EXERCISE-1

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SECTION A : CALCULATION OF COM

A 1. Can centre of mass of a body coincide with the geometrical centre of the body?

A 2. If one of the particles is heavier than the other, to which side will their centre of mass shift?

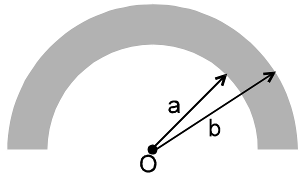
A 3. Does centre of mass of a system of two particles lie on the line joining the particles?

A 4. Can centre of mass of a body lie at a point where there is absolutely no mass?

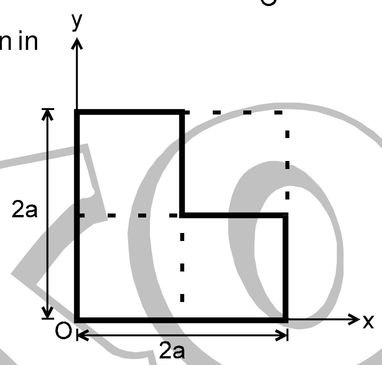
A 5. Where does centre of mass of a uniform triangular lamina lie?

A 6. 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 7. Find the distance of centre of mass of a uniform plate having semicircular inner and outer boundaries of radii a and b from the centre O.

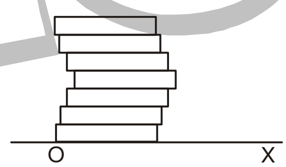


A 8. Find the position of centre of mass of the uniform planner section shown in figure with respect to the origin (O)



A 9. Seven 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/10.

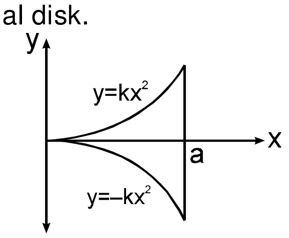
Find the x-coordinate of the centre of mass relative to the origin O shown.



A 10. A uniform disc of radius R is put over another uniform disc of radius 2R of the same thickness and density. The peripheries of the two discs touch each other. Locate the centre of mass of the system from the centre of large disc.

A 11. A disc of radius R is cut out from a larger 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 the residual disk.

A 12. 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.

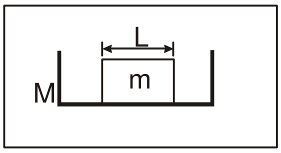


SECTION B : MOTION OF COM

B 1. (a) Two blocks of masses 10 kg and 20 kg are placed on the X-axis. The first mass is moved on the axis by a distance of 2 cm. By what distance should the second mass be moved to keep the position of the centre of mass unchanged?

(b) 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 ?

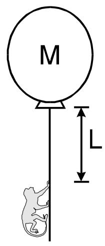
B 2. Consider a gravity-free hall in which a tray of mass M, carrying a cubical block of ice of mass m and edge L, is at rest in the middle (figure show). If the ice melts, by what distance does the centre of mass of " the tray plus the ice" system descend?



Gravity free hall

B 3. Mr. Verma (50 kg) and Mr. Mathur (60 kg) are sitting at the two extremes of a 4 m long boat (40 kg) standing still in water. To discuss a mechanics problem, they come to the middle of the boat. Neglecting friction with water, how far does the boat move in the water during the process ?

B 4. The balloon, the light rope and the monkey shown in figure are at rest in the air. If the monkey reaches the top of the rope, by what distance does the balloon descend? Mass of the balloon = M, mass of the monkey = m and the length of the rope ascended by the monkey = L.



SECTION C : CONSERVATION OF MOMENTUM

C 1. 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, whose initial speed is zero falls vertically. How far from the gun does the other fragment land, assuming a horizontal ground ? Take g = 10 m/s^2?

C 2. A particle of mass 2 m is projected at an angle of 45º with horizontal with a velocity of $20\sqrt{2}$ m/s. After 1 s explosion takes place and the particle is broken into two equal pieces. As a result of explosion one part comes to rest. Find the maximum height attained by the other part. Take g = 10 m/s^2.

C 3. A rail road car of mass M is at rest on frictionless rails when a man of mass m starts moving on the car towards the engine. If the car recoils with a speed v backward on the rails, with what velocity is the man approaching the engine?

