DPP – 3 (COM)

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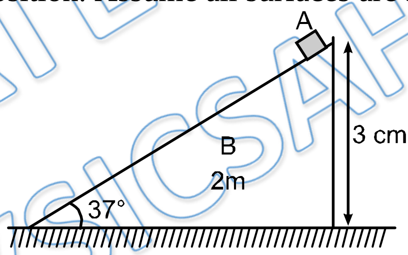
Q 1. A man of mass M stands at one end of a plank of length L which lies at rest on a frictionless surface. The man walks to the other end of the plank. If the mass of plank is M/3, the distance that the plank moves relative to the ground is:
(a) 3L/4 (b) L/4 (c) 4L/5 (d) L/3

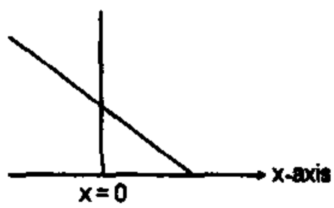
Q 2. The motion of the centre of mass of a system of two particles is unaffected by their internal forces:
(a) irrespective of the actual directions of the internal forces
(b) only if they are along the line joining the particles
(c) only if they are at right angles to the line joining the particles
(d) only if they are obliquely inclined to the line joining the particles.

Q 3. A particle A of mass m is situated at highest point of wedge B of mass 2 m is released from rest. Then distance travelled by wedge B (With respect to ground) when particle A reaches at lowest position. Assume all surfaces are smooth.



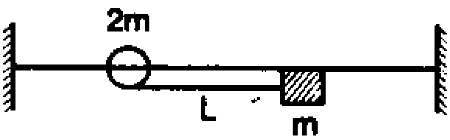
(a) 4/3cm (b) 8/3 cm (c) 2/3 cm (d) none of these

Q 4. A uniform rod of length! is kept vertically on a rough horizontal surface at x =0. It is rotated slightly and released. When the rod finally falls on the horizontal surface, the lower end will remain at:



(a) x = $l/2$ (b) x > $l/2$ (c) x < $l/2$ (d) x = 0

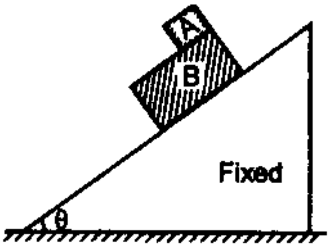
Q 5. A bead can slide on a smooth straight wire and a particle of mass m is attached to the bead by a light string of length L. The particle is held in contact with the wire with the string taut and is then let fall. If the bead has mass 2 m. Then, when the string makes an angle θ with the wire the bead will have slipped a distance:



(a) L(1 – cos θ) (b) $\frac{L}{2}(1 - \cos\theta)$

(c) $\frac{L}{3}(1 - \cos\theta)$ (d) $\frac{L}{6}(1 - \cos\theta)$

Q 6. A block A slides over another block B which is placed over a smooth inclined plane as shown in figure. The coefficient of friction between the two blocks A and B is μ. Mass of block B is two times the mass of block A. The acceleration of the centre of mass of two blocks is:



(a) g sin θ (b) $\frac{g\sin\theta - \mu g\cos\theta}{3}$

(c) $\frac{g\sin\theta}{3}$ (d) $\frac{2g\sin\theta - \mu g\cos\theta}{3}$

Q 7. Velocity of centre of mass of two particles is v and the sum of the masses of two particles is m. Kinetic energy of the system:

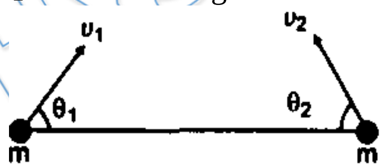
(a) will be equal to $1/2\ mv^2$

(b) will always be less than $1/2\ mv^2$

(c) will be greater than or equal to $1/2\ mv^2$

(d) will always be greater than $1/2\ mv^2$

Q 8. Two particles of equal mass m are projected from the ground with speeds v_1 and v_2 at angles θ_1 and θ_2 as shown in figure. The centre of mass of the two particles:



(a) will move in a parabolic path for any values of v_1, v_2, θ_1 and θ_2

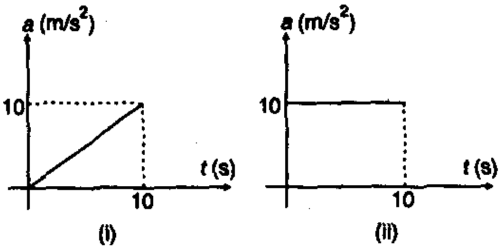
(b) can move in a vertical line

(c) can move in a horizontal line

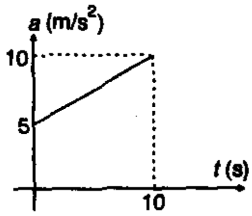
(d) will move in a straight line for any values of v_1, v_2, θ_1 and θ_2

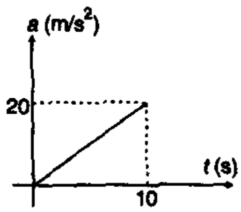
COMPREHENSION

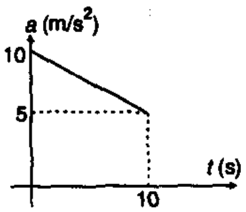
Acceleration of two Identical particles moving in a straight line are as shown in figure.

