the tank in 3 hours? Efficiency of motor is 70%.

[Imp]

☆ Soln. $v = 250\,m^3$, $h = 20m$, $t = 3$ hours $= 3 \times 60 \times 60$ Sec $= 10800\,s$., density of water $= 1000\,kg\,m^{-3}$

We have,

Energy $= mgh = V.\rho.gh$

$= 250 \times 1000 \times 10 \times 20$

$\Rightarrow E = 50000000\ J$

And, $P_{out} = \frac{E}{t} = \frac{50000000}{10800} = 4629.62963$ Watt

Again, We know,

$\eta\% = \frac{P_{out}}{P_{in}} \times 100\%$

or, $70\% = \frac{4629.62963}{P_{in}} \times 100\%$

or, $P_{in} = \frac{462962.963}{70}$

$\Rightarrow P_{in} = 6614$ watt

Hence, 6614 watt power is needed to fill the tank by the electric motor.

Q.8[A] The Constant force resisting the motion of a car of mass 1500 kg is equal to one fifteenth of its weight if, when travelling at 48 kmh⁻¹, the car is brought to rest in a distance of 50 m by applying the brakes, find the additional retarding force due to the brakes (assumed constant) and heat developed in the brakes.

Solution:-

$v = 0\ ms^{-1}$, $u = 48\ kmh^{-1} = 13.33\ ms^{-1}$, $s = 50\ m$, $a = ?$

$m = 1500\ kg$, $W = mg = 1500 \times 10 = 15000\ N$, $f_f = \frac{W}{15} = \frac{15000}{15} = 1000\ N$

We have, $v^2 = u^2 + 2as$

or, $0^2 = (13.33)^2 + 2a(50)$

$\Rightarrow \boxed{a = -1.78\ ms^{-2}}$

Then, we have, $F = ma + f_f$

or, $F = 1500(-1.78) + 1000$

$\therefore \boxed{F = -1666.67\ N}$

Again, Heat developed = work done

$= F \times s$

$= 1666.67 \times 50$

$\therefore \boxed{\text{Heat} = 83333.5\ J}$

Thus, retardation force is 1666.67 N.# and 83333.5 J heat developed in the brakes.#