Exercise-1

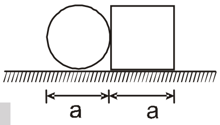
✍ **Marked Questions can be used as Revision Questions.**

PART - I : SUBJECTIVE QUESTIONS

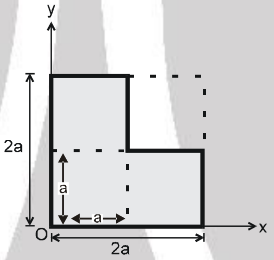
Section (A) : Calculation OF centre of mass

A-1. Three particles of mass 1 kg, 2 kg and 3 kg are placed at the corners A, B and C respectively of an equilateral triangle ABC of edge 1 m. Find the distance of their centre of mass from A.

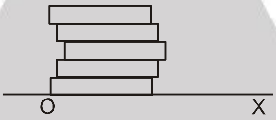
A-2. A square plate of edge 'a' and a circular disc of same diameter are placed touching each other at the midpoint of an edge of the plate as shown in figure. If mass per unit area for the two plates are same then find the distance of centre of mass of the system from the centre of the disc.



A-3.✍ Find the position of centre of mass of the uniform planner sheet shown in figure with respect to the origin (O)



A-4. Five homogeneous bricks, each of length L, are arranged as shown in figure. Each brick is displaced with respect to the one in contact by L/5. Find the x-coordinate of the centre of mass relative to the origin O shown.

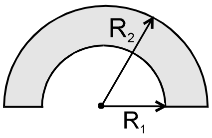


A-5. A uniform disc of radius R is put over another uniform disc of radius 2R made of same material having same thickness. The peripheries of the two discs touches each other. Locate the centre of mass of the system taking center of large disc at origin.

A-6. The linear mass density of a straight rod of length L varies as $\rho = A + Bx$ where x is the distance from the left end. Locate the center of mass from left end.

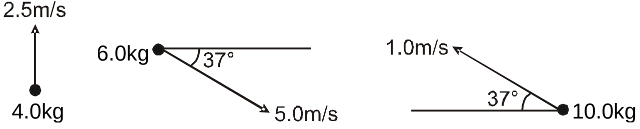
A-7. A disc of radius R is cut out from a larger uniform disc of radius 2R in such a way that the edge of the hole touches the edge of the disc. Locate the centre of mass of **remaining** part.

A-8.✍ Find the centre of mass of an annular half disc shown in figure



Section (B) : motion OF centre of mass

B-1.✍# Calculate the velocity of the centre of mass of the system of particle shown in figure.



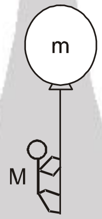
B-2. Two blocks of masses 10 kg and 30 kg are placed along a vertical line. The first block is raised through a height of 7 cm. By what distance should the second mass be moved to raise the centre of mass by 1 cm ?

B-3. A projectile is fired from a gun at an angle of 45º with the horizontal and with a speed of 20 m/s relative to ground. At the highest point in its flight the projectile explodes into two fragments of equal mass. One fragment comes at rest just after explosion. How far from the gun does the other fragment land, assuming a horizontal ground? and also find its speed just after explosion. Take g = 10 m/s^2

B-4. A mercury thermometer is placed in a gravity free hall without touching anything. As temperature rises mercury expands and ascend in thermometer. If height ascend by mercury in thermometer is h then by what height centre of mass of " mercury and thermometer" system descend?

B-5. Two men 'A' and 'B' are standing on opposite edge of a 6m long platform which is further kept on a smooth floor. They starts moving towards each other and finally meet at the midpoint of platform. Find the displacement of platform if mass of A, B and platform are 40kg, 60kg and 50kg respectively.

B-6. A man of mass M hanging with a light rope which is connected with a balloon of mass m. The system is at rest and equilibrium in air. When man rises a distance h with respect to balloon Find.
(a) The distance raised by man
(b) The distance descended by balloon



Section (C) : Conservation of linear momentum

C-1. A block moving horizontally on a smooth surface with a speed of 20 m/s bursts into two equal parts continuing in the same direction. If one of the parts moves at 30 m/s, with what speed does the second part move and what is the fractional change in the kinetic energy of the system.

C-2. A stone of mass 5 kg is thrown upwards with a speed of 36 m/sec. With what speed earth recoil. Mass of the earths 6 × 10^{24} kg (assuming that there is no external force on the system)

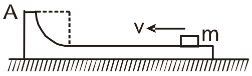
C-3. In a process a neutron which is initially at rest, decays into a proton, an electron and an antineutrino. The ejected electron has a momentum of p_1 and the antineutrino has p_2 . Find the recoil speed of the proton if the electron and the antineutrino are ejected (a) along the same direction. (b) in mutually perpendicular directions. (Mass of the proton = m_p)

C-4. Three particles of mass 20 g, 30 g and 40 g are initially moving along the positive direction of the three coordinate axes x, y and z respectively with the same velocity of 20 cm/s. If due to their mutual interaction, the first particle comes to rest, the second acquires a velocity $10\hat{i}+20\hat{k}$. What is the velocity (in cm/s) of the third particle?

C-5. A truck of mass M is at rest on a frictionless road. When a monkey of mass m starts moving on the truck in forward direction, the truck recoils with a speed v backward on the road, with what velocity is the monkey moving with respect to truck?

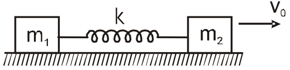
C-6. A boy of mass 60 kg is standing over a platform of mass 40 kg placed over a smooth horizontal surface. He throws a stone of mass 1 kg with velocity v = 10 m/s at an angle of 45º with respect to the ground. Find the displacement of the platform (with boy) on the horizontal surface when the stone lands on the ground. (g = 10 m/s^2)

C-7. A small block of mass m moving with speed 'V' on a smooth horizontal part of a bigger block of mass M which is further kept on smooth floor. The curved part of the surface shown is one fourth of a circle. Find the speed of the bigger block when the smaller block reaches the point A of the surface.



Section (D) : spring - mass system

D-1. Two block of masses m_1 and m_2 are connected with the help of a spring of spring constant k initially the spring in its natural length as shown. A sharp impulse is given to mass m_2 so that it acquires a velocity v_0 towards right. If the system is kept on smooth floor then find (a) the velocity of the centre of mass, (b) the maximum elongation that the spring will suffer**?**



D-2. Two masses m_1 and m_2 are connected by a spring of spring constant k and are placed on a smooth horizontal surface. Initially the spring is stretched through a distance 'd' when the system is released from rest. Find the distance moved by the two masses when spring is compressed by a distance 'd'.

D-3. Two blocks A and B of mass m_A and m_B are connected together by means of a spring and are resting on a horizontal frictionless table. The blocks are then pulled apart so as to stretch the spring and then released. Show that the ratio of their kinetic energies at any instant is in the inverse ratio of their masses.

Section (E) : Impulse

E-1. Velocity of a particle of mass 2 kg varies with time t according to the equation $\vec{v} = (2t\hat{i} + 4\hat{j})m/s$. Here t is in seconds. Find the impulse imparted to the particle in the time interval from t = 0 to t = 2 s.

E-2. A ball of mass 100 g moving with a speed of 4 m/sec strikes a horizontal surface at an angle of 30º from the surface. The ball is reflected back with same speed and same angle of reflection find (a) The impulse imparted to the ball (b) change in magnitude of momentum of the ball.

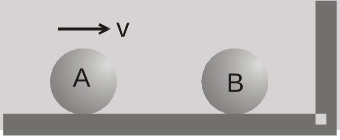
E-3. During a heavy rain, hailstones of average size 1.0 cm in diameter fall with an average speed of 20 m/s. Suppose 2000 hailstones strike every square meter of a 10 m × 10 m roof perpendicularly in one second and assume that the hailstones do not rebound. Calculate the average force exerted by the falling hailstones on the roof. Density of hailstones is 900 kg/m^3, take (π = 3.14)

E-4. A ball of mass = 100 gm is released from a height h_1 = 2.5 m from the ground level and then rebounds to a height h_2 = 0.625 m. The time of contact of the ball and the ground is Δt = 0.01 sec. The impulsive (impact) force offered by the ball on the ground is ?

Section (F) : Collision

F-1. A particle moving with kinetic energy K makes a head on elastic collision with an identical particle at rest. Find the maximum elastic potential energy of the system during collision.

F-2. Two balls shown in figure are identical. Ball A is moving towards right with a speed v and the second ball is at rest. Assume all collisions to be elastic. Show that the speeds of the balls remain unchanged after all the collisions have taken place. (Assume frictionless surface)



F-3. A ball of mass m moving at a speed v makes a head on collision with an identical ball at rest. The kinetic energy of the balls after the collision is 3/4 of the original kinetic energy. Calculate the coefficient of restitution.

F-4. A particle of mass m moving with a speed v hits elastically another stationary particle of mass 2m in a fixed smooth horizontal circular tube of radius r. Find the time when the next collision will take place?

F-5. A block of mass 1 kg moving at a speed of 2.5 m/s collides with another block of mass 0.5 kg. If both the blocks come to rest after collision what was the velocity of the 0.5 kg block before the collision?

