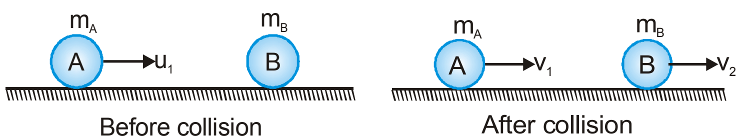
SOLVED EXAMPLES

Ex. 1 Consider an one dimensional elastic collision between a given incoming body A and body B, initially at rest. The mass of B in comparison to the mass of A in order that B should recoil with greatest kinetic energy is

Sol.



Velocity of block B after collision

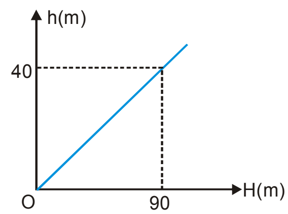
$$v_2 = \frac{2m_A u_1}{m_A + m_B}$$

KE of block

$$B = \frac{1}{2}m_B v_2^2 = \frac{1}{2}m_B\left[\frac{4m_A^2 u_1^2}{(m_A + m_B)^2}\right] = \frac{2m_A^2 m_B}{(m_A+m_B)^2}u_1^2$$

which is maximum if $m_A = m_B$

Ex. 2 A ball of mass 2 kg dropped from a height H above a horizontal surface rebounds to a height h after one bounce. The graph that relates H to h is shown in figure. If the ball was dropped from an initial height of 81 m and made ten bounces, the kinetic energy of the ball immediately after the second impact with the surface was



Sol. From graph $e = \sqrt{\frac{h}{H}} = \sqrt{\frac{40}{90}} = \frac{2}{3}$

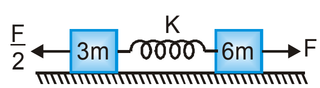
Kinetic energy of the ball just after second bounce

$$= \frac{1}{2}m(e^2u)^2 = \frac{1}{2}me^4u^2 = (e^4)(mgH) = \left(\frac{2}{3}\right)^4(2)(10)(81) = 320\text{J}$$

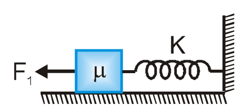
Ex. 3 An object is moving through air at a speed v. If the area of the object normal to the direction of velocity is A and assuming elastic collision with the air molecules, then the resistive force on the object is proportional to– (assume that molecules striking the object were initially at rest)

Sol. Velocity of air molecule after collision = 2v . The number of air– molecules accelerated to a velocity 2v in time Δt is proportional to $Av\Delta t$. Therefore $F = \frac{\Delta p}{\Delta t} \propto (Av\Delta t)\left(\frac{2v}{\Delta t}\right) \Rightarrow F \propto 2Av^2$

Ex. 4 For shown situation find the maximum elongation in the spring. Neglect friction everywhere. Initially, the blocks are at rest and spring is unstretched.



Sol. By using reduced mass concept this system can be reduced to

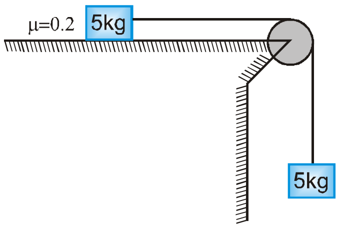


Where $\mu = \frac{(3m)(6m)}{3m+6m} = 2\ \text{m}$ and F_1 = Force on either block w.r.t. centre of mass of the system

$$= \frac{F}{2} + (3m)a_{cm} = \frac{F}{2} + (3m)\left(\frac{F - F/2}{9m}\right) = \frac{F}{2} + \frac{F}{6} = \frac{2}{3}F$$

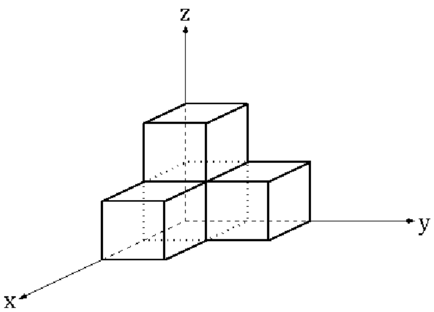
Now from work energy theorem, $\frac{2F}{3}x_m = \frac{1}{2}Kx_m^2 \Rightarrow x_m = \frac{4F}{3K}$

Ex. 5 The magnitude of acceleration of centre of mass of the system is



Sol. $a = \frac{\text{Net force on system}}{\text{total mass of system}} = \frac{5g - \mu(5g)}{5+5} = \frac{50(1-0.2)}{10} = 4\ m/s^2$; $a_{cm} = \left|\frac{m_1\vec{a}_1 + m_2\vec{a}_2}{m_1+m_2}\right| = \frac{a}{\sqrt{2}} = 2\sqrt{2}\ m/s^2$

Ex. 6 Find the center of mass (x,y,z) of the following structure of four identical cubes if the length of each side of a cube is 1 unit.

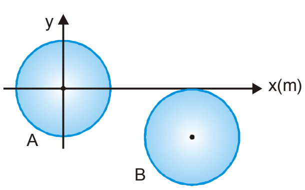


Sol. First we find the center of mass of each cube. It is located by symmetry: (0.5,0.5,0.5), (1.5,0.5,0.5), (0.5,1.5,0.5), (0.5,0.5,1.5). Now we find the center of mass by treating the COM of each cube as a point particle:

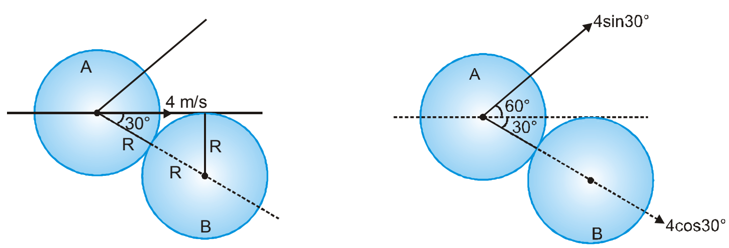
$$x_{COM} = \frac{0.5+1.5+0.5+0.5}{4} = 0.75\ ;\ y_{COM} = \frac{0.5+0.5+1.5+0.5}{4} = 0.75$$

$$z_{COM} = \frac{0.5+0.5+0.5+1.5}{4} = 0.75$$

Ex. 7 Two smooth balls A and B, each of mass m and radius R, have their centre at (0, 0, R) and (5R, –R, R) respectively, in a coordinate system as shown. Ball A, moving along positive x-axis, collides with ball B. Just before the collision, speed of ball A is 4 m/s and ball B is stationary. The collision between the balls is elastic. Velocity of the ball A just after the collision is



Sol.



Before collision

After collision

$$v_A = 4\sin 30°\left[\cos 60\tilde{i} + \sin 60\tilde{j}\right] = \tilde{i} + \sqrt{3}\tilde{j}$$

Ex. 8 A small sphere of mass 1kg is moving with a velocity $(6\hat{i}+\hat{j})$ m/s. It hits a fixed smooth wall and rebounds with velocity $(4\hat{i}+\hat{j})$ m/s . The coefficient of restitution between the sphere and the wall is-

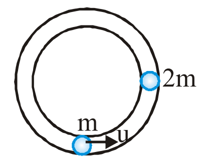
Sol. Impulse = Change in momentum $=1(4\hat{i}+\hat{j})-1(6\hat{i}+\hat{j})=-2\hat{i}$

Which is perpendicular to the wall.

Component of initial velocity along $\hat{i}=6\hat{i}$ $\Rightarrow$ Speed of approach = 6 m/s

Similarly speed of separation = $4ms^{-1}$ $\Rightarrow$ $e=\frac{4}{6}=\frac{2}{3}$

Ex. 9 Two masses m and 2m are placed in fixed horizontal circular smooth hollow tube of radius r as shown. The mass m is moving with speed u and the mass 2m is stationary. After their first collision, the time elapsed for next collision. (coefficient of restitution e = 1/2)



Sol. Let the speeds of balls of mass m and 2m after collision be v_1 and v_2 as shown in figure. Applying conservation of momentum $mv_1+2mv_2=mu$ & $-v_1+v_2=\frac{u}{2}$. Solving we get $v_1=0$ and $v_2=\frac{u}{2}$

Hence the ball of mass m comes to rest and ball of mass 2m moves with speed $\frac{u}{2}$. $t=\frac{2\pi r}{u/2}=\frac{4\pi r}{u}$

Ex. 10 A man is sitting in a boat floating in water of a pond. There are heavy stones placed in the boat.

(A) When the man throws the stones in water from the pond, the level of boat goes down.

(B) When the man throws the stones in water from the pond, the level of boat rises up.

(C) When the man drinks some water from the pond, the level of boat goes down

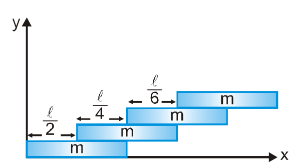
(D) When the man drinks some water from the pond, the level of boat remains unchanged.

Sol. **(B, D)**

For (A/B) : Force of buoyancy increases. Therefore level of boat rises up.

For (C/D): When man drinks some water, the level of boat remains unchanged.

Ex. 11 Find the x coordinate of the centre of mass of the bricks shown in figure :



Sol. $$X_{cm}=\frac{m\left(\frac{\ell}{2}\right)+m\left(\frac{\ell}{2}+\frac{\ell}{2}\right)+m\left(\frac{\ell}{2}+\frac{\ell}{4}+\frac{\ell}{2}\right)+m\left(\frac{\ell}{2}+\frac{\ell}{4}+\frac{\ell}{6}+\frac{\ell}{2}\right)}{m+m+m+m}=\frac{25}{24}\ell$$

Ex. 12 Object A strikes the stationary object B with a certain given speed u head–on in an elastic collision. The mass of A is fixed, you may only choose the mass of B appropriately for following cases. Then after the collision :

(A) For B to have the greatest speed, choose $m_B=m_A$

(B) For B to have the greatest momentum, choose $m_B<<m_A$

(C) For B to have the greatest speed, choose $m_B<<m_A$

(D) For the maximum fraction of kinetic energy transfer, choose $m_B=m_A$

Sol. $m_A u = m_A v_A + m_B v_B$ and $e = 1 = \frac{v_B - v_A}{u} \Rightarrow v_B = \frac{2m_A u}{m_A + m_B}$

For $m_A >> m_B$, $v_B = 2u$

For $m_A = m_B$, $v_B = u$

For $m_A << m_B$, $v_B = 0$

kinetic energy $K_B = \frac{1}{2} m_B v_B^2 = \frac{2m_B u^2}{\left(1 + \frac{m_B}{m_A}\right)^2}$

Ex. 13 In which of the following cases, the centre of mass of a rod may be at its centre?

(A) The linear mass density continuously decreases from left to right.

(B) The linear mass density continuously increases from left to right.

(C) The linear mass density decreases from left to right upto centre and then increases.

(D) The linear mass density increases from left to right upto centre and then decreases.

Sol. **(CD)**

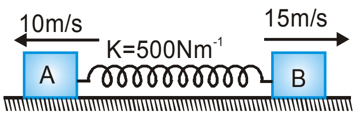
Ex. 14 Two blocks A and B are joined together with a compressed spring. When the system is released, the two blocks appear to be moving with unequal speeds in the opposite directions as shown in figure. Select incorrect statement(s) :

(A) The centre of mass of the system will remain stationary.

(B) Mass of block A is equal to mass of block B.

(C) The centre of mass of the system will move towards right.

(D) It is an impossible physical situation.



Sol. **(BCD)**

As net force on system = 0 (after released)

So centre of mass of the system remains stationary.

Ex. 15 A body moving towards a body of finite mass at rest, collides with it. It is impossible that

(A) both bodies come to rest

(B) both bodies move after collision

(C) the moving body stops and body at rest starts moving

(D) the stationary body remains stationary and the moving body rebounds

Sol. **(AD)**

For **(A)** : Momentum can't destroyed by internal forces.

For **(D)** : If mass of stationary body is infinite then the moving body rebounds.

Ex. 16 A man of mass 80 kg stands on a plank of mass 40 kg. The plank is lying on a smooth horizontal floor. Initially both are at rest. The man starts walking on the plank towards north and stops after moving a distance of 6 m on the plank. Then

(A) The centre of mass of plank-man system remains stationary.

(B) The plank will slide to the north by a distance 4 m

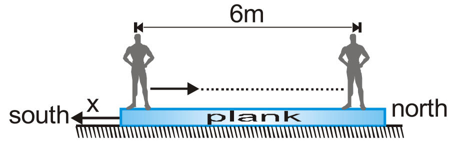
(C) The plank will slide to the south by a distance 4 m

(D) The plank will slide to the south by a distance 12 m

Sol. Let x be the displacement of the plank.

Since CM of the system remains stationary

So $80(6-x) = 40x \Rightarrow 12 - 2x = x \Rightarrow x = 4m$



Ex. 17 Three interacting particles of masses 100 g, 200 g and 400 g each have a velocity of 20 m/s magnitude along the positive direction of x-axis, y-axis and z-axis. Due to force of interaction the third particle stops moving. The velocity of the second particle is $(10\hat{j} + 5\hat{k})$. What is the velocity of the first particle?

(A) $20\hat{i} + 20\hat{j} + 70\hat{k}$ **(B)** $10\hat{i} + 20\hat{j} + 8\hat{k}$ **(C)** $30\hat{i} + 10\hat{j} + 7\hat{k}$ **(D)** $15\hat{i} + 5\hat{j} + 60\hat{k}$

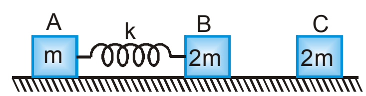
Sol. Initial momentum $= m_1\vec{v}_1 + m_2\vec{v}_2 + m_3\vec{v}_3 = 2\hat{i} + 4\hat{j} + 8\hat{k}$

When the third particle stops the final momentum $= m_1\vec{v}_1 + m_2\vec{v}_2 + m_3\vec{v}_3 = 0.1\vec{v}_1 + 0.2(10\hat{j} + 5\hat{k}) + \vec{0}$

By principle of conservation of momentum $0.1\,\vec{v}_1 + 2\hat{j} + \hat{k} = 2\hat{i} + 4\hat{j} + 8\hat{k}$; $\vec{v}_1 = 20\hat{i} + 20\hat{j} + 70\hat{k}$

Exa. 18 to 20

Two blocks A and B of masses m and 2m respectively are connected by a spring of spring constant k. The masses are moving to the right with a uniform velocity v_0 each, the heavier mass leading the lighter one. The spring is of natural length during this motion. Block B collides head on with a third block C of mass 2m. at rest, the collision being completely inelastic.



18. The velocity of block B just after collision is-

(A) v_0 **(B)** $\frac{v_0}{2}$ **(C)** $\frac{3v_0}{5}$ **(D)** $\frac{2v_0}{5}$

19. The velocity of centre of mass of system of block A, B & C is-

(A) v_0 **(B)** $\frac{3v_0}{5}$ **(C)** $\frac{2v_0}{5}$ **(D)** $\frac{v_0}{2}$

20. The maximum compression of the spring after collision is -

(A) $\sqrt{\frac{mv_0^2}{12k}}$ **(B)** $\sqrt{\frac{mv_0^2}{5k}}$ **(C)** $\sqrt{\frac{mv_0^2}{10k}}$ **(D)** None of these

Sol.

18. By applying conservation of linear momentum $2mv_0 = (2m + 2m)v \Rightarrow v = \frac{v_0}{2}$

19. $v_{cm} = \frac{mv_0 + 2mv_0}{m + 2m + 2m} = \frac{3v_0}{5}$

20. At maximum compression, velocity of all blocks are same & equal to velocity of centre of mass.

$$\frac{1}{2}kx_m^2 = \left[\frac{1}{2}mv_0^2 + \frac{1}{2}(4m)\left(\frac{v_0}{2}\right)^2\right] - \frac{1}{2}(5m)\left(\frac{3v_0}{5}\right)^2$$

$$\Rightarrow \frac{1}{2}kx_m^2 = \frac{1}{10}mv_0^2 \Rightarrow x_m = \sqrt{\frac{mv_0^2}{5k}}$$

Ex. 21 to 23

A bullet of mass m is fired with a velocity 10 m/s at angle θ with the horizontal. At the highest point of its trajectory, it collides head-on with a bob of mass 3m suspended by a massless string of length 2/5 m and gets embedded in the bob. After the collision the string moves through an angle of 60°.

21. The angle θ is

(A) 53° **(B)** 37° **(C)** 45° **(D)** 30°

22. The vertical coordinate of the initial position of the bob w.r.t. the point of firing of the bullet is

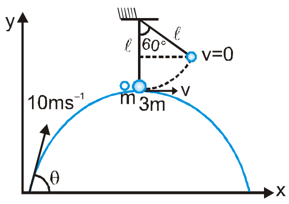
(A) $\frac{9}{4}$m **(B)** $\frac{9}{5}$m **(C)** $\frac{24}{5}$m **(D)** None of these

23. The horizontal coordinate of the initial position of the bob w.r.t. the point of firing of the bullet isn

(A) $\frac{9}{5}$m **(B)** $\frac{24}{5}$m **(C)** $\frac{9}{4}$m **(D)** None of these

Sol.

21. Velocity of combined mass just after collision



$m(10\cos\theta) = 4mv \Rightarrow v = \frac{5}{2}\cos\theta$

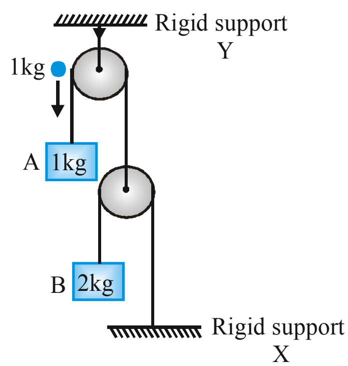
But from energy conservation $\frac{1}{2}(4m)v^2 = 4mg\ell(1-\cos 60°)$

$\Rightarrow v = \sqrt{g\ell} = \frac{5}{2}\cos\theta \Rightarrow \cos\theta = \frac{2}{5}\sqrt{g\ell} = \frac{2}{5}\sqrt{10\times\frac{2}{5}} = \frac{4}{5} \Rightarrow \theta = 37°$

22. $H_{max} = \frac{u^2\sin^2\theta}{2g} = \frac{(100)(9/25)}{20} = \frac{9}{5}$m

23. $\frac{R}{2} = \frac{2u^2\sin\theta\cos\theta}{2g} = \frac{(100)\left(\frac{3}{5}\right)\left(\frac{4}{5}\right)}{10} = \frac{24}{5}$m

Ex. 24 Collision between ball and block A is perfectly inelastic as shown. If impulse on ball (at the time of collision) is J then

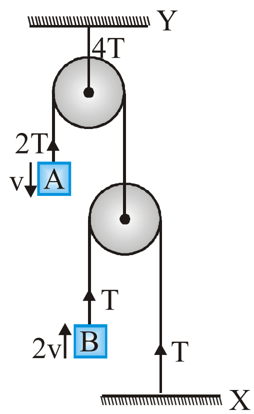


	Column-I		Column-II
(A)	Net impulse on block A is	(P)	J
(B)	Net impulse on block B is	(Q)	4J/9
(C)	Impulse due to rigid support Y is	(R)	16J/9
(D)	Impulse due to rigid support X is	(S)	2J/9
		(T)	J/9

Sol. By using impulse momentum theorem :

on A : $J - 2T = 1(v)$

on B : $T = 2(2v)$ Therefore $J = 9v$



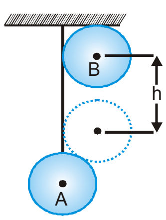
Net impulse on A $= 1(v) = \dfrac{J}{9}$

Net impulse on B $= 4v = \dfrac{4J}{9}$

Impulse due to rigid support Y $= 4T = \dfrac{16J}{9}$

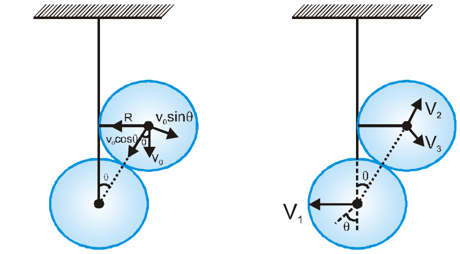
Impulse due to rigid support X $= T = \dfrac{4J}{9}$

Ex. 25 A smooth ball A of mass m is attached to one end of a light inextensible string, and is suspended from fixed point O. Another identical ball B, is dropped from a height h, so that the string just touches the surface of the sphere.



