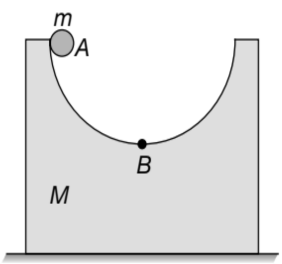
PRACTICE EXERCISES

SINGLE CORRECT CHOICE TYPE QUESTIONS

This section contains Single Correct Choice Type Questions. Each question has four choices (A), (B), (C) and (D), out of which ONLY ONE is correct.

1. A particle of mass $2m$ is projected at an angle of 45° with horizontal with a velocity of $20\sqrt{2}\ \text{ms}^{-1}$. After $1\ \text{s}$ explosion takes place and the particle is broken into two equal pieces. As a result of this explosion, one part comes to rest. The maximum height from the ground attained by the other part is $\left(g = 10\ \text{ms}^{-2}\right)$
   (A) 25 m (B) 35 m
   (C) 40 m (D) 50 m

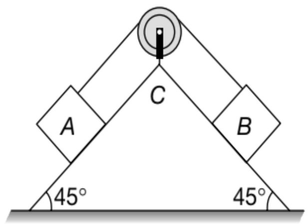
2. A block of mass $M = 2\ \text{kg}$ with a semi-circular track of radius $R = 1.1\ \text{m}$ rests on a horizontal frictionless surface. A uniform cylinder of radius $r = 10\ \text{cm}$ and mass $m = \frac{M}{2}$ is released from rest from the top point A. The cylinder slips on the semi-circular frictionless track. The speed of the block when the cylinder reaches the bottom of the track at B is $\left(\text{Take } g = 10\ \text{ms}^{-2}\right)$



   (A) $\sqrt{\frac{10}{3}}\ \text{ms}^{-1}$ (B) $\sqrt{\frac{4}{3}}\ \text{ms}^{-1}$
   (C) $\sqrt{\frac{5}{2}}\ \text{ms}^{-1}$ (D) $\sqrt{10}\ \text{ms}^{-1}$

3. Three point masses of $1\ \text{g}$, $2\ \text{g}$ and $3\ \text{g}$ have their centre of mass at $(2, 2, 2)$. A fourth mass of $4\ \text{g}$ is placed at position vector $\vec{r}$ such that the centre of mass of new system is now at $(0, 0, 0)$.
   (A) $\vec{r} = (-1, -1, -1)$ (B) $\vec{r} = (-2, -2, -2)$
   (C) $\vec{r} = (-3, -3, -3)$ (D) $\vec{r} = (-4, -4, -4)$

4. A system of two blocks A and B (having masses m and $2m$) and a wedge C (having mass $2m$) is released from rest as shown in figure. The displacement of wedge C when block B slides down the plane, a distance $10\ \text{cm}$ is (neglect friction)

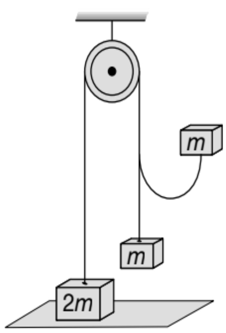


   (A) $2\sqrt{2}\ \text{cm}$ (B) $3\sqrt{2}\ \text{cm}$
   (C) $4\sqrt{2}\ \text{cm}$ (D) $5\sqrt{2}\ \text{cm}$

5. A body of mass m_0 is placed on a smooth horizontal surface. The mass of the body is decreasing exponentially with disintegration constant λ. Assuming that the mass is ejected backward with a relative velocity u. Assuming the body to be at rest initially, the speed of body at time t is
   (A) $ue^{\lambda t}$ (B) $u\lambda t$
   (C) $ue^{-\lambda t}$ (D) $u\left(1 - e^{-\lambda t}\right)$

6. A bullet, moving with a speed of $150\ \text{ms}^{-1}$, strikes a wooden plank. After passing through the plank, its speed becomes $125\ \text{ms}^{-1}$. Another bullet of the same mass and size strikes the plank with a speed of $90\ \text{ms}^{-1}$. Its speed after passing through the plank would be
   (A) $25\ \text{ms}^{-1}$ (B) $35\ \text{ms}^{-1}$
   (C) $50\ \text{ms}^{-1}$ (D) $70\ \text{ms}^{-1}$

7. A mass $2m$ lying on a horizontal table is attached to a light inextensible string which passes over a smooth pulley and carries a mass m at the other end. If the mass m is raised vertically through a distance h and is then dropped, then the speed with which the mass $2m$ begins to rise is



(A) $\frac{\sqrt{gh}}{2}$ (B) $\sqrt{gh}$

(C) $\sqrt{2gh}$ (D) $\frac{\sqrt{2gh}}{3}$

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

(A) $y = -5$ cm (B) $y = +20$ cm

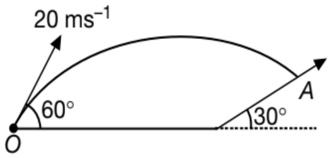
(C) $y = +5$ cm (D) $y = -20$ cm

9. A non-zero external force acts on a system of particles. The velocity and the acceleration of the centre of mass are found to be v_0 and a_0 at an instant t. It is possible that

(A) $v_0 = 0$, $a_0 = 0$ (B) $v_0 = 0$, $a \neq 0$

(C) $v_0 \neq 0$, $a_0 = 0$ (D) $v_0 \neq 0$, $a_0 \neq 0$

10. A ball is projected from the point O with velocity $20\ \text{ms}^{-1}$ at an angle of 60^o with horizontal as shown in figure.



At highest point of its trajectory it strikes a smooth plane of inclination 30^o at point A. The collision is perfectly inelastic. The maximum height from the ground attained by the ball is $(\text{Take } g = 10\ \text{ms}^{-2})$

(A) 15 m (B) 18.75 m

(C) 20.25 m (D) 22.5 m

11. A small block of mass M moves with a velocity of $5\ \text{ms}^{-1}$ towards another block of same mass M placed at a distance of 2 m on a rough horizontal surface. The coefficient of friction between the blocks and ground is 0.25 and the collision between the two blocks is elastic. The separation between the blocks, when both of them come to rest, is $(\text{Take } g = 10\ \text{ms}^{-2})$

(A) 1.5 m (B) 2 m

(C) 3 m (D) 4 m

12. After perfectly inelastic collision between two identical particles moving with same speed in different directions, the speed of the particles become half the initial speed. The angle between the velocities of the two before collision is

(A) 30° (B) 45°

(C) 60° (D) 120°

13. In one dimensional collision of two particles, the velocities are interchanged when

(i) collision is elastic and masses are equal

(ii) collision is inelastic but masses are unequal

Select the correct alternative

(A) only (i) is correct

(B) only (ii) is correct

(C) both (i) and (ii) are correct

(D) both (i) and (ii) are wrong

14. A hemisphere and a solid cone have a common base. The centre of mass of the common structure coincides with the centre of the common base. If R is the radius of hemisphere and h is height of the cone, then

(A) $\frac{h}{R} = \sqrt{3}$ (B) $\frac{h}{R} = \frac{1}{\sqrt{3}}$

(C) $\frac{h}{R} = 3$ (D) $\frac{h}{R} = \frac{1}{3}$

15. Velocity of centre of mass of two particles is v and the sum of the masses of two particles is m. Kinetic energy of the system is K. Then

(A) $K = \frac{1}{2}mv^2$ (B) $K < \frac{1}{2}mv^2$

(C) $K \geq \frac{1}{2}mv^2$ (D) $K > \frac{1}{2}mv^2$

16. A circular plate of uniform thickness has a diameter of 56 cm. A circular portion of diameter 42 cm is removed from the right edge of the plate with centres for both lying on the same line. The position of the centre of mass of the remaining portion is

(A) 9 cm to the right of the centre of full plate (thereafter referred to as "Origin").

(B) 9 cm to the left of the "Origin".

(C) $\frac{49}{9}$ cm to the right of the "Origin".

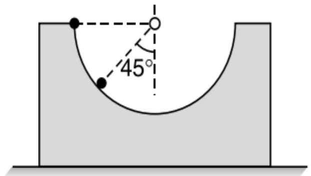
(D) $\frac{49}{9}$ cm to the left of the "Origin".

17. A neutron collides head-on and elastically with an atom of mass number A, which is initially at rest. The fraction of kinetic energy retained by the neutron is

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

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

18. A ball of mass m is released from point A inside a smooth wedge also of mass m as shown in Figure.



The speed of the wedge when the ball reaches point B is

(A) $\sqrt{\frac{gR}{3\sqrt{2}}}$ (B) $\sqrt{2gR}$

(C) $\sqrt{\frac{5gR}{2\sqrt{3}}}$ (D) $\sqrt{\frac{3gR}{2}}$

19. A ball moving with a speed v towards north, collides with an identical ball, moving with a speed v towards east. After collision the two balls stick together and move towards north-east. The speed of the combination is

(A) v (B) $v\sqrt{2}$

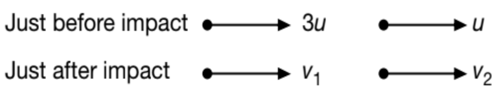
(C) $\frac{v}{\sqrt{2}}$ (D) $\frac{v}{2}$

20. In a one dimensional collision between two identical particles A and B, B is stationary and A has momentum P before impact. During impact B gives an impulse J to A. Then coefficient of restitution between the two is

(A) $\frac{2J}{P}+1$ (B) $\frac{2J}{P}-1$

(C) $\frac{J}{P}+1$ (D) $\frac{J}{P}-1$

21. Two smooth objects with a coefficient of restitution e, collide directly and bounce as shown, then Newton's Law of Restitution gives



(A) $4eu = v_2 + v_1$ (B) $2eu = v_1 - v_2$

(C) $2eu = v_2 - v_1$ (D) $2eu = v_2 + v_1$

22. Two particles of equal masses have velocities $\vec{v}_1 = 2\hat{i}\ \text{ms}^{-1}$ and $\vec{v}_2 = 2\hat{j}\ \text{ms}^{-1}$. First particle has an acceleration $\vec{a}_1 = (3\hat{i}+3\hat{j})\ \text{ms}^{-2}$ while the acceleration of the other particle is zero. The centre of mass of the two particles moves in a

(A) circle (B) parabola

(C) straight line (D) ellipse

23. A rope thrown over a pulley has a ladder with a man of mass m on one of its ends and a counterbalancing mass M on its other end. The man climbs with a velocity v_r relative to ladder. Ignoring the masses of the pulley and the rope as well as the friction on the pulley axis, the velocity of the centre of mass of this system is

(A) $\frac{m}{M}v_r$ (B) $\frac{m}{2M}v_r$

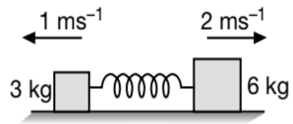
(C) $\frac{M}{m}v_r$ (D) $\frac{2M}{m}v_r$

24. Consider a system of two identical particles. One of the particle is at rest and the other has an acceleration a. The centre of mass has an acceleration

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

(C) $\vec{a}$ (D) $2\vec{a}$

25. 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 $k = 200\ \text{Nm}^{-1}$. Initially the spring is unstretched and velocities of $1\ \text{ms}^{-1}$ and $2\ \text{ms}^{-2}$ are imparted in opposite directions to the respective blocks as shown in figure.



The maximum extension of the spring will be

(A) 15 cm (B) 20 cm

(C) 25 cm (D) 30 cm

26. A ball moving horizontally with speed v strikes the bob of a simple pendulum at rest. The mass of the bob is equal to that of the ball. It the collision is elastic the bob will rise to a height

(A) $\frac{v^2}{g}$ (B) $\frac{v^2}{2g}$

(C) $\frac{v^2}{4g}$ (D) $\frac{v^2}{8g}$

27. In PROBLEM 26, if the collision is completely inelastic, the height to which the ball-bob system will rise is

(A) $\frac{v^2}{g}$ (B) $\frac{v^2}{2g}$

(C) $\frac{v^2}{4g}$ (D) $\frac{v^2}{8g}$

28. A particle of mass m collides elastically with a stationary particle and continues to move at an angle of 45° with respect to the original direction. The second particle also recoils at an angle of 45° to this direction. The mass of the second particle is

(A) m (B) $\sqrt{2}m$

(C) $\frac{m}{\sqrt{2}}$ (D) $\frac{m}{2}$

29. Two blocks m_1 and m_2, having masses 10 kg and 5 kg respectively, are placed on a frictionless horizontal surface and are connected by a light spring of force constant $5\ \text{Nm}^{-1}$. m_1 is in contact with a rigid wall. m_2 is pushed through a distance of 4 cm towards m_1 and then released. The velocity of the centre of mass (in cms^{-1}) of the system when m_1 breaks off the wall is

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

(C) 2 (D) 4

30. A steel ball of radius 2 cm is initially at rest on a horizontal frictionless surface. It is struck head-on and elastically by another steel ball of radius 4 cm moving with a speed of 81 cms^{-1}. The speeds of the two balls after the collision are, respectively

(A) 63 cms^{-1}, 144 cms^{-1} (B) 144 cms^{-1}, 63 cms^{-1}

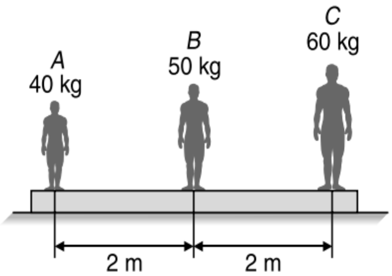
(C) 126 cms^{-1}, 72 cms^{-1} (D) 72 cms^{-1}, 126 cms^{-1}

31. A 1 kg ball, moving at 12 ms^{-1}, collides head-on with a 2 kg ball moving in the opposite direction at 24 ms^{-1}. If the coefficient of restitution is $\frac{2}{3}$, then the energy lost in the collision is

(A) 60 J (B) 120 J

(C) 240 J (D) 480 J

32. Three men A, B and C of mass 40 kg, 50 kg and 60 kg are standing on a plank of mass 90 kg, which is kept on a smooth horizontal plane. If A and C exchange their positions then B



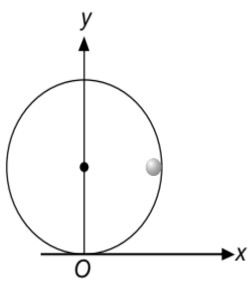
(A) shifts $\frac{1}{3}$ m, towards left

(B) shifts $\frac{1}{3}$ m, towards right

(C) shifts $\frac{5}{3}$ m, towards left

(D) will not shift at all

33. A small sphere of radius R held against the inner surface of a smooth spherical shell of radius $6R$ as shown in figure.