F-6. A 3kg block 'A' moving with 4 m/sec on a smooth table collides inelastically and head on with an 8kg block 'B' moving with speed 1.5 m/sec towards 'A'. Given e = 1/2

(a) What is final velocities of both the blocks
(b) Find out the impulse of reformation and deformation
(c) Find out the maximum potential energy of deformation
(d) Find out loss in kinetic energy of system.

Section (G) : Variable mass

G-1.✍ A rocket of mass m = 20 kg has M = 180kg fuel. The uniform exhaust velocity of the fuel is v_r = 1.6 km/s.
(i) Calculate the minimum rate of consumption of fuel so that the rocket may rise from the ground.
(ii) Also calculate the maximum vertical speed gained by the rocket when the rate of consumption of fuel μ is (g = 10 m/s^2) & (ℓn 10 = 2.30)
(a) 2 kg/s (b) 20 kg/s

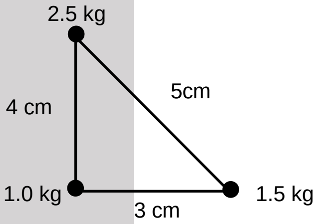
G-2. Sand drops from a stationary hopper at the rate of 5 kg/s falling on a conveyor belt moving with a constant speed of 2 m/s. What is the force required to keep the belt moving and what is the power delivered by the motor moving the belt?

PART - II : ONLY ONE OPTION CORRECT TYPE

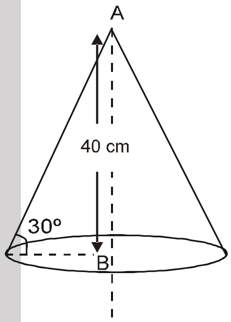
Section (A) : Calculation OF centre of mass

A-1. The centre of mass of a body :
(A) Lies always at the geometrical centre
(B) Lies always inside the body
(C) Lies always outside the body
(D) Lies within or outside the body

A-2. Three point particles of masses 1.0 kg, 1.5 kg and 2.5 kg are placed at three corners of a right angle triangle of sides 4.0 cm, 3.0 cm and 5.0 cm as shown in the figure. The center of mass of the system is at a point :
(A) 0.6 cm right and 2.0 cm above 1kg mass
(B) 2.0 cm right and 0.9 cm above 1 kg mass
(C) 0.9 cm right and 2.0 cm above 1kg mass
(D) 1.5 cm right and 1.2 cm above 1kg mass



A-3.✍ A uniform solid cone of height 40 cm is shown in figure. The distance of centre of mass of the cone from point B (centre of the base) is :
(A) 20 cm
(B) 10/3 cm
(C) 20/3 cm
(D) 10 cm

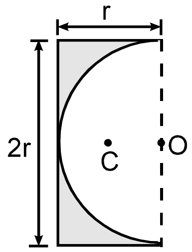


A-4.✍ A thin uniform wire is bent to form the two equal sides AB and AC of triangle ABC, where AB = AC = 5 cm. The third side BC, of length 6cm, is made from uniform wire of twice the linear mass density of the first. The distance of centre of mass from A is :
(A) $\frac{34}{11}$ cm (B) $\frac{11}{34}$ cm (C) $\frac{34}{9}$ cm (D) $\frac{11}{45}$ cm

A-5. The centre of mass of a system of particles is at the origin. From this we conclude that
(A) The number of particles on positive x-axis is equal to the number of particles on negative x-axis
(B) The total mass of the particles on positive x-axis is same as the total mass on negative x-axis
(C) The number of particles on X-axis may be equal to the number of particles on Y-axis.
(D) If there is a particle on the positive X-axis, there must be at least one particle on the negative X-axis.

A-6. All the particles of a system are situated at a distance r from the origin. The distance of the centre of mass of the system from the origin is
(A) = r (B) ≤ r (C) > r (D) ≥ r

A-7. A semicircular portion of radius ‘r’ is cut from a uniform rectangular plate as shown in figure. The distance of centre of mass 'C' of remaining plate, from point ‘O’ is :



(A) $\frac{2r}{(3-\pi)}$ (B) $\frac{3r}{2(4-\pi)}$

(C) $\frac{2r}{(4+\pi)}$ (D) $\frac{2r}{3(4-\pi)}$

Section (B) : Motion of centre of mass

B-1. Two particles of mass 1 kg and 0.5 kg are moving in the same direction with speed of 2m/s and 6m/s respectively on a smooth horizontal surface. The speed of centre of mass of the system is :

(A) $\frac{10}{3}$ m/s (B) $\frac{10}{7}$ m/s (C) $\frac{11}{2}$ m/s (D) $\frac{12}{3}$ m/s

B-2. Two particles of equal mass have initial velocities $2\hat{i}$ ms^{-1} and $2\hat{j}$ ms^{-1}. First particle has a constant acceleration $(\hat{i}+\hat{j})$ ms^{-2} while the acceleration of the second particle is always zero. The centre of mass of the two particles moves in

(A) Circle (B) Parabola

(C) Ellipse (D) Straight line

B-3. Two particles having mass ratio n : 1 are interconnected by a light inextensible string that passes over a smooth pulley. If the system is released, then the acceleration of the centre of mass of the system is :

(A) $(n-1)^2$ g (B) $\left(\frac{n+1}{n-1}\right)^2$ g (C) $\left(\frac{n-1}{n+1}\right)^2$ g (D) $\left(\frac{n+1}{n-1}\right)$ g

B-4. A bomb travelling in a parabolic path under the effect of gravity, explodes in mid air. The centre of mass of fragments will:

(A) Move vertically upwards and then downwards
(B) Move vertically downwards
(C) Move in irregular path
(D) Move in the parabolic path which the unexploded bomb would have travelled.

B-5. If a ball is thrown upwards from the surface of earth then initially (assuming that there is no external force on the system):

(A) The earth remains stationary while the ball moves upwards
(B) The ball remains stationary while the earth moves downwards
(C) The ball and earth both move towards each other
(D) The ball and earth both move away from each other

B-6. Internal forces in a system can change

(A) Linear momentum only
(B) Kinetic energy only
(C) Both kinetic energy and linear momentum
(D) Neither the linear momentum nor the kinetic energy of the system.

B-7. Two balls of different masses are thrown in air with different velocities. While they are in air acceleration of centre of mass of the system. (neglect air resistance)

(A) Depends on the direction of the motion of two balls
(B) Depends on the masses of the two balls
(C) Depends on the magnitude of velocities of the two balls
(D) Is equal to g

B-8. There are two particles of same mass. If one of the particles is at rest always and the other has an acceleration $\vec{a}$. Acceleration of centre of mass is

(A) zero (B) $\frac{1}{2}\vec{a}$ (C) $\vec{a}$

(D) centre of mass for such a system can not be defined.

Section (C) : Conservation of linear momentum

C-1. Two particles A and B initially at rest move towards each other under a mutual force of attraction. The speed of centre of mass at the instant when the speed of A is v and the speed of B is 2v is

(A) v (B) Zero (C) $2v$ (D) $3v/2$

C-2. If the KE of a particle becomes four times of its initial value, then the new momentum will be more than its initial momentum by

(A) 50% (B) 100% (C) 125% (D) 150%

C-3. A particle of mass 4m which is at rest explodes into three fragments. Two of the fragments each of mass m are found to move with a speed 'v' each in mutually perpendicular directions. The minimum energy released in the process of explosion is

(A) (2/3) mv^2 (B) (3/2) mv^2 (C) (4/3) mv^2 (D) (3/4) mv^2

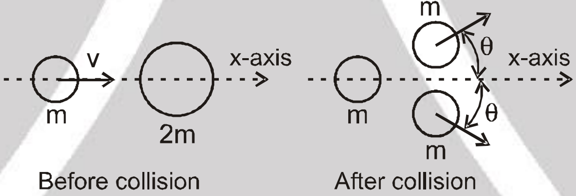
C-4. A 500 kg boat has an initial speed of 10 ms^{-1} as it passes under a bridge. At that instant a 50 kg man jumps straight down into the boat from the bridge. The speed of the boat after the man and boat attaing a common speed is

(A) $\frac{100}{11}$ ms^{-1} (B) $\frac{10}{11}$ ms^{-1} (C) $\frac{50}{11}$ ms^{-1} (D) $\frac{5}{11}$ ms^{-1}

C-5. The spacecraft of mass M moves with velocity V in free space at first, then it explodes breaking into two pieces. If after explosion a piece of mass m comes to rest, the other piece of space craft will have a velocity:

(A) MV/(M – m) (B) MV/(M + m) (C) mV/(M – m) (D) mV/(M + m)

C-6. 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 ? ($\theta > 0$)



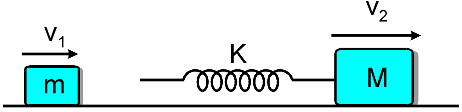
(A) Each piece moves with speed v.
(B) Each piece moves with speed v/2.
(C) One of the pieces moves with speed v/2, the other moves with speed greater than v/2
(D) Each piece moves with speed greater than v/2.