	Column I		Column II
(A)	If collision between balls is completely elastic then speed of ball A just after collision is	(P)	$\dfrac{3m}{5}\sqrt{2gh}$
(B)	If collision between balls is completely elastic then impulsive tension provided by string is	(Q)	$\dfrac{\sqrt{6gh}}{5}$
(C)	If collision between balls is completely inelastic then speed of ball A just after collision is	(R)	$\dfrac{6m}{5}\sqrt{2gh}$
(D)	If collision between balls is completely inelastic then impulsive tension provided by string is	(S)	$\dfrac{2\sqrt{6gh}}{5}$
		(T)	None of these

Sol. **For(A)** $v_0 = \sqrt{2gh}$, $\sin\theta = \frac{R}{2R} = \frac{1}{2}$. By definition of e, $e = 1 = \frac{v_1 \sin\theta + v_2}{v_0 \cos\theta}$



Let impulse given by ball B be N. then by impulse momentum theorem

$N = m(v_2 + v_0\cos\theta)$ & $N\sin\theta = mv_1$

$$\Rightarrow v_1 = \frac{2v_0\sin\theta\cos\theta}{1+\sin^2\theta} = \frac{\left(2\sqrt{2gh}\right)\left(\frac{1}{2}\right)\left(\frac{\sqrt{3}}{2}\right)}{1+\left(\frac{1}{2}\right)^2} = \frac{2\sqrt{6gh}}{5}$$

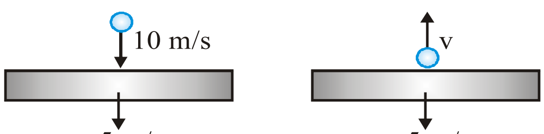
For(B) Impulsive tension $= N\cos\theta = \left(\frac{mv_1}{\sin\theta}\right)\cos\theta = mv_1\cot\theta = \frac{6m}{5}\sqrt{2gh}$

For (C) For completely inelastic collision e=0, so $v_1\sin\theta + v_2 = 0 \Rightarrow v_1 = \frac{v_0\sin\theta\cos\theta}{1+\sin^2\theta} = \frac{\sqrt{6gh}}{5}$

For (D) Impulsive tension $= N\cos\theta = \left(\frac{mv_1}{\sin\theta}\right)\cos\theta = mv_1\cot\theta = \frac{3m}{5}\sqrt{2gh}$

Ex. 26 A ball moving vertically downward with a speed of 10 m/s collides with a platform. The platform moves with a velocity of 5 m/s in downward direction. If e = 0.8, find the speed (in m/s) of the ball just after collision.

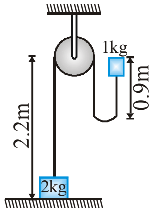
Sol.



Just before collision **Just after collision**

By definition of e : $e = \frac{v_2 - v_1}{u_1 - u_2}$; we have $0.8 = \frac{v+5}{10-5} \Rightarrow v = 1$ m/s

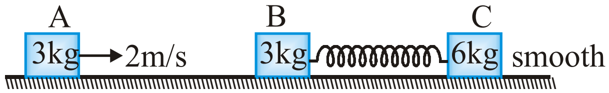
Ex. 27 In the shown figure, the heavy block of mass 2 kg rests on the horizontal surface and the lighter block of mass 1 kg is dropped from a height of 0.9 m. At the instant the string gets taut, find the upward speed (in m/s) of the heavy block.



Sol. Velocity of lighter block at the instant the string just gets taut $v = \sqrt{2gh} = \sqrt{2\times10\times1.8} = 6$ m/s

Now by impulse - momentum theorem, let common speed be v_1 then $(2+1)\,v_1 = (1)\,v \Rightarrow v_1 = \frac{v}{3} = \frac{6}{3} = 2$ m/s

Ex. 28 For shown situation, if collision between block A and B is perfectly elastic, then find the maximum energy stored in spring in joules.



Sol. At maximum compression of spring, velocities of block B and C are same (say v_0)

then by conservation of linear momentum $3(2) = (3 + 6)v_0 \Rightarrow v_0 = \frac{2}{3}$ m/s

At this instant energy stored in spring $= \frac{1}{2}(3)(2)^2 - \frac{1}{2}(3+6)\left(\frac{2}{3}\right)^2 = 6 - 2 = 4$ J

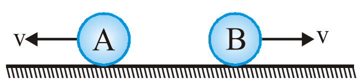
Ex. 29 A thin rod of length 6 m is lying along the x-axis with its ends at x=0 and x = 6 m. Its linear density (mass/length) varies with x as kx^4. Find the position of centre of mass of rod in meters.

Sol.
$$x_{cm} = \frac{\int x\,dm}{\int dm} = \frac{\int_0^6 x(kx^4dx)}{\int_0^6 (kx^4dx)} = \frac{\int_0^6 x^5dx}{\int_0^6 x^4dx} = \frac{\left(\frac{x^6}{6}\right)_0^6}{\left(\frac{x^5}{5}\right)_0^6} = 5\text{m}$$

Ex. 30 Two balls of equal mass have a head-on collision with speed 6 m/s. If the coefficient of restitution is $\frac{1}{3}$, find the speed of each ball after impact in m/s.

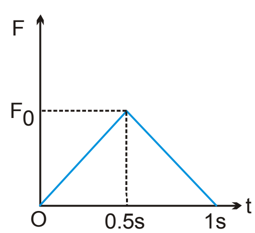
Sol. Just before collision

Just after collision



By definition of e : $e = \frac{v_2 - v_1}{u_1 - u_2} \Rightarrow \frac{1}{3} = \frac{v+v}{6+6} \Rightarrow v = 2$ m/s

Ex. 31 A body of mass 1 kg moving with velocity 1 m/s makes an elastic one dimensional collision with an identical stationary body. They are in contact for brief time 1 sec. Their force of interaction increases from zero to F_0 linearly in time 0.5 s and decreases linearly to zero in further time 0.5 sec as shown in figure. Find the magnitude of force F_0 in newton.

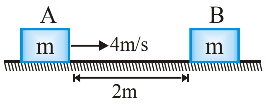


Sol. In the one dimensional elastic collision with one body at rest, the body moving initially comes to rest & the one which was at rest earlier starts moving with the velocity that first body had before collision.

so, if m & V_0 be the mass & velocity of body,

the change in momentum $= mV_0 \Rightarrow \int F dt = mV_0 \Rightarrow \int F dt = mV_0 \Rightarrow F = \frac{2mV_0}{\Delta t} = 2\text{N}$

Ex. 32 The friction coefficient between the horizontal surface and blocks A and B are $\frac{1}{15}$ and $\frac{2}{15}$ respectively. The collision between the blocks is perfectly elastic. Find the separation (in meters) between the two blocks when they come to rest.



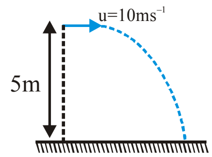
Sol. Velocity of block A just before collision $v_A = \sqrt{u_A^2 - 2\mu g x} = \sqrt{16 - 2\left(\frac{1}{15}\right)(10)(2)} = \sqrt{\frac{40}{3}}$

Velocity of Block B just after collision $v_B = v_A = \sqrt{\frac{40}{3}}$

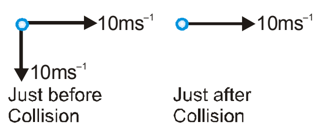
Velocity of Block A just after collision = 0

Total distance travelled by block B = $\frac{v_B^2}{2\mu g} = \frac{40/3}{2\left(\frac{2}{15}\right)(10)} = 5\text{m}$

Ex. 33 A ball of mass 1 kg is projected horizontally as shown in figure. Assume that collision between the ball and ground is totally inelastic. The kinetic energy of ball (in joules) just after collision is found to be 10α. Find the value of α.



Sol. Vertical velocity just before collision $v_y = \sqrt{2gh} = \sqrt{2 \times 10 \times 5} = 10$ m/s



$\Rightarrow$ Kinetic energy of ball just after collision = $\frac{1}{2} \times 1 \times 10^2 = 50$ J

Ex. 34 An 80 kg man is riding on a 40 kg cart travelling at a speed of 2.5 m/s on a frictionless horizontal plane. He jumps off the cart, such that, his velocity just after jump is zero with respect to ground. The work done by him on the system during his jump is given as $\frac{A}{4}$ KJ ($A \in$ integer). Find the value of A.

Sol. By conservation of linear momentum $(80 + 40)(2.5) = 80(0) + 40(v) \Rightarrow v = 7.5$ m/s

work done = $\Delta KE = \frac{1}{2}40(7.5)^2 - \frac{1}{2}(80+40)(2.5)^2 = 750$ J

Ex. 35 An object A of mass 1 kg is projected vertically upward with a speed of 20 m/s. At the same moment another object B of mass 3 kg, which is initially above the object A, is dropped from a height h = 20 m. The two point like objects (A and B) collide and stick to each other. The kinetic energy is K (in J) of the combined mass just after collision, find the value of K/25.

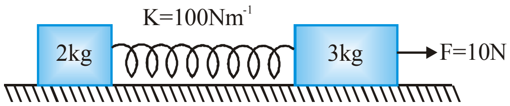
Sol. Using relative motion, the time of collision is $t = \frac{h}{20+0} = 1s$

By conservation of momentum for collision 3(10) + 1 (–10) = 4 (V)

$\Rightarrow$ V = 5 m/s

$$KE = \frac{1}{2}(4)(5)^2 = 50J$$

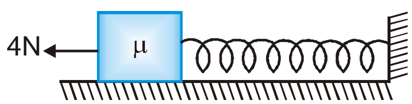
Ex. 36 At t = 0, a constant force is applied on 3 kg block. Find out maximum elongation in spring in cm.



Sol. Given system can be reduced by using reduced mass concept $\mu = \frac{2 \times 3}{2+3} = \frac{6}{5}$ kg

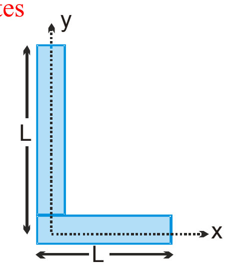
and $F_{reduced}$ = force on any block w.r.t. centre of mass = $\frac{m_1F_2 + m_2F_1}{m_1 + m_2} = \frac{2 \times 10 + 3 \times 0}{2+3} = 4$ N

$$\frac{1}{2}kx^2 = 4x \Rightarrow x = \frac{8}{k} = \frac{8}{100} = 8 \times 10^{-2} m = 8 \text{ cm}$$



Exercise # 1 [Single Correct Choice Type Questions]

1. Centre of mass of two uniform rods of same length but made up of different materials & kept as shown, if the meeting point is the origin of co–ordinates

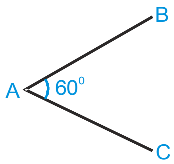


(A) (L/2,L/2) **(B)** (2L/3,L/2) **(C)** (L/3,L/3) **(D)** (L/3,L/6)

2. The centre of mass of a non uniform rod of length L whose mass per unit length varies as $\rho = kx^2/L$ (where k is a constant and x is the distance measured from one end) is at the following distance from the same end.

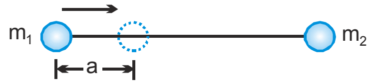
(A) 3L/4 **(B)** L/4 **(C)** 2L/3 **(D)** L/3

3. A uniform wire of length ℓ is bent into the shape of 'V' as shown. The distance of its centre of mass from the vertex A is



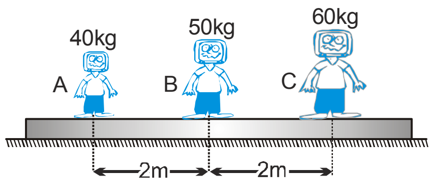
(A) $\ell / 2$ **(B)** $\frac{\ell\sqrt{3}}{4}$ **(C)** $\frac{\ell\sqrt{3}}{8}$ **(D)** None of these

4. Considering a system having two masses m_1 and m_2 in which first mass is pushed towards centre of mass by a distance a, the distance required to be moved for second mass to keep centre of mass at same position is



(A) $\frac{m_1}{m_2}a$ **(B)** $\frac{m_1 m_2}{a}$ **(C)** $\frac{m_2}{m_1}a$ **(D)** $\left(\frac{m_2 m_1}{m_1 + m_2}\right)$ a

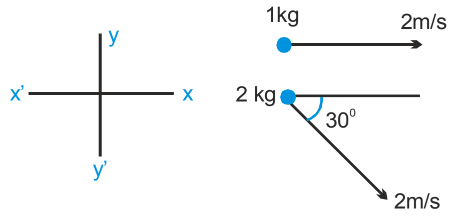
5. Three man A, B & C of mass 40 kg, 50 kg & 60 kg are standing on a plank of mass 90 kg, which is kept on a smooth horizontal plane. If A & C exchange their positions then mass B will shift



(A) 1/3 m towards left **(B)** 1/3m towards right

(C) will not move w.r.t. ground **(D)** 5/3 m towards left

6. The velocity of centre of mass of the system as shown in the figure



(A) $\left(\frac{2-2\sqrt{3}}{3}\right)\tilde{i}-\frac{1}{3}\tilde{j}$ **(B)** $\left(\frac{2+2\sqrt{3}}{3}\right)\tilde{i}-\frac{2}{3}\tilde{j}$ **(C)** $4\tilde{i}$ **(D)** None of these

7. Two particles A and B 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) 3v **(B)** v **(C)** 1.5v **(D)** zero

8. An isolated particle of mass m is moving in horizontal plane (x–y), along the x–axis, at a certain height above the ground. It suddenly explodes into two fragment of masses $\frac{m}{4}$ and $\frac{3m}{4}$. An instant later, the smaller fragment is at y = +15 cm. The larger fragment at this instant is at :–

(A) y = –5 cm **(B)** y = +20 cm **(C)** y = +5 cm **(D)** y = –20 cm

9. The figure shows the positions and velocities of two particles. If the particles move under the mutual attraction of each other, then the position of centre of mass at t =1 s is

(A) x = 5m **(B)** x = 6m **(C)** x = 3m **(D)** x = 2m

10. A particle of mass m is made to move with uniform speed v_0 along the perimeter of a regular hexagon, inscribed in a circle of radius R. The magnitude of impulse applied at each corner of the hexagon is

(A) $2mv_0\sin\pi/6$ **(B)** $mv_0\sin\pi/6$ **(C)** $mv_0\sin\pi/3$ **(D)** $2mv_0\sin\pi/3$

11. A particle of mass 2m is connected by an inextensible string of length 1.2 m to a ring of mass m which is free to slide on a horizontal smooth rod. Initially the ring and the particle are at the same level with the string taut. Both are then released simultaneously. The distance in meters moved by the ring when the string becomes vertical is

(A) 0 **(B)** 0.4 **(C)** 0.8 **(D)** 1.2

12. A ball of mass 1 kg drops vertically on to the floor with a speed of 25 m/s. It rebounds with an initial velocity of 10 m/s. What impulse acts on the ball during contact?

(A) 35kg m/s downwards **(B)** 35 kg m/s upwards
(C) 30 kg m/s downwards **(D)** 30kg m/s upwards

13. An impulse $\vec{I}$ changes the velocity of a particle from $\vec{v}_1$ to $\vec{v}_2$. Kinetic energy gained by the particle is

(A) $\frac{1}{2}\vec{I}\,(\vec{v}_1+\vec{v}_2)$ **(B)** $\frac{1}{2}\vec{I}\,(\vec{v}_1-\vec{v}_2)$ **(C)** $\vec{I}\,(\vec{v}_1-\vec{v}_2)$ **(D)** $\vec{I}\,(\vec{v}_1+\vec{v}_2)$

14. Two balls of same mass are dropped from the same height h, on to the floor. The first ball bounces to a height h/4 ,after the collision & the second ball to a height h/16. The impulse applied by the first & second ball on the floor are I_1 and I_2 respectively. Then

(A) $5I_1 = 6I_2$ **(B)** $6I_1 = 5I_2$ **(C)** $I_1 = 2I_2$ **(D)** $2I_1 = I_2$

15. Two blocks A(3 kg) and B(2 kg) resting on a smooth horizontal surface is connected by a spring of stiffness 480N/m. Initially the spring is undeformed and a velocity of 2 m/s is imparted to A along the line of the spring away from B. The maximum extension in meters of the spring during subsequent motion is

(A) $\frac{1}{10}$ **(B)** $\frac{1}{2\sqrt{10}}$ **(C)** $\frac{1}{2\sqrt{15}}$ **(D)** 0.15

16. A particle of mass 4m which is at rest explodes into masses m, m & 2m. Two of the fragments of masses m and 2m are found to move with equal speeds v each in opposite directions. The total mechanical energy released in the process of explosion is

(A) mv^2 **(B)** $2mv^2$ **(C)** $1/2\ mv^2$ **(D)** $4mv^2$

17. A cannon of mass 5m (including a shell of mass m) is at rest on a smooth horizontal ground, fires the shell with its barrel at an angle θ with the horizontal at a velocity u relative to cannon. Find the horizontal distance of the point where shell strikes the ground from the initial position of the cannon:

(A) $\frac{4u^2 \sin 2\theta}{5g}$ **(B)** $\frac{u^2 \sin 2\theta}{5g}$ **(C)** $\frac{3u^2 \sin 2\theta}{5g}$ **(D)** $\frac{8u^2 \sin 2\theta}{5g}$

18. A ball hits the floor and rebounds after an inelastic collision. In this case :–

(A) the momentum of the ball just after the collision is the same as that just before the collision

(B) the mechanical energy of the ball remains the same in the collision

(C) the total momentum of the ball and the earth is conserved

(D) the total energy of the ball and the earth is conserved

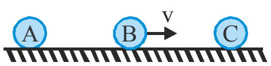
19. A shell is fired from a cannon with a velocity v (m/s) at an angle θ with the horizontal direction. At the highest point in its path it explodes into two pieces of equal mass. One of the pieces retraces its path to the cannon and the speed (m/s) of the other piece immediately after the explosion is :–

(A) $3v\cos\theta$ **(B)** $2v\cos\theta$ **(C)** $\frac{3}{2}v\cos\theta$ **(D)** $\sqrt{\frac{3}{2}}\,v\cos\theta$

20. A body of mass 1 kg strikes elastically with another body at rest and continues to move in the same direction with one fourth of the initial velocity. The mass of the other body is –

(A) 0.6 kg **(B)** 2.4 kg **(C)** 3 kg **(D)** 4 kg

21. Three balls A, B and C ($m_A = m_C = 4m_B$) are placed on a smooth horizontal surface. Ball B collides with ball C with an initial velocity v as shown in the figure. Total number of collisions between the balls will be (All collisions are elastic)



(A) One **(B)** Two **(C)** Three **(D)** Four

22. A particle moving horizontally collides with a fixed plane inclined at 60° to the horizontal. If it bounces vertically, the coefficient of restitution is:

(A) $\frac{1}{\sqrt{3}}$ **(B)** $\frac{2}{\sqrt{3}}$ **(C)** $\frac{1}{3}$ **(D)** None of these

23. A small bucket of mass M kg is attached to a long inextensible cord of length L m . The bucket is released from rest when the cord is in a horizontal position. At its lowest position, the bucket scoops up m kg of water and swings up to a height h. The height h in meters is

(A) $\left(\frac{M}{M+m}\right)^2 L$ **(B)** $\left(\frac{M}{M+m}\right)L$ **(C)** $\left(\frac{M+m}{M}\right)^2 L$ **(D)** $\left(\frac{M+m}{M}\right)L$

24. A body of mass 2kg is projected upward from the surface of the ground at t = 0 with a velocity of 20m/s. One second later a body B, also of mass 2kg, is dropped from a height of 20m. If they collide elastically, then velocities just after collision are

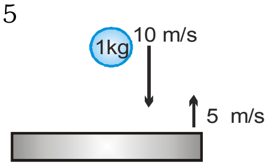
(A) v_A = 5 m/s downward, v_B = 5 m/s upward **(B)** v_A = 10 m/s downward, v_B= 5 m/s upward

(C) v_A = 10 m/s upward, v_B = 10 m/s downward **(D)** both move downward with velocity 5 m/s

25. A ball of mass 2m impinges directly on a ball of mass m, which is at rest. If the velocity with which the larger ball impinges be equal to the velocity of the smaller mass after impact then the coefficient of restitution

(A) $\frac{1}{3}$ **(B)** $\frac{3}{4}$ **(C)** $\frac{1}{2}$ **(D)** $\frac{2}{5}$

26. A ball of mass 1 kg strikes a heavy platform, elastically, moving upwards with a velocity of 5m/s. The speed of the ball just before the collision is 10m/s downwards.
Then the impulse imparted by the platform on the ball is

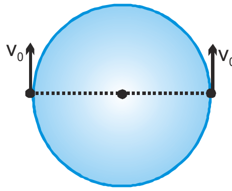


(A) 15 N–s **(B)** 10 N–s **(C)** 20 N–s **(D)** 30 N–s

27. Two objects move in the same direction in a straight line. One moves with a constant velocity v_1 . The other starts at rest and has constant acceleration a. They collide when the second object has velocity $2v_1$. The distance between the two objects when the second one starts moving is

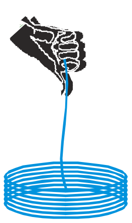
(A) zero **(B)** $\frac{v_1^2}{2a}$ **(C)** $\frac{v_1^2}{a}$ **(D)** $\frac{2v_1^2}{a}$

28. Two particles of mass m, constrained to move along the circumference of a smooth circular hoop of equal mass m, are initially located at opposite ends of a diameter and given equal velocities v_0 shown in the figure. The entire arrangement is located in gravity free space. Their velocity just before collision is



(A) $\frac{1}{\sqrt{3}}v_0$ **(B)** $\frac{\sqrt{3}}{2}v_0$ **(C)** $\frac{2}{\sqrt{3}}v_0$ **(D)** $\frac{\sqrt{7}}{3}v_0$

29. A uniform rope of linear mass density λ and length ℓ is coiled on a smooth horizontal surface. One end is pulled up with constant velocity v. Then the average power applied by the external agent in pulling the entire rope just off the ground is :

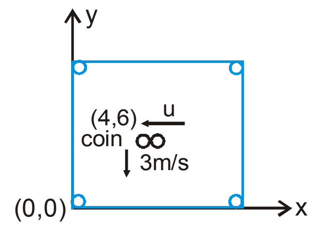


(A) $\frac{1}{2}\lambda\ell v^2 + \frac{\lambda\ell^2 g}{2}$ **(B)** $\lambda\ell gv$ **(C)** $\frac{1}{2}\lambda v^3 + \frac{\lambda\ell vg}{2}$ **(D)** $\lambda\ell gv + \frac{1}{2}\lambda v^3$

Exercise # 2

Part # I [Multiple Correct Choice Type Questions]

1. On a smooth carom board, a coin moving in negative y–direction with a speed of 3 m/s is being hit at the point (4, 6) by a striker moving along negative x–axis. The line joining centres of the coin and the striker just before the collision is parallel to x–axis. After collision the coin goes into the hole located at the origin. Masses of the striker and the coin are equal. Considering the collision to be elastic, the initial and final speeds of the striker in m/s will be–



(A) (1.2, 0) **(B)** (2, 0) **(C)** (3, 0) **(D)** None of these

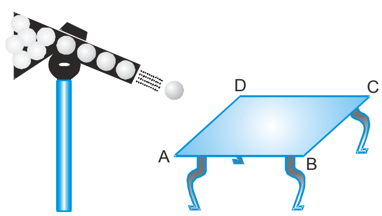
2. Two particles A and B start moving due to their mutual interaction only. If at any time 't', $\vec{a}_A$ and $\vec{a}_B$ are their respective accelerations, $\vec{v}_A$ and $\vec{v}_B$ are their respective velocities, and upto that time W_A and W_B are the work done on A and B respectively by the mutual force, m_A and m_B are their masses respectively, then which of the following is always correct.

(A) $\vec{v}_A + \vec{v}_B = 0$ **(B)** $m_A\vec{v}_A + m_B\vec{v}_B = 0$ **(C)** $W_A + W_B = 0$ **(D)** $\vec{a}_A + \vec{a}_B = 0$

3. A balloon having mass 'm' is filled with gas and is held in hands of a boy. Then suddenly it gets released and gas starts coming out of it with a constant rate. The velocity of the ejected gas is 2m/s with respect to the balloon. Find out the velocity of the balloon when the mass of gas is reduced to half.

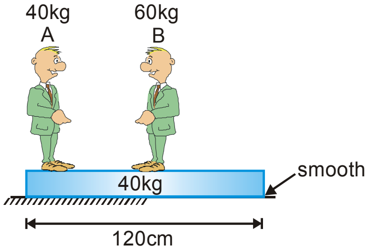
(A) $\ell n\ 2$ **(B)** $2\ell n\ 4$ **(C)** $2\ell n\ 2$ **(D)** None of these

4. A gun which fires small balls of mass 20 gm is firing 20 balls per second on the smooth horizontal table surface ABCD. If the collision is perfectly elastic and balls are striking at the centre of table with a speed 5 m/s at an angle of 60° with the vertical just before collision, then force exerted by one of the leg on ground is (assume total weight of the table is 0.2 kg and g = 10 m/s^2) :



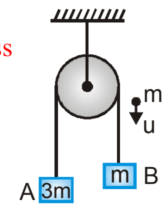
(A) 0.5 N **(B)** 1 N **(C)** 0.25 N **(D)** 0.75 N

5. Two men 'A' and 'B' are standing on a plank. 'B' is at the middle of the plank and 'A' is at the left end of the plank. Surface of the plank is smooth. System is initially at rest and masses are as shown in figure. A and B starts moving such that the position of 'B' remains fixed with respect to ground then 'A' meets 'B'. Then the point where A meets B is located at–



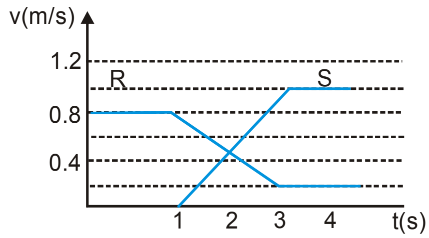
(A) the middle of the plank **(B)** 30 cm from the left end of the plank
(C) the right end of the plank **(D)** None of these

6. A system of two blocks A and B are connected by an inextensible massless strings as shown. The pulley is massless and frictionless. Initially the system is at rest when, a bullet of mass 'm' moving with a velocity 'u' as shown hits the block 'B' and gets embedded into it. The impulse imparted by tension force to the block of mass 3m is–



(A) $\frac{5mu}{4}$ **(B)** $\frac{4mu}{5}$ **(C)** $\frac{2mu}{5}$ **(D)** $\frac{3mu}{5}$

7. The diagram shows the velocity–time graph for two masses R and S that collided elastically. Which of the following statements is true ?



I. R and S moved in the same direction after the collision

II. The velocities of R and S were equal at the mid time of the collision.

III. The mass of R was greater than mass of S.

(A) I only **(B)** II only **(C)** I and II only **(D)** I, II and III

8. A ball is bouncing down a set of stairs. The coefficient of restitution is e. The height of each step is d and the ball bounces one step at each bounce. After each bounce the ball rebounds to a height h above the next lower step. Neglect width of each step in comparison to h and assume the impacts to be effectively head on. Which of the following relation is correct ?

(A) $\frac{h}{d} = 1 - e^2$ **(B)** $\frac{h}{d} = 1 - e$ **(C)** $\frac{h}{d} = \frac{1}{1-e^2}$ **(D)** $\frac{h}{d} = \frac{1}{1-e}$

9. A piece of paper (shown in figure1) is in form of a square. Two corners of this square are folded to make it appear like figure.2 Both corners are put together at centre of square 'O'. If O is taken to be (0,0), the centre of mass of new system will be at

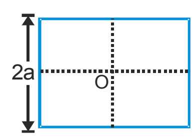


Fig.1

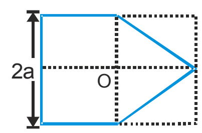


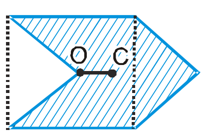
Fig.2

(A) $\left(-\frac{a}{8}, 0\right)$ **(B)** $\left(-\frac{a}{6}, 0\right)$ **(C)** $\left(\frac{a}{12}, 0\right)$ **(D)** $\left(-\frac{a}{12}, 0\right)$

10. A continuous stream of particles of mass m and velocity v, is emitted from a source at a rate of n per second. The particles travel along a straight line, collide with a body of mass M and get embedded in the body. If the mass M was originally at rest, its velocity when it has received N particles will be

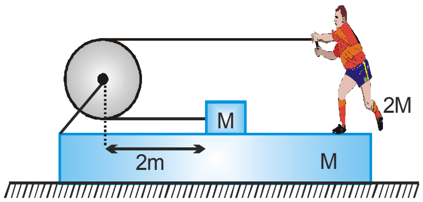
(A) $\frac{mvn}{Nm+n}$ **(B)** $\frac{mvN}{Nm+M}$ **(C)** $\frac{mv}{Nm+M}$ **(D)** $\frac{Nm+M}{mv}$

11. An arrow sign is made by cutting and rejoining a quarter part of a square plate of side 'L' as shown. The distance OC, where 'C' is the centre of mass of the arrow, is



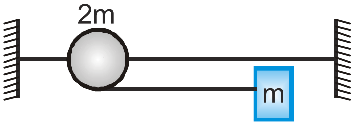
(A) $\frac{L}{3}$ **(B)** $\frac{L}{4}$ **(C)** $\frac{3L}{8}$ **(D)** None of these

12. A block of mass M is tied to one end of a massless rope. The other end of the rope is in the hands of a man of mass 2M as shown in the figure. The block and the man are resting on a rough wedge of mass M as shown in the figure. The whole system is resting on a smooth horizontal surface. The man pulls the rope. Pulley is massless and frictionless. What is the displacement of the wedge when the block meets the pulley. (Man does not leave his position during the pull)



(A) 0.5m **(B)** 1m **(C)** Zero **(D)** 2/3 m

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

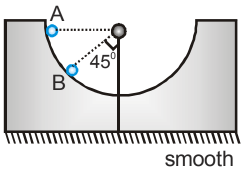


(A) $L(1-\cos\theta)$ **(B)** $\left(\frac{L}{2}\right)(1-\cos\theta)$ **(C)** $\left(\frac{L}{3}\right)(1-\cos\theta)$ **(D)** $\left(\frac{L}{6}\right)(1-\cos\theta)$

14. Three particles start from origin at the same time with a velocity $2ms^{-1}$ along positive x–axis, the second with a velocity $6ms^{-1}$ along negative y–axis. Find the velocity of the third particle along x=y line so that the three particles may always lie in a straight line

(A) $-3\sqrt{3}$ **(B)** $3\sqrt{2}$ **(C)** $-3\sqrt{2}$ **(D)** $2\sqrt{2}$

15. A ball of mass m is released from A inside a smooth wedge of mass m as shown in the figure. What is the speed of the wedge when the ball reaches point B ?

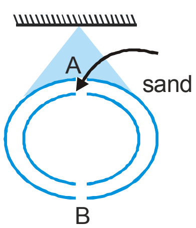


(A) $\left(\frac{gR}{3\sqrt{2}}\right)^{1/2}$ **(B)** $\sqrt{2gR}$ **(C)** $\left(\frac{5gR}{2\sqrt{3}}\right)^{1/2}$ **(D)** $\sqrt{\frac{3}{2}gR}$

16. A body of mass M moves in outer space with velocity v. It is desired to break the body into two parts so that the mass of one part is one–tenth of the total mass. After the explosion, the heavier part comes to rest while the lighter part continues to move in the original direction of motion. The velocity of the small part will be

(A) v **(B)** $\left(\frac{v}{2}\right)$ **(C)** $\left(\frac{v}{10}\right)$ **(D)** 10 v

17. A uniform metallic spherical shell is suspended from ceiling. It has two holes A and B at top and bottom respectively. Which of the following is/are true:



(A) If B is closed and sand is poured from A, centre of mass first rises and then falls

(B) If shell is completely filled with sand and B is opened then centre of mass falls initially

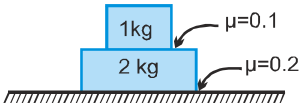
(C) If shell is slightly filled with sand and B is opened, then centre of mass falls.

(D) None of these

18. A bead of mass m and diameter d is sliding back and forth with velocity v on a wire held between two rigid walls of length L. Assume that the collisions with the wall are perfectly elastic and there is no friction. The average force that the bouncing bead exerts on the one of the walls is

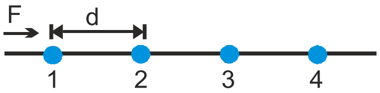
(A) $\frac{mv^2}{L-d}$ **(B)** $\frac{mv^2}{L+d}$ **(C)** $\frac{2mv^2}{L-d}$ **(D)** $\frac{2mv^2}{L+d}$

19. If both the blocks as shown in the given arrangement are given together a horizontal velocity towards right. If a_{cm} be the subsequent acceleration of the centre of mass of the system of blocks then a_{cm} equals



(A) 0 m/s² **(B)** $\frac{5}{3}$ m/s² **(C)** $\frac{7}{3}$ m/s² **(D)** 2 m/s²

20. The Fig. shows a string of equally placed beads of mass m, separated by distance d. The beads are free to slide without friction on a thin wire. A constant force F acts on the first bead initially at rest till it makes collision with the second bead. The second bead then collides with the third and so on. Suppose that all collisions are elastic,



(A) Speed of the first bead immediately before and immediately after its collision with the second bead is $\sqrt{\frac{2Fd}{m}}$ and zero respectively.

(B) Speed of the first bead immediately before and immediately after its collision with the second bead is $\sqrt{\frac{2Fd}{m}}$ and $\frac{1}{2}\sqrt{\frac{2Fd}{m}}$ respectively.

(C) Speed of the second bead immediately after its collision with third bead is zero.

(D) The average speed of the first bead is $\frac{1}{2}\sqrt{\frac{2Fd}{m}}$.

21. A set of n–identical cubical blocks lies at rest parallel to each other along a line on a smooth horizontal surface. The separation between the near surfaces of any two adjacent blocks is L. The block at one end is given a speed v towards the next one at time t = 0. All collisions are completely inelastic, then

(A) The last block starts moving at $t = n(n-1)\frac{L}{2v}$

(B) The last block starts moving at $t = (n-1)\frac{L}{v}$

(C) The centre of mass of the system will have a final speed $\frac{v}{n}$

(D) The centre of mass of the system will have a final speed v.

22. In a one dimensional collision between two identical particles A and B, B is stationary and A has momentum p before impact. During impact, B gives impulse J to A.

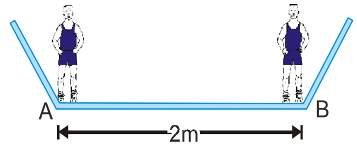
(A) The total momentum of the 'A plus B' system is p before and after the impact, and (p–1) during the impact.

(B) During the impact A gives impulse J to B

(C) The coefficient of restitution is $\frac{2J}{p}-1$

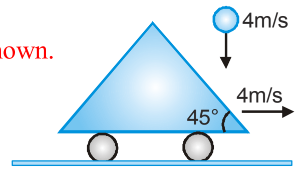
(D) The coefficient of restitution is $\frac{J}{p}+1$

23. Two persons A and B of weight 80 kg and 50 kg respectively are standing at opposite ends of a boat of mass 70 kg and length 2m at rest. When they interchange their positions then displacement of the centre of mass of the boat will be:



(A) 60 cm towards left **(B)** 30 cm towards right **(C)** 30 cm towards left **(D)** stationary

24. A small ball falling vertically downward with constant velocity 4m/s strikes elastically a massive inclined cart moving with velocity 4m/s horizontally as shown. The velocity of the rebound of the ball is



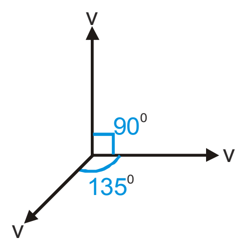
(A) $4\sqrt{2}$ m/s **(B)** $4\sqrt{3}$ m/s

(C) 4 m/s **(D)** $4\sqrt{5}$ m/s

25. Two balls of same mass are dropped from the same height onto the floor. The first ball bounces upwards from the floor elastically. The second ball sticks to the floor. The first applies an impulse to the floor of I_1 and the second applies an impulse I_2 . The impulses obey

(A) $I_2 = 2I_1$ **(B)** $I_2 = \frac{I_1}{2}$ **(C)** $I_2 = 4I_1$ **(D)** $I_2 = \frac{I_1}{4}$

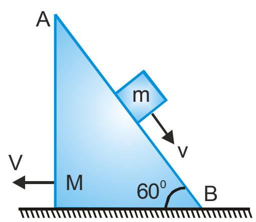
26. A particle of mass 4m which is at rest explodes into four equal fragments. All 4 fragments scattered in the same horizontal plane. Three fragments are found to move with velocity v each as shown in the fig. The total energy released in the process of explosion is



(A) $mv^2 (3-\sqrt{2})$ **(B)** $mv^2 (3-\sqrt{2})/2$

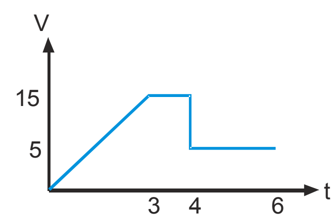
(C) $2mv^2$ **(D)** $mv^2 (1+\sqrt{2})/2$

27. A particle of mass m = 0.1 kg is released from rest from a point A of a wedge of mass M = 2.4 kg free to slide on a frictionless horizontal plane. The particle slides down the smooth face AB of the wedge. When the velocity of the wedge is 0.2 m/s the velocity of the particle in m/s relative to the wedge is



(A) 4.8 **(B)** 5 **(C)** 7.5 **(D)** 10

28. The fig. shows the velocity as a function of the time for an object with mass 10 kg being pushed along a frictionless surface by external force. At t= 3s, the force stops pushing and the object moves freely. It then collides head on and sticks to another object of mass 25 kg.