The masses of the shell and small spheres are $4M$ and M respectively. This arrangement is placed on a smooth horizontal table. The small sphere is now released. The x-coordinate of the centre of the shell when the smaller sphere reaches the other extreme position is

(A) R (B) $2R$

(C) $3R$ (D) $4R$

34. A ball hits the floor and rebounds after an inelastic collision. In this case

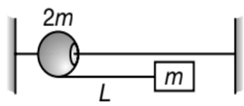
(A) the momentum of the ball just after the collision is the same as that just before the collision

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

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

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

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



(A) $\frac{L}{2}(1-\cos\theta)$ (B) $L(1-\cos\theta)$

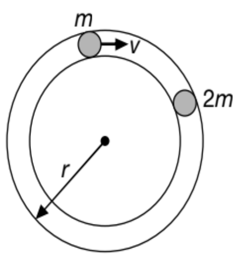
(C) $\frac{L}{6}(1-\cos\theta)$ (D) $\frac{L}{3}(1-\cos\theta)$

36. A particle of mass m moving with a velocity $\vec{v}$ makes a head-on elastic collision with another identical particle which is initially at rest. The velocity of the first particle after the collision is

(A) $-\vec{v}$ (B) $\vec{v}$

(C) $\frac{\vec{v}}{2}$ (D) ZERO

37. A particle of mass m moving with a speed v hits elastically another stationary particle of mass $2m$ on a smooth horizontal circular tube of radius r. The time in which the next collision will take place is equal to



(A) $\frac{\pi r}{v}$ (B) $\frac{2\pi r}{v}$

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

38. A body of mass 2.9 kg is suspended from a string of length 2.5 m and is at rest. A bullet of mass 100 g, moving horizontally with a speed of 150 ms^{-1}, strikes and sticks to it. What is the maximum angle made by the string with the vertical after the impact? $(g = 10\ ms^{-2})$

(A) 30° (B) 45°

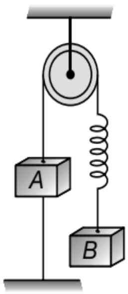
(C) 60° (D) 90°

39. A ball of mass m collides head-on and elastically with a ball of mass nm, initially at rest. The fraction of the incident energy transferred to the heavier ball is

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

(C) $\frac{2n}{(n+1)^2}$ (D) $\frac{4n}{(n+1)^2}$

40. In the figure shown, the blocks A and B have equal masses m. The system is released from rest with the spring unstretched. The string between A and ground is cut, when there is maximum extension in the spring. The acceleration of centre of mass of the two blocks at this instant is



(A) g (B) $\frac{g}{2}$

(C) $2g$ (D) ZERO

41. A particle of mass $3m$ is projected from the ground at some angle with horizontal such that its horizontal range is R. At the highest point of its path it breaks into two pieces of masses m and $2m$ respectively. The smaller mass comes to rest. The larger mass finally falls at a distance x from the point of projection where x equals

(A) $\frac{3}{4}R$ (B) $\frac{3}{2}R$

(C) $\frac{5}{4}R$ (D) $3R$

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

(A) 30 ms^{-1} (B) 20 ms^{-1}

(C) 10 ms^{-1} (D) 5 ms^{-1}

43. Two blocks of masses 10 kg and 4 kg are connected by a spring of negligible mass and placed on a frictionless horizontal surface. An impulse gives a velocity of 14 ms^{-1} to the heavier block in the direction of the lighter block. The velocity of the center of mass is

(A) 30 ms^{-1} (B) 20 ms^{-1}

(C) 10 ms^{-1} (D) 5 ms^{-1}

44. A man hangs from a rope attached to a hot-air balloon. The mass of the man is greater than the mass of the balloon and its contents. The system is stationary in air. If the man now climbs up to the balloon using the rope, the centre of mass of the 'man plus balloon' system will

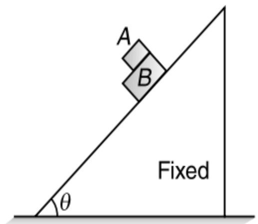
(A) remain stationary

(B) move up

(C) move down

(D) first move up and then returns to its initial position

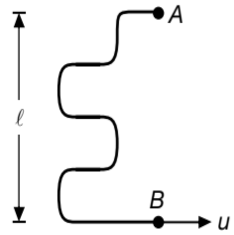
45. A block A slides over another block B which is placed over a smooth inclined plane as shown in figure. The coefficient of friction between the two blocks A and B is μ. Mass of block B is twice the mass of block A. The acceleration of the centre of mass of two blocks is



(A) $\frac{g\sin\theta - \mu g\cos\theta}{3}$ (B) $\frac{2g\sin\theta - \mu g\cos\theta}{3}$

(C) $\frac{g\sin\theta}{3}$ (D) $g\sin\theta$

46. 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 perpendicular to AB. Velocity of ball A just after the string is taut is



(A) $\frac{u\sqrt{3}}{4}$ (B) $u\sqrt{3}$

(C) $\frac{u\sqrt{3}}{2}$ (D) $\frac{1}{2}u$

47. When a ball collides head-on and elastically with an identical ball on a horizontal frictionless surface, the first one comes to rest while the second one moves with the same velocity as that of the first ball before collision. This result

(A) can be derived by using momentum conservation alone

(B) can be derived by using energy conservation alone

(C) cannot be derived by using any of the two conservation principles

(D) can be derived by using both conservation of energy and momentum

48. In gravity-free space, a man of mass M standing at a height h above the floor throws a ball of mass m straight down with a speed u. When the ball reaches the floor, the distance of the man above the floor will be

(A) $h\left(1+\frac{m}{M}\right)$

(B) $h\left(2-\frac{m}{M}\right)$

(C) $2h$

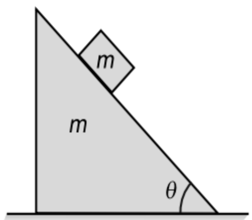
(D) a function of m, M, h and u

49. A body of mass m_1 moving with velocity u_1 collides with another body of mass m_2 at rest. After the collision the velocity of mass m_1 is $\frac{2}{3}u_1$, what is the ratio of $\frac{m_1}{m_2}$?

(A) 1 : 25 (B) 1 : 5

(C) 5 : 1 (D) 25 : 1

50. A block of mass m slides down an inclined wedge of same mass m shown in figure. Friction is absent everywhere. Acceleration of centre of mass of the block and wedge is



(A) ZERO (B) $\frac{g\cos^2\theta}{(1+\sin^2\theta)}$

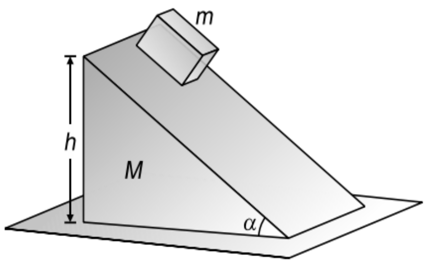
(C) $\frac{g\sin^2\theta}{(1+\sin^2\theta)}$ (D) $\frac{g\sin\theta}{(1+\cos\theta)}$

51. All the particles of a body are situated at a distance R from the origin. The distance of the centre of mass of the body from the origin is

(A) $=R$ (B) $\le R$

(C) $>R$ (D) $\ge R$

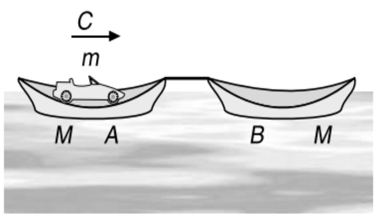
52. In the arrangement shown, the mass m starts from the top of the wedge of mass M. The system $(m+M)$ was initially at rest. Assume all surfaces in contact to be frictionless. The distance moved by M when m just reaches the floor is



(A) $\frac{mh}{M+m}$ (B) $\frac{mh\tan\alpha}{M+m}$

(C) $\frac{mh\cot\alpha}{M+m}$ (D) $\frac{mh\sin\alpha}{M+m}$

53. A car C of mass m is initially at rest on the boat A of mass M tied to the identical boat B of same, mass m through a massless inextensible string as shown in Figure.



The car accelerates from rest to velocity v_0 with respect to boat A in time t_0 sec. At time t_0 the car applies brake and comes to rest relative to boat in negligible time. Neglect friction between boat and water, the velocity of boat A just after applying brake is

(A) $\frac{Mmv_0}{(2M+m)(M+m)}$ (B) $\frac{Mmv_0}{(M+2m)(M+m)}$

(C) $\frac{2Mmv_0}{(M+2m)(M+m)}$ (D) ZERO

54. A gardener waters the plants by a pipe of diameter $1\ \text{cm}$. The water comes out at the rate of $20\ \text{ccs}^{-1}$. The reactionary force exerted on the hand of the gardener is

(A) ZERO (B) 1.62×10^{-3} N

(C) 2.54×10^{-5} N (D) 5.1×10^{-3} N

55. A particle of mass m is made to move with uniform speed v along the perimeter of a regular polygon of $2n$ sides. The magnitude of impulse applied at each corner of the polygon is

(A) $mv\sin\left(\frac{\pi}{2n}\right)$ (B) $mv\cos\left(\frac{\pi}{2n}\right)$

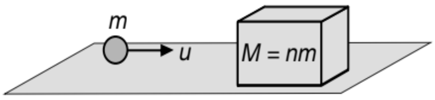
(C) $2mv\cos\left(\frac{\pi}{2n}\right)$ (D) $2mv\sin\left(\frac{\pi}{2n}\right)$

56. Two particles, each of mass m, moving in opposite directions with equal speeds along the same straight line strike elastically. If the velocities of the first and the second particle before collision are denoted by $+\vec{v}$, and $-\vec{v}$, respectively, then if there is no change in the line of motion of the two particles, their velocities after collision are

(A) $-\vec{v}$ and $+\vec{v}$ (B) $+\vec{v}$ and $-\vec{v}$

(C) 0 and $2\vec{v}$ (D) $2\vec{v}$ and 0

57. A bullet of mass m moving with velocity u passes through a wooden block having mass $M=nm$. The block is resting on a smooth horizontal floor. After passing through the block, the velocity of bullet is v. Its velocity relative to block is



(A) $\frac{nv-u}{n+1}$ (B) $\frac{nu-v}{n+1}$

(C) $\frac{(1+n)v-u}{n}$ (D) $\frac{(n+1)u+v}{2n+1}$

58. A girl throws a ball with initial velocity v at an inclination of 45°. The ball strikes a smooth vertical wall at a horizontal distance d from the girl and after rebounding returns to her hand. The coefficient of restitution between the wall and the ball is

(A) $\frac{gd}{v^2}$ (B) $\frac{v^2}{gd}$

(C) $\frac{gd}{v^2-gd}$ (D) $\frac{v^2-gd}{v^2}$

59. 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 surface. The acceleration of the centre

(A) is maximum at $h=0$

(B) is maximum when $h=R$

(C) is maximum when $h=2R$

(D) is independent of h

60. A ball of mass m approaches a wall of mass $M(\gg m)$ with speed $4\ \text{ms}^{-1}$ along the normal to the wall. The speed of wall is $1\ \text{ms}^{-1}$ towards the ball. The speed of the ball after an elastic collision with the wall is

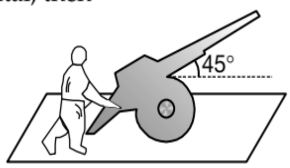
(A) $5\ \text{ms}^{-1}$ away from the wall

(B) $9\ \text{ms}^{-1}$ away from the wall

(C) $3\ \text{ms}^{-1}$ away from the wall

(D) $6\ \text{ms}^{-1}$ away from the wall

61. A bullet is fired from a gun whose barrel is inclined at an angle of 45° with horizontal. When the bullet leaves the barrel, it will be travelling at an angle ϕ to the horizontal, then



(A) $\phi=45°$ (B) $\phi<45°$

(C) $\phi>45°$ (D) $\phi=0$

62. Mass is non-uniformly distributed on the circumference of a ring of radius a and centre at origin. Let b be the distance of centre of mass of the ring from origin. Then

(A) $b=a$ (B) $b<a$

(C) $b>a$ (D) $0\le b\le a$

63. A bomb of mass $1\ \text{kg}$, initially at rest, explodes into three fragments of masses in the ratio $1:1:3$. The two pieces of equal mass fly off perpendicular to each other, each with a speed of $30\ \text{ms}^{-1}$. What is the velocity of the heavier fragment?