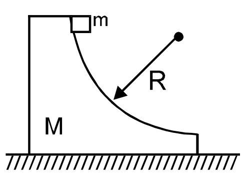
C 4. A (trolley + child) of total mass 200 kg is moving with a uniform speed of 36 km/h on a frictionless track. The child of mass 20 kg starts running on the trolley from one end to the other (10 m away) with a speed of 10 m s^{-1} relative to the trolley in the direction of the trolley's motion and jumps out of the trolley with the same relative velocity. What is the final speed of the trolley? How much has the trolley moved from the time the child begins to run?

C 5. 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 6. A uranium-238 nucleus, initially at rest, emits an alpha particle with a speed of 1.17×10^7 m/s. Calculate the recoil speed of the residual nucleus thorium-234. Assume that the mass of a nucleus is proportional to the mass number.

C 7. A neutron initially at rest, decays into a proton, an electron and an antineutrino. The ejected electron has a momentum of 1.4×10^{-26} kg-m/s and the antineutrino 6.5×10^{-27} kg-m/s. Find the recoil speed of the proton (a) if the electron and the antineutrino are ejected along the same direction and (b) if they are ejected along perpendicular directions. Mass of the proton = 1.67×10^{-27} kg.

C 8. A small cube of mass 'm' slides down a circular path of radius 'R' cut into a large block of mass 'M'. 'M' rests on a table and both blocks move without friction. The blocks initially are at rest and 'm' starts from the top of the path. Find the velocity 'v' of the cube as it leaves the block. Initially the line joining m and the centre is horizontal.



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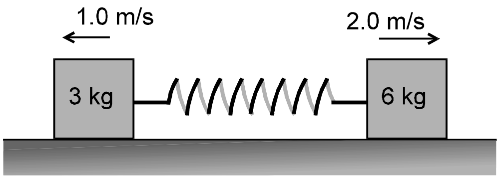
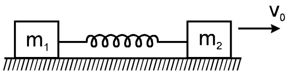
SECTION D : SPRING - MASS SYSTEM

D 1. 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 un stretched. The indicated velocities are imparted to the blocks. Find the maximum extension of the spring.



D 2. The block of mass m_2 is given a sharp impulse so that it acquires a velocity v_0 towards right. Find (a) the velocity of the centre of mass, (b) the maximum elongation that the spring will suffer.



D 3. Consider the situation of the previous problem. Suppose each of the blocks is pulled by a constant force F instead of any impulse. Find the maximum elongation that the spring will suffer and the distances moved by the two blocks in the process.

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. 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 a hailstones is 900 kg/m^3, take π = 3.14 .

E 3. A steel ball of mass 0.5 kg is dropped from a height of 4 m on to a horizontal heavy steel slab. The collision is elastic and the ball rebounds to its original height.
(a) Calculate the impulse delivered to the ball during impact.
(b) If the ball is in contact with the slab for 0.002s, find the average reaction force on the ball during impact.

E 4. 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 start falling from table then, find the speed of B when it starts to move. Also find the impulsive tension in the string at that moment.

SECTION F : COLLISION

F 1. After an elastic collision between two balls of equal masses, one is observed to have a speed of 3 m/s along the positive x-axis and the other has a speed of 2 m/s along the negative x-axis. What were the original velocities of the balls?

F 2. 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 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 K.E. 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 on a smooth horizontal circular tube or radius r. Find the time when the next collision will take place?

F 5. A ball falls on the ground from a height of 2.0 m and rebounds upto a height of 1.5 m. Find the coefficient of restitution.

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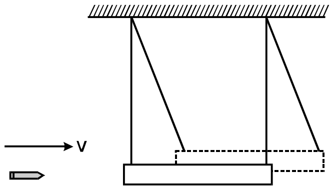
F 6. A bullet of mass 25 g is fired horizontally into a ballistic pendulum of mass 5.0 kg and gets embedded in it (figure). If the centre of the pendulum rises by a distance of 10 cm, find the speed of the bullet.



SECTION G : VARIABLE MASS

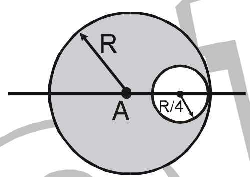
G 1. Sand drops from a stationary hopper at the rate of 5 kg/s on to a conveyor belt moving with a constant speed of 2 m/s. What is the force required to keep the belt moving and what is the power delivered by the motor moving the belt?