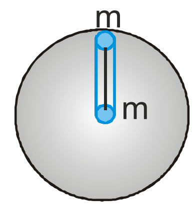
(A) External force acting on the system is 50 N

(B) Velocity of the 2nd particle just before the collision is 1 m/s

(C) Before collision both bodies are moving in the same direction

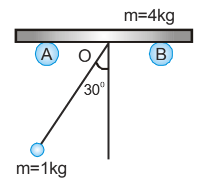
(D) Before collision, bodies are moving in opposite direction with respect to each other

29. Find the distance between centre of gravity and centre of mass of a two particle system attached to the ends of a light rod. Each particle has same mass. Length of the rod is R, where R is the radius of earth



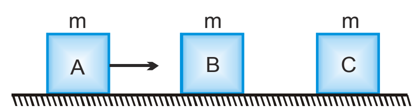
(A) R **(B)** R/2 **(C)** zero **(D)** R/4

30. A ball of mass 1 kg is suspended by an inextensible string 1 m long attached to a point O of a smooth horizontal bar resting on a fixed smooth supports A and B. The ball is released from rest from the position when the string makes an angle of 30° with the vertical. The mass of the bar is 4 kg. The displacement in meters of the bar when the string makes the maximum angle on the other side of the vertical is



(A) 0 **(B)** 0.2 **(C)** 0.25 **(D)** 0.5

31. Three blocks A, B and C each of mass m are placed on a surface as shown in the figure. Blocks B and C are initially at rest. Block A is moving to the right with speed v. It collides with block B and sticks to it. The A–B combination collides elastically with block C. Which of the following statement is (are) true about the velocity, of block B and C.



(A) Velocity of the block C after collision is 2/3 v towards right

(B) Velocity of the A–B combination after collision is $\frac{v}{3}$ towards left

(C) Velocity of the A–B combination after collision is $\frac{2}{3}$ v towards left

(D) Velocity of the block C after collision is $\frac{v}{3}$ towards right.

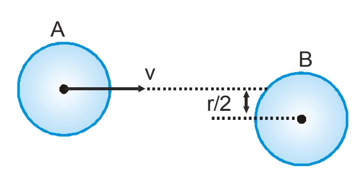
32. After scaling a wall of 3 m height a man of weight W drops himself to the ground. If his body comes to a complete stop in 0.15 s. After his feet touch the ground, calculate the average impulsive force in the vertical direction exerted by ground on his feet.

(A) 5W **(B)** 5.21W **(C)** 3W **(D)** 6W

33. An open water tight railway wagon of mass 5 x 10^3 kg coasts at an initial velocity 1.2 m/s without friction on a railway track. Rain drops fall vertically downwards into the wagon. The velocity of the wagon after it has collected 10^3 kg of water will be

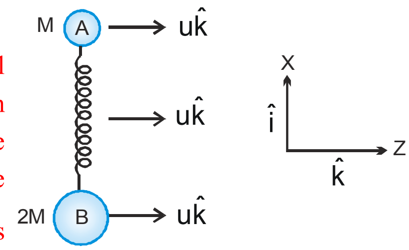
(A) 0.5 m/s **(B)** 2m/s **(C)** 1 m/s **(D)** 1.5 m/s

34. A disk A of radius r moving on perfectly smooth surface at a speed v undergoes an elastic collision with an identical stationary disk B. Find the velocity of the disk B after collision if the impact parameter is r/2 as shown in the figure



(A) $\frac{\sqrt{15}}{4}v$ **(B)** $\frac{v}{4}$ **(C)** $\frac{v}{2}$ **(D)** $\frac{\sqrt{3}v}{2}$

35. Two masses A and B of mass M and 2M respectively are connected by a compressed ideal spring. The system is placed on a horizontal frictionless table and given a velocity $u\hat{k}$ in the z–direction as shown in the figure. The spring is then released. In the subsequent motion the line from B to A always points along the $\hat{i}$ unit vector. At some instant of time mass B has a x–component of velocity as $v_x\hat{i}$. The velocity $\vec{v}_A$ of mass A at that instant is



(A) $v_x\hat{i} + u\hat{k}$ **(B)** $-v_x\hat{i} + u\hat{k}$ **(C)** $-2v_x\hat{i} + u\hat{k}$ **(D)** $2v_x\hat{i} + u\hat{k}$

36. A smooth sphere A of mass m collides elastically with an identical sphere B at rest. The velocity of A before collision is 8 m/s in a direction making 60° with the line of centres at the time of impact.

(A) The sphere A comes to rest after collision.

(B) The sphere B will move with a speed of 8 m/s after collision.

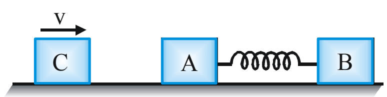
(C) The directions of motion A and B after collision are at right angles.

(D) The speed of B after collision is 4 m/s.

37. A spherical ball of mass 1 kg moving with a uniform speed of 1 m/s collides symmetrically with two identical spherical balls of mass 1 kg each at rest touching each other. If the two balls move with 0.5m/s in two directions at the same angle of 60° with the direction of the first ball, the loss of kinetic energy on account of the collision is :

(A) 0.125 J **(B)** 0.5J **(C)** 1.0 J **(D)** 0.75J

38. Two blocks A and B each of mass m, are connected by a massless spring of natural length L and spring constant k. The blocks are initially resting on a smooth horizontal floor with the spring at its natural length, as shown in fig. A third identical block C, also of mass m, moves on the floor with a speed v along the line joining A and B, and collides elastically with A. Then :–



(A) the kinetic energy of the A–B system, at maximum compression of the spring, is zero

(B) the kinetic energy of the A–B system, at maximum compression of the spring, is $\frac{mv^2}{4}$

(C) the maximum compression of the spring is $v\sqrt{\left(\frac{m}{k}\right)}$

(D) the maximum compression of the spring is $v\sqrt{\frac{m}{2k}}$

39. A particle moving with kinetic energy = 3J makes an elastic head–on collision with a stationary particle which has twice its mass. During the impact,

(A) the minimum kinetic energy of the system is 1J.

(B) the maximum elastic potential energy of the system is 2J.

(C) momentum and total energy are conserved at every instant.

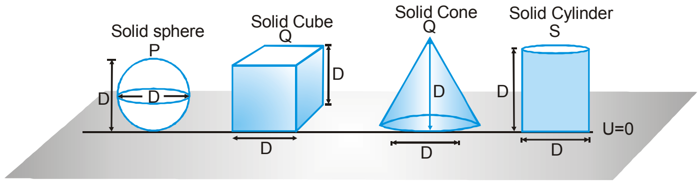
(D) the ratio of kinetic energy to potential energy of the system first decreases and then increases.

40. A bag of mass M hangs by a long thread and a bullet (mass m) comes horizontally with velocity v and gets caught in the bag. Then for the combined system (bag + bullet) :

(A) Momentum is $mMv/(M + m)$ **(B)** kinetic energy is $(1/2)\ Mv^2$

(C) Momentum is mv **(D)** kinetic energy is $m^2v^2/2(M + m)$

41. Assuming potential energy 'U' at ground level to be zero.



All objects are made up of same material.

U_P = Potential energy of solid sphere U_Q = Potential energy of solid cube

U_R = Potential energy of solid cone U_S = Potential energy of solid cylinder

(A) $U_S > U_P$ **(B)** $U_Q > U_S$ **(C)** $U_P > U_Q$ **(D)** $U_S > U_R$

42. A ball moving with a velocity v hits a massive wall moving towards the ball with a velocity u. An elastic impact lasts for a time Δt.

(A) The average elastic force acting on the ball is $\frac{m(u+v)}{\Delta t}$

(B) The average elastic force acting on the ball is $\frac{2m(u+v)}{\Delta t}$

(C) The kinetic energy of the ball increases by 2mu(u + v)

(D) The kinetic energy of the ball remains the same after the collision

Part # II   [Assertion & Reason Type Questions]

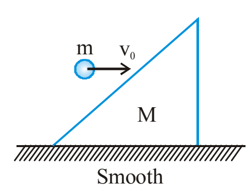
These questions contains, Statement 1 (assertion) and Statement 2 (reason).
(A) Statement-I is true, Statement-II is true ; Statement- II is correct explanation for Statement-I.
(B) Statement-I is true, Statement-II is true; Statement-II is NOT a correct explanation for statement-I.
(C) Statement-I is true, Statement-II is false.
(D) Statement-I is false and Statement-II is true.
(E) Statement- I is false, Statement-II is false.

1. Statement–1 : When a girl jumps from a boat, the boat slightly moves away from the shore.
Statement–2 : The total linear momentum of an isolated system remain conserved.

2. Statement–1 : In case of bullet fired from gun, the ratio of kinetic energy of gun and bullet is equal to ratio of mass of bullet and gun.
Statement–2 : In firing, momentum is conserved.

3. Statement–1 : In a two body collision, the momenta of the particles are equal and opposite to one another, before as well as after the collision when measured in the center of mass frame.
Statement–2 : The momentum of the system is zero from the centre of mass frame.

4. Statement–1 : A particle of mass m strikes a smooth wedge of mass M as shown in the figure. Linear momentum of particle along the inclined surface of wedge is conserved during collision.
Statement–2 : Wedge exerts a force on particle perpendicular to inclined face of wedge during collision.



5. Statement–1 : The centre of mass and centre of gravity of a body are two different positions in general.
Statement–2 : The centre of mass and centre of gravity of a body coincide if gravitational field is uniform.

6. **Statement–1** : A sphere of mass m moving with speed u undergoes a perfectly elastic head on collision with another sphere of heavier mass M at rest (M>>>m), then direction of velocity of sphere of mass m is reversed due to collision [no external force acts on system of two spheres]

Statement–2 : During a collision of spheres of unequal masses, the heavier exerts more force on lighter mass in comparison to the force which lighter mass exerts on heavier mass.

7. **Statement–1** : No external force acts on system of two spheres which undergo a perfectly elastic head on collision. The minimum kinetic energy of this system is zero if the net momentum of this system is zero.

Statement–2 : In any two body system undergoing perfectly elastic head on collision, at the instant of maximum deformation, the complete kinetic energy of the system is converted to deformation potential energy of the system.

8. **Statement–1** : The coefficient of restitution is less than one for all collisions studied under Newton's laws of restitution.

Statement–2 : For a perfectly elastic collision, coefficient of restitution is equal to one.

9. **Statement–1** : If a ball projected up obliquely from the ground breaks up into several fragments in its path, the centre of mass of the system of all fragments move in same parabolic path compared to initial one till all fragments are in air.

Statement–2 : In the situation of statement–1, at the instant of breaking, the fragments may be thrown in different directions with different speeds.

Exercise # 3 Part # I [Matrix Match Type Questions]

Following question contains statements given in two columns, which have to be matched. The statements in **Column-I** are labelled as A, B, C and D while the statements in **Column-II** are labelled as p, q, r and s. Any given statement in **Column-I** can have correct matching with **one or more** statement(s) in **Column-II**.

1. Two balls of mass m and 2m each have momentum 2p and p in the direction shown in figure. During collision they exert an impulse of magnitude p on each other.

	Column I		Column II
(A)	After collision momentum of m	(P)	2p
(B)	After collision momentum of 2m	(Q)	p
(C)	Coefficient of restitution between them	(R)	1
		(S)	None

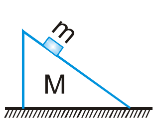
2. A particle of mass m, kinetic energy K and momentum p collides head on elastically with another particle of mass 2 m at rest. After collision :

	Column I		Column II
(A)	Momentum of first particle	(P)	3/4 p
(B)	Momentum of second particle	(Q)	– K/9
(C)	Kinetic energy of first particle	(R)	– p/3
(D)	Kinetic energy of second particle	(S)	$\frac{8K}{9}$
		(T)	None

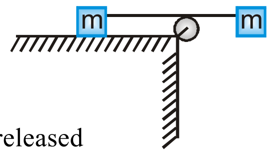
3. A particle of mass 1kg has velocity $\vec{v}_1 = (2t)\hat{i}$ and another particle of mass 2 kg has velocity $\vec{v}_2 = (t^2)\hat{j}$.

	Column I		Column II
(A)	Net force on centre of mass at 2 s	(P)	$\frac{20}{9}$ unit
(B)	Velocity of centre of mass at 2s	(Q)	$\sqrt{68}$ unit
(C)	Displacement of centre of mass in 2s	(R)	$\frac{\sqrt{80}}{3}$ unit
		(S)	None

4. In each situation of column–I, a system involving two bodies is given. All strings and pulleys are light and friction is absent everywhere. Initially each body of every system is at rest. Consider the system in all situation of column I from rest till any collision occurs. Then match the statements in column – I with the corresponding results in column–II

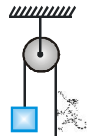
	Column I			Column II
(A)	The block plus wedge system is placed over smooth horizontal surface. After the system is released from rest, the centre of mass of system		(P)	Shifts towards right

(B) The string connecting both the blocks of mass m is horizontal. Left block is placed over smooth horizontal table as shown. After the two block system is released from rest, the centre of mass of system



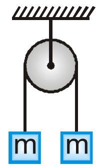
(Q) Shifts downwards

(C) The block and monkey have same mass. The monkey starts climbing up the rope. After the monkey starts climbing up, the centre of mass of monkey + block system



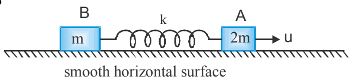
(R) Shifts upwards

(D) Both block of mass m are initially at rest. The left block is given initial velocity u downwards. Then, the centre of mass of two block system afterwards



(S) Does not shift

5. Two blocks A and B of mass 2m and m respectively are connected by a massless spring of spring constant k. This system lies over a smooth horizontal surface. At t = 0 the block A has velocity u towards right as shown while the speed of block B is zero, and the length of spring is equal to its natural length at that instant. In each situation of column–I, certain statements are given and corresponding results are given in column II.



Column I		Column II	
(A)	The velocity of block A	**(P)**	Can never be zero
(B)	The velocity of block B	**(Q)**	May be zero at certain instants of time
(C)	The kinetic energy of system of two blocks	**(R)**	is minimum at maximum compression of spring
(D)	The potential energy of spring	**(S)**	Is maximum at maximum extension of spring

6.

Column I		Column II	
(A)	Elastic collision	**(P)**	KE is conserved
(B)	Inelastic collision	**(Q)**	KE after collision = KE before collision
(C)	Perfectly inelastic collision	**(R)**	KE after collision ≠ KE before collision
		(S)	Particles stick after collision
		(T)	Linear momentum is conserved
		(U)	Relative velocity of separation after is zero

7. If net force on a system of particles is zero, then

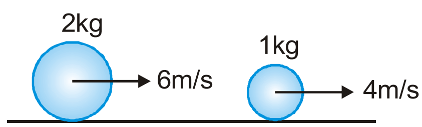
Column I		Column II	
(A)	Acceleration of centre of mass	**(P)**	Constant
(B)	Velocity of centre of mass	**(Q)**	Zero
(C)	Momentum of centre of mass	**(R)**	May be zero
(D)	Velocity of an individual particle of the system	**(S)**	May be constant

Part # II [Comprehension Type Questions]

Comprehension # 1

When two bodies collide normally they exert equal and opposite impulses on each other. Impulse = change in linear momentum. Coefficient of restitution between two bodies is given by :–

$$e = \frac{|\text{Relative velocity of separation}|}{|\text{Relative velocity of approach}|} = 1, \text{ for elastic collision}$$



Two bodies collide as shown in figure. During collision they exert impulse of magnitude J on each other.

1. If the collision is elastic, the value of J is .... N–s :

(A) 10/3 **(B)** 5/4 **(C)** 8/3 **(D)** 3/2

2. For what values of J (in N–s) the 2 kg block will change its direction of velocity :

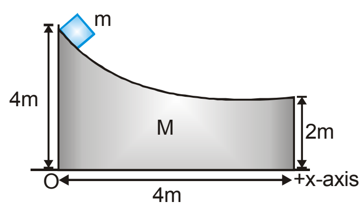
(A) J < 12 **(B)** J > 12 **(C)** J < 10 **(D)** J > 10

Comprehension # 2

If net force on a system in a particular direction is zero (say in horizontal direction) we can apply:

$\Sigma m_R x_R = \Sigma m_L x_L$, $\Sigma m_R v_R = \Sigma m_L v_L$ and $\Sigma m_R a_R = \Sigma m_L a_L$

Here R stands for the masses which are moving towards right and L for the masses towards left, x is displacement, v is velocity and a the acceleration (all with respect to ground). A small block of mass m = 1 kg is placed over a wedge of mass M = 4 kg as shown in figure. Mass m is released from rest. All surfaces are smooth. Origin O is as shown.



1. Final velocity of the wedge is .... m/s :–

(A) $\sqrt{3}$ **(B)** $\sqrt{2}$ **(C)** $\frac{1}{\sqrt{2}}$ **(D)** $\frac{1}{\sqrt{3}}$

2. The block will strike the x–axis at x = ...m :–

(A) 4.2 **(B)** 7.6 **(C)** 5.6 **(D)** 6.8

3. Normal reaction between the two blocks at an instant when absolute acceleration of m is $5\sqrt{3}$ m/s² at 60° with horizontal is .... N. Normal reaction at this instant is making 30° with horizontal :

(A) 6 **(B)** 10 **(C)** 4 **(D)** 5

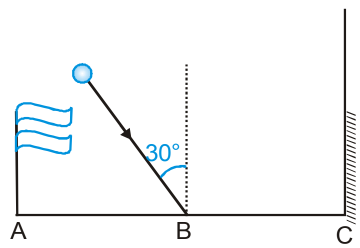
4. At the same instant reaction on the wedge from the ground is .... N.

(A) 42.5 **(B)** 40 **(C)** 43.46 **(D)** None of these

Comprehension # 3

In an oblique collision component parallel to common tangent remains unchanged while along common normal direction, relative velocity of separation becomes e times the relative velocity of approach.

1. A ball collides at B with velocity 10 m/s at 30° with vertical.
There is a flag at A and a wall at C. Collision of ball with ground is perfectly inelastic (e = 0) and that with wall is elastic (e = 1). Given AB = BC = 10m. The ball will collide with the flag after time t = ...s.



(A) 4 **(B)** 5
(C) 6 **(D)** Ball will not collide with the flag

Comprehension # 4

One particle of mass 1 kg is moving along positive x–axis with velocity 3 m/s. Another particle of mass 2 kg is moving along y–axis with 6 m/s. At time t = 0, 1 kg mass is at (3m, 0) and 2 kg at (0, 9m), x–y plane is the horizontal plane. (Surface is smooth for question 1 and rough for question 2 and 3)

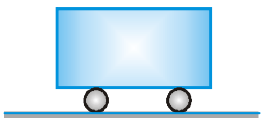
1. The centre of mass of the two particles is moving in a straight line which equation is :
(A) y = x + 2 **(B)** y = 4x + 2 **(C)** y = 2x – 4 **(D)** y = 2x + 4

2. If both the particles have the same value of coefficient of friction μ = 0.2. The centre of mass will stop at time t = ...s :
(A) 1.5 **(B)** 4.5 **(C)** 3.0 **(D)** 2.0

3. Co–ordinates of centre of mass where it will stop finally are :–
(A) (2.0 m, 14.25 m) **(B)** (2.25 m, 10 m) **(C)** (3.75 m, 9 m) **(D)** (1.75 m, 12 m)

Comprehension # 5

When the mass of a system is variable, a thrust force has to be applied on it in addition to all other forces acting on it. This thrust force is given by : $\vec{F} = \vec{v}_r\left(\pm\frac{dm}{dt}\right)$



Here $\vec{v}_r$ is the relative velocity with which the mass dm either enters or leaves the system. A car has total mass 50 kg. Gases are ejected from this backwards with relative velocity 20 m/s. The rate of ejection of gas is 2 kg/s. Total mass of gas is 20 kg. Coefficient of friction between the car and road is $\mu = 0.1$.