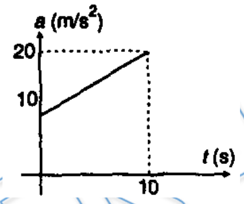


Q 9. The corresponding a-t graph of their centre of mass will be:

(a)


(b)


(c)


(d)


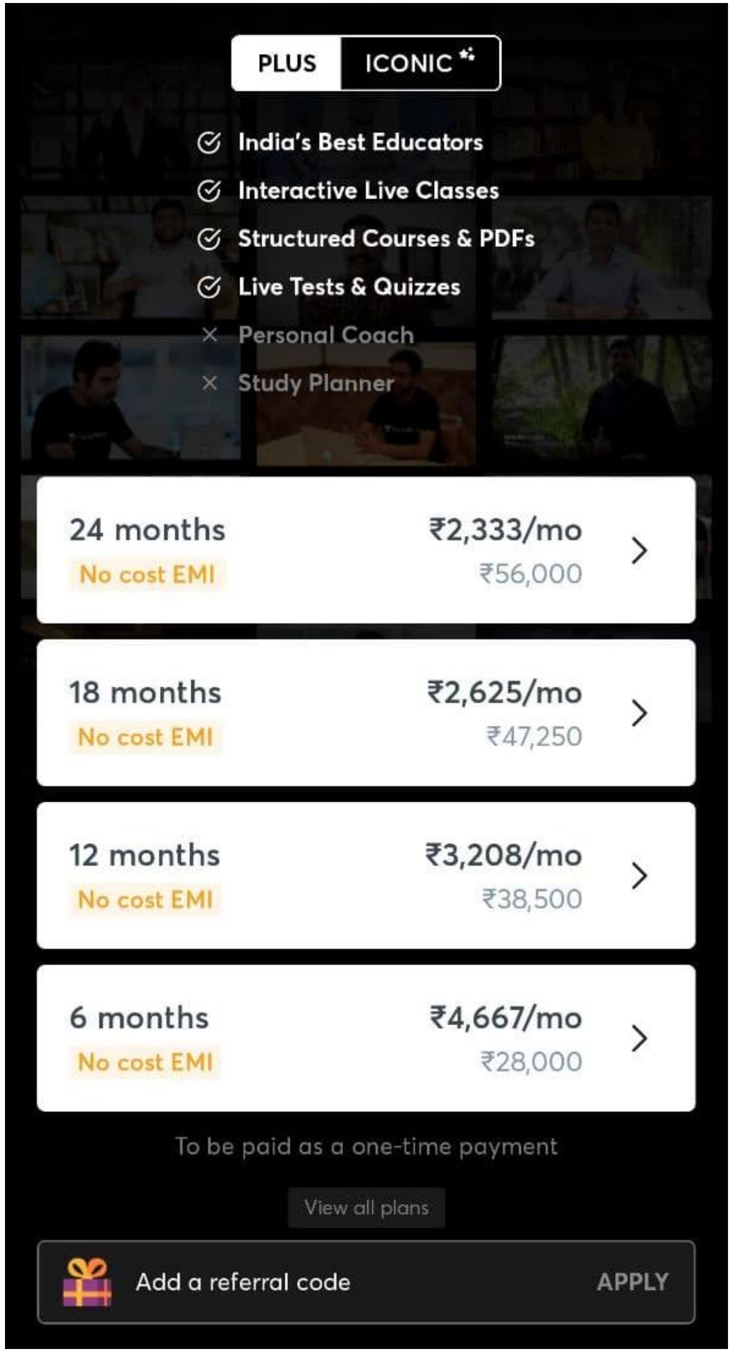
Q 10. If initial velocity of both the particles was zero. Then velocity of their centre of mass after 10 s will be:
(a) 40 m/s (b) 60 m/s (c) 75 m/s (d) 120 m/s

Q 11. Two particles A and B which are initially at rest move towards each other under the mutual force of attraction. At the instant when the speed of A is v and the speed of B is 2v. the speed of the centre of mass of the system is -
(a) v (b) 1.5v
(c) 3v (d) zero

Q 12. Mark the correct statement
(a) Momentum of system w.r.t. COM of system is always zero.
(b) Net force on system w.r.t. COM of system is always zero.
(c) Among all possible frames kinetic energy of a system has minimum magnitude from COM frame.
(d) Among all possible frames kinetic energy of a system has maximum magnitude from COM frame.