EXERCISE-2

SECTION A : CALCULATION OF COM

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. The centre of mass of the shaded portion of the disc is : (The mass is uniformly distributed in the shaded portion) :

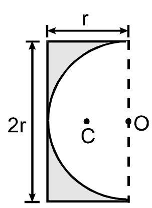


(A) $\frac{R}{20}$ to the left of A
(B) $\frac{R}{12}$ to the left of A
(C) $\frac{R}{20}$ to the right of A
(D) $\frac{R}{12}$ to the right of A

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

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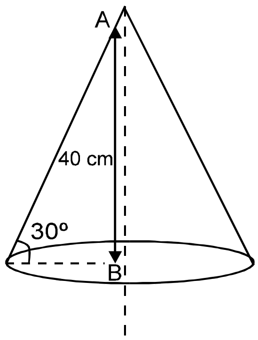
A-5. A uniform solid cone of height 40 cm is shown in figure. The distance of centre of mass of the cone from point B (centre of the base) is :



(A) 20 cm (B) 10/3 cm (C) 20/3 cm (D) 10 cm

A 6.* The centre of mass of a system of particles is at the origin. It follows that
(A) the number of particles to the right of the origin is equal to the number of particles to the left
(B) the total mass of the particles to the right of the origin is same as the total mass to the left of the origin
(C) the number of particles on X-axis should 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 7.* A body has its centre of mass at the origin. The x-coordinates of the particles
(A) may be all positive
(B) may be all negative
(C) may be all non-negative
(D) may be positive for some cases and negative in other cases

A 8.* In which of the following cases the centre of mass of a rod is certainly not at its centre ?
(A) the density continuously increases from left to right
(B) the density continuously decreases from left to right
(C) the density decreases from left to right upto the centre and then increases
(D) the density increases from left to right upto the centre and then decreases

SECTION B : MOTION OF COM

B 1. Two particles bearing 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 2. 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 3. If a ball is thrown upwards from the surface of earth:
(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 moves towards each other
(D) The ball and earth both move away from each other

B 4. Consider a system of two identical particles. One of the particles is at rest and the other has an acceleration $\vec{a}$. The centre of mass has an acceleration.

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

B 5. Internal forces can change
(A) the linear momentum but not the kinetic energy

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(B) the kinetic energy but not the linear momentum
(C) linear momentum as well as kinetic energy
(D) neither the linear momentum nor the kinetic energy

B 6. A body at rest breaks into two pieces of equal masses. The parts will move
(A) in same direction
(B) along different lines
(C) in opposite directions with equal speeds
(D) in opposite directions with unequal speeds

B 7.* If the external forces acting on a system have zero resultant, the centre of mass
(A) must not move
(B) must not accelerate
(C) may move
(D) may accelerate

SECTION C : CONSERVATION OF 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. Two masses of 1g and 4g are moving with equal K.E. The ratio of the magnitude of their linear momentum is -
(A) 1 : 1 (B) 1 : 2 (C) 1 : 3 (D) 1 : 4

C-3. A stationary body explodes into two fragments of masses m_1 and m_2. If momentum of one fragment is p, the 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) $\frac{p^2}{2(m_1-m_2)}$

C 4. A railway flat car has an artillery gun installed on it. The combined system has a mass M and moves with a velocity v_0. The barrel of the gun makes an angle α with the horizontal. A shell of mass m leaves the barrel at a speed 'u' relative to barrel in the forward direction. The speed of the flat car so that it may stop after the firing is

(A) $\frac{mu}{M+m}$ (B) $\left(\frac{Mu}{M+m}\right)\cos\alpha$ (C) $\left(\frac{mu}{M}\right)\cos\alpha$ (D) $(M + m)\, u \cos\alpha$

C 5.* A block moving in air breaks in two parts and the parts separate
(A) the total momentum must be conserved
(B) the total kinetic energy must be conserved
(C) the total momentum must change
(D) the total kinetic energy must change

C 6. A shell is fired from a canon with a velocity V at an angle θ with the horizontal direction. At the highest point in its path, it explodes into two pieces of equal masses. One of the pieces retraces its path to the cannon. The speed of the other piece immediately after the explosion is