1. Car will start moving after time t = ... second :

(A) 4 **(B)** 10 **(C)** 5 **(D)** 8

2. Maximum speed of car will be v = ... m/s : (Take $\ell n \frac{4}{3} = 0.28$)

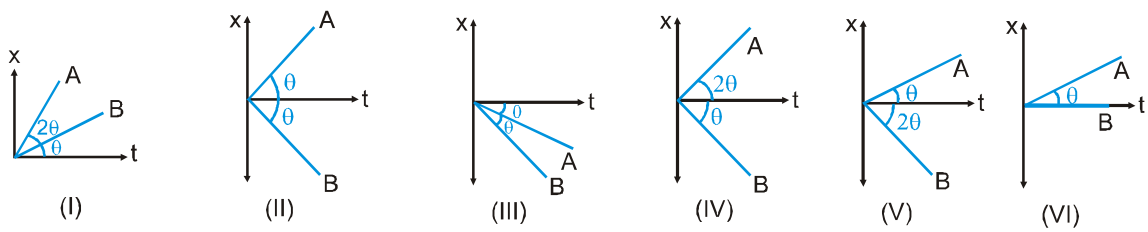
(A) 0.6 **(B)** 0.8 **(C)** 1.0 **(D)** 1.2

3. Car will stop after (from starting) t = ... seconds :

(A) 12.2 **(B)** 6.4 **(C)** 10.6 **(D)** 5.8

Comprehension # 6

An initially stationary box on a frictionless floor explodes into two pieces, piece A with mass m_A and piece B with mass m_B. Two pieces then move across the floor along x–axis. Graph of position versus time for the two pieces are given.



1. Which graphs pertain to physically possible explosions ?

(A) II, V **(B)** VI **(C)** I, III **(D)** IV

2. Based on the above question, Match column A with the column B.

	Column A	Column B (Graph number)
(P)	$m_A = m_B$	I
(Q)	$m_A > m_B$	II
(R)	$m_A < m_B$	III
		IV
		V
		VI

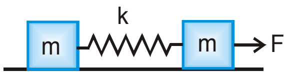
(A) P – VI, Q – III, R – I **(B)** P – II, Q – V, R – IV

(C) P – II, Q – IV, R – V **(D)** P – VI, Q – II, R – IV

3. If all the graphs are possible then, in which of the following cases external force must be acting on the box :-

(A) II **(B)** V **(C)** VI **(D)** I

Comprehension # 7



Two blocks of equal mass m are connected by an unstretched spring and the system is kept at rest on a frictionless horizontal surface. A constant force F is applied on the first block pulling it away from the other as shown in figure.

1. Then the displacement of the centre of mass at time t is :-

(A) $\frac{Ft^2}{2m}$ **(B)** $\frac{Ft^2}{3m}$ **(C)** $\frac{Ft^2}{4m}$ **(D)** $\frac{Ft^2}{m}$

2. If the extension of the spring is x_0 at time t, then the displacement of the first block at this instant is :-

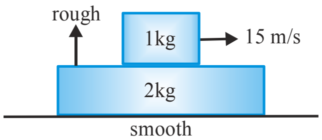
(A) $\frac{1}{2}\left(\frac{Ft^2}{2m}+x_0\right)$ **(B)** $-\frac{1}{2}\left(\frac{Ft^2}{2m}+x_0\right)$ **(C)** $\frac{1}{2}\left(\frac{Ft^2}{2m}-x_0\right)$ **(D)** $\left(\frac{Ft^2}{2m}+x_0\right)$

3. If the extension of the spring is x_0 at time t, then the displacement of the second block at this instant is :-

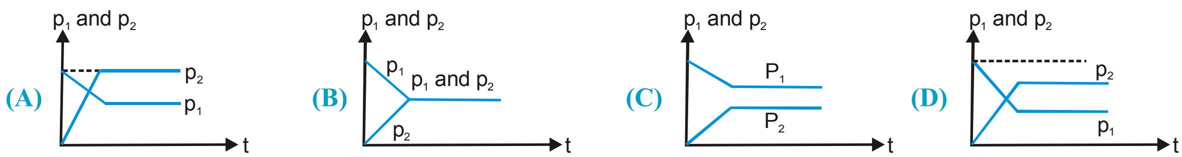
(A) $\left(\frac{Ft^2}{2m}-x_0\right)$ **(B)** $\frac{1}{2}\left(\frac{Ft^2}{2m}+x_0\right)$ **(C)** $\frac{1}{2}\left(\frac{2Ft^2}{m}-x_0\right)$ **(D)** $\frac{1}{2}\left(\frac{Ft^2}{2m}-x_0\right)$

Comprehension # 8

A 1 kg block is given a velocity of 15 m/s towards right over a very long rough plank of mass 2 kg as shown in figure.



1. The correct graph showing linear momentum of 1 kg (i.e. p_1) and of 2kg (i.e. p_2) versus time is :



2. If coefficient of friction between the two blocks is equal to 0.4, then magnitude of initial slope of p_1 versus t and p_2 versus t (in SI unit) will be :–

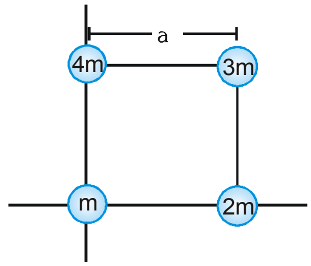
(A) 4 and 2 **(B)** 2 and 4 **(C)** 4 and 4 **(D)** 2 and 2

3. Momentum of both the blocks are equal at time t = ...seconds :

(A) 1.75 **(B)** 1.875 **(C)** 2.5 **(D)** 1.25

Exercise # 4 [Subjective Type Questions]

1. Four particles of masses m, 2m, 3m, 4m are placed at corners of a square of side 'a' as shown in fig. Find out coordinates of centre of mass.



2. Figure shows a uniform square plate from which four identical squares at the corners will be removed.

(i) Where is the centre of mass of the plate originally.

(ii) Where is C.M. after square 1 is removed.

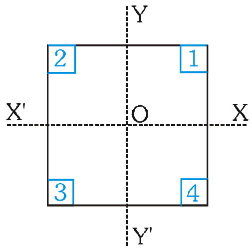
(iii) Where is C.M. after squares 1 and 2 removed.

(iv) Where is C.M. after squares 1 and 3 are removed.

(vi) Where is C.M. after squares 1, 2 and 3 are removed.

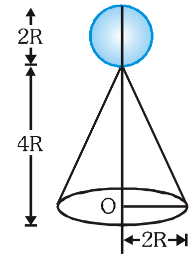
(vi) Where is C.M. after all the four squares are removed.

Give Answers in terms of quadrants and axes.



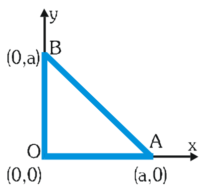
3. A rigid body consists of a 3 kg mass connected to a 2 kg mass by a massless rod. The 3kg mass is located at $\vec{r}_1 = (2\hat{i} + 5\hat{j})$ m and the 2 kg mass at $\vec{r}_2 = (4\hat{i} + 2\hat{j})$ m. Find the length of rod and the coordinates of the centre of mass.

4. A man has constructed a toy as shown in fig. If density of the material of the sphere is 12 times of the cone compute the position of the centre of mass. [Centre of mass of a cone of height h is at height of $\frac{h}{4}$ from its base.]

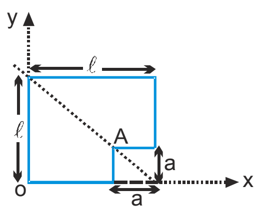


5. Three rods of the same mass are placed as shown in the figure.

Calculate the coordinates of the centre of mass of the system.

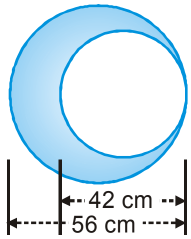


6. The figure shows a square metal plate of side ℓ from which a square plate of side a has been cut as shown in the figure. Find the ratio (a/ℓ) so that the centre of mass of the remaining L–shaped plate coincides with the point A .

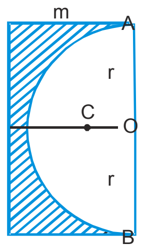


7. A circular plate of uniform thickness has a diameter of 56 cm. A circular portion of diameter 42 cm is removed from one edge of the plate as shown in figure.

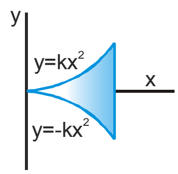
Find the position of the centre of mass of the remaining portion.



8. Determine the centre of gravity of a thin homogeneous plate having the form of a rectangle with sides r and 2r from which a semicircle with a radius r is cut out of figure.

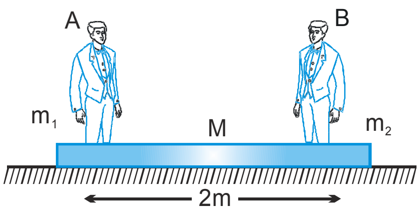


9. A thin sheet of metal of uniform thickness is cut into the shape bounded by the line x = a and $y = \pm kx^2$, as shown. Find the coordinates of the centre of mass.



10. A body of mass 1 kg initially at rest, explodes and breaks into three fragments of masses in the ratio 1 : 1 : 3. The two pieces of equal mass fly–off perpendicular to each other with a speed of 30 m/s each. What is the velocity of the heavier fragment ?

11. In the figure shown, when the persons A and B exchange their positions, then



$m_1 = 50$kg; $m_2 = 70$kg; M = 80kg

(i) the distance moved by the centre of mass of the system is _____.

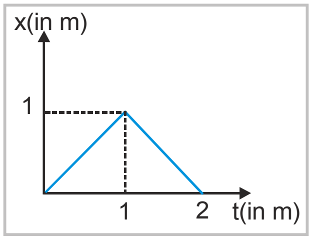
(ii) the plank moves toward ________.

(iii) the distance moved by the plank is ____.

(iv) the distance moved by A with respect to ground is ______.

(v) the distance moved by B with respect to ground is __.

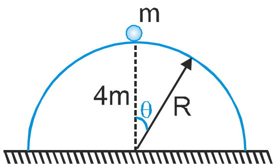
12 2 bodies m_1 & m_2 of mass 1 and 2 kg respectively are moving along x–axis under the influence of mutual force only. The velocity of their centre of mass at a given instant is 2 m/s. The x–coordinate of m_1 is plotted against time. Then plot the x–coordinate of m_2 against time (Both are located at origin).



13. A man whose mass is m kg jumps vertically into air from a sitting position in which his centre of mass is at a height h_1 from the ground. When his feet are just about to leave the ground his centre of mass is h_2 from the ground and finally rises to h_3 when he is at the top of the jump. What is the average upward force exerted by the ground on him ?

14. Two bodies of same mass tied with an inelastic string of length ℓ lie together. One of them is projected vertically upwards with velocity $\sqrt{6g\ell}$. Find the maximum height up to which the centre of mass of system of the two masses rises.

15. 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. Find the angular velocity of the particle relative to hemisphere an angular displacement θ when velocity of hemisphere has become v.



16. A uniform thin rod of mass M and length L is standing vertically along the y–axis on a smooth horizontal surface, with its lower end at the origin (0, 0). A slight disturbance at t = 0 causes the lower end to slip on the smooth surface the positive x–axis, and the rod starts falling.

(i) What is the path followed by the centre of mass of the rod during its fall ?

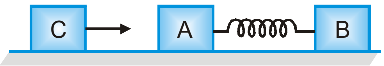
(ii) Find the equation of the trajectory of a point on the rod located at a distance r from the lower end. What is the shape of the path of this point ?

17. A ball of mass 100 g is projected vertically upwards from the ground with a velocity of 49m/s. At the same time another identical ball is dropped from a height of 98 m to fall freely along the same path as that followed by the first ball. After some time the two balls collide and stick together and finally fall to the ground. Find the time of flight of the masses.

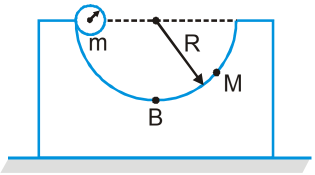
18. Two bodies A and B of masses m and 2m respectively are placed on a smooth floor. They are connected by a spring. A third body C of mass m moves with velocity v_0 along the line joining A and B and collides elastically with A as shown in fig. At a certain instant of time t_0 after collision, it is found that the instantaneous velocities of A and B are the same. Further at this instant the compression of the spring is found to be x_0. Determine–

(i) The common velocity of A and B at time t_0 and

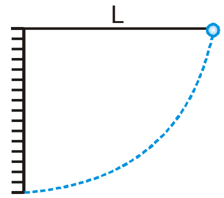
(ii) The spring constant.



19. A block of mass M with a semicircular track of radius R, rests on a horizontal frictionless surface. A uniform cylinder of radius r and mass m is released from rest at the top point A (see Fig). The cylinder slips on the semicircular frictionless track. How far has the block moved when the cylinder reaches the bottom (point B) of the track ? How fast is the block moving when the cylinder reaches the bottom of the track ?



20. A simple pendulum is suspended from a peg on a vertical wall. The pendulum is pulled away from the wall to a horizontal position (see fig.) and released.

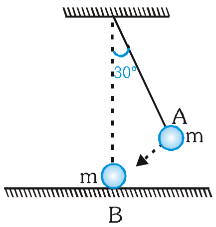


The ball hits the wall, the coefficient of restitution being $\frac{2}{\sqrt{5}}$.

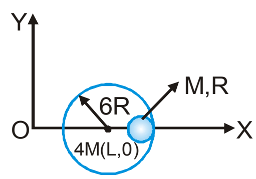
What is the minimum number of collisions after which the amplitude of oscillations becomes less than 60 degrees ?

21. A sphere of mass m_1 in motion hits directly another sphere of mass m_2 at rest and sticks to it, the total kinetic energy after collision is 2/3 of their total K.E. before collision. Find the ratio of $m_1 : m_2$.

22. The bob A of a pendulum released from 30° to the vertical hits another bob B of the same mass at rest on a table as shown in figure. How high does the bob A rise after the collision ? Neglect the size of the bob and assume the collision to be elastic.



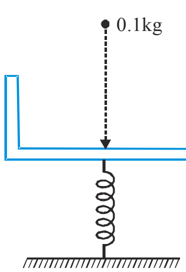
23. A small sphere of radius R is held against the inner surface of a larger sphere of radius 6R. The masses of large and small spheres are 4M and M respectively. This arrangement is placed on a horizontal table. There is no friction between any surfaces of contact. The small sphere is now released. Find the co–ordinates of the centre of the larger sphere when the smaller sphere reaches the other extreme position.



24. In an elastic collision of two billiard balls, is the total kinetic energy conserved during the short time of collision of the balls (i.e. when they are in contact) ?

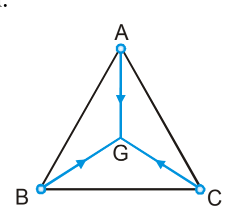
25. A massless platform is kept on a light elastic spring, shown in Fig. When a sand particle of 0.1 kg mass is dropped on the pan from a height 0.24 m, the particle strikes the pan, and the spring compresses by 0.01 m.

From what height should the particle be dropped to cause a compression of 0.04 m ?



26. A body 'A' moving in a straight line with velocity v makes a collision with a body 'B' initially at rest. After collision, B acquires a velocity of 1.6 v. Assuming the bodies to be perfectly elastic, what is the ratio of the mass of A to that of B ? What percentage of A's energy is transferred to B as a result of collision.

27. Three particles A, B and C of equal mass move with equal speed v along the medians of an equilateral triangle as shown in fig. They collide at the centroid G of the triangle. After the collision, A comes to rest, B retraces its path with the speed v. What is the velocity of C ?



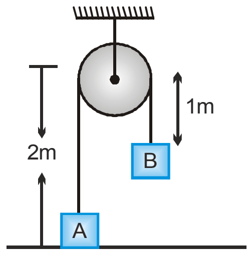
28. A particle of mass 2 kg moving with a velocity $5\hat{i}$ m/s collides head–on with another particle of mass 3 kg moving with a velocity $-2\hat{i}$ m/s. After the collision the first particle has speed of 1.6 m/s in negative x direction. Find :

(i) Velocity of the centre of mass after the collision

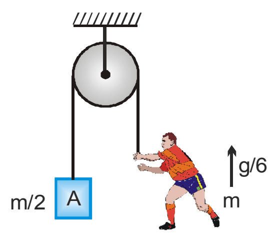
(ii) Velocity of the second particle after the collision

(iii) Coefficient of restitution.

29. Two masses A & B each of 5 kg are suspended by a light inextensible string passing over a smooth massless pulley such that mass A rest on smooth table & B is held at the position shown. Mass B is now gently lifted up to the pulley and allowed to fall from rest. Determine up to what height will A rise for the ensuing motion.

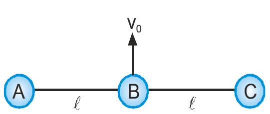


30. Block A of mass m/2 is connected to one end of light rope which passes over a pulley as shown in the Fig. Man of mass m climbs the other end of rope with a relative acceleration of g/6 with respect to rope find acceleration of block A and tension in the rope.



31. An object of mass 5 kg is projected with a velocity of 20 m/s at an angle of 60° to the horizontal. At the highest point of its path the projectile explodes and breaks up into two fragments of masses 1 kg and 4 kg. The fragments separate horizontally after the explosion. The explosion releases internal energy such that the kinetic energy of the system at the highest point is doubled. Calculate the separation between the two fragments when they reach the ground.

32. Three identical balls each of mass m = 0.5 kg are connected with each other as shown in Fig. and rest over a smooth horizontal table. At moment t = 0, ball B is imparted a horizontal velocity v_0=9ms^{-1}. Calculate velocity of A just before it collides with ball C.

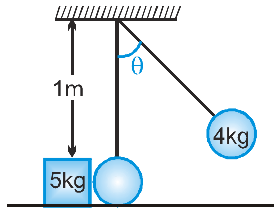


33 A bullet of mass M is fired with a velocity 50 m/s at an angle θ with the horizontal. At the highest point of its trajectory, it collides head–on with a bob of mass 3M suspended by a massless string of length $\frac{10}{3}$ metres and gets embedded in the bob, after the collision the string moves through an angle of 120°. Find :

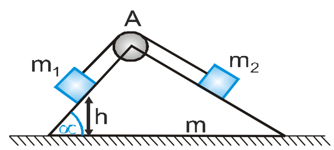
(i) the angle θ,

(ii) the vertical and horizontal coordinates of the initial position of the bob with respect to the point of firing of the bullet. (Take g = 10 m/s^2).

34. The 4 kg sphere from rest when θ =60° strikes a block mass of 5 kg placed on a rough horizontal plane and comes to rest after collision. The 5 kg block comes to rest after moving a distance of 0.8m. Find μ of ground & block & coefficient of restitution e.



35. Two blocks of masses m_1 and m_2 are connected by a massless pulley A, slides along the smooth sides of a rectangular wedge of mass m, which rests on a smooth horizontal plane. Find the distance covered by the wedge on the horizontal plane till the mass m_1 is lowered by the vertical distance h.



36. Two particles, each of mass m, are connected by a light inextensible string of length 2ℓ. Initially they lie on a smooth horizontal table at points A and B distant ℓ apart. The particle at A is projected across the table with velocity u. Find the speed with which the second particle begins to move if the direction of u is :-

(i) along BA,

(ii) at an angle of 120° with AB

(iii) perpendicular to AB. In each case calculate (in terms of m and u) the impulsive tension in the string.