C-7. Two particles approach each other with different velocities. After collision, one of the particles has a momentum $\vec{p}$ in their center of mass frame. In the same frame, the momentum of the other particle is

(A) 0 (B) $-\vec{p}$ (C) $-\vec{p}/2$ (D) $-2\vec{p}$

Section (D) : spring - mass system

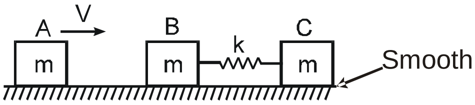
D-1. Two blocks of masses m and M are moving with speeds v_1 and v_2 ($v_1 > v_2$) in the same direction on the frictionless surface respectively, M being ahead of m. An ideal spring of force constant k is attached to the backside of M (as shown). The maximum compression of the spring when the block collides is :



(A) $v_1\sqrt{\frac{m}{k}}$ (B) $v_2\sqrt{\frac{M}{k}}$

(C) $(v_1 - v_2)\sqrt{\frac{mM}{(M+m)\ K}}$ (D) None of above is correct.

D-3.✍ Mass A hits B inelastically (e = 0) while moving horizontally with some velocity along the common line of centres of the three equal masses each of same mass. Initially mass B and C are stationary and the spring is unstretched. Then which is incorrect.



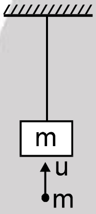
(A) compression will be maximum when blocks have same velocity
(B) velocity of C is maximum when (A + B) is at rest
(C) velocity of C is maximum when spring is undeformed.
(D) velocity of C is minimum when spring is undeformed.

Section (E) : impulse

E-1. A ball of mass 50 gm is dropped from a height h = 10 m. It rebounds losing 75 percent of its kinetic energy. If it remains in contact with the ground for $\Delta t = 0.01$ sec., the impulse of the impact force is : (take $g = 10\ m/s^2$)
(A) 1.3 N–s (B) 1.06 N-s (C) 1300 N–s (D) 105 N–s

E-2. The area of F-t curve is A, where 'F' is the force acting on one mass due to the other. If one of the colliding bodies of mass M is at rest initially, its speed just after the collision is :
(A) A/M (B) M/A (C) AM (D) $\sqrt{\frac{2A}{M}}$

E-3.✍ A bullet of mass m moving vertically upwards instantaneously with a velocity 'u' hits the hanging block of mass 'm' and gets embedded in it, as shown in the figure. The height through which the block rises after the collision. (assume sufficient space above block) is :

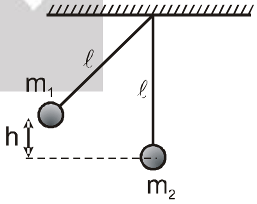


(A) $u^2/2g$ (B) u^2/g (C) $u^2/8g$ (D) $u^2/4g$

Section (F) : Collision

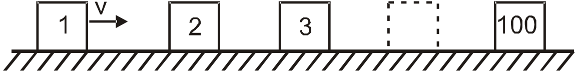
F-1. A bullet of mass m = 50 gm strikes ($\Delta t \approx 0$)a sand bag of mass M = 5 kg hanging from a fixed point, with a horizontal velocity $\vec{v}_p$. If bullet sticks to the sand bag then just after collision the ratio of final & initial kinetic energy of the bullet is :
(A) 10^{-2} (B) 10^{-3} (C) 10^{-6} (D) 10^{-4}

F-2. In the arrangement shown, the pendulum on the left is pulled aside. It is then released and allowed to collide with other pendulum which is at rest. A perfectly inelastic collision occurs and the system rises to a height h/4 . The ratio of the masses (m_1 / m_2) of the pendulum is :



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

F-3. There are hundred identical sliders equally spaced on a frictionless track as shown in the figure. Initially all the sliders are at rest. Slider 1 is pushed with velocity v towards slider 2. In a collision the sliders stick together. The final velocity of the set of hundred stucked sliders will be :

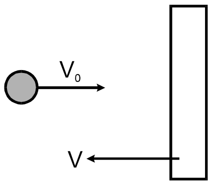


(A) $\frac{v}{99}$ (B) $\frac{v}{100}$ (C) zero (D) v

F-4. A solid iron ball A of radius r collides head on with another stationary solid iron ball B of radius 2r. The ratio of their speeds just after the collision (e = 0.5) is :

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

F-5. A particle of mass m moves with velocity v_0 = 20 m/sec towards a large wall that is moving with velocity v = 5 m/sec. towards the particle as shown . If the particle collides with the wall elastically, the speed of the particle just after the collision is :



(A) 30 m/s (B) 20 m/s
(C) 25 m/s (D) 22 m/s

F-6. Two perfectly elastic balls of same mass m are moving with velocities u_1 and u_2. They collide head on elastically n times. The kinetic energy of the system finally is :

(A) $\frac{1}{2}\frac{m}{n}u_1^2$ (B) $\frac{1}{2}\frac{m}{n}(u_1^2 + u_2^2)$

(C) $\frac{1}{2}m(u_1^2 + u_2^2)$ (D) $\frac{1}{2}mn(u_1^2 + u_2^2)$

F-7. A massive ball moving with speed v collides head-on with a tiny ball at rest having a mass very less than the mass of the first ball. If the collision is elastic, then immediately after the impact, the second ball will move with a speed approximately equal to:

(A) v (B) 2v (C) v/2 (D) ∞

F-8. A sphere of mass m moving with a constant velocity hits another stationary sphere of the same mass. If e is the coefficient of restitution, then ratio of speed of the first sphere to the speed of the second sphere after head on collision will be :

(A) $\left(\frac{1-e}{1+e}\right)$ (B) $\left(\frac{1+e}{1-e}\right)$ (C) $\left(\frac{e+1}{e-1}\right)$ (D) $\left(\frac{e-1}{e+1}\right)$

F-9. A ball of mass 'm', moving with uniform speed, collides elastically with another stationary ball. The incident ball will lose maximum kinetic energy when the mass of the stationary ball is

(A) m (B) 2m (C) 4m (D) infinity

F-10. Ball 1 collides head on with an another identical ball 2 at rest. Velocity of ball 2 after collision becomes two times to that of ball 1 after collision. The coefficient of restitution between the two balls is :

(A) e = 1/3 (B) e = 1/2 (C) e = 1/4 (D) e = 2/3

Section (G) : Variable mass

G-1. If the thrust force on a rocket which is ejecting gases with a relative velocity of 300 m/s, is 210 N. Then the rate of combustion of the fuel will be :

(A) 10.7 kg/sec (B) 0.07 kg/sec (C) 1.4 kg/sec (D) 0.7 kg/sec

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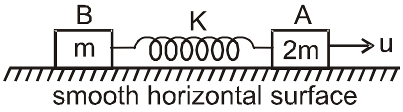
PART - III : MATCH THE COLUMN

1. 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. Match the statements in column I corresponding to results in column II .

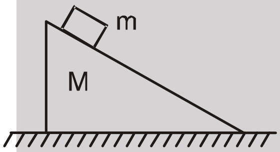


Column I	Column II
(A) The velocity of block A	(p) can never be zero
(B) The velocity of block B	(q) may be zero at certain instants of time
(C) The kinetic energy of system of two blocks	(r) is minimum at maximum compression of spring
(D) The potential energy of spring	(s) is maximum at maximum extension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

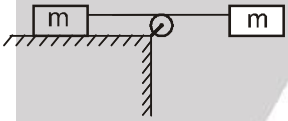
2. In each situation of column-I, a system involving two bodies is given. All strings and pulleys are light and friction is absent everywhere. Initially each body of every system is at rest. Consider the system in all situation of column I from rest till any collision occurs. Then match the statements 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
	(t) shifts towards left

(A)

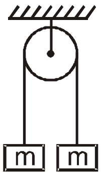


(B)



(C)

(D)



Exercise-2

✍ **Marked Questions can be used as Revision Questions.**

PART - I : ONLY ONE OPTION CORRECT TYPE

1. A uniform sphere is placed on a smooth horizontal surface and a horizontal force F is applied on it at a distance h above the centre. The acceleration of the centre of mass of the sphere

(A) is maximum when h = 0
(B) is maximum when h = R
(C) is maximum when h = R/2
(D) is independent of h

2. A ball moves horizontally in a closed box making several collisions with the walls. The box is kept on a smooth horizontal surface. During the motion of the ball, the velocity of the centre of mass:-

(A) of the box remains constant
(B) of the box plus the ball system remains constant
(C) depends on value of e
(D) of the ball relative to the box remains constant

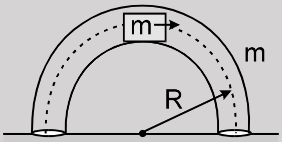
3. A ring of mass m and a particle of same mass are fixed on a disc of same mass such that centre of mass of the system lies at centre of the disc. The system rotates such that centre of mass of the disc moves in a circle of radius R with a constant angular velocity ω. From this we conclude that

(A) An external force $m\omega^2R$ must be applied to central particle
(B) An external force $m\omega^2R$ must be applied to the ring
(C) An external force $3m\omega^2R$ must be applied to central particle
(D) An external force $3m\omega^2R$ must be applied any where on the system

4.✍ 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 along the positive x-axis, and the rod starts falling. The acceleration vector of centre of mass of the rod during its fall is : [$\vec{R}$ is reaction from surface]

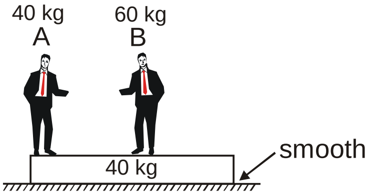
(A) $\vec{a}_{CM} = \frac{M\vec{g}+\vec{R}}{M}$
(B) $\vec{a}_{CM} = \frac{M\vec{g}-\vec{R}}{M}$
(C) $\vec{a}_{CM} = M\vec{g}-\vec{R}$
(D) None of these

5. 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, displacement of the tube will be (where 'R' is mean radius of tube). Assume that the tube remains in vertical plane.