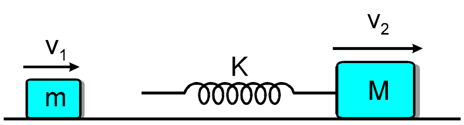
(A) $3V\cos\theta$ (B) $2V\cos\theta$ (C) $\frac{3}{2}V\cos\theta$ (D) $V\cos\theta$

C 7. A skater of mass m standing on ice throws a stone of mass M with a velocity of v m/s in a horizontal direction. The distance over which the skater will move back (the coefficient of friction between the skater and the ice is μ) :

(A) $\frac{M^2v^2}{2m\mu g}$ (B) $\frac{Mv^2}{2m^2\mu g}$ (C) $\frac{M^2v^2}{2m^2\mu g}$ (D) $\frac{M^2v^2}{2m^2\mu^2 g}$

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 :



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(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.

SECTION E : COLLISION

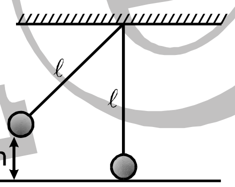
E 1. A bullet in motion hits and gets embedded in a solid block resting on a frictionless table. Which of the following is conserved ?
(A) Momentum and KE (B) Kinetic energy alone
(B) Neither KE nor momentum (D) Momentum alone

E 2.* A body moving towards a finite body at rest collides with it. It is possible that
(A) both the bodies come to rest
(B) both the bodies move after collision
(C) the moving body comes to rest and the stationary body starts moving
(D) the stationary body remains stationary, the moving body changes its velocity.

E 3.* In head on elastic collision of two bodies of equal masses
(A) the velocities are interchanged
(B) the speeds are interchanged
(C) the momenta are interchanged
(D) the faster body slows down and the slower body speeds up.

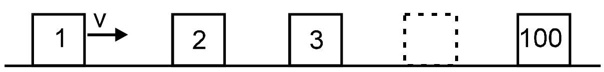
E 4. A particle of mass 1 g moving with a velocity $\vec{u}_1 = (3\hat{i} - 2\hat{j})ms^{-1}$ experiences a perfectly inelastic collision with another particle of mass 2 g and velocity $\vec{u}_2 = (4\hat{j} - 6\hat{k})ms^{-1}$. The velocity of the combined particle is :
(A) $\hat{i}+2\hat{j}-4\hat{k}$ (B) $\hat{i}-2\hat{j}+4\hat{k}$ (C) $\hat{i}-2\hat{j}-4\hat{k}$ (D) $\hat{i}+3.33\hat{j}+4\hat{k}$

E-5. 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 1/4 h. The ratio of the masses of the pendulum is :



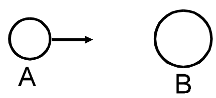
(A) 1 (B) 2 (C) 3 (D) 4

E 6. 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

E 7. A solid iron ball A collides with another stationary solid iron ball B. If the ratio of radii of the balls is n = 2, then the ratio of their speeds just after the collision (e = 0.5) is :



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

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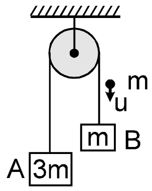
EXERCISE-3

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

2. Consider the following two statements :
(a) linear momentum of the system remains constant
(b) centre of mass of the system remains at rest.
(A) a implies b and b implies a
(B) a does not imply b and b does not imply a
(C) a implies b but b does not imply a
(D) b implies a but a does not imply b

3. Consider the following two statements :
(a) Linear momentum of the system of particles is zero
(b) Kinetic energy of a system of particles is zero
(A) a implies b and b implies a
(B) a does not imply b and b does not imply a
(C) a implies b but b does not imply a
(D) b implies a but a does not imply b

4. Consider the following two statements :
(a) the linear momentum of a particle is independent of the frame of reference
(b) the kinetic energy of a particle is independent of the frame of reference
(A) both a and b are true (B) a is true but b is false
(C) a is false but b is true (D) both a and b are false

5. A ball kept in a closed box moves in the box making collisions with the walls. The box is kept on a smooth surface. The velocity of the centre of mass
(A) of the box remains constant
(B) of the box plus the ball system remains constant
(C) of the ball remains constant
(D) of the ball relative to the box remains constant