37. Two particles A and B of mass 2m and m respectively are attached to the ends of a light inextensible string of length 4a which passes over a small smooth peg at a height 3a from an inelastic table. The system is released from rest with each particle at a height a from the table. Find–

(i) The speed of B when A strikes the table.

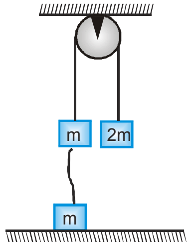
(ii) The time that elapses before A first hits the table.

(iii) The time for which A is resting on the table after the first collision & before it is first jerked off.

38. A cylindrical solid of mass 10^{-2} kg and cross–sectional area 10^{-4} m^2 is moving parallel to its axis (the x–axis) with a uniform speed of 10^3 m/s in the positive direction. At t = 0, its front face passes the plane x = 0. The region to the right of this plane is filled with the dust particle of uniform density 10^{-3} kg/m^3. When a dust particles collides with the face of the cylinder, it sticks to its surface. Assuming that the dimensions of the cylinder remain practically unchanged and that the dust sticks only to the front face of the cylinder find the x–coordinate of the front of the cylinder at t = 150 s.

39. After a completely inelastic collision two objects of the same mass and same initial speed are found to move away together at half their initial speed. Find the angle between the initial velocities of the objects.

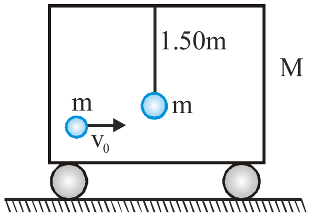
40. The Atwood machine in figure has a third mass attached to it by a limp string After being released, the 2m mass falls a distance x before the limp string becomes taut. Thereafter both the mass on the left rise at the same speed. What is the final speed? Assume that pulley is ideal.



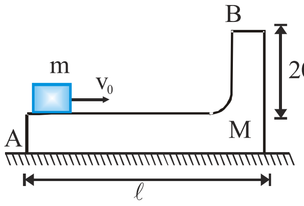
41. Two particles each of mass m are connected by a light inextensible string and a particle of mass M is attached to the midpoint of the string. The system is at rest on a smooth horizontal table with the string just taut and in a straight line. The particle M is given a velocity v along the table perpendicular to the string. Prove that when the two particles are about to collide :

(i) The velocity of M is $\frac{Mv}{(M+2m)}$ **(ii)** The speed of each of the other particles is $\left(\frac{\sqrt{2M(M+m)}}{(M+2m)}\right)$ v.

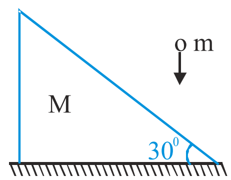
42. A ball of mass m=1 kg is hung vertically by a thread ℓ=1.50 m. Upper end of the thread is attached to the ceiling of a trolley of mass M = 4 kg. Initially, trolley is stationary and it free to move along horizontal rails without friction. A shell of mass m = 1 kg moving horizontally with velocity v_0=6 ms^{-1} collides with the ball and gets stuck with it. As a result, thread starts to deflected towards right. Calculate its maximum deflection with the vertical. (g = 10 ms^{-2})



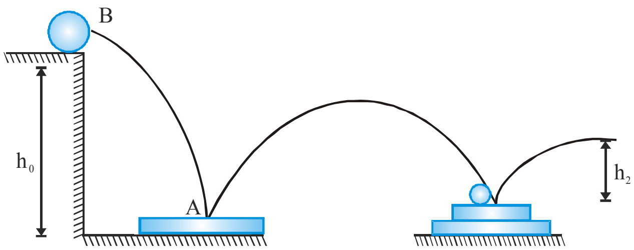
43. A wedge of mass M=2m rests on a smooth horizontal plane. A small block of mass m rests over it at left end A as shown in figure. A sharp impulse is applied on the block, due to which it starts moving to the right with velocity v_0 = 6 ms^{-1}. At highest point of its trajectory, the block collides with a particle of same mass m moving vertically downwards with velocity v = 2 ms^{-1} and gets stuck with it. If the combined body lands at the end point A of body of mass M, calculate length ℓ. Neglect friction (g = 10 ms^{-2})



44. A ball of mass m = 1 kg falling vertically with a velocity v_0 = 2 m/s strikes a wedge of mass M = 2 kg kept on a smooth, horizontal surface as shown in figure. The coefficient of resitution between the ball and the wedge is e =1/2. Find the velocity of the wedge and the ball immediately after collision.



45. A 70 g ball B dropped from a height h_0 = 9 m reaches a height h_2 = 0.25 m after bouncing twice from identical 210 g plates. Plate A rests directly on hard ground, while plate C rests on a foam –rubber mat. Determine.



(i) the coefficient of restitution between the ball and the plates,

(ii) the height h_1 of the ball's first bounce.

Exercise # 5 Part # I [Previous Year Questions] [AIEEE/JEE-MAIN]

1. Two identical particles move towards each other with velocity 2v and v respectively. The velocity of centre of mass is- **[AIEEE - 2002]**

(A) v **(B)** v/3 **(C)** v/2 **(D)** zero

2. Consider the following two statements :- **[AIEEE - 2003]**

A : Linear momentum of a system of particles is zero. B : Kinetic energy of a system of particles is zero.

Then-

(A) A does not imply B and B does not imply A **(B)** A implies B but B does not imply A

(C) A does not imply B but B implies A **(D)** A implies B and B implies A

3. Two spherical bodies of mass M and 5M and radii R and 2R respectively are released in free space with initial separation between their centres equal to 12 R. It they attract each other due to gravitational force only, then the distance covered by the smaller body just before collision is- **[AIEEE - 2003]**

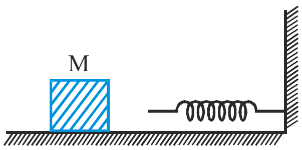
(A) 2.5 R **(B)** 4.5 R **(C)** 7.5 R **(D)** 1.5 R

4. A body A of mass M while falling vertically downwards under gravity breaks into two parts; a body B of mass $\frac{1}{3}$ M and, a body C of mass $\frac{2}{3}$ M. The centre of mass of bodies B and C taken together shifts compared to that of body A towards- **[AIEEE - 2005]**

(A) depends on height of breaking **(B)** does not shift

(C) body C **(D)** body B

5. The block of mass M moving on the frictionless horizontal surface collides with the spring of spring constant k and compresses it by length L. The maximum momentum of the block after collision is- **[AIEEE - 2005]**

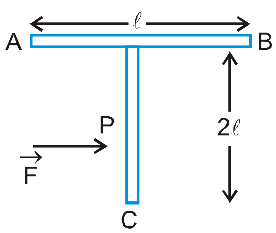


(A) $\sqrt{Mk}\,L$ **(B)** $\frac{kL^2}{2M}$ **(C)** zero **(D)** $\frac{ML^2}{k}$

6. A mass m moves with a velocity v and collides inelastically with another identical mass. After collision the Ist mass moves with velocity $\frac{v}{\sqrt{3}}$ in a direction perpendicular to the initial direction of motion. Find the speed of the second mass after collision- **[AIEEE-2005]**

(A) v **(B)** $\sqrt{3}$ v **(C)** $\frac{2}{\sqrt{3}}$ v **(D)** $\frac{v}{\sqrt{3}}$

7. A T shaped object with dimensions shown in the figure, is lying on a smooth floor. A force $\vec{F}$ is applied at the point P parallel to AB, such that the object has only the translational motion without rotation. Find the location of P with respect to C. **[AIEEE - 2005]**



(A) $\frac{2}{3}\ell$ **(B)** $\frac{3}{2}\ell$ **(C)** $\frac{4}{3}\ell$ **(D)** ℓ

8. A bomb of mass 16 kg at rest explodes into two pieces of masses 4 kg and 12 kg. The velocity of the 12 kg mass is 4 ms^{-1}. The kinetic energy of the other mass is- **[AIEEE - 2006]**

(A) 144 J **(B)** 288 J **(C)** 192 J **(D)** 96 J

9. Consider a two particle system with particles having masses m_1 and m_2. If the first particle is pushed towards the centre of mass through a distance d, by what distance should the second particle be moved, so as to keep the centre of mass at the same position ? **[AIEEE - 2006]**

(A) $\frac{m_2}{m_1}d$ **(B)** $\frac{m_1}{m_1+m_2}d$ **(C)** $\frac{m_1}{m_2}d$ **(D)** d

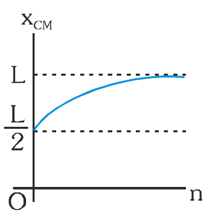
10. A circular disc of radius R is removed from a bigger circular disc of radius 2R such that the circumferences of the discs coincide. The centre of mass of the new disc is αR from the centre of the bigger disc. The value of α is : - **[AIEEE - 2007]**

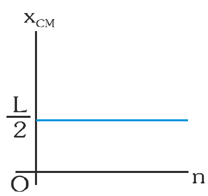
(A) 1/3 **(B)** 1/2 **(C)** 1/6 **(D)** 1/4

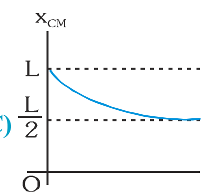
11. A block of mass 0.50 kg is moving with a speed of 2.00 ms^{-1} on a smooth surface. It strikes another mass of 1.00 kg and then they move together as a single body. The energy loss during the collision is :- **[AIEEE - 2008]**

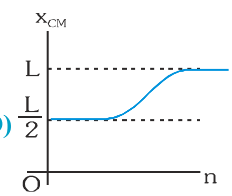
(A) 0.16 J **(B)** 1.00 J **(C)** 0.67 J **(D)** 0.34 J

12. A thin rod of length 'L' is lying along the x-axis with its ends at x = 0 and x = L. It linear density (mass/length) varies with x as $k\left(\frac{x}{L}\right)^n$ where n can be zero or any positive number. If the position x_{CM} of the centre of mass of the rod is plotted against 'n', which of the following graphs best approximates the depence of x_{CM} on n? **[AIEEE - 2008]**

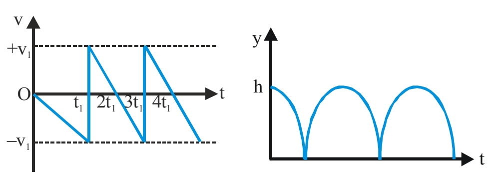
(A)


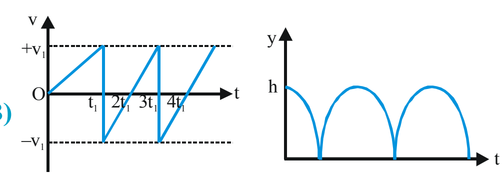
(B)


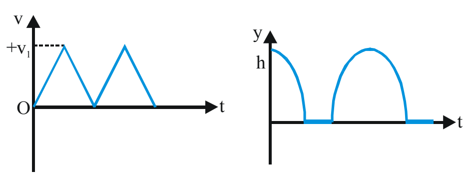
(C)


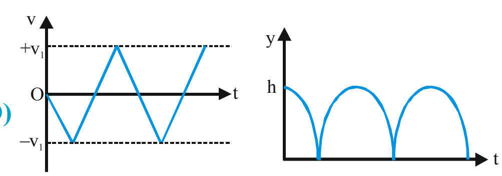
(D)


13. Consider a rubber ball freely falling from a height h = 4.9 m onto a horizontal elastic plate. Assume that the duration of collision is negligible and the collision with the plate is totally elastic.Then the velocity as a function of time and the height as a function of time will be :- **[AIEEE - 2009]**

(A)


(B)


(C)


(D)


Directions : This Questions contain Statement-1 and Statement-2.

Of the four choices given after the statements, choose the one that best discribes the two statements.

14. **Statement-1 :** Two particles moving in the same direction do not lose all their energy in a completely inelastic collision.

Statement-2 : Principle of conservation of momentum holds true for all kinds of collisions. **[AIEEE - 2010]**

(A) Statement–1 is true, Statement–2 is false

(B) Statement–1 is true, Statement–2 is true; Statement–2 is the correct explanation of Statement–1

(C) Statement–1 is true, Statement–2 is true; Statement–2 is not the correct explanation of Statement–1

(D) Statement–1 is false, Statement–2 is true

15. A bob of mass m attached to an inextensible string of length l is suspended from a vertical support. The bob rotates in a horizontal circle with an angular speed ω rad/s about the vertical. About the point of suspension : **[JEE (Main) - 2014]**

(A) angular momentum changes in direction but not in magnitude.

(B) angular momentum changes both in direction and magnitude.

(C) angular momentum is conserved.

(D) angular momentum changes in magnitude but not in direction.

16. Distance of the centre of mass of a solid uniform cone from its vertex if z_0. If the radius of its base is R and its height is h then z_0 is equal to : **[JEE (Main) - 2015]**

(A) $\frac{5h}{8}$ **(B)** $\frac{3h^2}{8R}$ **(C)** $\frac{h^2}{4R}$ **(D)** $\frac{3h}{4}$

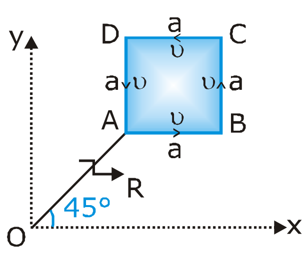
17. From a solid sphere of mass M and radius R a cube of maximum possible volume is cut. Moment of inertia of cube about an axis passing through its center and perpendicular to one of its faces is : **[JEE (Main) - 2015]**

(A) $\frac{4MR^2}{9\sqrt{3}\pi}$ **(B)** $\frac{4MR^2}{3\sqrt{3}\pi}$ **(C)** $\frac{MR^2}{32\sqrt{2}\pi}$ **(D)** $\frac{MR^2}{16\sqrt{2}\pi}$

18. A particle of mass m moving in the x direction with speed 2υ is hit by another particle of mass 2m moving in the y direction with speed υ. if the collision is perfectly inelastic, the percentage loss in the energy during the collision is close to : **[JEE (Main) - 2015]**

(A) 56% **(B)** 62% **(C)** 44% **(D)** 50%

19. A particle of mass m is moving along the side of a square of side 'a', with a uniform speed υ in the x-y plane as shown in the figure: **[JEE (Main) - 2016]**



Which of the following statements is false for the angular momentum $\vec{L}$ about the origin?

(A) $\vec{L} = m\upsilon\left[\frac{R}{\sqrt{2}} - a\right]\hat{k}$ when the particle is moving from C to D.

(B) $\vec{L} = m\upsilon\left[\frac{R}{\sqrt{2}} + a\right]\hat{k}$ when the particle is moving from B to C.

(C) $\vec{L} = \frac{m\upsilon}{\sqrt{2}} R\,\hat{k}$ when the particle is moving from D to A.

(D) $\vec{L} = -\frac{m\upsilon}{\sqrt{2}} R\,\hat{k}$ when the particle is moving from A to B.

Part # II [Previous Year Questions][IIT-JEE ADVANCED]

MCQ's with one correct answer

1. Two particles of masses m_1 and m_2 in projectile motion have velocities $\vec{v}_1 < \vec{v}_2$ respectively at time t = 0. They collide at time t_0. Their velocities become $\vec{v}'_1$ and $\vec{v}'_2$ at time $2t_0$ while still moving in air. The value of : $[(m_1\vec{v}'_1 + m_2\vec{v}'_2) - (m_1\vec{v}_1 + m_2\vec{v}_2)]$ is :– **[IIT-JEE 2001]**

(A) zero **(B)** $(m_1 + m_1)gt_0$ **(C)** $2(m_1 + m_2)gt_0$ **(D)** $\frac{1}{2}(m_1 + m_2)gt_0$

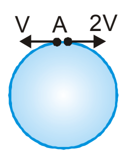
2. Two blocks of masses 10 kg and 4 kg are connected by a spring of negligible mass and placed on a frictionless horizontal surface. An impulse gives a velocity of 14 m/s to the heavier block in the direction of the lighter block. The velocity of the centre of mass is :– **[IIT-JEE 2002]**

(A) 30 m/s **(B)** 20 m/s **(C)** 10 m/s **(D)** 5 m/s

3. A particle moves in the X–Y plane under the influence of a force such that its linear momentum is $\vec{p}(t) = A[\tilde{i}\cos(kt) - \tilde{j}\sin(kt)]$, where A and k are constants. The angle between the force and the momentum is :– **[IIT-JEE 2007]**

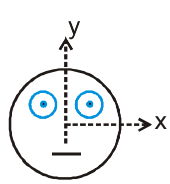
(A) 0° **(B)** 30° **(C)** 45° **(D)** 90°

4. Two small particles of equal masses start moving in opposite directions from a point A in a horizontal circular orbit. Their tangential velocities are v and 2v, respectively, as shown in the figure. Between collisions, the particles move with constant speeds. After making how many elastic collisions, other that at A, these two particles will again reach the point A ? **[IIT-JEE 2009]**



(A) 4 **(B)** 3 **(C)** 2 **(D)** 1

5. Look at the drawing given in the figure which has been drawn with ink of uniform line– thickness. The mass of ink used to draw each of the two inner circles, and each of the two line segments in m. The mass of the ink used to draw the outer circle is 6m. The coordinates of the centres of the different parts are : outer circle (0, 0), left inner circle (– a, a), right inner circle (a, a), vertical line (0, 0) and horizontal line (0, – a). The y–coordinates of the centre of mass of the ink in this drawing is :– **[IIT-JEE 2009]**



(A) $\frac{a}{10}$ **(B)** $\frac{a}{8}$ **(C)** $\frac{a}{12}$ **(D)** $\frac{a}{3}$

6. A particle of mass m is projected from the ground with an initial speed u_0 at an angle α with the horizontal. At the highest point of its trajectory, it makes a completely inelastic collision with another identical particle, which was thrown vertically upward from the ground with the same initial speed u_0. The angle that the composite system makes with the horizontal immediately after the collision is :- **[IIT-JEE 2013]**

(A) $\frac{\pi}{4}$ **(B)** $\frac{\pi}{4}+\alpha$ **(C)** $\frac{\pi}{2}-\alpha$ **(D)** $\frac{\pi}{2}$

MCQ's with one or more than one correct answers

1. Two balls, having linear momenta $\vec{p}_1 = p\hat{i}$ and $\vec{p}_2 = -p\hat{i}$, undergo a collision in free space. There is no external force acting on the balls. Let $\vec{p}_1'$ and $\vec{p}_2'$ be their final momenta. The following option(s) is (are) NOT ALLOWED for any non–zero value of p, a_1, a_2, b_1, b_2, c_1 and c_2. **[IIT-JEE 2008]**

(A) $\vec{p}_1' = a_1\hat{i} + b_1\hat{j} + c_1\hat{k}$, $\vec{p}_2' = a_2\hat{i} + b_2\hat{j}$

(B) $\vec{p}_1' = c_1\hat{k}$, $\vec{p}_2' = c_2\hat{k}$

(C) $\vec{p}_1' = a_1\hat{i} + b_1\hat{j} + c_1\hat{k}$, $\vec{p}_2' = a_2\hat{i} + b_2\hat{j} - c_2\hat{k}$

(D) $\vec{p}_1' = a_1\hat{i} + b_1\hat{j}$, $\vec{p}_2' = a_2\hat{i} + b_1\hat{j}$

Assertion – Reason

1. **Statement –I** In an elastic collision between two bodies, the relative speed of the bodies after collision is equal to the relative speed before the collision. **[IIT-JEE 2007]**

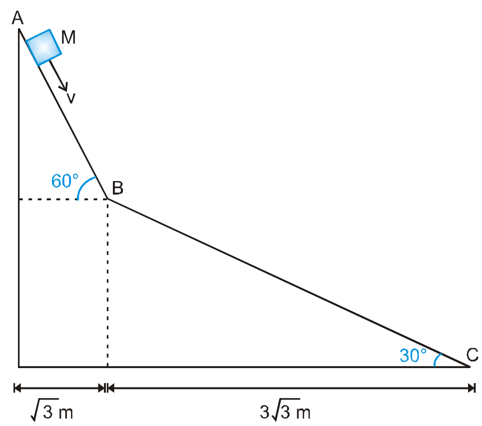
Statement – II In an elastic collision, the linear momentum of the system is conserved.