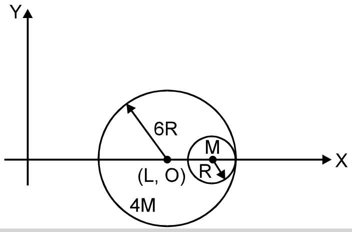
(A) $\frac{2R}{\pi}$
(B) $\frac{4R}{\pi}$
(C) $\frac{R}{2}$
(D) R

6.✍ 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. Bottom surface of the plank is smooth. System is initially at rest and masses are as shown in figure. 'A' and 'B' start moving such that the position of 'B' remains fixed with respect to ground and '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

7. 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 as shown. There is no friction between any surfaces of contact. The small sphere is now released. The coordinates of the centre of the large sphere when the smaller sphere reaches the other extreme position is :



(A) (L – 2R, 0) (B) (L + 2R, 0) (C) (2R, 0) (D) (2R – L, 0)

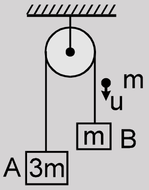
8. An isolated particle of mass m is moving in a horizontal (x – y) plane along the x-axis, at a certain height above the ground. It suddenly explodes into two fragments of masses $\frac{m}{4}$ & $\frac{3m}{4}$. An instant later, the smaller fragment is at y = +15 cm. The larger fragment at this instant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

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

9. A stationary body explodes into two fragments of masses m_1 and m_2. If momentum of one fragment is p, the minimum energy of explosion is

(A) $\frac{p^2}{2(m_1+m_2)}$ (B) $\frac{p^2}{2\sqrt{m_1m_2}}$ (C) $\frac{p^2(m_1+m_2)}{2m_1m_2}$ (D) $\frac{p^2}{2(m_1-m_2)}$

10. 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) $\frac{3mu}{5}$

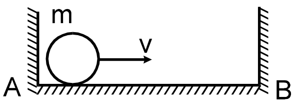
11. A ball of mass m hits directly another ball of mass M at rest and is brought to rest by the impact. One third of the kinetic energy of the ball is lost due to collision. The coefficient of restitutions is

(A) 1/3 (B) ½ (C) 2/3 (D) $\sqrt{\frac{2}{3}}$

12. A super-ball is to bounce elastically back and forth between two rigid walls at a distance d from each other. Neglecting gravity and assuming the velocity of super-ball to be v_0 horizontally, the average force (in large time interval) being exerted by the super-ball on one wall is :

(A) $\frac{1}{2}\frac{mv_0^2}{d}$ (B) $\frac{mv_0^2}{d}$ (C) $\frac{2mv_0^2}{d}$ (D) $\frac{4mv_0^2}{d}$

13. A small ball on a frictionless horizontal surface moves towards right with a velocity V. It collides with the wall and returns back and continues to and fro motion. If the average speed for first to and fro motion of the ball is $\left(\frac{2}{3}\right)$V, then the coefficient of restitution of impact is :

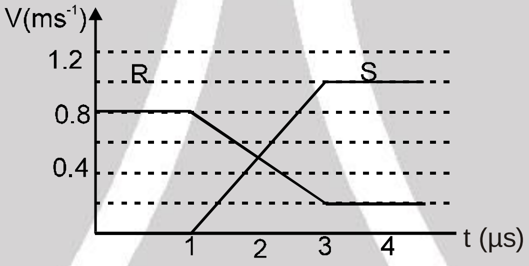


(A) 0.5 (B) 0.8 (C) 0.25 (D) 0.75

14.✍ 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 ? (given that h > d)

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

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



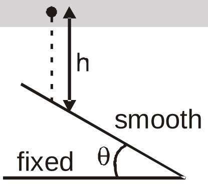
I. R and S moved in the same direction after the collision.
II. The velocities of R and S were equal at the mid time of the collision.
III. The mass of R was greater than mass of S.

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

16.✍ A ball collides with a smooth and fixed inclined plane of inclination θ after falling vertically through a distance h. If it moves horizontally just after the impact, the coefficient of restitution is :

(A) $\tan^2\theta$ (B) $\cot^2\theta$ (C) $\tan\theta$ (D) $\cot\theta$

17. A ball of mass m strikes the fixed inclined plane after falling through a height h. If it rebounds elastically, the impulse on the ball is :



(A) $2m\cos\theta\sqrt{2gh}$ (B) $2m\cos\theta\sqrt{gh}$ (C) $\frac{2m\sqrt{2gh}}{\cos\theta}$ (D) $2m\sqrt{2gh}$

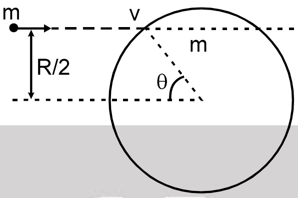
18.✍ A sphere of mass m_1 = 2kg collides with a sphere of mass m_2 = 3kg which is at rest. Mass m_1 will move at right angle to the line joining centres at the time of collision, if the coefficient of restitution is :

(A) $\frac{4}{9}$ (B) $\frac{1}{2}$ (C) $\frac{2}{3}$ (D) $\sqrt{\frac{2}{3}}$

19.✍ Two identical billiard balls are in contact on a smooth table. A third identical ball strikes them symmetrically and comes to rest after impact. The coefficient of restitution is :

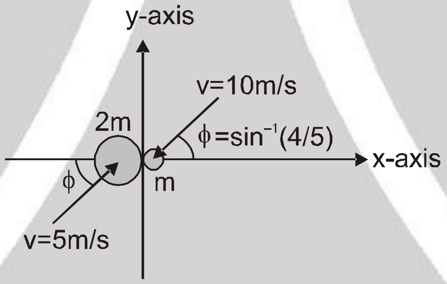
(A) $\frac{2}{3}$ (B) $\frac{1}{3}$ (C) $\frac{1}{6}$ (D) $\frac{\sqrt{3}}{2}$

20.✍ A particle of mass m strikes elastically with a disc of radius R, with a velocity $\vec{v}$ as shown in the figure. If the mass of the disc is equal to that of the particle and the surface of the contact is smooth, then the velocity of the disc just after the collision is :



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

21. Two smooth spheres made of identical material having masses 'm' and 2m undergoes an oblique impact as shown in figure. The initial velocities of the masses are also shown. The impact force is along the line joining their centres along the x-axis. The coefficient of restitution is $\frac{5}{9}$. The velocities of the masses after the impact and the approximate percentage loss in kinetic energy.



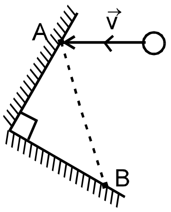
(A) $\frac{10}{3}\hat{i}+8\hat{j}$; $\frac{5}{3}\hat{i}+4\hat{j}$, 15%

(B) $\frac{5}{3}\hat{i}-8\hat{j}$; $\frac{-5}{3}\hat{i}+4\hat{j}$, 20%

(C) $\frac{10}{3}\hat{i}-8\hat{j}$; $\frac{-5}{3}\hat{i}+4\hat{j}$, 25%

(D) $\frac{10}{3}\hat{i}-8\hat{j}$; $\frac{-5}{3}\hat{i}+4\hat{j}$, 20%

22. 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

23. A wagon filled with sand has a hole so that sand leaks through the bottom at a constant rate λ. An external force $\vec{F}$ acts on the wagon in the direction of motion. Assuming instantaneous velocity of the wagon to be $\vec{v}$ and initial mass of system to be m_0, the force equation governing the motion of the wagon is :

(A) $\vec{F} = m_0 \dfrac{d\vec{v}}{dt} + \lambda \vec{v}$

(B) $\vec{F} = m_0 \dfrac{d\vec{v}}{dt} - \lambda \vec{v}$

(C) $\vec{F} = (m_0 - \lambda t) \dfrac{d\vec{v}}{dt}$

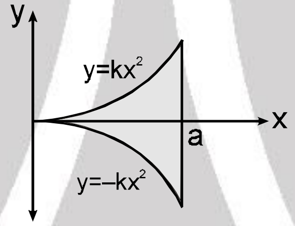
(D) $\vec{F} = (m_0 - \lambda t) \dfrac{d\vec{v}}{dt} + \lambda \vec{v}$

24. 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 velocity 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. (Neglect gravity & Bouyant force),

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

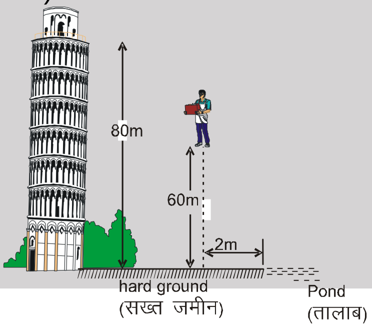
PART - II : NUMERICAL VALUE

1.✍ A thin uniform 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.