6. A heavy ring of mass m is clamped on the periphery of a light circular disc. A small particle having equal mass is clamped at the centre of the disc. The system is rotated in such a way that the centre moves in a circle of radius r with a uniform speed v. We conclude that an external force

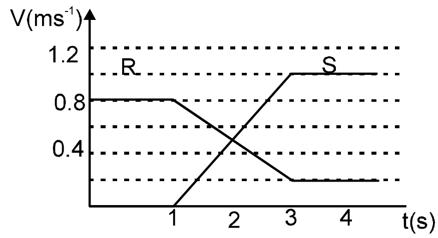
(A) $\frac{mv^2}{r}$ must be acting on the central particle (B) $\frac{2mv^2}{r}$ must be acting on the central particle

(C) $\frac{2mv^2}{r}$ must be acting on the system (D) $\frac{2mv^2}{r}$ must be acting on the ring.

7.* A ball hits a floor and rebounds after an inelastic collision. In this case
(A) the momentum of the ball just after the collision is same as that just before the collision

(B) the mechanical energy of the ball remains the same during the collision
(C) the total momentum of the ball and the earth is conserved
(D) the total energy of the ball and the earth remains the same

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

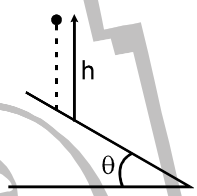


I. R and S moved in the same direction after the collision.
II. The velocities of R and S were equal at the mid time of the collision.
III. The mass of R was greater than mass of S.

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

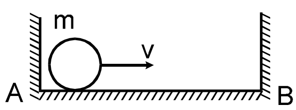
9. A ball collides with an inclined plane of inclination θ after falling through a distance h. If it moves horizontally just after the impact, the coefficient of restitution is :
(A) $\tan^2\theta$ (B) $\cot^2\theta$ (C) $\tan\theta$ (D) $\cot\theta$

10. 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) $2\,m\cos\theta\,\sqrt{2gh}$ (B) $2\,m\cos\theta\sqrt{gh}$ (C) $\dfrac{2m\sqrt{2gh}}{\cos\theta}$ (D) $2m\sqrt{2gh}$

11. A small ball 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

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

13.* 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

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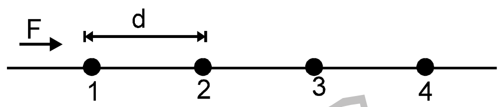
Successful People Replace the words like; "wish", "try" & "should" with "I Will". Ineffective People don't.

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

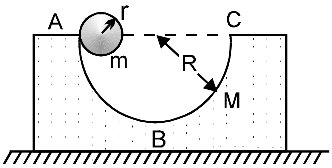
14.* A ball moving with a velocity v hits a massive wall moving towards the ball with a velocity u. An elastic impact lasts for a time Δt.
(A) The average elastic force acting on the ball is $\frac{m(u+v)}{\Delta t}$
(B) The average elastic force acting on the ball is $\frac{2m(u+v)}{\Delta t}$
(C) The kinetic energy of the ball increases by 2mu (u + v)
(D) The kinetic energy of the ball remains the same after the collision.

15.* The fig. shows a string of equally spaced 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 all collisions are elastic, then :



(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 $\frac{1}{2}\sqrt{\frac{2Fd}{m}}$.

16. 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 from the top point A. The cylinder slips on the semicircular frictionless track. The distance travelled by the block when the cylinder reaches the point B is :



(A) $\frac{M(R-r)}{M+m}$ (B) $\frac{m(R-r)}{M+m}$ (C) $\frac{(M+m)R}{M}$ (D) none

17. 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. 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 which of the following is/are correct :
(A) K E of the AB system at maximum compression of the spring is zero
(B) The KE of AB system at maximum compression is $(1/4)\ mv^2$
(C) The maximum compression of spring is $v\sqrt{m/k}$
(D) The maximum compression of spring is $v\sqrt{m/2k}$

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18. 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 : **[JEE - 93]**

[$\vec{R}$ is reaction from surface]

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

19.* A set of n-identical cubical blocks lie 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 $t = n(n-1)\dfrac{L}{2V}$