Answer Key

Q.1 a	Q.2 a	Q.3 a	Q.4 c	Q.5 c
Q.6 a	Q.7 c	Q.8 b	Q.9 a	Q.10 c
Q.11 d	Q.12 a, c			



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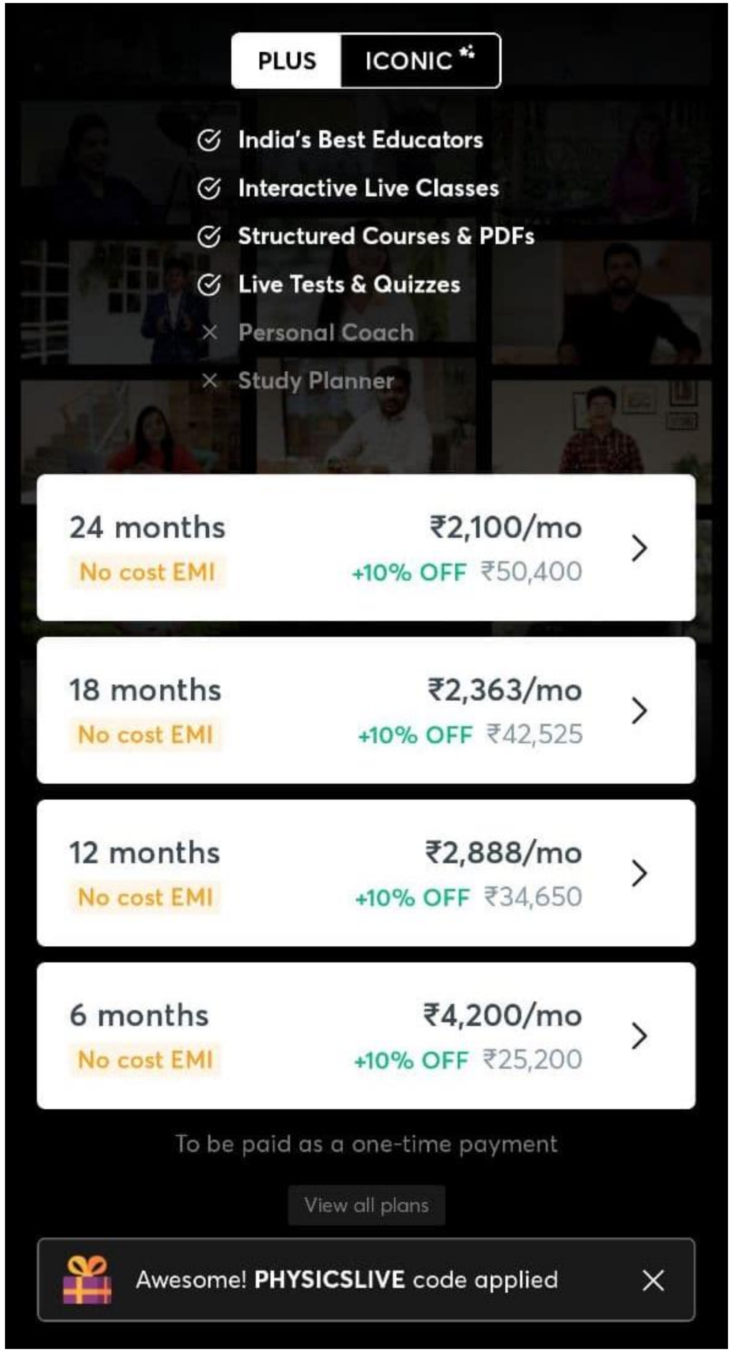


Written Solution

DPP- 4: Conservation of Momentum.

By Physicsaholics Team

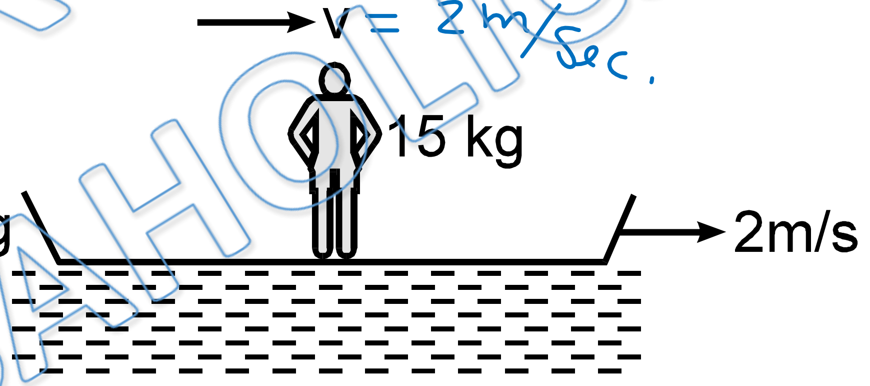
Q.1) In the figure shown the initial velocity of boat (30 kg) + person (15 kg) is 2 m/s. Man starts moving on boat. Find velocity of person w.r.t. boat so that velocity of boat will be 1 m/s in right (Neglect friction between boat and water)

by Conservation of momentum → +ve

$45 \times 2 = 30 \times 1 + 15V$

$15V = 60$

$V = 4$ m/sec



(a) 3 m/s towards right

(b) 3 m/s towards left

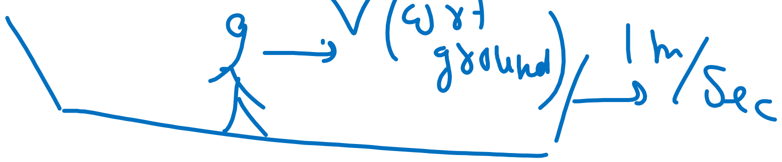
(c) 4 m/s towards right

(d) 4 m/s towards left

$V_{m,b} = V_{m,g} - V_{b,g}$

$= 4 - 1$

$= 3$ m/sec



Q.2) The resultant force on a system of particles is zero.