2. A train of mass $M = \pi$kg is moving on a circular track of radius ' R ' with constant speed V = 2m/s. The length of the train is half of the perimeter of the track. The linear momentum of the trian will be

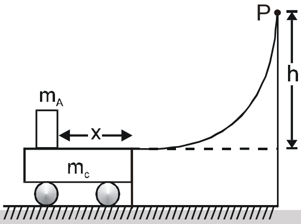
3. A man of mass 60 kg start falling from building of height 80 m with a bag of 2 kg in his hand. After falling through a distance 20 m he throw the bag horizontally with respect to him so that he fall in a pond 2m away from the vertical lines of fall. Calculate horizontal distance of bag from the vertical line of fall where it lands. (take $g = 10\ m/s^2$)



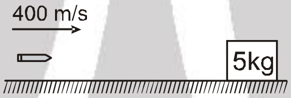
4. A car with a gun mounted on it is kept on horizontal friction less surface. Total mass of car, gun and shell is 50 kg. Mass of each shell is 1 kg. If shell is fired horizontally with relative velocity 100 m/sec with respect to gun. what is the recoil speed of car after second shot in nearest integer ?

5. A large stone of mass $\dfrac{M_e}{2}$ is released when centre of mass of the stone is at a height h ($h << R_e$). Find speed of stone when it is at a height of $\dfrac{h}{2}$. M_e and R_e are mass and radius of earth. Given $h = \dfrac{3}{20}$ m.

6. A block A having a mass m_A = 3kg is released from rest at the position P shown and slides freely down the smooth fixed inclined ramp. When it reaches the bottom of the ramp it slides horizontally onto the surface of a cart of mass m_c = 2kg for which the coefficient of friction between the cart and the block is $\mu = \frac{2}{5}$. If h = 6m be the initial height of A, determine the position 'x' (with respect to cart) of the box on the cart after it comes to rest relative to cart. (The cart moves on smooth horizontal surface.)

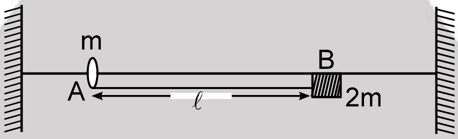


7. A bullet fired horizontally with a speed of 400 m/sec. It strikes a wooden block of mass 5 kg initially at rest placed on a horizontal floor as shown in the figure. It emerges with a speed of 200 m/sec and the block slides a distance 20 cm before coming to rest. If the coefficient of friction between block and the surface is $\frac{\lambda}{50}$ then find λ . Mass of bullet is 20 gm. (take g = 10 m/s^2)

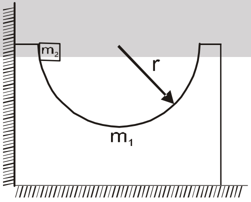


8. A bullet fired horizontally with a speed of 400 m/sec. It strikes a wooden block of mass 2 kg hanging vertically with the help of long string. After striking with bullet, block rises a height of 20 cm. If speed with which bullet emerges out from block is 10 λ then find λ. Mass of bullet is 20 gm. (take g = 10 m/s^2)

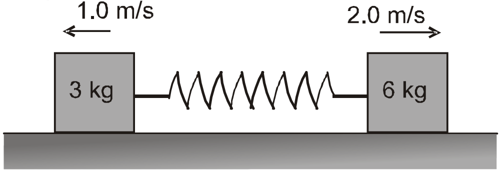
9. A small ring A of mass m = $\frac{1}{2}$kg is attached at an end of a light string the other end of which is tied to a block B of mass 2m. The ring is free to move on a fixed smooth horizontal rod as shown. Find tension in the string when it becomes vertical.



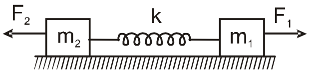
10. A symmetric block of mass m_1 = 1kg with a groove of hemispherical shape of radius r = 5m rests on a smooth horizontal surface in contact with the wall as shown in the figure. A small block of mass m_2 = 1kg slides without friction from the initial position. Find the maximum velocity of the block m_1.



11. Two blocks of mass 3 kg and 6 kg respectively are placed on a smooth horizontal surface. They are connected by a light spring of force constant k = 200 N/m. Initially the spring is unstretched and the indicated velocities are imparted to the blocks. Find maximum extension of the spring in cm ?

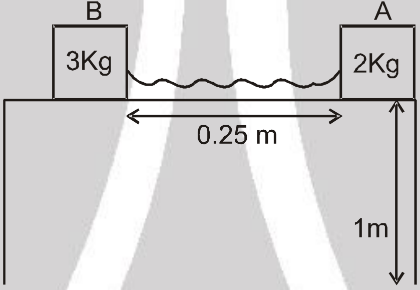


12. Two blocks initially at rest having masses m_1 and m_2 are connected by spring of spring constant $k = \frac{2}{3}$ N/m (as shown in the figure). The block of mass m_1 is pulled by a constant force $F_1 = 4N$ and the other block is pulled by a constant force $F_2 = 2N$ Find the maximum elongation of the spring (the spring is initially relaxed) Assuming $m_2 = 2m_1$

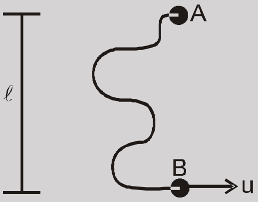


13. Two blocks of masses 10kg and 4kg are connected by a spring of negligible mass and are placed on a frictionless horizontal surface. An impulse gives a speed of 14 ms^{-1} to the heavier block in the direction of the lighter block. Then, find velocity of the centre of mass?

14. A particle A of mass 2kg lies on the edge of a table of height 1m. It is connected by a light inelastic string of length 0.7m to a second particle B of mass 3kg which is lying on the table 0.25m from the edge (line joining A & B is perpendicular to the edge). If A is pushed gently so that it starts falling from table. After some time string becomes tight. If the impulse of the tension in the string at that moment is $3\lambda/5$ then find λ . Assume all contacts are smooth. g = 10 m/s^2



15. Two particles A and B each of mass m are attached by a light inextensible string of length 2ℓ. The whole system lies on a smooth horizontal table with B initially at a distance ℓ from A. The particle at end B is projected across the table with speed $u = 4\sqrt{3}$ m/s perpendicular to AB. Find velocity of ball A just after the jerk ?



16. A block of mass 2 kg moving at 2.0 m/s collides head on with another block of equal mass kept at rest. If the loss in kinetic energy of system is half of the maximum possible loss of kinetic energy of system , If the coefficient of restitution $\frac{\lambda}{\sqrt{2}}$. then find λ.

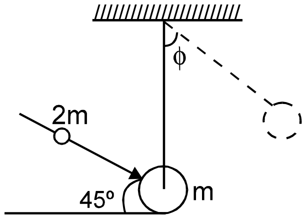
17. A projectile of mass m is fired with a speed v = 20 m/s at an angle $\theta = 45°$ from a smooth horizontal field. The coefficient of restitution of collision between the projectile and the field is $e = \frac{1}{2}$. How far from the starting point, does the projectile make its third collision with the field?

18. A body of mass 5kg moves along the x-axis with a velocity 2m/s. A second body of mass 10kg moves along the y-axis with a velocity of $\sqrt{3}$ m/s. They collide at the origin and stick together.

If the amount of heat liberated in the collision is $\frac{\lambda}{3}$ then find λ?

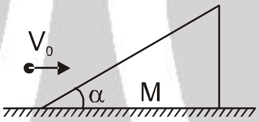
19. A ball released from rest collide elastically to a fixed inclined plane of inclination $\alpha = 30°$ after falling through a height h = 3m. Find the distance between the points along the incline where it strike the incline.

20. A ball of mass 'm' is suspended by a massless string of length 'ℓ' from a fixed point. A ball of mass 2m strikes in the direction of $\theta = 45^o$ from horizontal & sticks to it.



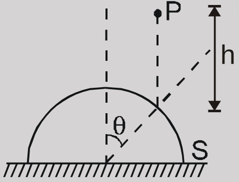
If the initial velocity of 2m is $x\sqrt{g\ell}$ so that system deflects by $\phi = \frac{\pi}{2}$ and if string is cut at $\phi = 60^o$, and the velocity at highest point of trajectory is $\frac{\sqrt{g\ell}}{y}$, then find x + y :

21. A wedge (free to move) of mass 'M' has one face making an angle α with horizontal and is resting on a smooth rigid floor. A particle of mass 'm' hits the inclined face of the wedge with a horizontal velocity v_0. It is observed that the particle rebounds in vertical direction after impact. Neglect friction between particle and the wedge & take $M = 2m$, $v_0 = 10m/s$, $\tan\alpha = 2$, $g = 10m/s^2$.

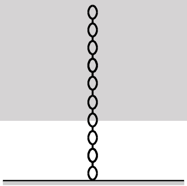


Assume that the inclined face of the wedge is sufficiently long so that the particle hits the same face once more during its downward motion. Calculate the time elapsed between the two impacts.