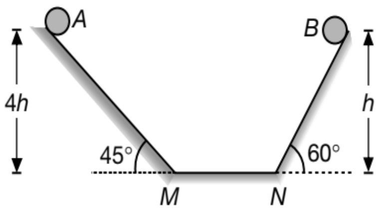
(A) $10\sqrt{2}\ \text{ms}^{-1}$ at 45° with each of the other two fragments

(B) $10\sqrt{2}\ \text{ms}^{-1}$ at 135° with each of the other two fragments

(C) $20\ \text{ms}^{-1}$ at 45° with each of the other two fragments

(D) $20\ \text{ms}^{-1}$ at 135° with each of the other two fragments

64. Two identical balls A and B are released from the positions shown in figure. They collide elastically on horizontal portion MN. The ratio of heights attained by A and B after collision will be (neglect friction)



(A) 1 : 4 (B) 2 : 1
(C) 4 : 13 (D) 2 : 5

65. From a circular disc of radius R, a square is cut out with the radius as its diagonal. The distance of the centre of mass of the remainder from the centre of the disc is

(A) $\frac{R}{\pi-2}$ (B) $\frac{R}{\pi}$

(C) $\frac{R}{2(2\pi-1)}$ (D) $\frac{R}{2(\pi-1)}$

66. A balloon has 2 g of air. If a small hole is pierced into it, the air comes out with a speed of $2\ \text{ms}^{-1}$. If the balloon shrinks completely in 5 s, the average thrust experienced by the balloon is

(A) 8×10^{-1} N (B) 8×10^{-2} N

(C) 8×10^{-3} N (D) 8×10^{-4} N

67. A ball A, moving with a speed u, collides directly with another similar ball B moving with a speed v in the opposite direction. A comes to rest after the collision. If the coefficient of restitution is e then $\frac{u}{v}$ is

(A) $\frac{1+e}{1-e}$ (B) $\frac{1-e}{1+e}$

(C) $\frac{e}{1-e}$ (D) $\frac{e}{1+e}$

68. A canon ball is fired with a velocity of $200\ \text{ms}^{-1}$ at an angle of 60° with the horizontal. At the highest point it explodes into three equal fragments. One goes vertically upwards with a velocity of $100\ \text{ms}^{-1}$ and other goes vertically downwards with $100\ \text{ms}^{-1}$. The third one moves with a velocity of

(A) $100\ \text{ms}^{-1}$ horizontally
(B) $300\ \text{ms}^{-1}$ horizontally
(C) $200\ \text{ms}^{-1}$ at 60° with horizontal
(D) $300\ \text{ms}^{-1}$ at 60° with horizontal

69. The maximum offset that can be obtained by piling up three identical bricks of length l is

(A) $\frac{2}{3}l$ (B) $\frac{4}{3}l$

(C) $\frac{5}{6}l$ (D) $\frac{11}{12}l$

70. A ball A of mass 1 kg, moving with a speed of $12\ \text{ms}^{-1}$, collides obliquely and elastically with another ball B which was initially at rest. Ball A then moves off at right angles to its initial direction with a speed of $5\ \text{ms}^{-1}$. The momentum of ball B after collision is

(A) $5\ \text{kgms}^{-1}$ (B) $11\ \text{kgms}^{-1}$

(C) $13\ \text{kgms}^{-1}$ (D) $17\ \text{kgms}^{-1}$

71. The displacement of a particle of mass 2 kg moving in a straight line varies with time as $x=(2t^3+2)m$. Impulse of the force acting on the particle over a time interval between $t=0$ and $t=1$ s is

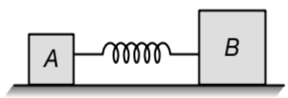
(A) 10 Ns (B) 12 Ns
(C) 8 Ns (D) 6 Ns

72. A man of mass m moves with a constant speed on a plank of mass M and length L kept initially at rest on a frictionless horizontal surface, from one end to the other in time t. The speed of the plank relative to ground while man is moving, is

(A) $\frac{L}{t}\left(\frac{M}{m}\right)$ (B) $\frac{L}{t}\left(\frac{m}{M+m}\right)$

(C) $\frac{L}{t}\left(\frac{M}{M-m}\right)$ (D) None of these

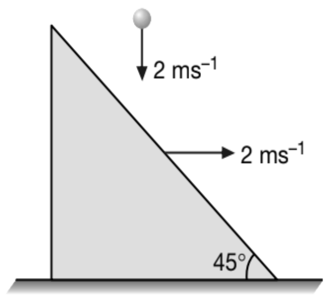
73. Two blocks A and B of mass m and $2m$ are connected by a massless spring of force constant k and are placed on a smooth horizontal plane. The spring is stretched by an amount x and then released. The relative velocity of the blocks when the spring comes to its natural length is



(A) $\left(\sqrt{\frac{3k}{2m}}\right)x$ (B) $\left(\sqrt{\frac{2k}{3m}}\right)x$

(C) $\sqrt{\frac{2kx}{m}}$ (D) $\sqrt{\frac{3km}{2x}}$

74. A small ball falling vertically downwards with constant velocity $2\ \text{ms}^{-1}$ strikes elastically an inclined plane moving with velocity $2\ \text{ms}^{-1}$ as shown in figure. The velocity of rebound of the ball with respect to ground is



(A) $2\ \text{ms}^{-1}$ (B) $2\sqrt{2}\ \text{ms}^{-1}$
(C) $4\ \text{ms}^{-1}$ (D) $2\sqrt{5}\ \text{ms}^{-1}$

75. A $6000\ \text{kg}$ rocket is set for vertical firing. If the exhaust speed is $1000\ \text{ms}^{-1}$, the amount of gas that must be ejected per second to supply the thrust needed to overcome the weight of the rocket is $(g = 10\ \text{ms}^{-2})$

(A) 30 kg (B) 60 kg
(C) 75 kg (D) 90 kg

76. In PROBLEM 75, the amount of gas that must be ejected to give the rocket an initial upward acceleration of $20\ \text{ms}^{-2}$ is

(A) $90\ \text{kgs}^{-1}$ (B) $120\ \text{kgs}^{-1}$
(C) $150\ \text{kgs}^{-1}$ (D) $180\ \text{kgs}^{-1}$

77. Two particles A and B, initially at rest, move towards each other under a mutual force of attraction. At the instant when the speed of A is V and the speed of B is $2V$, the speed of the centre of mass of the system is

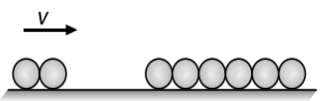
(A) ZERO (B) V
(C) $1.5V$ (D) $3V$

78. Ball A collides with an another identical ball B at rest as shown in Figure.

The value of coefficient of restitution e, for which the velocity of ball B becomes two times that of A after collision is

(A) $\frac{1}{2}$ (B) $\frac{1}{3}$
(C) $\frac{1}{4}$ (D) $\frac{1}{6}$

79. Six identical steel balls are lined up in a straight frictionless groove made on a horizontal surface. Two similar balls moving with speed v collide elastically with the row of 6 balls from the left. Then



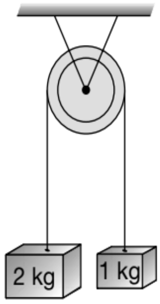
(A) all the 8 balls will move with a speed $\frac{v}{8}$ each

(B) all the 6 balls in the row will move with a speed $\frac{v}{6}$ each and the two incident balls will come to rest

(C) two balls from the row will move with a speed v other balls remaining at rest

(D) one ball from the row will move with a speed $2v$, other balls remaining at rest

80. Two blocks of masses $2\ \text{kg}$ and $1\ \text{kg}$ respectively are tied to the ends of a string which passes over a light frictionless pulley. The masses are held at rest at the same horizontal level and then released. The distance traversed by centre of mass in 2 second is $(\text{Take } g = 10\ \text{ms}^{-2})$



(A) 1.42 m (B) 2.22 m
(C) 3.12 m (D) 3.33 m

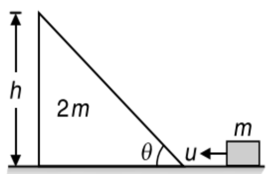
81. A shell is fired from a canon with a velocity v at an angle θ with the horizontal. At the highest point it explodes into two pieces of equal masses. One of the pieces retraces its path to the canon. The speed of the other piece immediately after the explosion is

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

82. A force $\vec{F} = (2\hat{i} + \hat{j} + 3\hat{k})N$ acts on a particle of mass 1 kg for $t = 2\ \text{s}$. If initial velocity of particle is $\vec{u} = (2\hat{i} + \hat{j})\ \text{ms}^{-1}$, then the speed of particle at the $t = 2\ \text{s}$ will be

(A) $4\ \text{ms}^{-1}$ (B) $6\ \text{ms}^{-1}$
(C) $9\ \text{ms}^{-1}$ (D) $12\ \text{ms}^{-1}$

83. A block of mass m is pushed towards a movable wedge of mass $2m$ and height h with a velocity u. All surfaces are smooth. The minimum value of u for which the block will reach the top of the wedge is



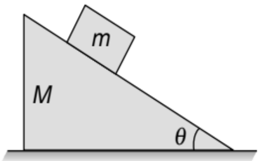
(A) $\sqrt{\frac{3}{2}gh}$ (B) $\sqrt{3gh}$
(C) $\sqrt{6gh}$ (D) $2\sqrt{gh}$

84. A moving particle of mass m makes a head-on elastic collision with a particle of mass $2m$ which is initially at rest. The fraction of the initial kinetic energy lost by the colliding particle is

(A) $\frac{1}{9}$ (B) $\frac{2}{9}$

(C) $\frac{4}{9}$ (D) $\frac{8}{9}$

85. A block of mass m slides over a smooth wedge of mass M which is placed over a rough horizontal surface. If μ be the coefficient of friction between the wedge and the ground, then the centre of mass of the system will move towards left



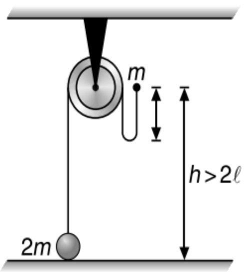
(A) if $mg\cos\theta\sin\theta > \mu(M+m)g$

(B) if $mg\sin\theta > \mu Mg$

(C) if $mg\cos\theta\sin\theta > \mu Mg$

(D) None of these

86. A heavy ball of mass $2m$ rests on the horizontal surface and the lighter balls of mass m is dropped from a height $h > 2l$ as shown in Figure. The upward velocity of the heavy ball at the instant when string gets taut is



(A) $\frac{4\sqrt{gl}}{3}$ (B) $\frac{2\sqrt{gl}}{3}$

(C) $\frac{\sqrt{gl}}{3}$ (D) $\frac{\sqrt{gl}}{2}$

87. A large tray of mass M has in it a cubical block of ice of mass m and edge length L. The ice starts melting. The shift in the height of centre of mass of system (ice + tray) is

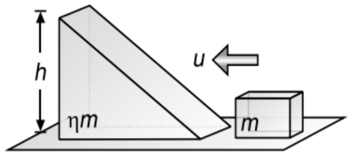
(A) $\frac{1}{2}\frac{mL}{(m+M)}$; upward

(B) $\frac{1}{2}\frac{ML}{(m+M)}$; upward

(C) $\frac{1}{2}\frac{mL}{(m+M)}$; downward

(D) $\frac{1}{2}\frac{ML}{(m+M)}$; downward

88. A block of mass m is pushed towards a movable wedge of mass ηm and height h, with a velocity u. Assume all surfaces to be smooth. The minimum value of u for which the block will reach the top of the wedge is



(A) $\sqrt{2gh}$ (B) $\eta\sqrt{2gh}$

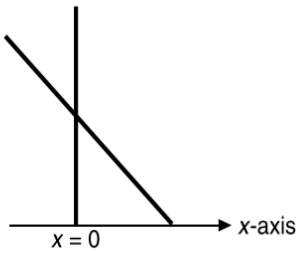
(C) $\sqrt{2gh\left(1+\frac{1}{\eta}\right)}$ (D) $\sqrt{2gh\left(1-\frac{1}{\eta}\right)}$

89. A particle of mass m_1 moves with speed v and collides head on with a stationary particle of mass m_2. If e be the coefficient of restitution and the first particle continues to move in the same direction, then $\frac{m_1}{m_2}$ is

(A) e (B) $> e$

(C) $< e$ (D) $> e^2$

90. A uniform rod of length l is kept vertically on a rough horizontal surface at $x = 0$. It is rotated slightly and released. When the rod finally falls on the horizontal surface the lower end will remain at



(A) $x = 0$ (B) $x = \frac{l}{2}$

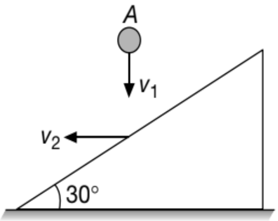
(C) $x < \frac{l}{2}$ (D) $x > \frac{l}{2}$

91. Two spheres of masses M and $2M$ are initially at rest at a distance R apart. Due to mutual force of attraction they approach each other. When they are at separation $\frac{R}{2}$, the acceleration of their centre of mass would be

(A) 0 (B) g ms^{-2}

(C) $3g$ ms^{-2} (D) $12g$ ms^{-2}

92. A ball A is falling vertically downwards with velocity v_1. It strikes elastically a wedge moving horizontally with velocity v_2 as shown in figure.