$\vec{F}_{net} = 0 \Rightarrow \vec{a}_{cm} = 0 \Rightarrow \vec{V}_{cm} = \text{Constant}$

$\vec{a}_{cm} = \frac{m_1\vec{a}_1 + m_2\vec{a}_2 + \ldots}{m_1 + m_2}$

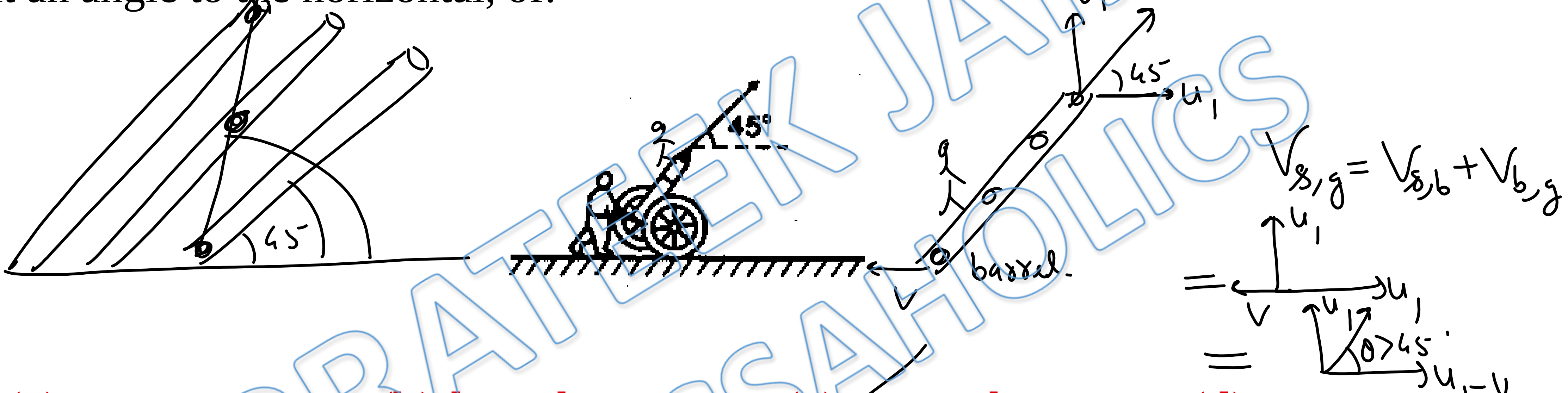
(a) The centre of mass of the system must be at rest.

(b) Acceleration of each particle may be in the same direction.

(c) Velocity of each particle may be in the same direction at some instant of time.

(d) If only one particle has initially non-zero velocity then it is possible that all the particles have zero velocity simultaneously, later on.

Q.3) A gun fires a bullet as shown in figure. The barrel of the gun is inclined at an angle of 45^0 with horizontal. When the bullet leaves the barrel, it will be travelling at an angle to the horizontal, of:



(a) 45° (b) less than 45° (c) more than 45° (d) zero

Q.4) A block of mass 1kg is pushed on a movable wedge of mass 2kg and height h = 30 cm with a velocity u = 6m/sec. Before striking the wedge it travels 2 m on a rough horizontal portion. Velocity is just sufficient for the block to reach the top of the wedge. Assuming all surfaces are smooth except the given horizontal part and collision of block and wedge is jerkless, the friction coefficient of the rough horizontal part is :

Using Conservation of momentum from A to B →

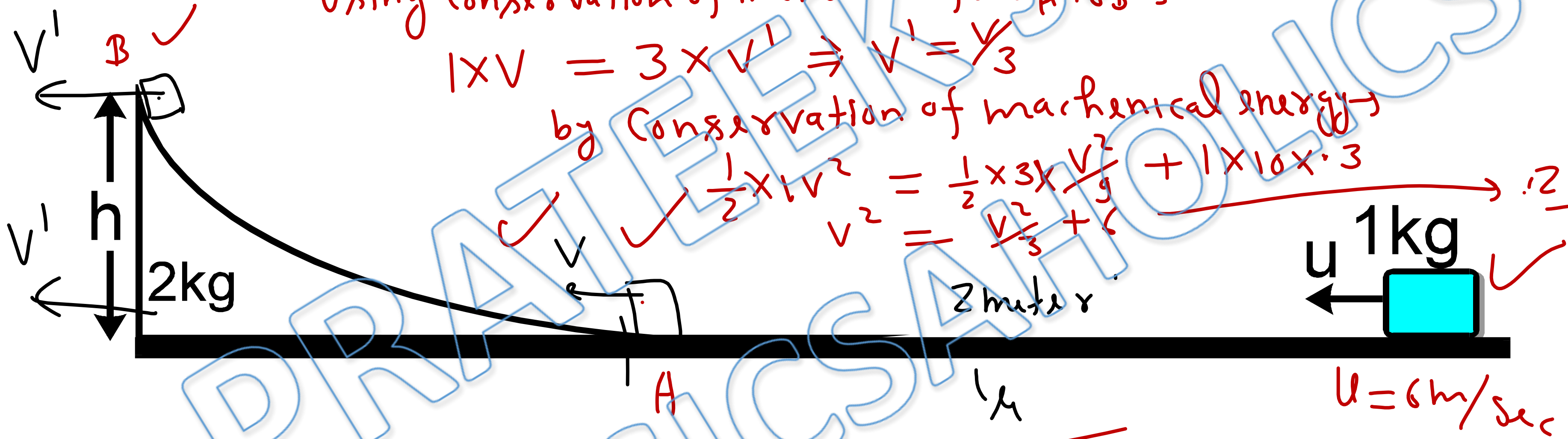
$1 \times V = 3 \times V' \Rightarrow V' = V/3$

by Conservation of mechanical energy →

$\frac{1}{2} \times 1 \times V^2 = \frac{1}{2} \times 3 \times \frac{V^2}{9} + 1 \times 10 \times .3$