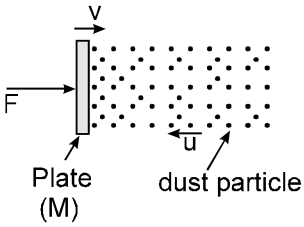
22. A hemisphere S and a particle P are of same mass $m = \sqrt{2}$ kg. P is dropped from a height 'h'. S is kept on a smooth horizontal surface. The friction between P and S is also absent. P collides elastically with S at the point shown in the figure. After collision the velocity of the particle becomes horizontal. Find ratio of impulse of ground on hemisphere to speed of hemisphere after collision ?



23. A uniform chain of mass m = 1kg and length ℓ = 1m hangs on a thread and touches the surface of a table by its lower end. Find the force exerted by the table on the chain when x = 0.5m length of chain has fallen on the table. The fallen part does not form heap.



24. A plate of mass M is moved with constant velocity v = 40m/s against powder of dust particles moving with constant velocity u = 40m/s in opposite direction stick to plate as shown. The density of the dust is $\rho = 10^{-3}$ kg/m^3 and plate area is A = 10m^2 Find the force F required to keep the plate moving uniformly.



PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

1.✍ A system of particles has its centre of mass at the origin. The x-coordinates of all the particles
(A) may be positive (B) may be negative
(C) may be non-negative (D) may be non-positive

2*.✍ In which of the following cases the centre of mass of a system is certainly not at its centre?
(A) A rod whose density continuously increases from left to right
(B) A rod whose density continuously decreases from left to right
(C) A rod whose density decreases from left to right upto the centre and then increases
(D) A rod whose density increases from left to right upto the centre and then decreases

3.✍ Two particles of equal mass m are projected form the ground with speed v_1 and v_2 at angle θ_1 and θ_2 (θ_1 , $\theta_2 \neq 0, 180^o$) as shown in figure. The centre of mass of the two particles

(A) will move in a parabolic path for any values of v_1, v_2, θ_1 and θ_2
(B) can move in a vertical line
(C) can move in a horizontal line
(D) will move in a straight line for any value of v_1, v_2, θ_1 and θ_2

4.* In an elastic collision in absence of external force, which of the following is/are correct :
(A) The linear momentum is conserved
(B) The potential energy is conserved in collision
(C) The final kinetic energy is less than the initial kinetic energy
(D) The final kinetic energy is equal to the initial kinetic energy

5.*✍ A small ball collides with a heavy ball initially at rest. In the absence of any external impulsive force, it is possible that
(A) Both the balls come to rest
(B) Both the balls move after collision
(C) The moving ball comes to rest and the stationary ball starts moving
(D) The stationary ball remains stationary, the moving ball changes its velocity.

6. A block moving in air explodes in two parts then just after explosion (neglect change in momentum duet to gravity)
(A) The total momentum of two parts must be equal to the momentum of the block before explosion.
(B) The total kinetic energy of two parts must be equal as that of block before explosion.
(C) The total momentum must change
(D) The total kinetic energy must increase

7.✍ Two bodies of same mass collide head on elastically then
(A) Their velocities are interchanged
(B) Their speeds are interchanged
(C) Their momenta are interchanged
(D) The faster body slows down and the slower body speeds up.

8. External force $\overrightarrow{F}(\overrightarrow{F} \neq 0)$ acts on a system of particles. The velocity and the acceleration of the centre of mass are found to be v_{cm} and a_{cm} at an instant, then it is possible that
(A) $v_{cm} = 0$, $a_{cm} = 0$ (B) $v_{cm} = 0$, $a_{cm} \neq 0$ (C) $v_{cm} \neq 0$, $a_{cm} = 0$ (D) $v_{cm} \neq 0$, $a_{cm} \neq 0$

9. 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 $m^2v^2/2(M + m)$

10. A set of n-identical cubical blocks lie at rest along a line on a smooth horizontal surface. The separation between 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 v/n

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

11. A ball of mass m 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.

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

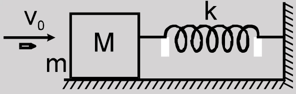
(A) is less than $\frac{1}{2}mv^2$ if he walks along the rails

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

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

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

13. A bullet of mass m = 1kg strikes a block of mass M =2kg connected to a light spring of stiffness k =3N/m with a speed V_0 = 3m/s. If the bullet gets embedded in the block then.



(A) linear momentum of bullet and block system is not conserve during impact because spring force is impulsive.

(B) linear momentum of bullet and block system isconserve during impact because spring force is nonimpulsive.

(C) Maximum compression in the spring is 2m.

(D) The maximum compression in the spring is 1m.

14. 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 :

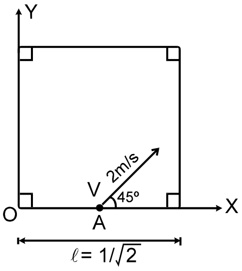
(A) the impulse delivered by the floor to the body is $mu(1 + e)\sin\theta$.

(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 $(\cos^2\theta + e^2\sin^2\theta)$

15. A striker is shot from a square carrom board from a point A exactly at midpoint of one of the walls with a speed 2 m/sec at an angle of 45° with the x-axis as shown. The collisions of the striker with the walls of the fixed carrom are perfectly elastic. The coefficient of kinetic friction between the striker and board is 0.2.



(A) x coordinate of the striker when it stops (taking point O to be the origin and neglect friction between wall and striker) is $\frac{1}{2\sqrt{2}}$.

(B) y coordinate of the striker when it stops (taking point O to be the origin and neglect friction between wall and striker) is $\frac{1}{\sqrt{2}}$.

(C) x coordinate of the striker when it stops (taking point O to be the origin and neglect friction between wall and striker) is $\frac{1}{\sqrt{2}}$.

(D) y coordinate of the striker when it stops (taking point O to be the origin and neglect friction between wall and striker) is $\frac{1}{2\sqrt{2}}$.

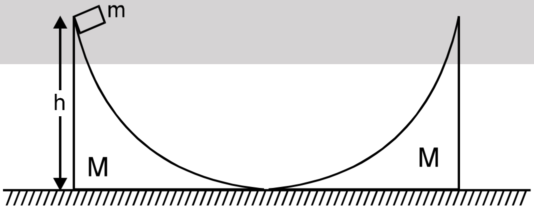
16. Two balls A and B moving in the same direction collide. The mass of B is p times that of A. Before the collision the velocity of A was q times that of B. After the collision A comes to rest. If e be the coefficient of restitution then which of the following conclusion/s is/are correct?

(A) $e = \frac{p+q}{pq-p}$ (B) $e = \frac{p+q}{pq+q}$ (C) $p \geq \frac{q}{q-2}$ (D) $p \geq 1$

PART - IV : COMPREHENSION

Comprehension-1

The inclined surfaces of two moveable wedges of the same mass M = 2kg are smoothly placed just in contact with each other and placed on the horizontal plane as shown in the figure. A small block of mass m = 1kg slides down the left wedge from a height h= 9m. Neglect the friction and both wedges can move independently.



1. Find velocity of left wedge just after when block leave the wedge

(A) $\sqrt{30}$ m/s (B) $\sqrt{50}$ m/s (C) $\sqrt{25}$ m/s (D) $\sqrt{45}$ m/s

2. To what maximum height will the block rise along the right wedge?

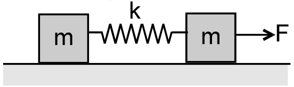
(A) 5m (B) 4m (C) 2m (D) 3m

3. Find velocity of right wedge when samller bolck is at maximum height on right wedge.

(A) $\sqrt{\frac{40}{3}}$ (B) $\sqrt{\frac{20}{3}}$ (C) $\sqrt{\frac{15}{3}}$ (D) $\sqrt{\frac{42}{3}}$

Comprehension-2

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. (initially system is at rest)



4. Then the displacement of the centre of mass in time t is

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

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

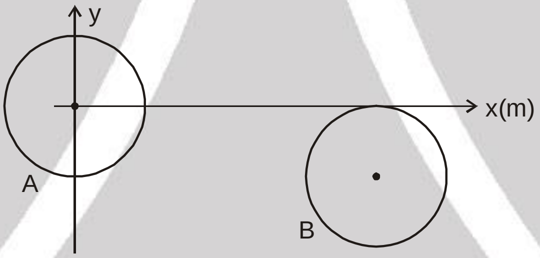
(A) $\frac{1}{2}\left(\frac{Ft^2}{2m}+x_0\right)$ (B) $-\frac{1}{2}\left(\frac{Ft^2}{2m}+x_0\right)$ (C) $\frac{1}{2}\left(\frac{Ft^2}{2m}-x_0\right)$ (D) $\left(\frac{Ft^2}{2m}+x_0\right)$

6. 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–3✍

Two smooth balls A and B, each of mass m and radius R, have their centres at (0, 0, R) and at (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.



7.✍ Velocity of the ball A just after the collision is :

(A) (i + $\sqrt{3}$ j) m/s (B) (i – $\sqrt{3}$ j) m/s (C) (2i + $\sqrt{3}$ j) m/s (D) (2i + 2j) m/s

8.✍ Impulse of the force exerted by A on B during the collision, is equal to

(A) $(\sqrt{3}mi+3mj)\ \frac{kgm}{s}$ (B) $\left(\frac{\sqrt{3}}{2}mi-\sqrt{3}mj\right)\frac{kgm}{s}$

(C) $(3mi-\sqrt{3}mj)\ \frac{kgm}{s}$ (D) $(2\sqrt{3}mi+3j)\ \frac{kgm}{s}$

Exercise-3

✍ Marked Questions can be used as Revision Questions.