The ratio $\frac{v_2}{v_1}$, so that the ball bounces back vertically upwards relative to the wedge is

(A) $\sqrt{3}$ (B) $\frac{1}{\sqrt{3}}$

(C) 2 (D) $\frac{1}{2}$

93. The mass per unit length of a non-uniform rod of length L varies as $m = m_0 \frac{x^2}{L}$, where m_0 is a constant and x is the distance of any point on the rod measured from one end. The centre of mass of the rod is at

(A) $\frac{L}{2}$ (B) $\frac{L}{3}$

(C) $\frac{3L}{2}$ (D) $\frac{3L}{4}$

94. A gun fires a shell and recoils horizontally. If the shell travels along the barrel with speed v, the ratio of speed with which the gun recoils if
CASE-1 the barrel is horizontal
CASE-2 inclined at an angle of 30° with the horizontal is

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

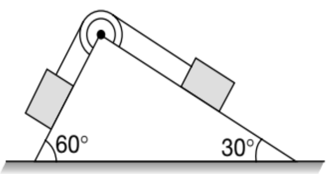
(C) $\frac{\sqrt{3}}{2}$ (D) $\frac{1}{2}$

95. A radioactive nucleus of mass number A, initially at rest, emits an α particle with speed v. The recoil speed of the daughter nucleus is

(A) $\frac{4v}{A-4}$ (B) $\frac{4v}{A}$

(C) $\frac{(A-4)v}{A}$ (D) $\frac{(A-4)v}{4}$

96. Two blocks of equal masses are tied to a light string, which passes over a massless pulley as shown in figure.



The magnitude of acceleration of centre of mass of both the blocks is (neglect friction everywhere)

(A) $\left(\frac{\sqrt{3}-1}{4\sqrt{2}}g\right)$ (B) $(\sqrt{3}-1)g$

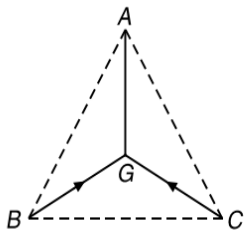
(C) $\frac{g}{2}$ (D) $\left(\frac{\sqrt{3}-1}{\sqrt{2}}\right)g$

97. A tennis ball bounces down a flight of stairs striking each step in turn and rebounding to the height of the step above. The coefficient of restitution is

(A) $\frac{1}{2}$ (B) $\frac{1}{\sqrt{2}}$

(C) $+\frac{1}{4}$ (D) 1

98. Three particles A, B and C of equal masses, moving with the same speed v along the medians of an equilateral triangle, collide at the centroid G of the triangle. After collision, A comes to rest and B retraces its path with speed v. The speed of C after the collision is



(A) ZERO (B) $\frac{v}{2}$ along GB

(C) v along BG (D) v along CG

99. A bomb of mass 12 kg, initially at rest, explodes into two pieces of masses 4 kg and 8 kg. The speed of the 8 kg mass is 6 ms^{-1}. The kinetic energy of the 4 kg mass is

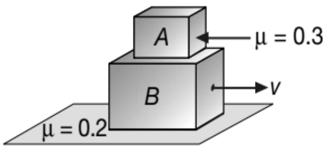
(A) 32 J (B) 48 J
(C) 144 J (D) 288 J

100. The momentum of a particle is $\vec{P} = \vec{A} + \vec{B}t^2$, where $\vec{A}$ and $\vec{B}$ are constant perpendicular vectors. The force acting on the particle when its acceleration makes an angle of 45° with the velocity is

(A) ZERO (B) $\left(2\sqrt{\frac{B}{A}}\right)\vec{A}$

(C) $\left(2\sqrt{\frac{A}{B}}\right)\vec{B}$ (D) $2\vec{B}$

101. The blocks A (of mass m) and B (of mass $2m$), in the given arrangement shown, are given together a horizontal velocity towards right. If a_{cm} be the subsequent acceleration of the centre of mass of the system of blocks then a_{cm} equals



(A) $0\ \text{ms}^{-2}$ (B) $2\ \text{ms}^{-2}$

(C) $\frac{5}{3}\ \text{ms}^{-2}$ (D) $\frac{7}{3}\ \text{ms}^{-2}$

102. A moving mass of $8\ \text{kg}$ collides elastically with a stationary mass of $2\ \text{kg}$. If E be the initial kinetic energy of the mass, the kinetic energy left with it after collision will be

(A) $0.80E$ (B) $0.64E$

(C) $0.36E$ (D) $0.08E$

103. A particle of mass 1 kg is projected with velocity $u = 40\ \text{ms}^{-1}$ at an angle of $30°$ with horizontal. The change in linear momentum of the particle after time $t = 1\ \text{s}$ is $\left(\text{Take } g = 10\ \text{ms}^{-2}\right)$

(A) $7.5\ \text{kgms}^{-1}$ (B) $15\ \text{kgms}^{-1}$

(C) $10\ \text{kgms}^{-1}$ (D) $20\ \text{kgms}^{-1}$

104. A projectile of mass $3\ \text{m}$ explodes at the highest point of its path and breaks into three equal parts such that one part retraces its path and the second one comes to rest. The range of the projectile was $100\ \text{m}$ if no explosion would have taken place. The distance of the third part from the point of projection when it finally lands on the ground is

(A) 100 m (B) 150 m

(C) 250 m (D) 300 m

105. A $6\ \text{kg}$ box sled is travelling on ice at a speed of $9\ \text{ms}^{-1}$ when a $12\ \text{kg}$ packet is dropped into it vertically. The velocity of the sled will now be

(A) $3\ \text{ms}^{-1}$ (B) $4\ \text{ms}^{-1}$

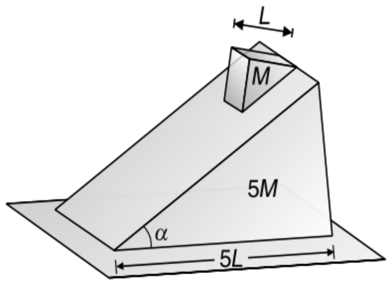
(C) $6\ \text{ms}^{-1}$ (D) $8\ \text{ms}^{-1}$

106. A smooth sphere is moving on a horizontal surface with velocity vector $2\hat{i} + 2\hat{j}$ immediately before it hits a vertical wall. The wall is parallel to $\hat{j}$ vector and the coefficient of restitution between the sphere and the wall is $e = \frac{1}{2}$. The velocity vector of the sphere after it hits the wall is

(A) $\hat{i} - \hat{j}$ (B) $-\hat{i} + 2\hat{j}$

(C) $-\hat{i} - \hat{j}$ (D) $2\hat{i} - \hat{j}$

107. The figure shows a small prism of mass M sliding on the bigger prism of mass $5M$ from the top to the bottom. Assuming all surfaces to be frictionless and the system (big prism + small prism) to be at rest initially, the distance moved by the prism combination is



(A) $\frac{3}{2}L$ to left (B) $\frac{3}{2}L$ to right

(C) $\frac{2}{3}L$ to right (D) $\frac{2}{3}L$ to left

108. A drum major's baton consists of two masses $2M$ and M separated by a thin light rod of length L. The baton is thrown into the air. Neglecting air drag, if $\vec{R}$ is the position vector of the centre of mass of the baton then the equation of motion for the centre of mass is

(A) $\frac{d^2\vec{R}}{dt^2} = \frac{2\vec{g}}{3}$ (B) $\frac{d^2\vec{R}}{dt^2} = \frac{\vec{g}}{3}$

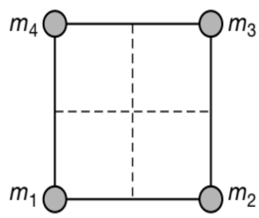
(C) $\frac{d^2\vec{R}}{dt^2} = \vec{g}$ (D) $\frac{d^2\vec{R}}{dt^2} = \frac{4\vec{g}}{3}$

109. Two billiard balls of the same size and mass are in contact on a billiard table. A third ball of the same size and mass strikes them symmetrically and comes to rest after the impact. The coefficient of restitution between the balls is

(A) $\frac{1}{4}$ (B) $\frac{1}{2}$

(C) $\frac{2}{3}$ (D) $\frac{3}{4}$

110. Four particles of masses $m_1 = 2m$, $m_2 = 4m$, $m_3 = m$ and m_4 are placed at four corners of a square. What should be the value of m_4, so that the centre of mass of all the four particles are exactly at the centre of the square?



(A) $2m$ (B) $6m$

(C) $8m$ (D) None of these

111. A ball strikes a horizontal floor at an angle $\theta = 45°$. If the coefficient of restitution between the ball and the floor is $e = \frac{1}{2}$, then the fraction of its kinetic energy lost in collision is

(A) $\frac{1}{4}$ (B) $\frac{3}{4}$

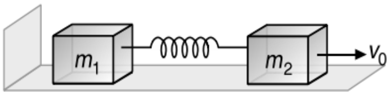
(C) $\frac{3}{8}$ (D) $\frac{5}{8}$

112. Two particles of masses m_1 and m_2 in projectile motion have velocities v_1 and v_2 respectively at time $t = 0$. They collide at time t_0. Their velocities become $\vec{v}_1'$ and $\vec{v}_2'$ at time $2t_0$, while still moving in air. The value of $|(m_1\vec{v}_1' + m_2\vec{v}_2') - (m_1\vec{v}_1 + m_2\vec{v}_2)|$ is

(A) ZERO (B) $(m_1 + m_2)gt_0$

(C) $2(m_1 + m_2)gt_0$ (D) $\frac{1}{2}(m_1 + m_2)gt_0$

113. Two block m_1 and m_2 are pulled on a smooth horizontal surface, and are joined together with a spring of stiffness k as shown in Figure. Suddenly, the block m_2 receives a horizontal velocity v_0, then the maximum extension x_{max} in the spring is



(A) $v_0\sqrt{\frac{m_1}{k}}$ (B) $v_0\sqrt{\frac{2m_1m_2}{k(m_1+m_2)}}$

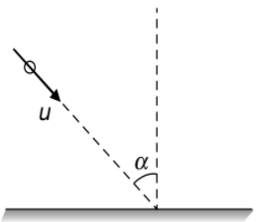
(C) $v_0\sqrt{\frac{m_1m_2}{2k(m_1+m_2)}}$ (D) $v_0\sqrt{\frac{m_1m_2}{k(m_1+m_2)}}$

114. A man of mass 80 kg is riding on a small cart of mass 40 kg which is rolling along a level floor at a speed of $2\ \text{ms}^{-1}$. He is running on the cart, so that his velocity relative to the cart is $3\ \text{ms}^{-1}$ in the direction opposite to the motion of cart. The speed of the centre of mass of the system is

(A) ZERO (B) $1\ \text{ms}^{-1}$

(C) $1.5\ \text{ms}^{-1}$ (D) $3\ \text{ms}^{-1}$

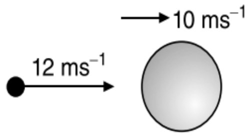
115. A ball of mass m collides with the ground at an angle α with the vertical. If the collision lasts for time t and e is coefficient of restitution between the ball and ground, then the average force exerted by the ground on the ball is



(A) $\frac{emu}{t}$ (B) $\frac{emu\cos\alpha}{t}$

(C) $\frac{2(1+e)mu\cos\alpha}{t}$ (D) $\frac{(1+e)mu\cos\alpha}{t}$

116. A light particle moving horizontally with a speed of $12\ \text{ms}^{-1}$ strikes head-on a very heavy block moving in the same direction at $10\ \text{ms}^{-1}$. The collision is one-dimensional and elastic. After the collision, the particle will



(A) move at $2\ \text{ms}^{-1}$ in its original direction
(B) move at $8\ \text{ms}^{-1}$ in its original direction
(C) move at $8\ \text{ms}^{-1}$ opposite to its original direction
(D) move at $12\ \text{ms}^{-1}$ opposite to its original direction

117. A small block of superdense material has a mass $\frac{M}{3}$, where M is the mass of earth. It is released from rest from a height h ($\ll$ radius of earth) above the surface of earth. The speed of the block at a height $\frac{h}{2}$ is

(A) $\sqrt{\frac{2gh}{3}}$ (B) $\sqrt{gh}$

(C) $\frac{\sqrt{3gh}}{2}$ (D) $\sqrt{2gh}$

118. An object, initially at rest, explodes into three fragments. The momenta of two parts are $2p\hat{i}$ and $p\hat{j}$ where p is a positive number. The momentum of the third part

(A) will be of magnitude $3p$ inclined at $\tan^{-1}\left(\frac{1}{2}\right)$ with x-axis
(B) will be of magnitude $\sqrt{5}p$ inclined at $\tan^{-1}(2)$ with x-axis
(C) will be of magnitude $3p$ inclined at $\pi - \tan^{-1}(2)$ with x-axis
(D) will be of magnitude $\sqrt{5}p$ inclined at $\pi - \tan^{-1}\left(\frac{1}{2}\right)$ with x-axis

119. There are some passengers inside a stationary railway compartment. The centre of mass of the compartment itself (without the passengers) is C_1, while the centre of mass of the 'compartment plus passengers' system is C_2. If the passengers move about inside the compartment,

(A) both C_1 and C_2 will move with respect to the ground
(B) neither C_1 nor C_2 will move with respect to the ground
(C) C_1 will move but C_2 will be stationary with respect to the ground
(D) C_2 will move but C_1 will be stationary with respect to the ground

120. A ball, moving with a speed of $9\ ms^{-1}$, strikes an identical stationary ball such that after the collision the direction of each ball makes an angle of $30°$ with the original line of motion. The speeds of the two balls after the collision are

(A) $3\sqrt{3}\ ms^{-1}$ and $3\ ms^{-1}$

(B) $3\ ms^{-1}$ and $3\sqrt{3}\ ms^{-1}$

(C) $3\ ms^{-1}$ and $3\ ms^{-1}$

(D) $3\sqrt{3}\ ms^{-1}$ and $3\sqrt{3}\ ms^{-1}$

121. A ball of mass m_1 collides head-on and elastically with an identical ball of mass m_2, initially at rest. The transfer of energy will be maximum when

(A) $m_1 = m_2$ (B) $m_1 = \frac{m_2}{2}$

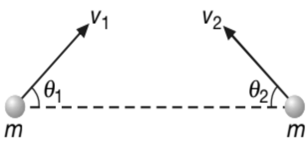
(C) $m_1 = 2m_2$ (D) None of these

122. A meter rule weighing 100 g rests on a table with a part projecting over the edge. The length of the part to be projected out if a 5 g body hung at the end just tilts the rule is

(A) 26.8 cm (B) 37.5 cm

(C) 40.2 cm (D) 47.6 cm

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



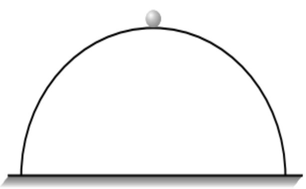
(A) will move in a parabolic path for any values of v_1, v_2, θ_1 and θ_2

(B) can move in a vertical line

(C) can move in a horizontal line

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

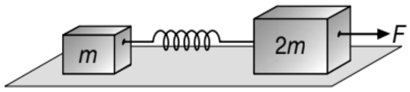
124. A hemisphere of radius R and of mass $4m$ is free to slide with its base on a smooth horizontal table. A particle of mass m is placed on the top of the hemisphere. The angular velocity of the particle relative to hemisphere at an angular displacement θ, when velocity of hemisphere has become v is



(A) $\frac{2v}{R\cos\theta}$ (B) $\frac{3v}{R\sin\theta}$

(C) $\frac{5v}{R\cos\theta}$ (D) $\frac{5v}{R\sin\theta}$

125. Two blocks of masses m and $2m$, kept on a smooth horizontal surface, are connected by an ideal spring of force constant k. Initially the spring is unstretched. A constant force is applied to the heavier block in the direction shown in figure. If the displacement of the smaller block at time t is x, then displacement of the heavier block at this moment is



(A) $\frac{x}{2}$ (B) $\frac{Ft^2}{4m} - \frac{x}{2}$

(C) $\frac{x}{3}$ (D) $\frac{Ft^2}{6m} + \frac{x}{3}$

126. A space-craft of mass M is moving in free space with velocity V. It explodes and breaks into two. One part, which has a mass m, is left stationary. The velocity of the other part is

(A) $\frac{MV}{m+m}$ (B) $\frac{mV}{M+m}$

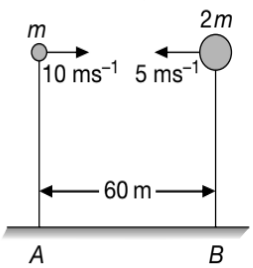
(C) $\frac{MV}{M-m}$ (D) $\frac{mV}{M-m}$

127. 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 $u = 10\ ms^{-1}$ at an angle of $45°$ with respect to ground. The displacement of platform (with boy) on the horizontal surface, when the stone lands on the ground is (Take $g = 10\ ms^{-2}$)

(A) 5 cm (B) 10 cm

(C) 25 cm (D) 50 cm

128. Two particles one of mass m and the other of mass $2m$ are projected horizontally towards each other from the same level above the ground with velocities $10\ ms^{-1}$ and $5\ ms^{-1}$ respectively. They collide in air and stick to each other. The distance from A, where the combined mass finally land is



(A) 40 m (B) 20 m

(C) 30 m (D) 45 m

MULTIPLE CORRECT CHOICE TYPE QUESTIONS

This section contains Multiple Correct Choice Type Questions. Each question has four choices (A), (B), (C) and (D), out of which ONE OR MORE is/are correct.