$V^2 = \frac{V^2}{3} + 6$ → $\frac{2V^2}{3} = 6$

$V = 3\ m/sec$



(a) 0.125 (b) 0.377 (c) 0.675 (d) 0.45

Using Work-Energy theorem :-

$-\mu \times 1 \times 10 \times 2 = \frac{1}{2} \times 1 (9 - 36)$

$20\mu = -\frac{27}{2}$

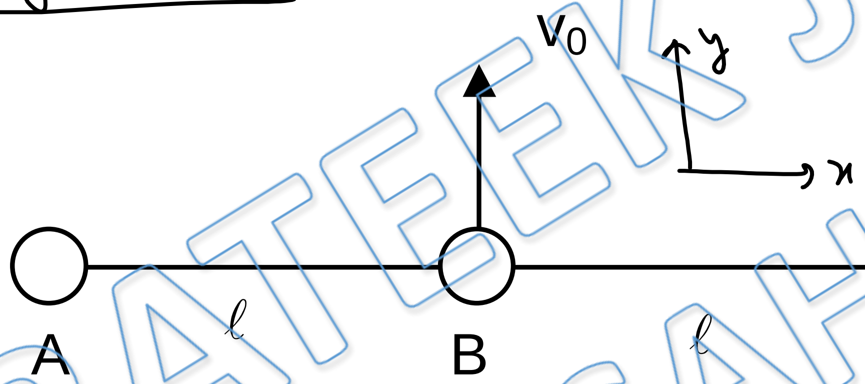
$\mu = \frac{27}{40}$

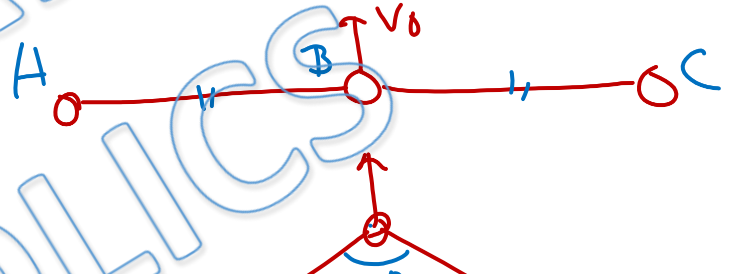
Q.5) Three identical balls each are connected by light inextensible strings with each other as shown and rest over a smooth horizontal table. At moment t = 0, ball B is imparted a velocity. Calculate the velocity of A when it collides with ball C.

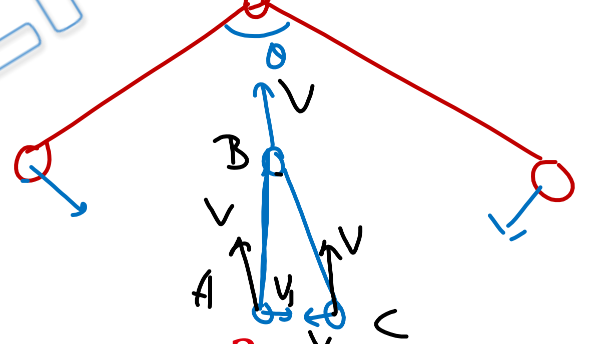
by COM in y direction

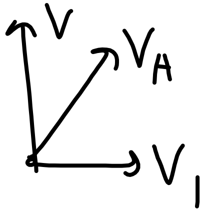
$mV_0 = 3mV$

$V = V_0/3$









(a) $\frac{2v_0}{3}$ (b) $\frac{v_0}{3}$ (c) $\frac{v_0}{2}$ (d) $\frac{2v_0}{5}$

by Conservation of mechanical energy →

$\frac{1}{2}mV_0^2 = \frac{1}{2}m\left(\frac{V_0}{3}\right)^2 + \frac{1}{2}mV_A^2 \times 2$

$\frac{1}{2}mV_0^2 \times \frac{8}{9} = mV_A^2 \Rightarrow V_A = \frac{2V_0}{3}$

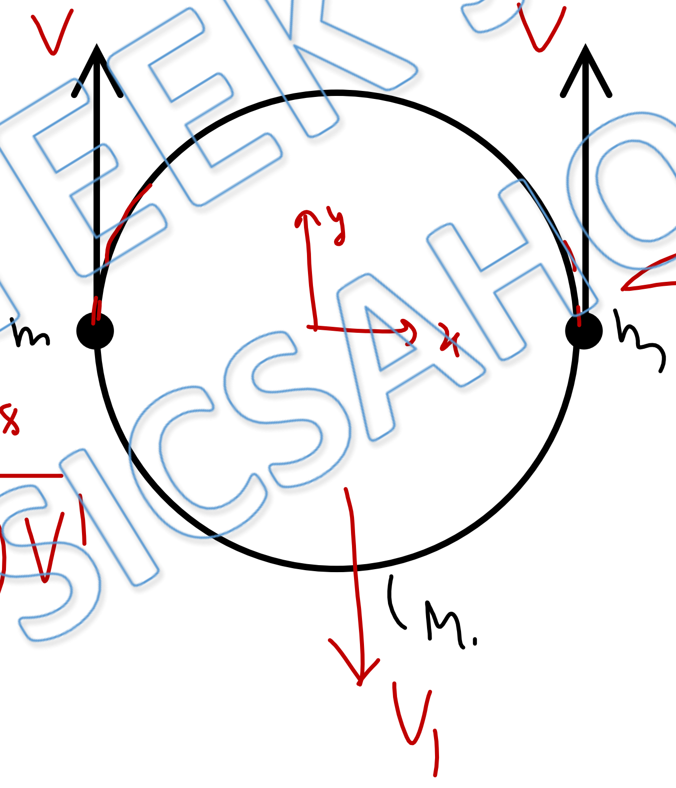
Q.6) On a smooth horizontal surface, a ring of mass M lies with two insects of mass m, on its diametrically opposite points. The insects move with velocity v in same direction relative to the ring. The velocity of the ring as the insects meet is