2. **Statement – I** If there is no external torque on a body about its centre of mass, then the velocity of the centre of mass remains constant. **[IIT-JEE 2007]**

Statement – II The linear momentum of an isolated system remains constant.

Comprehension based questions **[IIT-JEE 2008]**

A small block of mass M moves on a frictionless surface of an inclined plane, as shown in figure. The angle of the incline suddenly changes from 60° to 30° at point B. The block is initially at rest at A. Assume that collisions between the block and the incline are totally inelastic ($g = 10\ m/s^2$)



1. The speed of the block at point B immediately after it strikes the second incline is :–

(A) $\sqrt{60}$ m/s **(B)** $\sqrt{45}$ m/s **(C)** $\sqrt{30}$ m/s **(D)** $\sqrt{15}$ m/s

2. The speed of the block at point C, immediately before it leaves the second incline is :–

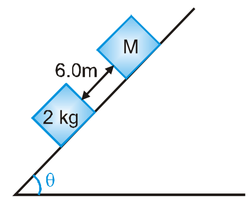
(A) $\sqrt{120}$ m/s **(B)** $\sqrt{105}$ m/s **(C)** $\sqrt{30}$ m/s **(D)** $\sqrt{75}$ m/s

3. If collision between the block and the incline is completely elastic, then the vertical (upward) component of the velocity of the block at point B, immediately after it strikes the second incline is :–

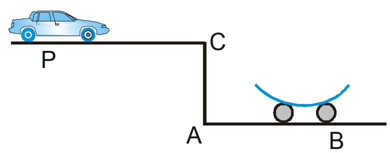
(A) $\sqrt{30}$ m/s **(B)** $\sqrt{15}$ m/s **(C)** 0 **(D)** $-\sqrt{15}$ m/s

Subjective Questions

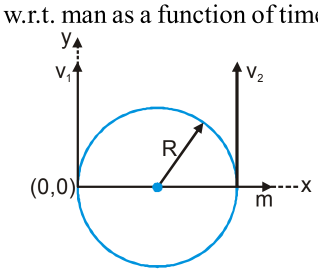
1. Two blocks of mass 2 kg and M are at rest on an inclined plane and are separated by a distance of 6.0 m as shown. The coefficient of friction between each block and the inclined plane is 0.25. The 2 kg block is given a velocity of 10.0 m/s up the inclined plane. It collides with M, comes back and has a velocity of 1.0 m/s when it reaches its initial position. The other block M after the collision moves 0.5 m up and comes to rest. Calculate the coefficient of restitution between the blocks and the mass of the block M. (Take $\sin\theta \approx \tan\theta = 0.05$ and $g = 10\ m/s^2$) **[IIT-JEE 1999]**



2. A car P is moving with a uniform speed of $5\sqrt{3}$ m/s towards a carriage of mass 9 kg at rest kept on the rails at a point B as shown in figure. The height AC is 120 m. Cannon balls of 1 kg are fired from the car with an initial velocity 100 m/s at an angle 30° with the horizontal. The first cannon balls hits the stationary carriage after a time t_0 and sticks to it. Determine t_0. At t_0, the second cannon ball is fired. Assume that the resistive force between the rails and the carriage is constant and ignore the vertical motion of the carriage throughout. If the second ball also hits and sticks of the carriage, what will be the horizontal velocity of the carriage just after the second impact ? **[IIT-JEE 2001]**

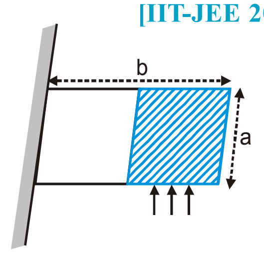


3. A particle of mass m, moving in a circular path of radius R with a constant speed v_2 is located at point (2R, 0) at time t = 0 and a man starts moving with a velocity v_1 along the positive y–axis from origin at time t = 0. Calculate the linear momentum of the particle w.r.t. man as a function of time. **[IIT-JEE 2003]**

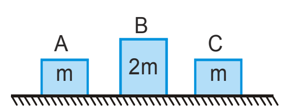


4. Two point masses m_1 and m_2 are connected by a spring of natural length ℓ_0. The spring is compressed such that the two point masses touch each other and then they are fastened by a string. Then the system is moved with a velocity v_0 along positive x–axis. When the system reaches the origin the string breaks (t = 0). The position of the point mass m_1 is given by $x_1 = v_0t - A(1-\cos\omega t)$ where A and ω are constants. Find the position of the second block as a function of time. Also find the relation between A and ℓ_0. **[IIT-JEE 2003]**

5. There is a rectangular plate of mass M kg of dimensions (a × b). The plate is held in horizontal position by striking n small balls each of mass m per unit area per unit time. These are striking in the shaded half region of the plate. The balls are colliding elastically with velocity v. What is v ? It is given n=100, M = 3 kg, m=0.01 kg, b=2m, a=1m, $g=10\ m/s^2$. **[IIT-JEE 2006]**



6. Three objects A, B and C are kept in a straight line on a frictionless horizontal surface. These have masses m, 2m and m, respectively. The object A moves towards B with a speed 9 m/s and makes an elastic collision with it. Thereafter, B makes completely inelastic collision with C. All motions occur on the same straight line Find the final speed (in m/s) of the object C. **[IIT-JEE 2009]**



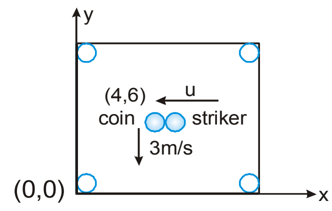
MOCK TEST

SECTION - I : STRAIGHT OBJECTIVE TYPE

1. Two particles A and B start moving due to their mutual interaction only. If at any time 't', $\vec{a}_A$ & $\vec{a}_B$ are their respective accelerations, $\vec{v}_A$ and $\vec{v}_B$ are their respective velocities and upto that time W_A and W_B are the work done on A & B respectively by the mutual force, m_A and m_B are their masses respectively, then which of the following is always correct.

(A) $\vec{v}_A + \vec{v}_B = 0$ **(B)** $m_A\vec{v}_A + m_B\vec{v}_B = 0$ **(C)** $W_A + W_B = 0$ **(D)** $\vec{a}_A + \vec{a}_B = 0$

2. On a smooth carom board, a coin moving in negative y–direction with a speed of 3 m/s is being hit at the point (4, 6) by a striker moving along negative x-axis. The line joining centres of the coin and the striker just before the collision is parallel to x-axis. After collision the coin goes into the hole located at the origin. Masses of the striker and the coin are equal. Considering the collision to be elastic, the initial and final speeds of the striker in m/s will be :



(A) (1.2, 0) **(B)** (2, 0) **(C)** (3, 0) **(D)** none of these

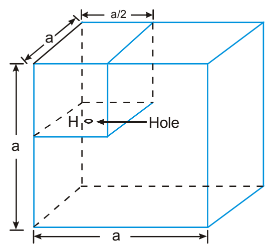
3. A train of mass M is moving on a circular track of radius 'R' with constant speed V. The length of the train is half of the perimeter of the track. The linear momentum of the train will be

(A) 0 **(B)** $\frac{2MV}{\pi}$ **(C)** MVR **(D)** MV

4. A canon shell moving along a straight line bursts into two parts. Just after the burst one part moves with momentum 20 Ns making an angle 30º with the original line of motion. The minimum momentum of the other part of shell just after the burst is :

(A) 0 Ns **(B)** 5 Ns **(C)** 10 Ns **(D)** 17.32 Ns

5. The figure shows a hollow cube of side 'a' of volume V. There is a small chamber of volume $\frac{V}{4}$ in the cube as shown. This chamber is completely filled by m kg of water. Water leaks through a hole H. Then the work done by gravity in this process assuming that the complete water finally lies at the bottom of the cube is :

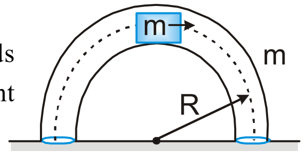


(A) $\frac{1}{2}$ mg a **(B)** $\frac{3}{8}$ mg a **(C)** $\frac{5}{8}$ mga **(D)** $\frac{1}{8}$ mga

6. A balloon having mass 'm' is filled with gas and is held in hands of a boy. Then suddenly it get released and gas starts coming out of it with a constant rate. The velocities of the ejected gases is also constant 2 m/s with respect to the balloon. Find out the velocity of the balloon when the mass of gas is reduced to half. [Effect of atmosphere and gravity is neglected]

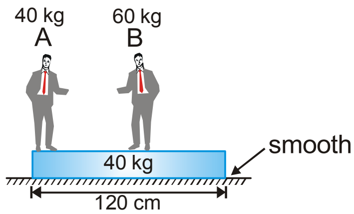
(A) $\ell n 2$ **(B)** $2\,\ell n 4$ **(C)** $2\,\ell n 2$ **(D)** none of these

7. In a vertical plane inside a smooth hollow thin tube a block of same mass as that of tube is released as shown in figure. When it is slightly disturbed, it moves towards right. By the time the block reaches the right end of the tube then the displacement of the tube will be (where 'R' is mean radius of tube). Assume that the tube remains in vertical plane.



(A) $\frac{2R}{\pi}$ **(B)** $\frac{4R}{\pi}$ **(C)** $\frac{R}{2}$ **(D)** R

8. Two men 'A' and 'B' are standing on a plank. 'B' is at the middle of the plank and 'A' is the left end of the plank. The surface between plank and ground is smooth. System is initially at rest and masses are as shown in figure. 'A' and 'B' starts moving such that the position of 'B' remains fixed with respect to ground. Then the point where A meets B is located at :

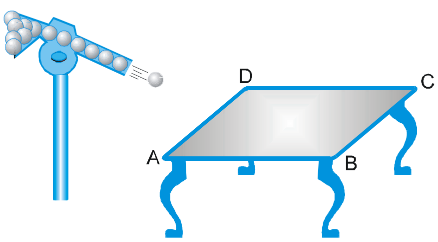


(A) the middle of the plank **(B)** 30 cm from the left end of the plank
(C) the right end of the plank **(D)** None of these

9. Three balls A, B and C ($m_A = m_C = 4\ m_B$) are placed on a smooth horizontal surface. Ball B collides with ball C with an initial velocity v as shown in the figure. Total number of collisions between the balls will be : (All collisions are elastic)

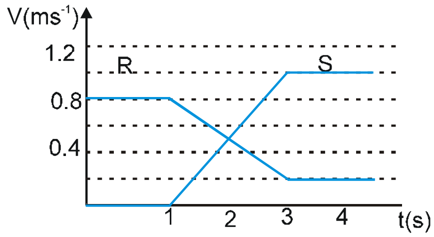
(A) one **(B)** two **(C)** three **(D)** four

10. A gun is firing 20 balls per seconds of mass 20 gm each on the smooth horizontal table surface ABCD. If the collision is perfectly elastic and balls are striking at the centre of table with a speed 5 m/sec at an angle of 60º with the vertical just before collision, then force exerted by one of the leg on ground is (assume total weight of the table is 0.2 kg and g = 10 m/s^2)



(A) 0.5 N **(B)** 1 N **(C)** 0.25 N **(D)** 0.75 N

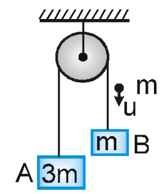
11. The diagram shows the velocity - time graph for two masses R and S that collided elastically. Which of the following statements is true?



I. R and S moved in the same direction after the collision.
II. The velocities of R and S were equal at the mid time of the collision.
III. The mass of R was greater than mass of S.

(A) I only **(B)** II only **(C)** I and II only **(D)** I, II and III

12. A system of two blocks A and B are connected by an inextensible massless string as shown in the figure . The pulley is massless and frictionless. Initially the system is at rest when, a bullet of mass 'm' moving with a velocity 'u' hits the block 'B' and gets embedded into it. The impulse imparted by tension force to the block of mass 3m is :



(A) $\frac{5mu}{4}$ **(B)** $\frac{4mu}{5}$ **(C)** $\frac{2mu}{5}$ **(D)** $\frac{3mu}{5}$

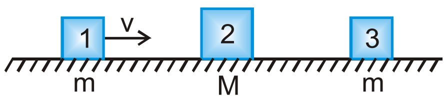
13. A stationary body explodes into four identical fragments such that three of them fly off mutually perpendicular to each other, each with same K.E., E_0 . The energy of explosion will be:

(A) $6E_0$ **(B)** $\frac{4E_0}{3}$ **(C)** $4E_0$ **(D)** $8E_0$

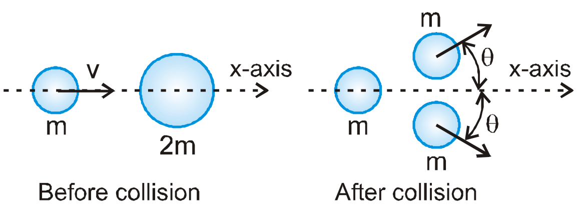
14. Three blocks are placed on smooth horizontal surface and lie on same horizontal straight line. Block 1 and block 3 have mass m each and block 2 has mass M (M > m). Block 2 and block 3 are initially stationary, while block 1 is initially moving towards block 2 with speed v as shown. Assume that all collisions are headon and perfectly elastic. What value of $\frac{M}{m}$ ensures that block 1 and block 3 have the same final speed ?

(A) $5+\sqrt{2}$ **(B)** $5-\sqrt{2}$

(C) $2+\sqrt{5}$ **(D)** $3+\sqrt{5}$



15. A particle of mass m is moving along the x-axis with speed v when it collides with a particle of mass 2m initially at rest. After the collision, the first particle has come to rest and the second particle has split into two equal-mass pieces that are shown in the figure. Which of the following statements correctly describes the speeds of the two pieces ? (θ > 0)

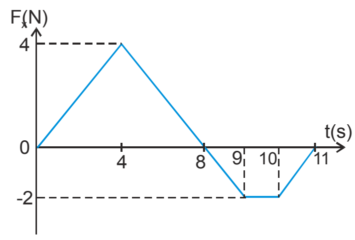


(A) Each piece moves with speed v. **(B)** Each piece moves with speed v/2.

(C) One of the pieces moves with speed v/2, the other moves with speed greater than v/2

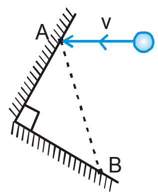
(D) Each piece moves with speed greater than v/2.

16. A 2 kg toy car can move along an x axis. Graph shows force F_x, acting on the car which begins at rest at time t = 0. The velocity of the car at t = 10 s is :



(A) – i m/s **(B)** – 1.5 i m/s **(C)** 6.5 i m/s **(D)** 13 i m/s

17. AB is an L shaped obstacle fixed on a horizontal smooth table. A ball strikes it at A, gets deflected and restrikes it at B. If the velocity vector before collision is $\vec{v}$ and coefficient of restitution of each collision is 'e', then the velocity of ball after its second collision at B is



(A) $e^2\vec{v}$ **(B)** $-e^2\vec{v}$

(C) $-e\vec{v}$ **(D)** data insufficient

18. For a two-body system in absence of external forces, the kinetic energy as measured from ground frame is K_o and from center of mass frame is K_{cm}. Pick up the wrong statement

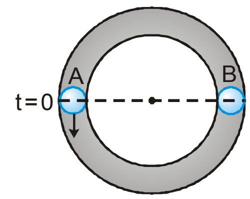
(A) The kinetic energy as measured from center of mass frame is least

(B) Only the portion of energy K_{cm} can be transformed from one form to another due to internal changes in the system.

(C) The system always retains at least $K_o - K_{cm}$ amount of kinetic energy as measured from ground frame irrespective of any kind of internal changes in the system.

(D) The system always retains at least K_{cm} amount of kinetic energy as measured from ground frame irrespective of any kind of internal changes in the system

19. Particle 'A' moves with speed 10 m/s in a frictionless circular fixed horizontal pipe of radius 5 m and strikes with 'B' of double mass that of A. Coefficient of restitution is 1/2 and particle 'A' starts its journey at t = 0. The time at which second collision occurs is :



(A) $\frac{\pi}{2}$ s **(B)** $\frac{2\pi}{3}$ s **(C)** $\frac{5\pi}{2}$ s **(D)** 4π s

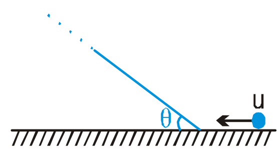
20. A particle of mass m is given initial speed u as shown in the figure. It transfers to the fixed inclined plane without a jump, that is, its trajectory changes sharply from the horizontal line to the inclined line. All the surfaces are smooth and $90° \geq \theta > 0°$. Then the height to which the particle shall rise on the inclined plane (assume the length of the inclined plane to be very large)

(A) increases with increase in θ

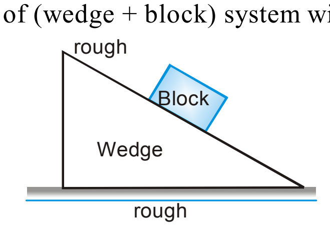
(B) decreases with increase in θ

(C) is independent of θ

(D) data insufficient



21. When a block is placed on a wedge as shown in the figure, the block starts sliding down and the wedge also start sliding on ground. All surfaces are rough. The centre of mass of (wedge + block) system will move



(A) leftward and downward.

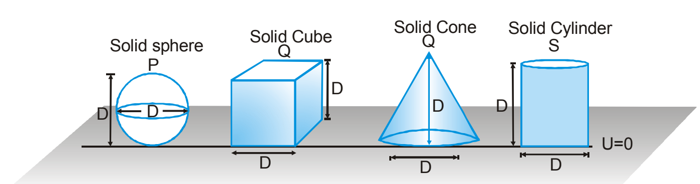
(B) right ward and downward.

(C) leftward and upwards.

(D) only downward.

SECTION - II : MULTIPLE CORRECT ANSWER TYPE

22. Assuming potential energy 'U' at ground level to be zero.



All objects are made up of same material.

U_P = Potential energy of solid sphere

U_Q = Potential energy of solid cube

U_R = Potential energy of solid cone

U_S = Potential energy of solid cylinder

(A) $U_S > U_P$ **(B)** $U_Q > U_S$ **(C)** $U_P > U_Q$ **(D)** $U_s > U_R$

23. A bag of mass M hangs by a long thread and a bullet (mass m) comes horizontally with velocity v and gets caught in the bag. Then for the combined system (bag + bullet) :

(A) Momentum is $mMv/(M + m)$
(B) KE is $(1/2)\,Mv^2$
(C) Momentum is mv
(D) KE is $m^2v^2/2(M + m)$

24. A ball of mass m moving with a velocity v hits a massive wall of mass M (M >>m) moving towards the ball with a velocity u. An elastic impact lasts for a time Δt.

(A) The average elastic force acting on the ball is $\dfrac{m(u+v)}{\Delta t}$

(B) The average elastic force acting on the ball is $\dfrac{2m(u+v)}{\Delta t}$

(C) The kinetic energy of the ball increases by $2mu\,(u + v)$

(D) The kinetic energy of the ball remains the same after the collision.