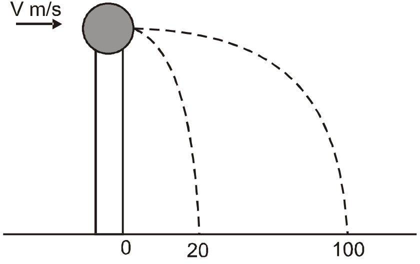
*** Marked Questions may have more than one correct option.**

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1. A point mass of 1kg collides elastically with a stationary point mass of 5 kg. After their collision, the 1 kg mass reverses its direction and moves with a speed of 2 ms^{-1}. Which of the following statement(s) is/are correct for the system of these two masses? **[JEE-2010, 3/163]**

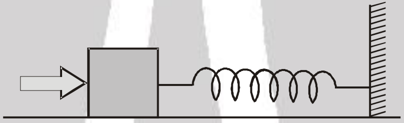
(A) Total momentum of the system is 3 kg ms^{-1}
(B) Momentum of 5 kg mass after collision is 4 kg ms^{-1}
(C) Kinetic energy of the centre of mass is 0.75 J
(D) Total kinetic energy of the system is 4 J

2. A ball of mass 0.2 kg rests on a vertical post of height 5 m. A bullet of mass 0.01 kg, traveling with a velocity V m/s in a horizontal direction, hits the centre of the ball. After the collision, the ball and bullet travel independently. The ball hits the ground at a distance of 20 m and the bullet at a distance of 100 m from the foot of the post. The initial velocity V of the bullet is **[JEE-2011, 3/160. –1]**



(A) 250 m/s (B) $250\sqrt{2}$ m/s (C) 400 m/s (D) 500 m/s

3.✍ A block of mass 0.18 kg is attached to a spring of force-constant 2 N/m. The coefficient of friction between the block and the floor is 0.1. Initially the block is at rest and the spring is un-stretched. An impulse is given to the block as shown in the figure. The block slides a distance of 0.06 m and comes to rest for the first time. The initial velocity of the block in m/s is V= N/10. Then N is **[JEE-2011, 4/160]**



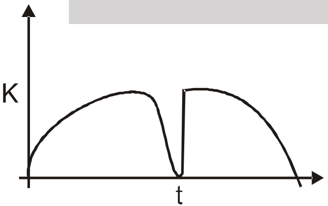
4. A bob of mass m, suspended by a string of length l_1, is given a minimum velocity required to complete a full circle in the vertical plane, At the highest point, it collides elastically with another bob of mass m suspended by a string of length l_2, which is initially at rest. Both the strings are mass-less and inextensible. If the second bob, after collision acquires the minimum speed required to complete a full circle in the vertical plane, the ratio $\frac{l_1}{l_2}$ is : **[JEE (Advanced) 2013; 4/60]**

5.✍ 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: **[JEE (Advanced) 2013,3/60, –1]**

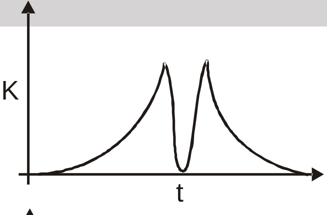
(A) $\frac{\pi}{4}$ (B) $\frac{\pi}{4}+a$ (C) $\frac{\pi}{4}-a$ (D) $\frac{\pi}{4}+\frac{a}{2}$

6.✍ A tennis ball is dropped on a horizontal smooth surface. It bounces back to its original position after hitting the surface. The force on the ball during the collision is proportional to the length of compression of the ball. Which one of the following sketches describes the variation of its kinetic energy K with time t most appropriately? The figures are only illustrative and not to the scale. **[JEE(Advanced) 2014,3/60,–1]**

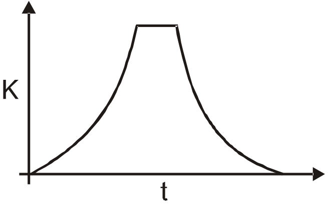
(A)



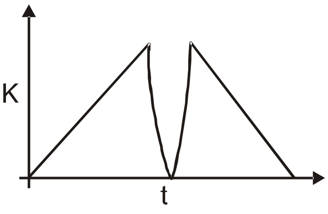
(B)



(C)

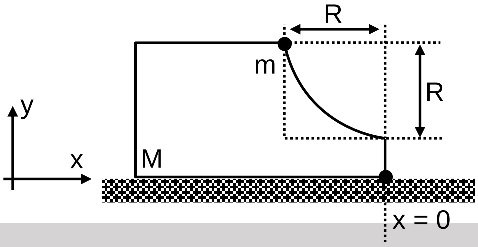


(D)



7. A block of mass M has a circular cut with a frictionless surface as shown. The block rests on the horizontal frictionless surface of a fixed table. Initially the right edge of the block is at x = 0, in a coordinate system fixed to the table. A point mass m is released from rest at the topmost point of the path as shown and its slides down. When the mass loses contact with the block, its position is x and the velocity is v. At the instant, which of the following options is/are correct ?

[JEE(Advanced) 2017 ; P-1, 4/61, –2]



(A) The velocity of the point mass m is : $v = \sqrt{\frac{2gR}{1+\frac{m}{M}}}$

(B) The x component of displacement of the center of mass of the block M is : $-\frac{mR}{M+m}$

(C) The position of the point mass is : $x = -\sqrt{2}\frac{mR}{M+m}$

(D) The velocity of the block M is : $V = -\frac{m}{M}\sqrt{2gR}$

8. A flat plate is moving normal to its plane through a gas under the action of a constant force F. The gas is kept at very low pressure. The speed of the plate v is much less than the average speed u of the gas molecules. Which of the following options is/are true? **[JEE(Advanced) 2017 ; P-1, 4/61, –2]**

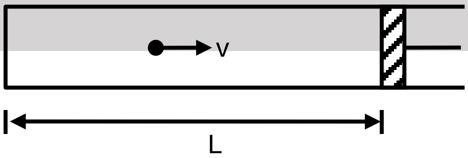
(A) The pressure difference between the leading and trailing faces of the plate is proportional to uv.

(B) At a later time the external force F balances the resistive force

(C) The resistive force experienced by the plate is proportional to v

(D) The plate will continue to move with constant non-zero acceleration, at all times

9. A small particle of mass m moving inside a heavy, hollow and straight tube along the tube axis undergoes elastic collision at two ends. The tube has no friction and it is closed at one end by a flat surface while the other end is fitted with a heavy movable flat piston as shown in figure. When the distance of the piston from closed end is $L = L_0$ the particle speed is $v = v_0$. The piston is moved inward at a very low speed V such that $V << \frac{dL}{L}v_0$. Where dL is the infinitesimal displacement of the piston. Which of the following statement(s) is/are correct? **[JEE (Advanced) 2019; P-2, 4/62, –1]**



(A) After each collision with the piston, the particle speed increases by 2V.

(B) If the piston moves inward by dL, the particle speed increases by $2v\frac{dL}{L}$

(C) The particle's kinetic energy increases by a factor of 4 when the piston is moved inward from L_0 to $\frac{1}{2}L_0$

(D) The rate at which the particle strikes the piston is v/L

PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

1. **STATEMENT-1 :** Two particles moving in the same direction do not lose all their energy in a completely inelastic collision. **[AIEEE 2010, 4/144]**
STATEMENT-2 : Principle of conservation of momentum holds true for all kinds of collisions.
(1) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1.
(2) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1
(3) Statement-1 is false, Statement-2 is true.
(4) Statement-1 is true, Statement-2 is false.

2.✍ This question has statement I and Statement II. Of the four choices given after the Statements, choose the one that best describes the two Statements.
STATEMENT-I : A point particle of mass m moving with speed υ collides with stationary point particle of mass M. If the maximum energy loss possible is given as $f\left(\frac{1}{2}m\upsilon^2\right)$ then $f = \left(\frac{m}{M+m}\right)$.
STATEMENT-II : Maximum energy loss occurs when the particles get stuck together as a result of the collision. **[JEE (Main) 2013, 4/120]**
(1) Statement -I is true, Statment -II is true, Statement -II is the correct explanation of Statement -I.
(2) Statement -I is true, Statment - II is true, Statement - II is not the correct explanation of Statement - I.
(3) Statement -I is true, Statment - II is false.
(4) Statement -I is false, Statment - II is true.