(a) $\frac{Mv}{2m}$

(b) $\frac{M-m}{M+m}$

(c) zero

(d) $\frac{2m}{M}v$



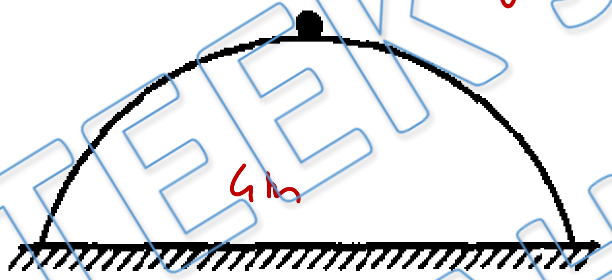
by COM along y axis

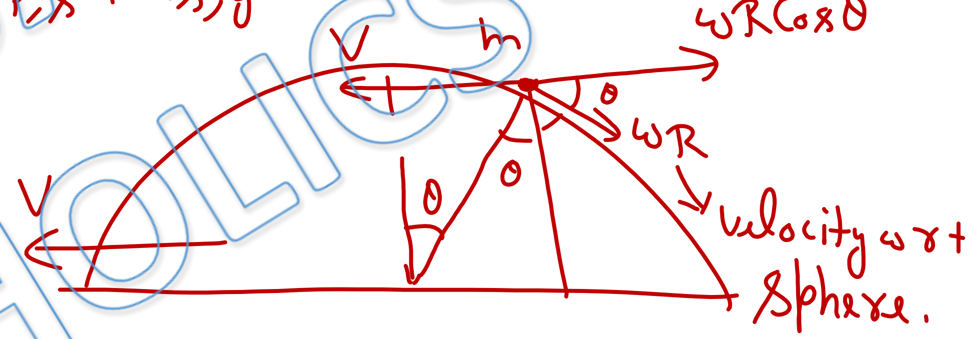
$0 = (M+2m)V'$

$V' = 0$

Q.7) A hemisphere of radius R and of mass 4m is free to slide with its base on a smooth horizontal table. A particle of mass m is placed on the top of the hemisphere. The angular velocity of the particle relative to hemisphere at an angular displacement θ when velocity of hemisphere has become v is:

$\vec{V}_{p,g} = \vec{V}_{p,s} + \vec{V}_{s,g}$





(a) $\frac{5v}{R\cos\theta}$ (b) $\frac{2v}{R\cos\theta}$ (c) $\frac{3v}{R\sin\theta}$ (d) $\frac{5v}{R\sin\theta}$

by Co Momentum in Horizontal direction →

$4mV = m(\omega R\cos\theta - V)$

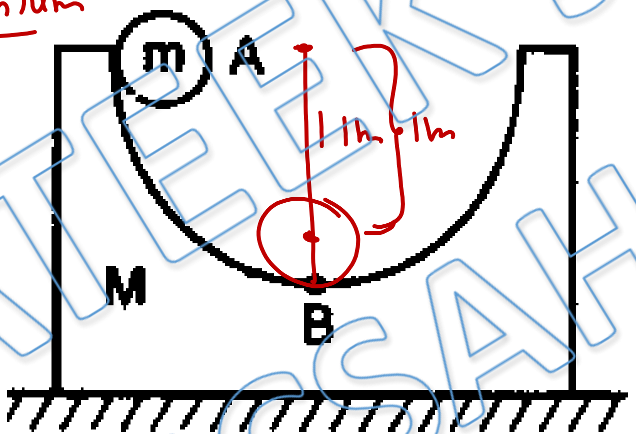
$5V = \omega R\cos\theta$

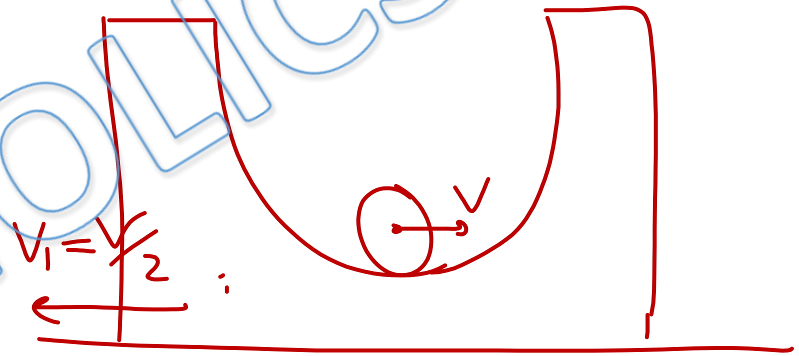
Q.8) A block of mass M = 2 kg with a semicircular track of radius R = 1.1 m rests on a horizontal frictionless surface. A uniform cylinder of radius r = 10 cm and mass m = 1.0 kg is released from rest from the top point A. The cylinder slips on the semicircular frictionless track. The speed of the block when the cylinder reaches the bottom of the track at B is :(g = 10 m/s²)