1. A ball B of mass m is lying at rest on the top surface of a smooth horizontal table 5 m high. Another moving ball A of same mass makes an elastic collision with B and B slides off the table and strikes the floor at a horizontal distance of 10 m from the table. Then select the correct alternative(s) $\left(g = 10\text{ ms}^{-2}\right)$

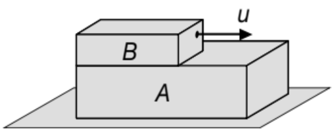
(A) The velocity of the ball A before collision is 5 ms^{-1}

(B) The kinetic energy of the ball B at the time of striking the ground is $(m \times 100)$ J

(C) The velocity of the ball A before collision is 10 ms^{-1}

(D) The kinetic energy of the ball B at the time when it strikes the ground is $(50 \times m)$ J

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



(A) the blocks will reach a final common velocity $\frac{u}{3}$

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

(C) before the blocks reach a common velocity, the acceleration of A relative to B is $\frac{2}{3}\mu g$

(D) before the blocks reach a common velocity, the acceleration of A relative to B is $\frac{3}{2}\mu g$

3. Two identical particles A and B each of mass m are connected together by a light and inextensible string of length l. The particles are held at rest in air in same horizontal level at a separation l. Both particles are released simultaneously, however particle A is given speed v_0 vertically upwards. Select the correct statement(s). Ignore air resistance.

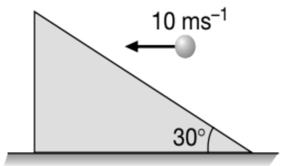
(A) The maximum height attained by the centre of mass of the system of A and B is $\frac{v_0^2}{8g}$

(B) The kinetic energy of the system of A and B when the centre of mass is at its highest point, is $\frac{mv_0^2}{2}$.

(C) The maximum height attained by the centre of mass of the system of A and B is $\frac{v_0^2}{4g}$

(D) The kinetic energy of the system of A and B when the centre of mass is its highest point, is $\frac{mv_0^2}{4}$

4. A ball of mass 1 kg strikes a wedge of mass 4 kg, horizontally with a velocity of 10 ms^{-1}. Just after collision, the velocity of wedge becomes 4 ms^{-1}. Assuming friction to be absent everywhere and collision to be elastic, select the correct statement(s)



(A) Speed of ball after collision is 6 ms^{-1}.

(B) Speed of ball after collision is 8 ms^{-1}.

(C) Impulse between ball and wedge during collision is 16 Ns.

(D) Impulse between ball and wedge during collision is 32 Ns.

5. A cannon and a supply of cannon balls are inside a sealed rail road car at rest. The cannon fires to the right, the car recoils to the left. The balls remain in the car after hitting the farther wall. Assume friction to be absent. If L is the length of the rail road car, D is the distance traversed by the rail road car relative to the ground, m is the total mass of cannon balls fired and M is the total mass of remaining system (cannon + car) then

(A) $D > L$

(B) $D < L$

(C) $D = \frac{ML}{M+m}$

(D) $D = \frac{mL}{M+m}$

6. A particle of mass m moving with a velocity $\left(3\hat{i} + 2\hat{j}\right)\text{ ms}^{-1}$ collides with another body of mass M and finally moves with velocity $\left(-2\hat{i} + \hat{j}\right)\text{ ms}^{-1}$. Then during the collision

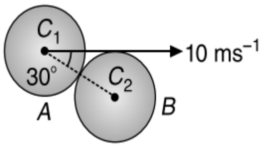
(A) impulse imparted to m is $m\left(5\hat{i} + \hat{j}\right)$

(B) impulse imparted to m is $m\left(-5\hat{i} - \hat{j}\right)$

(C) impulse imparted to M is $m\left(-5\hat{i} - \hat{j}\right)$

(D) impulse imparted to M is $m\left(5\hat{i} + \hat{j}\right)$

7. A ball A collides elastically with another identical ball B with a velocity of $10\ \text{ms}^{-1}$ making an angle of $30°$ with the line joining their centres C_1 and C_2. Select the correct statement(s).



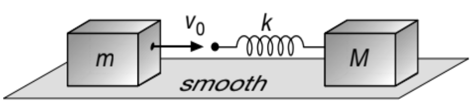
(A) Velocity of ball A after collision is $5\ \text{ms}^{-1}$.
(B) Velocity of ball B after collision is $5\sqrt{3}\ \text{ms}^{-1}$.
(C) Kinetic energy will not be conserved here, because collision is not head on.
(D) Both the balls move at right angles after collision.

8. Ball A of mass m strikes a stationary ball B of mass M and undergoes an elastic collision. After collision ball A has a speed one third of its initial speed. The ratio of $\frac{M}{m}$ is

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

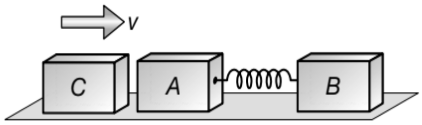
9. Velocity of a particle of mass 2 kg changes from $\vec{v}_1 = 2\hat{i} - 2\hat{j}\ \text{ms}^{-1}$ to $\vec{v}_2 = (\hat{i} - \hat{j})\ \text{ms}^{-1}$ after colliding with a plane surface. Select the correct statement(s).
(A) The angle made by the plane surface with the positive x-axis is $\tan^{-1}\left(\frac{1}{3}\right)$
(B) The angle made by the plane surface with the positive x-axis is $90° + \tan^{-1}\left(\frac{1}{3}\right)$
(C) The direction of change in momentum makes an angle $90° + \tan^{-1}\left(\frac{1}{3}\right)$ with the plane surface
(D) The direction of change in momentum makes an angle $\tan^{-1}\left(\frac{1}{3}\right)$ with the +ve x-axis

10. A block of mass m moving with a velocity v_0 collides with a stationary block of mass M at the back of which a spring of spring constant k is attached, as shown in the figure. Select the correct alternative(s)



(A) The velocity of centre of mass is $\frac{m}{m+M}v_0$
(B) The initial kinetic energy of the system in the centre of mass frame is $\frac{1}{4}\left(\frac{mM}{M+m}\right)v_0^2$
(C) The maximum compression in the spring is $v_0\sqrt{\frac{mM}{m+M}\frac{1}{k}}$
(D) When the spring is in the state of maximum compression the kinetic energy in the centre of mass frame is zero

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



(A) the kinetic energy of the $A-B$ system, at maximum compression of the spring is zero
(B) the kinetic energy of the $A-B$ system, at maximum compression of the spring is $\frac{mv^2}{4}$
(C) the maximum compression of the spring is $v\sqrt{\frac{m}{k}}$
(D) the maximum compression of the spring is $v\sqrt{\frac{m}{2k}}$

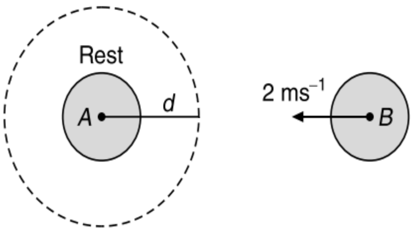
12. For the case of rocket propulsion, select the correct statements.
(A) Momentum of system always remains constant.
(B) Newton's Third Law is applicable.
(C) If exhaust velocity and rate of burning of mass is kept constant, then acceleration of rocket keeps on increasing.
(D) Newton's Second Law is applicable.

13. A bag of mass M hangs by a long thread. A bullet of mass m comes horizontally with a velocity v and gets embedded in the bag. Then for the combined system, immediately after the collision, the
(A) momentum is $\frac{mvM}{M+m}$
(B) momentum is mv
(C) kinetic energy is $\frac{m^2v^2}{2(M+m)}$
(D) kinetic energy is $\frac{mv^2}{2}$

14. In a one-dimensional collision between two particles A and B, the particle B is stationary and A has momentum p before impact. During impact, A gives an impulse J to B. Then select the incorrect statement(s)

(A) The total momentum of A plus B system before and after the impact is p and during the impact is $(p-J)$
(B) During the impact B gives an impulse J to A
(C) The coefficient of restitution is $\frac{2J}{p}-1$
(D) The coefficient of restitution is $\frac{2J}{p}+1$

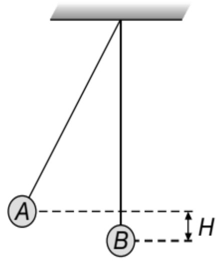
15. The elastic collision between two bodies, A and B can be considered using the model in which A and B are free to move along a common line without friction. When separation between the surfaces is greater than $d=1$ m, the interacting force is zero. However, when their distance less than d, a constant repulsive force $F=6$ N is present. The mass of body A is $m_A=1$ kg and it is initially at rest. The mass of body B is $m_B=3$ kg and it is approaching towards A with a speed $v_0=2\ \text{ms}^{-1}$. Then select the correct statement(s).



(A) The minimum separation between the bodies is 0.25 m
(B) The common velocity attained by the bodies are $1.5\ \text{ms}^{-1}$
(C) The common velocity attained by the bodies are $2.0\ \text{ms}^{-1}$
(D) The minimum separation between the bodies is 0.75 m

16. Two identical balls are thrown obliquely from the ground simultaneously. The acceleration of centre of mass
(A) does not depend on the mass of the two balls
(B) depends on the direction in which two balls are projected
(C) is equal to g
(D) is zero

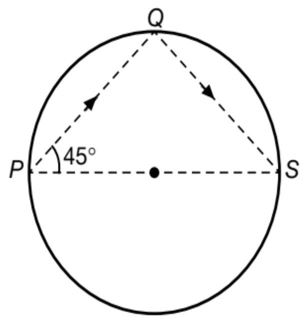
17. Two small balls A and B of mass M and $3M$ hang from the ceiling by strings of equal length. The ball is drawn aside so that it is raised to a height H. Now the ball A is released such that it collides with ball B. Select the correct statement(s).



(A) If collision is perfectly elastic, ball B will rise to a height $\frac{H}{4}$
(B) If the collision is perfectly elastic, ball A will rise upto a height $\frac{H}{4}$
(C) If the collision is perfectly inelastic, the combined mass will rise to a height $\frac{H}{4}$
(D) If the collision is perfectly inelastic, the combined mass will rise to a height $\frac{H}{16}$

18. A particle of mass m strikes a horizontal smooth floor with a velocity u making an angle θ with the floor and rebound with velocity v making an angle ϕ with the floor. 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 $\cos^2\theta+e^2\sin^2\theta$

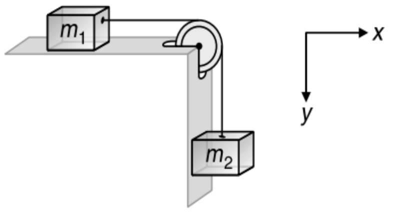
19. A body is fired from point P and strikes at Q inside a smooth circular wall as shown in the figure. It rebounds to point S (diametrically opposite to P), then



(A) the coefficient of restitution is zero
(B) the coefficient of restitution is 1
(C) kinetic energy is conserved in this collision
(D) the coefficient of restitution is $\frac{1}{\sqrt{3}}$

20. A particle of mass 0.1 kg moving with an initial speed v collides with another particle of same mass kept at rest. If after collision total energy becomes 0.2 J. Then
(A) minimum value of v is 3 ms^{-1}
(B) minimum value of v is 2 ms^{-1}
(C) maximum value of v is $2\sqrt{2}\text{ ms}^{-1}$
(D) maximum value of v is 6 ms^{-1}

21. In the arrangement shown, all surfaces are smooth and system is released from rest. The x and y components of acceleration of centre of mass are

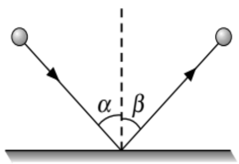


(A) $(a_{\text{cm}})_x = \dfrac{m_1 m_2 g}{m_1 + m_2}$ (B) $(a_{\text{cm}})_x = \dfrac{m_1 m_2 g}{(m_1 + m_2)^2}$

(C) $(a_{\text{cm}})_y = \left(\dfrac{m_2}{m_1 + m_2}\right)^2 g$ (D) $(a_{\text{cm}})_y = \left(\dfrac{m_2}{m_1 + m_2}\right) g$

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

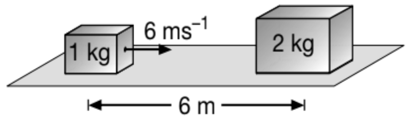
23. A ball strikes the ground at an angle α and rebound at an angle β with the vertical as shown in the figure. Then



(A) coefficient of restitution is $\dfrac{\tan\alpha}{\tan\beta}$
(B) if $\alpha < \beta$ the collision is inelastic
(C) if $\alpha = \beta$ the collision is elastic
(D) if $\alpha > \beta$ the collision is inelastic

24. A particle of mass m, moving with velocity v collides with a stationary particle of mass $2m$. As a result of collision, the lighter particle deviates by $45°$ and has final speed of $\dfrac{v}{2}$. For this situation, select the correct statement(s).
(A) The angle of divergence between particles after collision is $90°$
(B) The angle of divergence between particles after collision is less than $90°$
(C) Collision is elastic
(D) Collision is inelastic

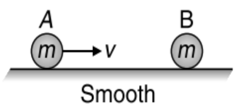
25. On a frictionless surface a block of mass 1 kg is pushed with a velocity of 6 ms^{-1} towards another block of mass 2 kg placed at a distance of 6 m from it as shown in Figure. Just after collision, the velocity of 2 kg block becomes 4 ms^{-1}. Select the correct statement(s).