25. A particle strikes a horizontal smooth floor with a velocity u making an angle θ with the floor and rebounds with velocity v making an angle ϕ with the floor. If the coefficient of restitution between the particle and the floor is e, then :

(A) the impulse delivered by the floor to the body is $mu(1 + e)\sin\theta$.

(B) $\tan\phi = e\tan\theta$.

(C) $v = u\sqrt{1-(1-e^2)\sin^2\theta}$.

(D) the ratio of the final kinetic energy to the initial kinetic energy is $(\cos^2\theta + e^2\sin^2\theta)$

26. A smooth sphere A of mass m collides elastically with an identical sphere B at rest. The velocity of A before collision is 8 m/s in a direction making 60º with the line joining the centres at the time of impact. Which of the following is/are possible :

(A) the sphere A comes to rest after collision

(B) the sphere B will move with a speed of 8 m/s after collision

(C) the directions of motion of A and B after collision are at right angles

(D) the speed of B after collision is 4 m/s.

SECTION - III : ASSERTION AND REASON TYPE

27. **Statement-1 :** No external force acts on system of two spheres which undergo a perfectly elastic head on collision. The minimum kinetic energy of this system is zero if the net momentum of this system is zero.

Statement-2 : In any two body system undergoing perfectly elastic head on collision, at the instant of maximum deformation, the complete kinetic energy of the system is converted to deformation potential energy of the system.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1

(B) Statement-1 is True, Statement-2 is True; Statement-2 is **NOT** a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True.

28. **Statement-1 :** A sphere of mass m moving with speed u undergoes a perfectly elastic head on collision with another sphere of heavier mass M at rest (M > m), then direction of velocity of sphere of mass m is reversed due to collision [no external force acts on system of two spheres]

Statement-2 : During a collision of spheres of unequal masses, the heavier exerts more force on lighter mass in comparison to the force which lighter mass exerts on heavier mass.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True

29. **Statement-1 :** A rocket launched vertically upward explodes at the highest point it reaches. The explosion produces three fragments with non-zero initial velocity. Then the initial velocity vectors of all the three fragments are in one plane.

Statement-2 : For sum of momentum of three particles to be zero all the three momentum vectors must be coplanar.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True

30. **Statement-1 :** Two spheres undergo a perfectly elastic collision. The kinetic energy of system of both spheres is always constant. [There is no external force on system of both spheres].

Statement-2 : If net external force on a system is zero, the velocity of centre of mass remains constant.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1

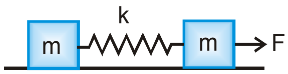
(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True

SECTION - IV : COMPREHENSION TYPE

Comprehension # 1

Two blocks of equal mass m are connected by an unstretched spring and the system is kept at rest on a frictionless horizontal surface. A constant force F is applied on the first block pulling it away from the other as shown in figure.



31. Then the displacement of the centre of mass at time t is :

(A) $\frac{Ft^2}{2m}$ **(B)** $\frac{Ft^2}{3m}$ **(C)** $\frac{Ft^2}{4m}$ **(D)** $\frac{Ft^2}{m}$

32. If the extension of the spring is x_0 at time t, then the displacement of the right block at this instant is :

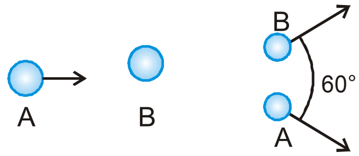
(A) $\frac{1}{2}\left(\frac{Ft^2}{2m}+x_0\right)$ **(B)** $-\frac{1}{2}\left(\frac{Ft^2}{2m}+x_0\right)$ **(C)** $\frac{1}{2}\left(\frac{Ft^2}{2m}-x_0\right)$ **(D)** $\left(\frac{Ft^2}{2m}+x_0\right)$

33. If the extension of the spring is x_0 at time t, then the displacement of the left block at this instant is :

(A) $\left(\frac{Ft^2}{2m} - x_0\right)$ **(B)** $\frac{1}{2}\left(\frac{Ft^2}{2m} + x_0\right)$ **(C)** $\frac{1}{2}\left(\frac{2Ft^2}{m} - x_0\right)$ **(D)** $\frac{1}{2}\left(\frac{Ft^2}{2m} - x_0\right)$

Comprehension # 2

A smooth ball 'A' moving with velocity 'V' collides with another smooth identical ball at rest. After collision both the balls move with same speed with angle between their velocities 60°. No external force acts on the system of balls.



34. The speed of each ball after the collision is

(A) $\frac{V}{2}$ **(B)** $\frac{V}{3}$ **(C)** $\frac{V}{\sqrt{3}}$ **(D)** $\frac{2V}{\sqrt{3}}$

35. If the kinetic energy lost is fully converted to heat then heat produced is

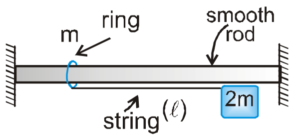
(A) $\frac{1}{3}mV^2$ **(B)** $\frac{2}{3}mV^2$ **(C)** 0 **(D)** $\frac{1}{6}mV^2$

36. The value of coefficient of restitution is

(A) 1 **(B)** $\frac{1}{3}$ **(C)** $\frac{1}{\sqrt{3}}$ **(D)** 0

Comprehension # 3

In given figure, the small block of mass 2m is released from rest when the string is in horizontal position,



37. Displacement of the ring when string makes an angle θ = 37° with the vertical will be:

(A) $\frac{4\ell}{15}$ **(B)** $\frac{\ell}{15}$ **(C)** $\frac{2\ell}{15}$ **(D)** none of these

38. Maximum possible velocity of ring of mass 'm' is (Assuming zero friction):

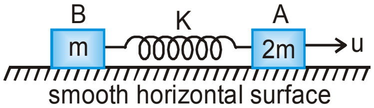
(A) $\sqrt{2g\ell}$ **(B)** $\sqrt{\frac{4g\ell}{3}}$ **(C)** $\sqrt{\frac{8g\ell}{3}}$ **(D)** none of these

39. Find the tension in the string when the block has maximum velocity.

(A) 12 mg **(B)** 14 mg **(C)** 8 mg **(D)** 20 mg

SECTION - V : MATRIX - MATCH TYPE

40. Two blocks A and B of mass m and 2m respectively are connected by a massless spring of spring constant K. This system lies over a smooth horizontal surface. At t = 0 the block A has velocity u towards right as shown while the speed of block B is zero, and the length of spring is equal to its natural length at that instant. In each situation of column I, certain statements are given and corresponding results are given in column II. Match the statements in column I with corresponding results in column II .

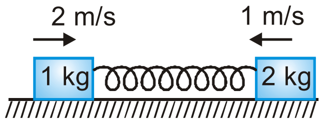


Column I	Column II
(A) The velocity of block A	(P) can never be zero
(B) The velocity of block B	(Q) may be zero at certain instants of time
(C) The kinetic energy of system of two blocks	(R) is minimum at maximum compression of spring
(D) The potential energy of spring	(S) is maximum at maximum extension of spring

41. In all cases in column–I, the blocks are placed on the smooth horizontal surface.

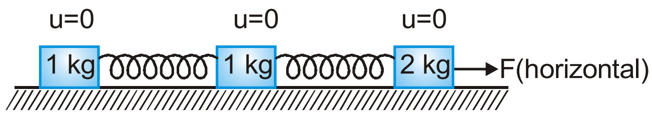
Column–I

(A) The initial velocities given to the blocks when spring is relaxed are as shown (friction is absent)



System (two blocks + spring)

(B) A constant force is applied on 2 kg block. Springs are initially relaxed & friction is absent

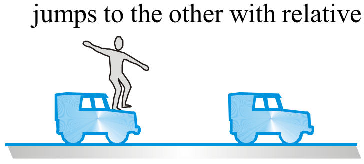


System (three blocks + two springs)

(C) There is no friction between plank and ground and initially system is at rest. Man starts moving on a large plank with constant velocity.

System (man and plank)

(D) Two trolleys are resting on a smooth horizontal surface and a man standing on one of the trolleys jumps to the other with relative velocity of 4 m/s



System (two trolleys + man)

Column–II

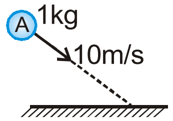
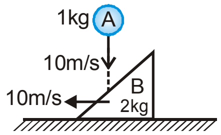
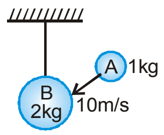
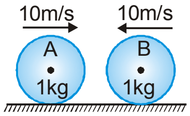
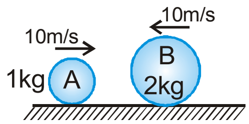
(P) Centre of mass of the complete system shown will not move horizontally

(Q) Centre of mass of the complete system shown will move horizontally

(R) Mechanical energy of the system will be conserved

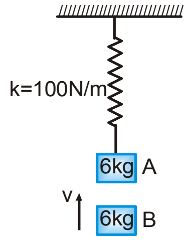
(S) Mechanical energy of the system will increase

42. In column–II different situations are shown in which one object collides with the another object. In each case friction is absent and neglect effect of non–impulsive forces. In column–I different direction are given.
You have to match the directions for each case in which momentum conservation can be applied on object A or object B or system A & B. (Assume that objects do not bounce off the ground)

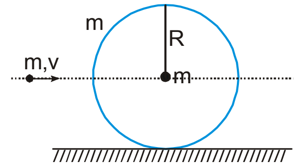
Column-I	Column-II
(A) Along the line of impact	(P) 
(B) Perpendicular to line of impact	(Q) 
(C) In horizontal direction	(R) 
(D) In vertical direction	(S)  $R_A = R_B$
	(T) 

SECTION - VI : INTEGER TYPE

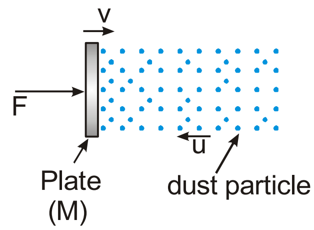
43. Block ' A ' is hanging from a vertical spring and is at rest. Block ' B ' strikes the block 'A' with velocity ' v ' and sticks to it. Then the value of ' v ' for which the spring just attains natural length is:



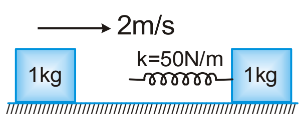
44. A hollow sphere of mass m = 1kg and radius R = 1m rests on a smooth horizontal surface. A simple pendulum having string of length R and bob of mass m = 1kg hangs from top most point of the sphere as shown in the figure. A bullet of mass m = 1kg and velocity v = 2m/sec partially penetrates the left side of the sphere. The velocity of the sphere just after collision with bullet is. (in m/sec.)



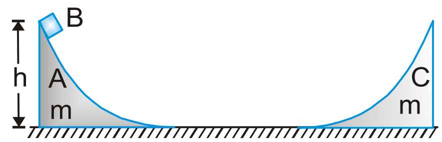
45. A plate of mass M is moved with constant velocity v against dust particles moving with velocity u in opposite direction as shown. The density of the dust is ρ and plate area is A. Find the force F required to keep the plate moving uniformly. (ρ in kg/m^3)



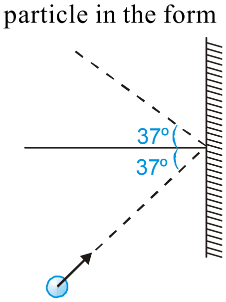
46. Each of the blocks shown in figure has mass 1 kg. The rear block moves with a speed of 2 m/s towards the front block kept at rest. The spring attached to the front block is light and has a spring constant 50 N/m. Find the maximum compression of the spring.(in cm.)



47. In the figure shown a small block B of mass m is released from the top of a smooth movable wedge A of the same mass m. The height of wedge A shown in figure is h = 100 cm. B ascends another movable smooth wedge C of the same mass. Neglecting friction any where find the maximum height (in cm) attained by block B on wedge C.



48. A particle moving on a smooth horizontal surface strikes a stationary wall. The angle of strike is equal to the angle of rebound & is equal to 37° and the coefficient of restitution with wall is $e = \frac{1}{5}$. Find the friction coefficient between wall and the particle in the form $\frac{X}{10}$ and fill value of X.:



ANSWER KEY

EXERCISE - 1

1. D **2.** A **3.** C **4.** A **5.** B **6.** B **7.** D **8.** A **9.** B **10.** A **11.** C **12.** B **13.** A
14. A **15.** A **16.** B **17.** A **18.** C **19.** A **20.** A **21.** B **22.** C **23.** A **24.** A **25.** C **26.** D
27. A **28.** D **29.** C

EXERCISE - 2 : PART # I

1. B **2.** B **3.** C **4.** B **5.** C **6.** D **7.** D **8.** C **9.** D **10.** B **11.** B **12.** A **13.** C
14. B **15.** A **16.** D **17.** B **18.** A **19.** D **20.** A,C **21.** A,C **22.** B,C **23.** C **24.** D **25.** B **26.** A
27. D **28.** A,B,C **29.** C **30.** B **31.** A **32.** B **33.** C **34.** A **35.** C **36.** C,D **37.** A **38.** B,C
39. A,B,C,D **40.** C,D **41.** A,B,D **42.** B,C

PART # II

1. A **2.** A **3.** A **4.** A **5.** A **6.** C **7.** C **8.** B **9.** B

EXERCISE - 3 : PART # I

1. A → Q ; B → P ; C → S
2. A → R ; B → T ; C → T ; D → S
3. A → Q ; B → R ; C → P
4. A – Q, B → P, Q ; C → R ; D → S
5. A → P,R ; B → Q,R ; C → P,R ; D → Q,S
6. A → Q,T ; B → R,T ; C → R,S,T,U
7. A → ; B → P,R ; C → P,R ; D → R,S

PART # II

Comprehension # 1 : **1.** C **2.** B
Comprehension # 2 : **1.** B **2.** D **3.** D **4.** A
Comprehension # 3: **1.** C
Comprehension # 4 : **1.** B **2.** C **3.** D
Comprehension # 5 : **1.** C **2.** A **3.** C
Comprehension # 6 : **1.** A, D **2.** B **3.** C, D
Comprehension # 7 : **1.** C **2.** A **3.** D
Comprehension # 8 : **1.** D **2.** C **3.** C

EXERCISE - 4

1. $\left(\frac{a}{2}, \frac{7a}{10}\right)$

2. **(i)** at O, **(ii)** diagonally from O to 3 **(iii)** along OY', **(iv)** at O **(v)** diagonally from O to 4 **(vi)** at O

3. $\sqrt{13}$ m, $\left(\frac{14}{5}, \frac{19}{5}\right)$

4. 4R from O

5. $\left(\frac{a}{3}, \frac{a}{3}\right)$

6. $\left(\frac{\sqrt{5}-1}{2}\right)$

7. 9 cm from centre of bigger circle (leftwards)

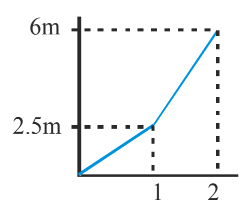
8. $OC = \frac{2r}{3(4-\pi)}$

9. $x = \frac{3a}{4}$

10. $10\sqrt{2}\ ms^{-1}$ at 45^0

11. **(i)** zero **(ii)** right **(iii)** 0.2 m **(iv)** 2.2 m **(v)** 1.8 m

12.



13. $\frac{mg(h_3 - h_1)}{(h_2 - h_1)}$

14. ℓ

15. $\frac{5v}{R\cos\theta}$

16. (i) straight line

(ii) $\frac{x^2}{\left(\frac{L}{R} - r\right)^2} + \frac{y^2}{r^2} = 1$

17. 6.53 s **18.** **(i)** $\frac{v_0}{3}$ **(ii)** $\frac{2mv_0^2}{3x_0^2}$ **19.** $\frac{m(R-r)}{M+m}$, $m\sqrt{\frac{2g(R-r)}{M(M+m)}}$

20. 4 **21.** 2:1 **22.** bob A does not rise **23.** (L+2R, 0) **24.** No **25.** 3.96 m

26. 64% **27.** $\vec{v}_C = -\vec{v}_B$ **28.** **(i)** $0.8\hat{i}\ ms^{-1}$ **(ii)** $2.4\hat{i}\ ms^{-1}$ **(iii)** $\frac{4}{7}$

29. 1.25 m **30.** $\frac{4g}{9}, \frac{13mg}{18}$ **31.** 44.25 m **32.** 6 ms^{-1} **33.** **(i)** 37^0 **(ii)** 120,45 **34.** $e = 0.8,\ \mu = 0.4$

35. $\frac{(m_2 + m_1\cot\alpha)h}{m + m_1 + m_2}$ **36.** **(i)** $\frac{u}{2}, \frac{mu}{2}$ **(ii)** $\frac{u\sqrt{3}}{8}, \frac{mu\sqrt{3}}{8}$ **(iii)** $\frac{u\sqrt{3}}{4}, \frac{mu\sqrt{3}}{4}$

37. **(i)** $\sqrt{\frac{2ag}{3}}$ **(ii)** $\frac{3v}{g}$ **(iii)** $\frac{2v}{g}$ **38.** 10^5 m **39.** 120^0 **40.** $\sqrt{\frac{3gx}{8}}$ **42.** 37^0

43. 40 cm **44.** $v_1 = \frac{1}{\sqrt{3}}\ ms^{-1}, v_2 = \frac{2}{\sqrt{3}}\ ms^{-1}$ **45.** **(i)** 0.66 **(ii)** 4 m

EXERCISE - 5 : PART # I

1. C **2.** C **3.** C **4.** D **5.** A **6.** C **7.** C **8.** B **9.** C **10.** A **11.** C **12.** A **13.** A
14. B **15.** A **16.** A **17.** D **18.** A **19.** A,C

PART # II

MCQ's with one correct answer **1.** C **2.** C **3.** D **4.** C **5.** A **6.** A

MCQ's with one or more than one correct answer **1.** A D

Assertion-Reasoning **1.** B **2.** D

Comprehension Based questions **1.** B **2.** B **3.** C

Subjective Questions

1. $e = 0.84, M = 15.21$ kg **2.** 12 s, 15.75 ms^{-1} **3.** $-mv_2 \sin\frac{v_2}{R}t\ \hat{i} + m\left(v_2\cos\frac{v_2}{R}t - v_1\right)\hat{j}$

4. $x_2 = v_0t + \frac{m_1}{m_2}A(1-\cos\omega t), \ell_0 = \left(\frac{m_1}{m_2}+1\right)A$ **5.** 10 ms^{-1} **6.** 4 m/s

MOCK TEST

1.	B	**2.**	B	**3.**	B	**4.**	C	**5.**	C	**6.**	C	**7.**	C
8.	C	**9.**	B	**10.**	B	**11.**	D	**12.**	D	**13.**	A	**14.**	C
15.	D	**16.**	C	**18.**	D	**19.**	C	**20.**	B	**21.**	B		
22.	A, B, D	**23.**	C, D	**24.**	B, C	**25.**	A,B,C,D	**26.**	C,D	**27.**	C	**28.**	C
29.	A	**30.**	D	**31.**	C	**32.**	A	**33.**	D	**34.**	C	**35.**	D
36.	B	**37.**	A	**38.**	C	**39.**	B	**40.**	A → P ; B → Q ; C → P,R ; D → Q,S				
41.	A → P,R ; B → Q, S ; C → P,S ; D → P,S					**42.**	A → S ; B → P,Q,R,S,T ; C → P,Q,R,S,T ; D → Q,R,S,T						
43.	6	**44.**	1	**45.**	Ar (v + u)^2								
46.	0.2 m.	**47.**	25	**48.**	5								