by Conservation of momentum

$0 = 1 \times V - 2V_1$

$V_1 = V/2$





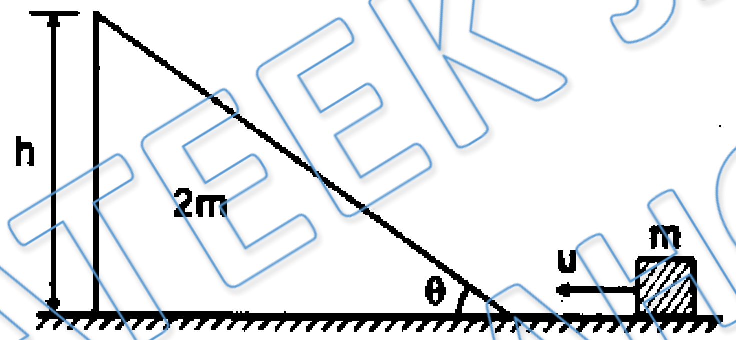
(a) $\sqrt{\frac{10}{3}}\,m/s$ (b) $\sqrt{\frac{4}{3}}\,m/s$ (c) $\sqrt{\frac{5}{2}}\,m/s$ (d) $\sqrt{10}\,m/s$

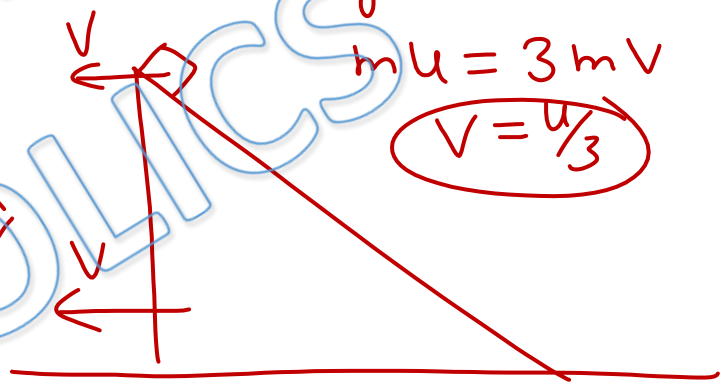
by COME →

$1 \times 10 \times 1 = \frac{1}{2} \times 1 V^2 + \frac{1}{2} \times 2 \times \frac{V^2}{4} \Rightarrow 10 = \frac{3V^2}{4}$

$V = \sqrt{\frac{40}{3}} \Rightarrow V_1 = \sqrt{\frac{10}{3}}$

Q.9) A block of mass m in is pushed towards a movable wedge of mass 2 m and height h with a velocity u. All surfaces axe smooth. The minimum value of a for which the block will reach the top of the wedge is:





by COM →

$mu = 3mV$

$V = u/3$

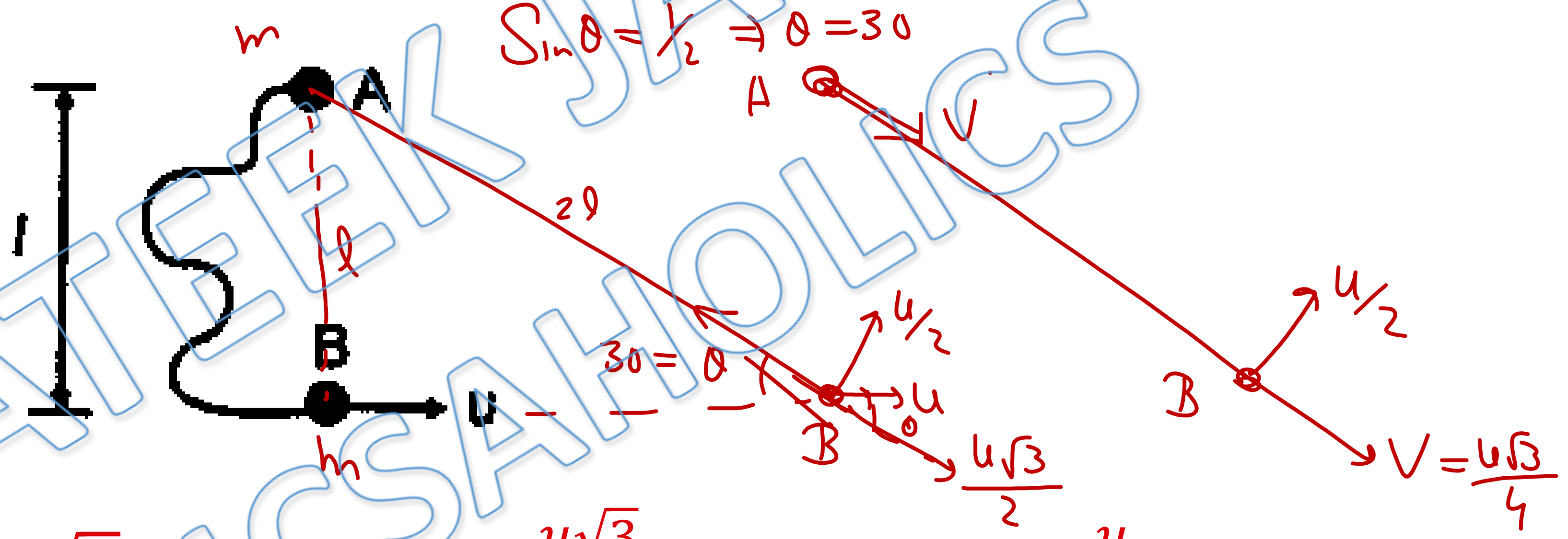
(a) $2\sqrt{gh}$ (b) $\sqrt{3gh}$ (c) $\sqrt{6gh}$ (d) $\frac{\sqrt{32}}{gh}$

by Conservation of mechanical energy

$\frac{1}{2}mu^2 = \frac{1}{2} \times 3m \frac{u^2}{9} + mgh$

$mu^2 - \frac{mu^2}{3} = 2ghm \Rightarrow \frac{2mu^2}{3} = 2ghm$

Q.10) Two particles A and B each of mass m are attached by a light inextensible suing of length 2 L The whole system lies on a smooth horizontal table with B initially at a distance *l* from A. The particle at end B is projected across the table with speed is perpendicular to AB. Velocity of ball A just after the string Is taut, is :