(A) Coefficient of restitution between two blocks is $\dfrac{1}{2}$
(B) Coefficient of restitution between two blocks is 1
(C) Velocity of centre of mass at $t = 2\text{ s}$ is 2 ms^{-1}
(D) Velocity of centre of mass at $t = 0.5\text{ s}$ is 2 ms^{-1}

26. A ball of mass 10 g is dropped on the ground from a height of 10 m. It rebounds to a height of 2.5 m. If the ball is in contact with the ground for 0.01 s, then which statement(s) is incorrect?
(A) Impulse force between the ground and ball is 15 N
(B) Impulse force between the ground and ball is $5\sqrt{2}\text{ N}$
(C) Coefficient of restitution between the ground and ball is 0.25
(D) Coefficient of restitution between the ground and ball is 0.5

27. If the coefficient of restitution between A and B (shown in Figure) is $e = \dfrac{1}{2}$, then select the correct statement(s).

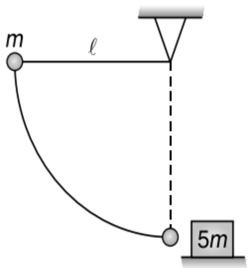


(A) Velocity of B after collision is $\dfrac{v}{2}$
(B) Impulse between the bodies during collision is $\dfrac{3}{4}mv$
(C) Loss in kinetic energy during the collision is $\dfrac{3}{16}mv^2$
(D) Loss in kinetic energy during the collision is $\dfrac{1}{4}mv^2$

28. A charged particle A moves directly towards another charged particle B. For the $(A+B)$ system, the total momentum is p and the total energy is E.
(A) p and E are conserved if both A and B are free to move
(B) Option (A) is true only if particles A and B have similar charges
(C) If B is fixed, E is conserved but not p.
(D) If B is fixed, neither E nor p is conserved

29. A projectile is fired from a point on the horizontal ground. The coefficient of restitution between the projectile and the ground is e. Let a, b and c be the ratio of the time of flights, the maximum heights and the horizontal ranges for the first two collisions with the horizontal ground, then
(A) $a=\frac{1}{e}$
(B) $b=\frac{1}{e^2}$
(C) $c=\frac{1}{e^2}$
(D) $a=be=c$

30. A pendulum bob of mass m connected to the end of an ideal string of length l is released from rest from horizontal position as shown in Figure. At the lowest point, the bob makes an elastic collision with a stationary block of mass $5m$, which is kept on a frictionless surface. Select the correct statement(s) for the instant just after the impact

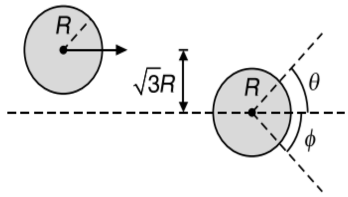


(A) Tension in the string is $3mg$
(B) Tension in the string is $\frac{17mg}{9}$
(C) The velocity of the block is $\frac{\sqrt{2gl}}{3}$
(D) The maximum height attained by the pendulum bob after impact is (measured from the lowest position) $\frac{4l}{9}$

31. A particle moving with kinetic energy K makes a head on elastic collision with an identical particle at rest. During collision, the
(A) elastic potential energy of the system is always zero.
(B) maximum elastic potential energy of the system is $\frac{K}{2}$.
(C) kinetic energy of the system is constant.
(D) minimum kinetic energy of the system is $\frac{K}{2}$.

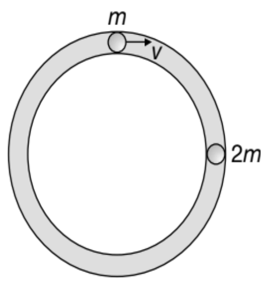
32. Two particles having equal masses are projected simultaneously from the roof of a tower of height 20 m with same speed 20 ms^{-1}, one horizontally and the other vertically upwards. Select the correct alternative(s).
(A) The acceleration of centre of mass is $\frac{g}{2}$ downwards.
(B) The acceleration of centre of mass is g downwards.
(C) Maximum height of centre of mass from the ground is 25 m.
(D) Maximum height of centre of mass from the ground is 40 m.

33. A disk moving on a frictionless horizontal table collides elastically with another identical disk as shown in Figure. The direction of motion of the two disks makes angle θ and ϕ with the initial line of motion. Select the correct values of θ and ϕ.



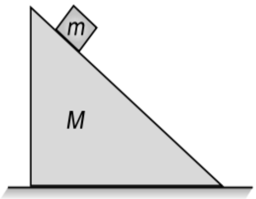
(A) $\theta=60^\circ$
(B) $\theta=30^\circ$
(C) $\phi=60^\circ$
(D) $\phi=30^\circ$

34. A particle of mass m moving with a speed v collides elastically with another particle of mass $2m$ on a horizontal circular tube of radius R, then select the correct alternative(s)



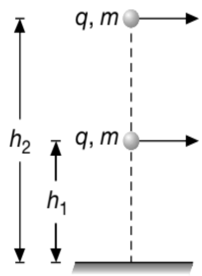
(A) The time after which the next collision will take place is $\frac{2\pi R}{v}$
(B) The time after which the next collision will take place is proportional to m
(C) The time after which the next collision will take place is inversely proportional to m
(D) The time after which the next collision will take place is independent of the mass of the balls

35. A block of mass m is lying at rest on a smooth wedge of mass M also lying at rest on a smooth horizontal surface. When the system is released select the correct statements.



(A) The CM of the system remains stationary.
(B) The CM of the system has an acceleration g vertically downward.
(C) Momentum of the system is conserved along the horizontal direction.
(D) Acceleration of CM is vertically downwards and $a < g$.

36. Two particles having same mass and charge are both thrown along the horizontal with same velocity v from two different height h_1 and h_2 $(h_1 < h_2)$. Initially they were located in the same vertical line. Select the correct alternative(s).



(A) Both the particles always lie on a vertical line.
(B) Acceleration of the centre of mass of the two particles is g downwards.
(C) Horizontal displacement of particle lying at h_1 is less than the value, which would had been in the absence of charges on them.
(D) Horizontal displacement of particle lying at h_2 is more than the value, which would had been in the absence of charges on them.

37. A man of mass m is standing 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. The work done by him

(A) is greater than $\frac{1}{2}mv^2$, if he walks along the rails.
(B) is less than $\frac{1}{2}mv^2$, if he walks along the rails.
(C) is equal to $\frac{1}{2}mv^2$, if he walks normal to rails.
(D) can never be less than $\frac{1}{2}mv^2$.

REASONING BASED QUESTIONS

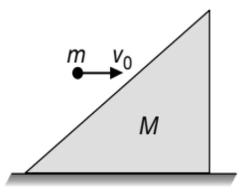
This section contains Reasoning type questions, each having four choices (A), (B), (C) and (D) out of which ONLY ONE is correct. Each question contains STATEMENT 1 and STATEMENT 2. You have to mark your answer as

Bubble (A) If both statements are TRUE and STATEMENT 2 is the correct explanation of STATEMENT 1.
Bubble (B) If both statements are TRUE but STATEMENT 2 is not the correct explanation of STATEMENT 1.
Bubble (C) If STATEMENT 1 is TRUE and STATEMENT 2 is FALSE.
Bubble (D) If STATEMENT 1 is FALSE but STATEMENT 2 is TRUE.

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

2. **Statement-1:** The position of centre of mass of a body does not depend upon shape and size of the body.
Statement-2: The centre of mass of a body may lie where there is no mass.

3. **Statement-1:** A particle of mass m strikes a smooth wedge of mass M as shown in the Figure.

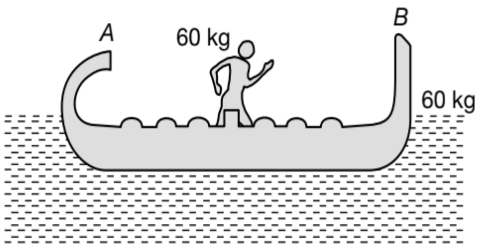


Smooth

Linear momentum of particle along the surface of wedge is conserved during collision.
Statement-2: Wedge exerts a force perpendicular to inclined face of wedge on particle during collision.

4. **Statement-1:** A body of mass m_1 collides head on elastically with another stationary body of mass m_2. After the collision, velocity of mass m_2 is maximum, when $m_1 \gg m_2$.
Statement-2: Velocity of second body is always maximum, when its mass m_2 is greater than mass of the hitting body.

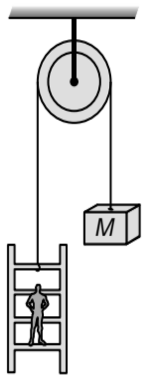
5. **Statement-1:** On a $8\ \text{m}$ boat as shown in figure, when man moves from centre to end B, the boat moves backward on water by $4\ \text{m}$.
Statement-2: Conservation of momentum principle is being followed.



6. **Statement-1:** If no external force acts on a system of particles, then the centre of mass will not move in any direction.
Statement-2: If net external force is zero, then the linear momentum of the system remains constant.

7. **Statement-1:** A block is kept at the top of a smooth wedge which is kept on a smooth horizontal surface. As the block slides down the wedge, centre of the mass of system will be accelerated.
Statement-2: When external force acting on the system is zero, centre of mass is in rest.

8. **Statement-1:** A block of mass M, balances a man at rest on a stationary ladder. If man moves upwards with respect to the ladder, the centre of mass will not move. Assume string to be massless and pulley to be smooth.
Statement-2: For a system on which no net external force acts and if $u_{cm} = 0$ then position of centre of mass will remain fixed.



9. **Statement-1:** Change in momentum of a particle in small time interval depends upon net impulse acting on it.
Statement-2: Internal force on the particle must be zero.

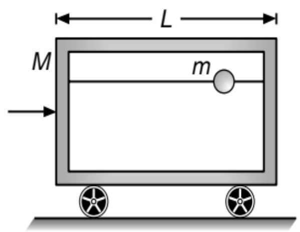
10. **Statement-1:** In a two body collision, the momenta of the particles are equal and opposite to one another, before as well as after the collision when measured in the center of mass frame.
Statement-2: The momentum of the system is zero when measured from the centre of mass frame.

LINKED COMPREHENSION TYPE QUESTIONS

This section contains Linked Comprehension Type Questions or Paragraph based Questions. Each set consists of a Paragraph followed by questions. Each question has four choices (A), (B), (C) and (D), out of which only one is correct. (For the sake of competitiveness there may be a few questions that may have more than one correct options)

Comprehension I

A horizontal frictionless string is threaded through a bead of mass m. The string is pulled between two vertical opposite sides of a cart of mass M, as shown in figure. The length of the cart is L and the radius of the bead, r, is very small in comparison with $L (r \ll L)$. Initially, the bead is at the right edge of the cart. The cart is struck and as a result, it moves with velocity v_0. When the bead collides with the cart's walls, assume the collisions to be completely elastic always.



Based on above information, answer the following questions.

1. The velocity of the centre of mass of the cart and the bead is

(A) $\frac{mv_0}{m+M}$ (B) $\frac{Mv_0}{m+M}$

(C) $\frac{Mv_0}{M-m}$ (D) $\frac{mv_0}{M-m}$

2. The first collision of the bead with the cart's wall takes place at the time t_1 given by

(A) $\frac{L}{v_0}$ (B) $\frac{L}{v_{cm}}$

(C) $\frac{2L}{v_{cm}}$ (D) $\frac{2L}{v_0}$

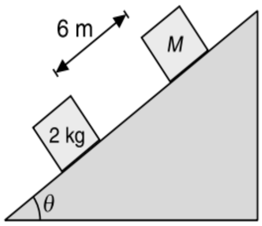
3. The velocity of the bead after the first collision, in the centre of mass frame is

(A) $\frac{2Mv_0}{M+m}$ (B) $\frac{Mv_0}{M+m}$

(C) $\frac{2mv_0}{m+M}$ (D) $\frac{2mMv_0}{m^2+M^2}$

Comprehension 2

Two blocks of mass 2 kg and M are at rest on an inclined plane and are separated by a distance of 6.0 m as shown in Figure.



The coefficient of friction between each block and the inclined plane is 0.25. The 2 kg block is given a velocity of 10.0 ms^{-1} up the inclined plane. It collides with M, comes back and has a velocity of 1.0 ms^{-1} when it reaches its initial position. The other block M after the collision moves 0.5 m up and comes to rest. Take $\sin\theta \approx \tan\theta = 0.05$ and $g = 10\text{ ms}^{-2}$. Based on the above facts, answer the following questions.

4. The approximate velocity of the 2 kg block just before collision is

(A) 4 ms^{-1} (B) 8 ms^{-1}

(C) 16 ms^{-1} (D) 32 ms^{-1}

5. The approximate velocity of 2 kg block just after collision is

(A) 1 ms^{-1} (B) 3 ms^{-1}

(C) 5 ms^{-1} (D) 7 ms^{-1}

6. The approximate velocity of block M just after collision is

(A) 1 ms^{-1} (B) 1.25 ms^{-1}

(C) 1.75 ms^{-1} (D) 2 ms^{-1}

7. If e be the coefficient of restitution between the blocks, then e equals

(A) 0.24 (B) 0.44

(C) 0.64 (D) 0.84

8. The approximate value of the mass M is

(A) 2.5 kg (B) 5 kg

(C) 10 kg (D) 15 kg

Comprehension 3

Two pendulum bobs of mass m and $2m$ are attached to threads of length L suspended from a rigid support. Both the bobs are taken to a height H from the lowest point and then released so they collide elastically at the lowest point in their motion. Based on the above facts, answer the following questions.