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

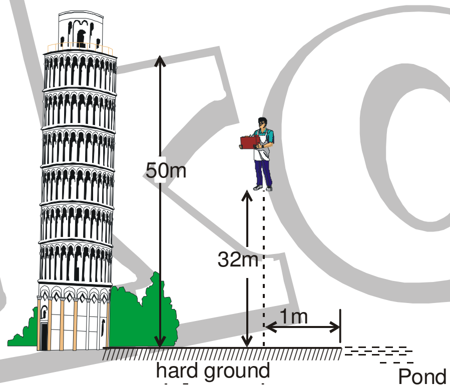
(C) The centre of mass of the system will have a final speed v/n

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

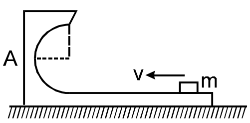
EXERCISE-4

Subjective Questions

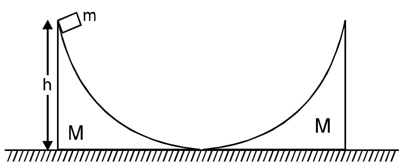
1. A man of mass 56 kg having a bag of mass 2 kg slips from the roof of a tall building of height 50 m and starts falling vertically (figure). When at a height 32 m from the ground, he notices that the ground below him is pretty hard, but there is a pond at a horizontal distance 1 m from the line of fall. In order to save himself he throws the bag horizontally (with respect to himself) in the direction opposite to the pond. Calculate the minimum horizontal velocity imparted to the bag so that the man lands in the water. If the man just succeeds to avoid the hard ground, where will the bag land?



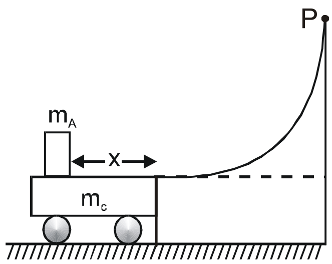
2. Figure shows a small block of mass m which is started with a speed v on the horizontal part of the bigger block of mass M placed on a horizontal floor. The curved part of the surface shown is semicircular. All the surfaces are frictionless. Find the speed of the bigger block when the smaller block reaches the point A of the surface.



3. The inclined surfaces of two moveable wedges of the same mass M are smoothly conjugated with the horizontal plane as shown in the figure. A small block of mass 'm' slides down the left wedge from a height 'h'. To what maximum height will the block rise along the right wedge?
Neglect the friction.



4. A block A having a mass 'm_A' is released from rest at the position P shown and slides freely down the smooth inclined ramp. When it reaches the bottom of the ramp it slides horizontally onto the surface of a cart of mass m_c for which the coefficient of friction between the cart and the box is 'μ'. If 'h' be the initial height of A, determine the final velocity of the cart once the block comes to rest in it. Also determine the position 'x' of the box on the cart after it comes to rest relative to cart. (The cart moves on smooth horizontal surface.)



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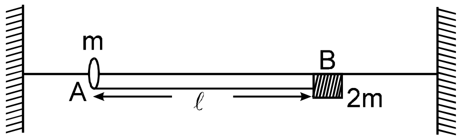
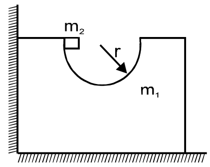
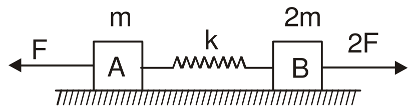
5. A small ring A of mass 'm' is attached at an end of a light string the other end of which is tied to a block B of mass 2m. The ring is free to move on a fixed smooth horizontal rod. Find the velocity of ring A and tension in the string when it becomes vertical.



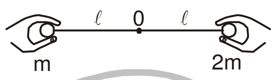
6. A symmetric block of mass m_1 with a groove of hemispherical shape of radius 'r' rests on a smooth horizontal surface near the wall as shown in the figure. A small block of mass m_2 slides without friction from the initial position. Find the maximum velocity of the block m_1.



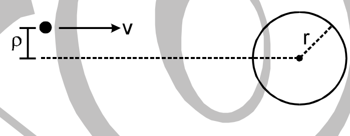
7. Two blocks A & B of mass 'm' & 2m respectively are joined to the ends of an under formed massless spring of spring constant ' k '. They can move on a horizontal smooth surface. Initially A & B have velocities ' u ' towards left and '2 u' towards right respectively. Constant forces of magnitudes F and 2 F are always acting on A and B respectively in the directions shown. Find the maximum extension in the spring during the motion.