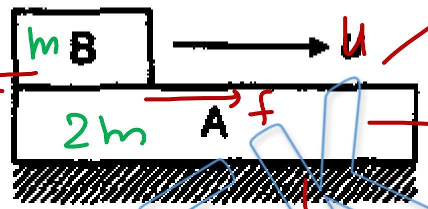


(a) $\frac{u\sqrt{3}}{4}$ (b) $u\sqrt{3}$ (c) $\frac{u\sqrt{3}}{2}$ (d) $\frac{u}{2}$

$m\frac{u\sqrt{3}}{2} = 2mV$

$V = \frac{u\sqrt{3}}{4}$

(Q.11) A horizontal block A is at rest on a smooth horizontal surface. A small block B, whose mass is half of A, is placed on A at one end and projected along other end with some velocity is given .The coefficient of friction between blocks is μ. Then:



(a) the blocks will reach a final common velocity u/3

(b) the work done against friction is two-third of the initial kinetic energy of B

(c) before the blocks reach a common velocity the acceleration of A relative to B is $(2/3)\mu g$

(d) before the blocks reach a common velocity, the acceleration of A relative to B is $(3/2)\mu g$

Q.12) A man of mass m is stationary on a stationary flat car. The car can move without friction along horizontal rails. The man starts walking with velocity v relative to the car. Work done by him:

(a) is less than $\frac{1}{2}mv^2$, if he walks along the rails

(b) is equal to $\frac{1}{2}mv^2$, if he walks normal to rails

(c) can never be less than $\frac{1}{2}mv^2$

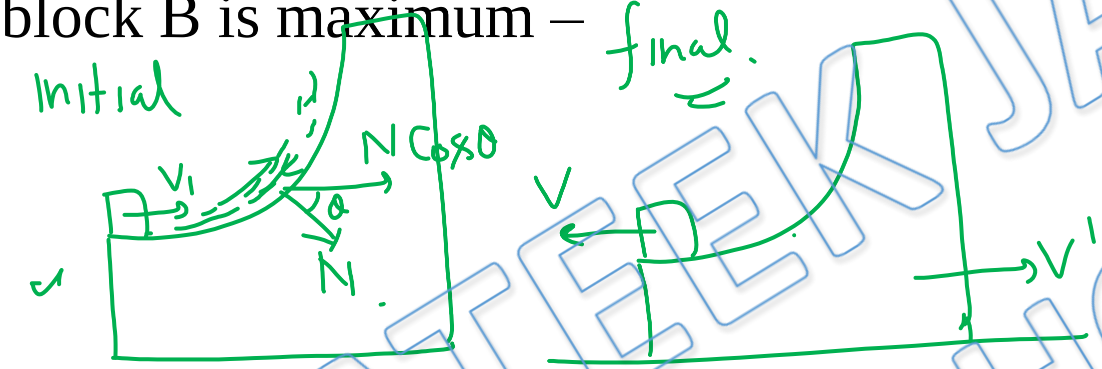
(d) is greater than $\frac{1}{2}mv^2$, if he walks along the rails

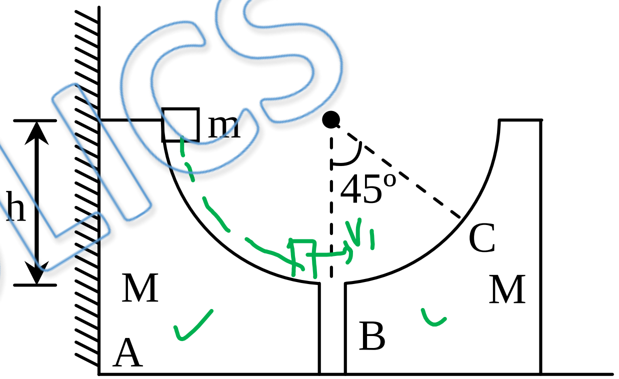
$V = V_1 + V_2$

work done by man = KE of system w.r.t ground = KE of system w.r.t CM (Since CM is at rest) $= \frac{1}{2}\mu V_{rel}^2 = \frac{1}{2}\mu V^2 < \frac{1}{2}mV^2$

$W = \frac{1}{2}mV^2$ if man moves normal to rails (car does not move)

Q.13) Two identical blocks having mass M each are smoothly conjugated and placed on a smooth horizontal floor as shown in figure. On left of block A, there is a wall. A small block of mass m is released from the position shown in figure. Velocity of block B is maximum –





(a) when m is at highest position on B

(b) when m is at lowest position and moving towards left

(c) when m is at point C

(d) is equal to $\frac{m\sqrt{2gh}}{m+M}$

$V_1 = \sqrt{2gh}$

by COM

$mV_1 = MV' - mV$ ——(1)

$\frac{1}{2}mV_1^2 = \frac{1}{2}mV^2 + \frac{1}{2}MV'^2$

$\frac{1}{2}m(V_1 - V)(V_1 + V) = \frac{1}{2}MV'^2$

$\Rightarrow m(V_1+V) = MV'$

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