9. Velocity of bob of mass m just after impact is

(A) $\frac{4}{3}\sqrt{2gH}$ (B) $\frac{5}{3}\sqrt{2gH}$

(C) $\frac{7}{3}\sqrt{2gH}$ (D) $\sqrt{2gH}$

10. The height to which $2m$ will rise after impact is

(A) $\frac{H}{9}$ (B) $\frac{4H}{9}$

(C) H (D) $\frac{16H}{9}$

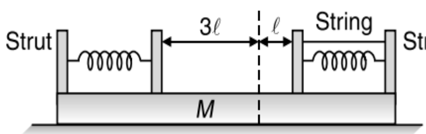
11. The height to which m will rise after impact is

(A) $\frac{H}{9}$ (B) H

(C) $\frac{25H}{9}$ (D) $\frac{16H}{9}$

Comprehension 4

A plank of mass M is placed on a smooth horizontal surface. Two light identical springs, each of stiffness K, are rigidly connected to struts at the end of the plank as shown in Figure.



When the springs are in their natural position, the distance between their free ends is $3l$. A block of mass m is placed on the plank and pressed against one of the springs so that it is compressed to l. To keep the block at rest it is connected to the strut by means of a light string. Initially, the system is at rest. Now if the string is burnt, then answer the following questions.

12. The maximum displacement of the plank is

(A) $\frac{5ml}{M}$ (B) $\frac{3ml}{M+m}$

(C) $\frac{4ml}{M+m}$ (D) $\frac{5ml}{M+m}$

13. The maximum velocity of the plank is

(A) $l\sqrt{\frac{km}{(M+M)}}$ (B) $l\sqrt{\frac{k}{(M+m)}}$

(C) $l\sqrt{\frac{km}{M(M+m)}}$ (D) $l\sqrt{\frac{kM}{m(M+m)}}$

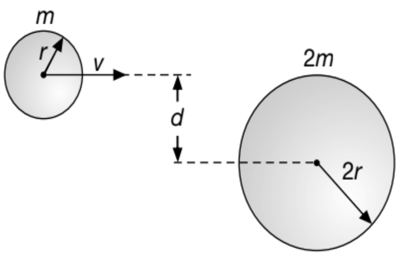
14. The maximum kinetic energy of the block m is

(A) $\frac{kml^2}{2M(M+m)}$ (B) $\frac{kMl^2}{2(M+m)}$

(C) $\frac{kml^2}{M(M+m)}$ (D) $\frac{2kMl^2}{m(M+m)}$

Comprehension 5

A uniform sphere with mass $2m$ and radius $2r$ is at rest in a place where no external forces are applied. A second sphere of mass m and radius r moves towards it with a velocity v (without rotating). The two spheres stick together and then continue their motion as one body. Given that $d = 2r$.



Based on above information, answer the following questions.

15. The distance of the centre of mass of system from the centre of bigger sphere at the moment of collision is

(A) r (B) $2r$

(C) $3r$ (D) $4r$

16. The velocity of centre of mass immediately after the collision is

(A) $\frac{2v}{3}$ (B) $\frac{2v}{5}$

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

17. The moment of inertia about the center of mass of the unified body after the collision is

(A) $\frac{24}{5}mr^2$ (B) $\frac{24}{3}mr^2$

(C) $\frac{48}{5}mr^2$ (D) $\frac{48}{3}mr^2$

Comprehension 6

To describe the momentum and kinetic energy of a particle, we need a reference frame. A very popular reference frame is the one which is attached with the centre of mass of a system. To describe the motion of the constituent particles of a system we have to find the velocity of centre of mass and then the velocities of the constituent particles with respect to centre of mass frame called C-frame. For simplicity consider a two particle system having masses m_1, m_2 and their velocities in a stationary frame of reference to be $\vec{v}_1$, $\vec{v}_2$ respectively. Based on information given, answer the following questions.

18. The total momentum of the system in the C-frame is

(A) $m_1\vec{v}_1 + m_2\vec{v}_2$ (B) $m_1\vec{v}_2 + m_2\vec{v}_1$

(C) $\left(\frac{m_1m_2}{m_1+m_2}\right)(\vec{v}_2 - \vec{v}_1)$ (D) ZERO

19. The total kinetic energy of the system in the C-frame is

(A) $\frac{1}{2}\left(m_1v_1^2 + m_2v_2^2\right)$

(B) $\frac{1}{2}(m_1+m_2)(\vec{v}_1 - \vec{v}_2)^2$

(C) $\frac{1}{2}\left(\frac{m_1m_2}{m_1+m_2}\right)(\vec{v}_1 - \vec{v}_2)^2$

(D) ZERO

20. Let the velocity of centre of mass of two particles is v and the sum of the masses of two particles is m. Kinetic energy of the system in stationary frame

(A) Will be equal to $\frac{1}{2}mv^2$

(B) Will always be less than $\frac{1}{2}mv^2$

(C) Will be greater than or equal to $\frac{1}{2}mv^2$

(D) Will always be greater than $\frac{1}{2}mv^2$

Comprehension 7

Two friends A and B (each weighing 40 kg) are sitting on a frictionless platform some distance d apart. A rolls a ball of mass 4 kg on the platform towards B, which B catches. Then B rolls the ball towards A and A catches it. The ball keeps on moving back and forth between A and B.

The ball has a fixed speed of $5\ ms^{-1}$ on the platform. Based on above information, answer the following questions.

21. The speed of A after he rolls the ball for the first time is

(A) $0.25\ ms^{-1}$ (B) $0.5\ ms^{-1}$
(C) $1\ ms^{-1}$ (D) $1.5\ ms^{-1}$

22. The speed of A after he catches the ball for the first time is

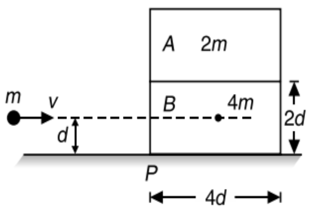
(A) $\frac{10}{11}\ ms^{-1}$ (B) $\frac{25}{11}\ ms^{-1}$
(C) $\frac{5}{11}\ ms^{-1}$ (D) $\frac{50}{11}\ ms^{-1}$

23. The speed of A and B after the ball has made four round trips and is held by A are

(A) $\frac{50}{11}\ ms^{-1}, \frac{25}{11}\ ms^{-1}$ (B) $\frac{40}{11}\ ms^{-1}, \frac{20}{11}\ ms^{-1}$
(C) $\frac{30}{11}\ ms^{-1}, \frac{25}{11}\ ms^{-1}$ (D) $\frac{50}{11}\ ms^{-1}, \frac{30}{11}\ ms^{-1}$

Comprehension 8

A block A of mass $2m$ is placed on another block B of mass $4m$ which in turn is placed of a fixed table. The two blocks have a same length $4d$ and they are placed as shown in figure. The coefficient of friction (both static and kinetic) between the block B and table is μ. There is no friction between the two blocks. A small object of mass m moving horizontally along a line passing through the centre of mass (CM) of the block B and perpendicular to its face with a speed v collides elastically with the block B at a height d above the table.



Based on the above facts, answer the following questions.

24. The minimum value of v (say v_0) so as to make the block A topple is

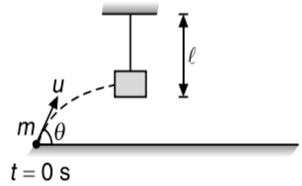
(A) $v_0 = \frac{2}{5}\sqrt{6\mu gd}$ (B) $v_0 = \frac{5}{2}\sqrt{3\mu gd}$
(C) $v_0 = \frac{5}{2}\sqrt{6\mu gd}$ (D) $v_0 = \frac{2}{5}\sqrt{3\mu gd}$

25. Assume $v = 2v_0$, the distance measured from point P at which the mass m falls on the table after collision (ignoring the role of friction during the collision) is

(A) $3d\sqrt{6\mu}$ (B) $6d\sqrt{3\mu}$
(C) $2d\sqrt{3\mu}$ (D) $3d\sqrt{2\mu}$

Comprehension 9

A small bullet of mass m is fired with velocity u at an angle θ with the horizontal, freely under gravity. At the highest point of its path, it strikes with a wooden block (mass M) and emerges out with half of its velocity (just before collision). During the impact (collision), the string (supporting the wooden block) remains almost vertical. (Given $(M > m)$)



26. Velocity of block as the bullet emerges out of it

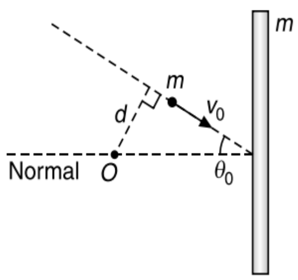
(A) $\frac{Mu\cos\theta}{2m}$ (B) $\frac{mu}{2M}$
(C) $\frac{mu\cos\theta}{2M}$ (D) $\frac{mu\cos\theta}{M}$

27. Loss in K.E. of (bullet + block) system as the bullet emerges out of block

(A) $\frac{m(3M-2m)}{8M}u^2\cos^2\theta$
(B) $\frac{m(3M-m)}{8M}u^2\cos^2\theta$
(C) $\frac{m}{8M}(3M+m)u^2\cos^2\theta$
(D) $\frac{3m}{8M}(M-m)u^2\cos^2\theta$

Comprehension 10

A uniform rod of mass m is lying on a frictionless horizontal surface. A particle of same mass as that of rod collides with rod at its centre with an angle θ_0 from the normal at mid-point of the rod as shown in the figure. Assume that there is no friction between the rod and particle and that the collision is elastic.



Based on above information, answer the following questions.

28. The magnitude of change in velocity of rod after collision is

(A) v_0 (B) $v_0 \sin\theta_0$

(C) $v_0 \cos\theta_0$ (D) None of these

29. The magnitude of change in velocity of particle after collision is

(A) v_0 (B) $v_0 \sin\theta_0$

(C) $v_0 \cos\theta_0$ (D) None of these

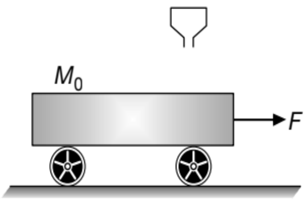
30. The magnitude of change in angular momentum of the particle about the point O after collision is

(A) $mv_0 d$ (B) ZERO

(C) $2mv_0 d$ (D) None of these

Comprehension 11

The figure shows a long cart moving on a smooth horizontal surface due to an external constant force of magnitude F. Initial mass of the cart is M_0 and its initial velocity is zero. At $t = 0$, sand starts falling from a stationary hopper onto the cart at constant rate μ kgs^{-1} and sticks to the cart. After time t_0 the sand starts leaking from the bottom at the same constant rate μ kgs^{-1}. Eventually at time $t = 2t_0$, the sand stops falling from the hopper on to the cart and force F also stops acting.



Based on above information, answer the following questions.

31. The velocity of the cart at time $t(< t_0)$

(A) $\dfrac{Ft}{M_0}$ (B) $\dfrac{Ft}{M_0}e^{\mu t}$

(C) $\dfrac{Ft}{M_0 + \mu t}e^{\mu t}$ (D) $\dfrac{Ft}{M_0 + \mu t}$

32. In the same model of the above question if the cart is to be moved with constant velocity v, then the power supplied by external agent applying that force is

(A) $2\mu v$ (B) μv

(C) μv^2 (D) $\dfrac{1}{2}\mu v^2$

33. In the above question the rate of increase of the kinetic energy of the cart (with sand) is

(A) $2\mu v^2$ (B) μv

(C) μv^2 (D) $\dfrac{1}{2}\mu v^2$

34. In the above model (for $t_0 < t < 2t_0$) what additional force over and above the force μv already applied to the right is required to move the cart with the speed acquired at t_0,

(A) μv towards right (B) $2\mu v$ towards right

(C) ZERO (D) μv towards left

Comprehension 12

A body of mass m_1 moving with velocity u_1, collides with a body of mass m_2 having velocity u_2, elastically. The collision is observed to be head on. Based on the above facts, answer the following questions.

35. Assume a massive body to collide with a light body at rest, then immediately after impact

(A) massive body comes to rest and the light body has velocity u_1

(B) massive body continues to move with the same velocity but light body attains velocity of massive body

(C) massive body continues to move with the same velocity but light body attains twice the velocity of massive body

(D) None of above seems to be correct

36. It is observed that for a ratio $\dfrac{m_1}{m_2} = (3 - x^2 + x)$, maximum transfer of momentum takes place from body 1 to body 2. Then

(A) $x = 1$ (B) $x = 2$

(C) $x = 3$ (D) $x = -1$

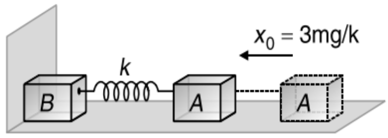
37. The fraction of total energy lost by m_1 is

(A) $\dfrac{4m_1m_2}{(m_1 + m_2)^2}$ (B) $\dfrac{m_1}{m_1 + m_2}$

(C) $\left(\dfrac{m_1 - m_2}{m_1 + m_2}\right)^2$ (D) $\dfrac{m_1 - m_2}{m_1 + m_2}$

Comprehension 13

A system consists of block A and B each of mass m connected by a light spring with block B in contact with a wall as shown in Figure.



The block A compresses the spring by $3mg/k$ from natural length of spring and then released from rest. Neglect friction everywhere, answer the following questions.