8. Two ball having masses m and 2m are fastened to two light strings of same length ℓ (figure). The other ends of the strings are fixed at O. The strings are kept in the same horizontal line and the system is released from rest. The collision between the balls is elastic. (a) Find the velocities of the balls just after their collision. (b) How high will the balls rise after the collision?



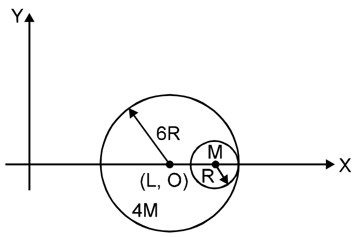
9. A small particle travelling with a velocity v collides elastically with a spherical body of equal mass and of radius r initially kept at rest. The centre of this spherical body is located at a distance ρ (< r) away from the direction of motion of the particle (figure). Find the final velocities of the two particles.



[***Hint :*** The force acts along the normal to the sphere through the contact. Treat the collision as one dimensional for this direction. In the tangential direction no force acts and the velocities do not change.]

EXERCISE-5

1. 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. 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)

2. 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 $\sqrt{3}$ m/s.

(a) If they collide at the origin and stick together, then the final velocity of the combined mass after collision is :

(A) $\frac{3}{4}$ m/s (B) $\frac{4}{3}$ m/s (C) $\frac{2}{3}$ m/s (D) $\frac{3}{2}$ m/s

(b) In the above question, the amount of heat liberated in the collision is :

(A) $\frac{35}{3}$ J (B) $\frac{30}{7}$ J (C) $\frac{36}{7}$ J (D) None of these

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3. 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

4. An isolated particle of mass m is moving in a horizontal plane (x – y) along the x-axis, 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

5. A particle of mass 'm' and velocity '$\vec{v}$' collides oblique elastically with a stationary particle of mass 'm'. The angle between the velocity vectors of the two particles after the collision is :
(A) 45° (B) 30° (C) 90° (D) None of these

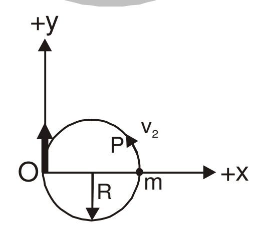
6.* A shell explodes in a region of negligible gravitational field, giving out n fragments of equal mass m. Then its total **[REE - 97]**
(A) Kinetic energy is smaller than that before the explosion
(B) Kinetic energy is greater than that before the explosion
(C) Momentum and kinetic energy depend on n
(D) Momentum is equal to that before the explosion.

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) $-2\vec{p}$

8. Two particles of masses m_1 and m_2 in projectile motion have velocities $\vec{u}_1$ and $\vec{u}_2$ 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 $[(m_1\vec{v}_1 + m_2\vec{v}_2) - (m_1\vec{u}_1 + m_2\vec{u}_2)]$ is **[JEE (Scr) - 01]**
(A) Zero (B) $(m_1 + m_2)gt_0$ (C) $2(m_1 + m_2)gt_0$ (D) $\frac{1}{2}(m_1 + m_2)gt_0$

9. 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, the velocity of the centre of mass is
(A) 30 ms^{-1} (B) 20 ms^{-1} (C) 10 ms^{-1} (D) 5 ms^{-1}

10. A person at the origin O starts moving with a constant speed v_1 along +y axis. At the same instant, a particle of mass m starts from point P with a uniform speed v_2 along a circular path of radius R, as shown in figure. Find the momentum of the particle with respect to the person as a function of time t.



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ANSWER

EXERCISE # 1

SECTION (A) : CALCULATION OF COM

A 1. Yes, when a body has a uniform mass density, its centre of mass of shall coincide with its geometrical centre.

A 2. The centre of mass will shift closer to the heavier particle.

A 3. Yes, always.

A 4. Yes, it can. For example, centre of mass of a uniform circular ring lies at the centre of ring, where there is no mass.

A 5. It lies at the centroid of the triangular lamina i.e. where the three medians of the triangle intersect.