3. A particle of mass m moving in the x direction with speed 2v is hit by another particle of mass 2m moving in the y direction with speed v. If the collision is perfectly inelastic, the percentage loss in the energy during the collision is close to: **[JEE (Main) 2015; 4/120, –1]**
(1) 44% (2) 50% (3) 56% (4) 62%

4. Distance of the centre of mass of a solid uniform cone from its vertex is z_0. If the radius of its base is R and its height is h then z_0 is equal to: **[JEE (Main) 2015; 4/120, –1]**
(1) $\frac{h^2}{4R}$ (2) $\frac{3h}{4}$ (3) $\frac{5h}{8}$ (4) $\frac{3h^2}{8R}$

5. It is found that if a neutron suffers an elastic collinear collision with deuterium at rest, fractional loss of its energy is p_d, while for its similar collision with carbon nucleus at rest, fractional loss of energy is p_c. The values of p_d and p_c are respectively: **[JEE (Main) 2018; 4/120, –1]**
(1) (0, 0) (2) (0, 1) (3) (.89, .28) (4) (.28, .89)

6. The mass of a hydrogen molecule is 3.32×10^{-27} kg. If 10^{23} hydrogen molecules strike, per second, a fixed wall of area $2cm^2$ at an angle of 45° to the normal, and rebound elastically with a speed of 10^3 m/s, then the pressure on the wall is nearly : **[JEE (Main) 2018; 4/120, –1]**
(1) 2.35×10^2 N/m^2 (2) 4.70×10^2 N/m^2 (3) 2.35×10^3 N/m^2 (4) 4.70×10^3 N/m^2

7. In a collinear collision, a particle with an initial speed v_0 strikes a stationary particle of the same mass. If the final total kinetic energy is 50% greater than the original kinetic energy, the magnitude of the relative velocity between the two particles, after collision, is: **[JEE (Main) 2018; 4/120, –1]**
(1) $\frac{v_0}{2}$ (2) $\frac{v_0}{\sqrt{2}}$ (3) $\frac{v_0}{4}$ (4) $\sqrt{2}v_0$

8. A body of mass m_1 moving with an unknown velocity of $v_1\hat{i}$, undergoes a collinear collision with a body of mass m_2 moving with a velocity $v_2\hat{i}$. After collision, m_1 and m_2 move with velocities of $v_3\hat{i}$ and $v_4\hat{i}$, respectively. If $m_2 = 0.5\ m_1$ and $\upsilon_3 = 0.5\,\upsilon_1$, then υ_1 is : **[JEE (Main) April 2019; 4/120, –1]**
(1) $\upsilon_4 - \frac{\upsilon_2}{4}$ (2) $\upsilon_4 - \upsilon_2$ (3) $\upsilon_4 + \upsilon_2$ (4) $\upsilon_4 - \frac{\upsilon_2}{2}$

9. A body A, of mass m = 0.1 kg has an initial velocity of $3\hat{i}$ ms^{-1}. It collides elastically with another body, B of the same mass which has an initial velocity of $5\hat{j}$ ms^{-1}. After collision, A moves with a velocity $\vec{v} = 4(\hat{i}+\hat{j})$. The energy of B after collision is written as $\frac{x}{10}$ J. The value of x is_______.

[JEE (Main) Jan 2020; 4/100]

10. A particle of mass m is dropped from a height h above the ground. At the same time another particle of the same mass is thrown vertically upwards from the ground with a speed of $\sqrt{2gh}$. If they collide head-on completely inelastically, the time taken for the combined mass to reach the ground, in units of $\sqrt{\frac{h}{g}}$ is : **[JEE (Main) Jan 2020; 4/100]**

(1) $\sqrt{\frac{3}{4}}$ (2) $\sqrt{\frac{3}{2}}$ (3) $\sqrt{\frac{1}{2}}$ (4) $\frac{1}{2}$

11. A rod of length L has non-uniform linear mass density given by $\rho(x) = a + b\left(\frac{x}{L}\right)^2$, where a and b are constants and $0 \le x \le L$. The value of x for the centre of mass of the rod is at : **[JEE (Main) Jan 2020; 4/100,–1]**

(1) $\frac{4}{3}\left(\frac{a+b}{2a+3b}\right)L$ (2) $\frac{3}{4}\left(\frac{2a+b}{3a+b}\right)L$ (3) $\frac{3}{2}\left(\frac{2a+b}{3a+b}\right)L$ (4) $\frac{3}{2}\left(\frac{a+b}{2a+b}\right)L$

Answers

EXERCISE # 1

PART – I

Section (A)

A-1. $\frac{\sqrt{19}}{6}$ m

A-2. $\frac{4a}{(4+\pi)}$ right of the disc centre

A-3. 5a/6, 5a/6 **A-4.** $\frac{33L}{50}$

A-5. At R/5 from the centre of the bigger disc towards the centre of the smaller disk.

A-6. $\frac{3AL+2BL^2}{3(2A+BL)}$

A-7. At R/3 from the centre of the original disc away from the centre of the hole.

A-8. $\frac{4(R_2^3-R_1^3)}{3\pi(R_2^2-R_1^2)}$

Section (B)

B-1. $\sqrt{0.65}$ m/s at an angle $\tan^{-1}\left(\frac{1}{8}\right)$ above the direction towards right.

B-2. 1 cm downward

B-3. 60m, $20\sqrt{2}$m/s **B-4.** zero

B-5. 0.4 m **B-6.** (a) $\frac{mh}{m+M}$ (b) $\frac{Mh}{m+M}$

Section (C)

C-1. v = 10 m/s, $\frac{1}{4}$ **C-2.** 3.0×10^{-23} m/s

C-3. (a) $\frac{p_1+p_2}{m_p}$ (b) $\frac{\sqrt{p_1^2+p_2^2}}{m_p}$

C-4. $2.5\hat{i}+15\hat{j}+5\hat{k}$ **C-5.** $\left(1+\frac{M}{m}\right)$ v

C-6. 10cm. **C-7.** $\frac{mv}{M+m}$

Section (D)

D-1. (a) $\frac{m_2\ v_0}{m_1+m_2}$ (b) $v_0\left[\frac{m_1\ m_2}{(m_1+m_2)\ k}\right]^{1/2}$

D-2. $\frac{2m_2d}{m_1+m_2}$, $\frac{2m_1d}{m_1+m_2}$ **D-3.** $\frac{K.E_A}{K.E_B} = \frac{m_B}{m_A}$.

Section (E)

E-1. $8\hat{i}$ m/s **E-2.** (a) 0.4 kg-m/s (b) zero

E-3. $\rho\left(\frac{4}{3}\pi\frac{d^3}{8}\right)$vNA =1884 N **E-4.** 105 N

Section (F)

F-1. K/2. **F-2.** **F-3.** $e = \frac{1}{\sqrt{2}}$

F-4. $t = \frac{2\pi r}{v}$

F-5. 5 m/s opposite to the direction of motion of the first ball.

F-6. (a) $V_A = +2 m/s$, $V_B = +\frac{3}{4} m/s$

(b) 6Ns, 12 Ns (c) 33J (d) $\frac{99}{4}$ J

Section (G)

G-1. (i) $\frac{(m+M)g}{v_r}$ = 1.25 kg/s,

(ii) $v = v_r \ \ell n\left(\frac{m+M}{m}\right) - g \left(\frac{M}{\mu}\right)$

(a) 2.8 km/s, (b) 3.6 km/s.

G-2. F_{ext} = 10N; P = 20 watt.

PART – II

Section (A)

A-1.	(D)	**A-2.**	(C)	**A-3.**	(D)
A-4.	(A)	**A-5.**	(C)	**A-6.**	(B)
A-7.	(D)				

Section (B)

B-1.	(A)	**B-2.**	(D)	**B-3.**	(C)
B-4.	(D)	**B-5.**	(D)	**B-6.**	(B)
B-7.	(D)	**B-8.**	(B)		

Section (C)

C-1.	(B)	**C-2.**	(B)	**C-3.**	(B)
C-4.	(A)	**C-5.**	(A)	**C-6.**	(D)
C-7.	(B)				

Section (D)

D-1.	(C)	**D-3.**	(B)

Section (E)

E-1.	(B)	**E-2.**	(A)	**E-3.**	(C)

Section (F)

F-1.	(D)	**F-2.**	(A)	**F-3.**	(B)
F-4.	(C)	**F-5.**	(A)	**F-6.**	(C)
F-7.	(B)	**F-8.**	(A)	**F-9.**	(A)
F-10.	(A)				

Section (G)

G-1. (D)

PART – III

1. (A) p (B) q (C) p,r (D) q,s
2. A (q) , (B) p,q (C) r (D) s

EXERCISE # 2

PART – I

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

PART – II

1.	$\left(\frac{3}{4}a, O\right)$	**2.**	4	**3.**	60
4.	4	**5.**	1	**6.**	6
7.	8	**8.**	20	**9.**	70
10.	10	**11.**	30		
12.	$\frac{2\ (m_1F_2 + m_2F_1)}{k\ (m_1 + m_2)} = 10$				
13.	10	**14.**	6	**15.**	3
16.	1	**17.**	70	**18.**	35
19.	12	**20.**	5	**21.**	3
22.	2	**23.**	15	**24.**	64

PART - III

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

PART - IV

1.	(A)	**2.**	(B)	**3.**	(A)
4.	(C)	**5.**	(A)	**6.**	(D)
7.	(A)	**8.**	(C)		

EXERCISE # 3

PART – I

1.	(A,C)	**2.**	(D)	**3.**	4
4.	5	**5.**	(A)	**6.**	(B)
7.	(A,B)	**8.**	(A,B,C)	**9.**	(A, C)

PART – II

1.	(1)	**2.**	(4)	**3.**	(3)
4.	(2)	**5.**	(3)	**6.**	(3)
7.	(4)	**8.**	(2)	**9.**	(1)
10.	(2)	**11.**	(2)		