A 6. $\frac{\sqrt{19}}{6}$ A 7. $\frac{4}{3\pi}\frac{(b^3-a^3)}{(b^2-a^2)}$

A 8. (5a/6, 5a/6) A 9. 22L/35

A 10. At R/5 from the centre of the bigger disc towards the centre of the smaller disk.

A 11. At R/3 from the centre of the original disc away from the centre of the hole.

A 12. $\frac{3}{4}$ a

SECTION B : MOTION OF COM

B 1. (a) 1 cm (b) 1 cm downward.

B 2. zero B 3. 40/3 cm

B 4. mL/ (m + M)

SECTION C : CONSERVATION OF MOMENTUM

C 1. **60 m.** C 2. **35 m.**

C 3. $\left(1+\frac{M}{m}\right)v$ C 4. 9m/s, 9m

C 5. **10 cm.** C 6. 2.0×10^5 m/s

C 7. (a) 12.3 m/s (b) 9.4 m/s

C 8. $v = \sqrt{\frac{2gR}{1+\frac{m}{M}}}$

SECTION D : SPRING - MASS SYSTEM

D 1. **30cm**

D 2. (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 3. 2F/k, $\frac{2Fm_2}{k(m_1+m_2)}$, $\frac{2Fm_1}{k(m_1+m_2)}$

SECTION E : IMPULSE

E 1. $8\hat{i}$ m/s. E 2. 1884 N

E 3. (a) $4\sqrt{5}$ Ns (b) $2000\sqrt{5}$ N

E 4. 1.2 m/s , 3.6 Ns

SECTION F : COLLISION

F 1. **2 m/s negative axis and 3m/s positive axis respectively**

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

F 4. $t = \frac{2\pi r}{v}$ F 5. $\sqrt{3}/2$

F 6. 280 m/s

SECTION G : VARIABLE MASS

G 1. **F_{ext} = 10N; P = 20 watt.**

EXERCISE # 2

SECTION A : CALCULATION OF COM

A-1. D A-2. A A-3. A
A-4. D A-5. D A 6.* **None**
A 7.* C D
A 8.* A B

SECTION B : MOTION OF COM

B 1. C B 2. D B 3. D
B 4. B B 5. B B 6. C
B 7.* C

SECTION C : CONSERVATION OF MOMENTUM

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

SECTION D : SPRING - MASS SYSTEM

D 1. C

SECTION E : COLLISION

E 1. D E 2.* BC E 3.* C D
E 4. A C E-5. A E 6. B
E 7. C

EXERCISE # 3

1. D 2. D 3. D
4. D 5. B 6. C
7.* CD 8. D 9. A
10. A 11. A 12. C
13.* BCD 14.* BC 15.* ACD
16. B 17. BD
18. B 19.* AC

EXERCISE # 4

Subjective Questions

1. 22 m/s, 28 m left to the line of fall.

2. $\frac{mv}{M+m}$ 3. $\frac{M^2h}{(M+m)^2}$

4. $\frac{m_A}{m_A+m_C}\sqrt{2gh}$, $\frac{h}{\mu\left(1+\frac{m_A}{m_C}\right)}$

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5. $v = \sqrt{\dfrac{8g\ell}{3}}$, T = 14 mg

6. $\dfrac{2m_2\sqrt{2gr}}{m_1+m_2}$

7. $x_{max} = \dfrac{4F+\sqrt{16F^2+54mu^2k}}{3k}$

8. (a) Light ball $\dfrac{\sqrt{50g\ell}}{3}$ towards left, heavy ball $\dfrac{\sqrt{2g\ell}}{3}$ towards right

(b) Light ball 2ℓ and heavy ball $\dfrac{\ell}{9}$

9. The small particle goes along the tangent with a speed of $v\rho/r$ and the spherical body goes perpendicular to the smaller particle with a speed of $\dfrac{v}{r}\sqrt{r^2-\rho^2}$.

EXERCISE # 5

1. B	**2.** (a) B (b) A	**3.** A
4. A	**5.** C	**6.*** BD
7. B	**8.** C	**9.** C

10. $m\left(-v_2 \sin\left(\dfrac{v_2}{R}t\right)\hat{i} + v_2\cos\left(\dfrac{v_2}{R}t\right)\hat{j} - v_1\hat{j}\right)$

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