38. Acceleration of centre of mass of system comprising A and B just after A is released is

(A) g (B) $\frac{g}{2}$

(C) $\frac{3g}{2}$ (D) $\frac{g}{4}$

39. Velocity of centre of mass of system comprising A and B when block B just loose contact with the wall is

(A) $\frac{g}{2}\sqrt{\frac{m}{k}}$ (B) $\frac{g}{4}\sqrt{\frac{m}{k}}$

(C) $\frac{3g}{2}\sqrt{\frac{m}{k}}$ (D) $\frac{3g}{4}\sqrt{\frac{m}{k}}$

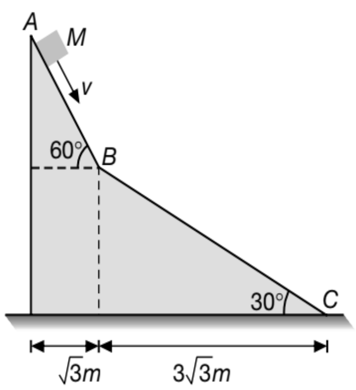
40. Maximum extension in the spring after system loses contact with wall is

(A) $\frac{mg}{k\sqrt{2}}$ (B) $\frac{mg}{3k\sqrt{2}}$

(C) $\frac{3mg}{k\sqrt{2}}$ (D) $\frac{mg}{k}$

Comprehension 14

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



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

(A) $\sqrt{60}\text{ ms}^{-1}$ (B) $\sqrt{45}\text{ ms}^{-1}$

(C) $\sqrt{30}\text{ ms}^{-1}$ (D) $\sqrt{15}\text{ ms}^{-1}$

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

(A) $\sqrt{120}\text{ ms}^{-1}$ (B) $\sqrt{105}\text{ ms}^{-1}$

(C) $\sqrt{90}\text{ ms}^{-1}$ (D) $\sqrt{75}\text{ ms}^{-1}$

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

(A) $\sqrt{30}\text{ ms}^{-1}$ (B) $\sqrt{15}\text{ ms}^{-1}$

(C) 0 (D) $-\sqrt{15}\text{ ms}^{-1}$

Comprehension 15

An experiment is done on two metal balls of equal masses moving with unequal speeds u_1 and u_2 collide inelastically head on. The experiment is repeated with initial same speeds of the two balls u_1 and u_2 but balls are charged with unequal charges of same polarity moving in the same line from a large separation. Assume no radiation loss during collision when balls are charged. Assume in second case balls do not touch each other.

Based on above information, answer the following questions.

44. Which of the following statements is correct for potential energy between balls?

(A) When balls are charged the maximum potential energy is more than the case when balls are uncharged during collision

(B) When balls are charged the maximum potential energy is less than the case when balls are uncharged during collision

(C) When balls are charged the maximum potential energy is equal to the case when balls are uncharged during collision

(D) Nothing can be said about the maximum potential energy as it depends on the magnitude of charges of the ball

45. Which of the following statement is correct about center of mass of the two balls during collision

1. In first case when balls are uncharged, the centre of mass of balls moves at uniform speed during collision
2. In second case when balls are charged, the centre of mass of balls moves at uniform speed during collision
3. In second case, centre of mass of balls will move at uniform speed only when the balls are equally charged

(A) only 1 is correct (B) 1 and 2 are correct

(C) 1 and 3 are correct (D) None of these

46. If an observer moving with constant velocity parallel to the line of motion of balls observes the collision when balls are uncharged

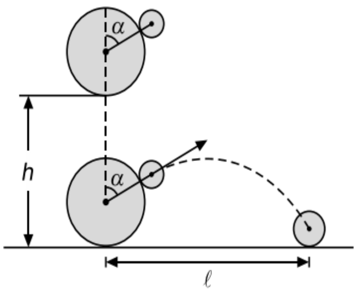
1. The kinetic energy of the system in the frame of observer remains conserved

2. The velocity of center of mass in the frame of observer remains constant

(A) only (1) is true
(B) only (2) is true
(C) both (1) and (2) are true
(D) both (1) and (2) are wrong

Comprehension 16

A large heavy sphere and a small light sphere are dropped onto a flat surface from a height h. The radii of both spheres is much smaller than height h. The large sphere collides with the surface with velocity v_0 and immediately thereafter with the small sphere. The spheres are dropped so that all motion is vertical before the second collision and the small sphere hits the larger sphere at an angle α from its uppermost point, as shown in Figure. If all collisions are perfectly elastic and there is no surface friction between the spheres.



47. The angle made by velocity vector of small sphere with the vertical just after the second collision in the frame of large sphere is

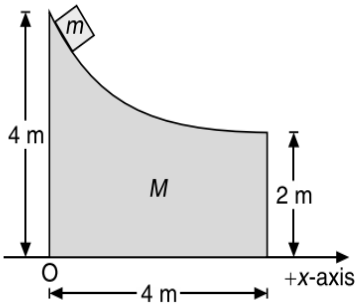
(A) α (B) 2α
(C) $\frac{3\alpha}{2}$ (D) ZERO

48. The vertical velocity of smaller sphere just after the collision with respect to ground is

(A) $2v_0\cos\alpha$ (B) $v_0\cos\alpha+v_0$
(C) $2v_0\cos2\alpha+v_0$ (D) $v_0\cos2\alpha+v_0$

Comprehension 17

A small block of mass $m=1\text{ kg}$ is placed over a wedge of mass $M=4\text{ kg}$ as shown in figure. Mass m is released from rest. All surfaces are smooth and the origin O is fixed on the ground shown. Based on above information, answer the following questions.



49. Final velocity of the wedge is

(A) $\frac{1}{\sqrt{3}}\text{ ms}^{-1}$ (B) $\sqrt{3}\text{ ms}^{-1}$
(C) $\frac{1}{\sqrt{2}}\text{ ms}^{-1}$ (D) $\sqrt{2}\text{ ms}^{-1}$

50. The block strikes the x-axis at

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

51. At an instant when absolute acceleration of m is $5\sqrt{3}\text{ ms}^{-2}$ at $60°$ with horizontal, the normal reaction (N) between the two blocks make an angle of $30°$ with horizontal. Then N (in newton) equals

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

52. At the same instant reaction on the wedge from the ground (in newton) is

(A) 38.5 (B) 40
(C) 42.5 (D) 45

Comprehension 18

A piece of wood of mass 0.03 kg is dropped from the top of a building 100 m high. At the same time a bullet of mass 0.02 kg is fired vertically upwards with a velocity of 100 ms^{-1} from the ground. The bullet gets embedded in the wooden piece after striking it. Taking $g=10\text{ ms}^{-2}$.

Based on above information, answer the following questions.

53. The time after which bullet strikes the wooden block is

(A) 1 sec (B) 0.5 sec
(C) 1.5 sec (D) 2 sec

54. If the time of collision is $100\,\mu s$ and $\vec{u}_1$, $\vec{u}_2$ and $\vec{v}_1$, $\vec{v}_2$ are velocities of block, bullet before and after the collision respectively, then the value of $\left|(m_1\vec{u}_1+m_2\vec{u}_2)-(m_1\vec{v}_1+m_2\vec{v}_2)\right|$ is

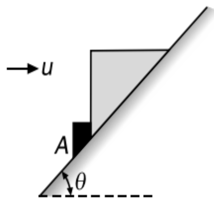
(A) $5\times10^{-4}\text{ Ns}$ (B) $5\times10^{-5}\text{ Ns}$
(C) $5\times10^{-3}\text{ Ns}$ (D) $5\times10^{-6}\text{ Ns}$

55. The velocity of the (block + bullet) system after the collision is

(A) 14 ms^{-1} (B) 21 ms^{-1}
(C) 42 ms^{-1} (D) 30 ms^{-1}

Comprehension 19

A block of mass M is held at rest on the smooth inclined plane by the stop block at A. The bullet of mass m is travelling at speed u, when it becomes embedded in the block. Based on this information, answer the following questions.



56. For the collision between block and bullet, which of the following conservative law can be applied?
(A) Conservation of mechanical energy
(B) Conservation of linear momentum along horizontal
(C) Conservation of linear momentum along vertical
(D) Conservation of linear momentum in a direction parallel to inclined surface

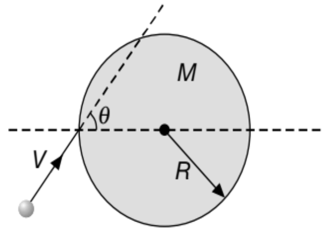
57. In which of the following directions, net impulsive force on the system is zero?
(A) Along horizontal
(B) Along vertical
(C) Along the inclined surface
(D) Along a normal to the inclined surface

58. What is the impulse generated between the block and the inclined plane?
(A) $mu\sin\theta$
(B) $mu\cos\theta$
(C) $(M+m)u\cos\theta$
(D) $(M+m)u\sin\theta$

59. The distance up to which the block slide before momentarily stopping is
(A) $\dfrac{u^2}{2g\sin\theta}$
(B) $\dfrac{m^2u^2}{2g\sin\theta(m+M)^2}$
(C) $\dfrac{m^2u^2\cos^2\theta}{2g\sin\theta(m+M)^2}$
(D) $\dfrac{m^2u^2\sin^2\theta}{2g\sin\theta(m+M)^2}$

Comprehension 20

A disc of mass M and radius of curvature R is lying on a frictionless ground. A small ball of mass M moving on the ground with a velocity V strikes the disc and collides with it. The coefficient of restitution being e.



Based on above information, answer the following questions.

60. Velocity of approach for the system (ball + disc) along line of impact is
(A) V
(B) $V\sin\theta$
(C) $V\cos\theta$
(D) ZERO

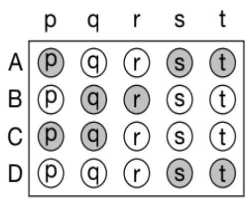
61. Velocity of the disc after collision is
(A) $\dfrac{V\cos\theta}{2}$
(B) $\dfrac{eV\cos\theta}{2}$
(C) $\dfrac{V\cos\theta(1-e)}{2}$
(D) $\dfrac{V\cos\theta(1+e)}{2}$

62. The speed of the ball after the collision is
(A) $eV\cos\theta$
(B) $V\sqrt{\dfrac{\cos^2\theta(1-e)^2}{4}+\sin^2\theta}$
(C) $V\sqrt{\cos^2\theta(1+e)^2+\dfrac{\sin^2\theta}{4}}$
(D) $V\sqrt{\dfrac{\cos^2\theta(1+e)^2}{4}+\sin^2\theta}$

MATRIX MATCH/COLUMN MATCH TYPE QUESTIONS

Each question in this section contains statements given in two columns, which have to be matched. The statements in **COLUMN-I** are labelled A, B, C and D, while the statements in **COLUMN-II** are labelled p, q, r, s (and t). Any given statement in **COLUMN-I** can have correct matching with **ONE OR MORE** statement(s) in **COLUMN-II**. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following examples:

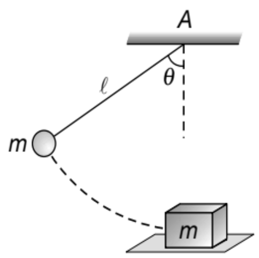
If the correct matches are A → p, s and t; B → q and r; C → p and q; and D → s and t; then the correct darkening of bubbles will look like the following:



1. Match the quantities in **COLUMN-I** to their respective values in **COLUMN-II**.

COLUMN-I	COLUMN-II
(A) Momentum is increased by 200%, corresponding change in kinetic energy as multiple of 100%	(p) 8
(B) Kinetic energy is increased by 300%, corresponding change in momentum as multiple of 100%	(q) 2
(C) Momentum is increased by 1%, corresponding change in kinetic energy as multiple of $\frac{1}{2}\%$	(r) 1
(D) Kinetic energy is increased by 1%, corresponding change in momentum as multiple of $\frac{1}{2}\%$	(s) 4
	(t) None of these

2. In the arrangement shown in figure, ball and block have the same mass $m = 1$ kg each, $\theta = 60^\circ$ and length $l = 2.5$ m. The coefficient of friction between block and floor is 0.5. When the ball is released from the position shown in the figure, it collide with the block and the block stops after moving a distance 2.5 m. Match the quantities in **COLUMN-I** with their respective values in **COLUMN-II**.



COLUMN-I	COLUMN-II
(A) velocity of ball just before collision (ms^{-1})	(p) 5
(B) velocity of block just after collision (ms^{-1})	(q) 3
(C) velocity of block after travelling 1.6 m (ms^{-1})	(r) 1
(D) coefficient of restitution (dimensionless)	(s) 0

(Continued)

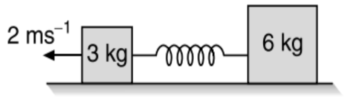
3. A particle is projected from the ground upwards with a velocity of 20 ms^{-1}. At the same instant, another identical particle is dropped from a height of 180 m but not along the same vertical line. Assume that collision of first particle with ground is perfectly inelastic, match the quantities given in **COLUMN-I** for the centre of mass of the two-particle system with their respective magnitudes in SI system given in **COLUMN-II**. Take $g = 10 \text{ ms}^{-2}$.

COLUMN-I	COLUMN-II
(A) Initial acceleration	(p) 5
(B) Initial velocity	(q) 10
(C) Acceleration at $t = 5$ s	(r) 20
(D) Velocity at $t = 5$ s	(s) 25

4. A particle of mass 1 kg has velocity $\vec{v}_1 = (2t)\hat{i}$ and another particle of mass 2 kg has velocity $\vec{v}_2 = (t^2)\hat{j}$. Match the quantities in **COLUMN-I** at $t = 2$ s to their respective values in **COLUMN-II**.

COLUMN-I	COLUMN-II
(A) Magnitude of net force on centre of mass	(p) $\frac{20}{9}$ unit
(B) Magnitude of momentum of centre of mass	(q) $\sqrt{68}$ unit
(C) Magnitude of velocity of centre of mass	(r) $\frac{\sqrt{80}}{3}$ unit
(D) Distance of centre of mass from origin	(s) $\sqrt{80}$ unit

5. Two blocks having masses 3 kg and 6 kg placed on a horizontal frictionless surface are connected by an ideal spring as shown in Figure. The 3 kg block is imparted a speed of 2 ms^{-1} towards left. Considering leftward to be the positive direction, match the quantities in **COLUMN-I** with their respective answers in **COLUMN-II**.

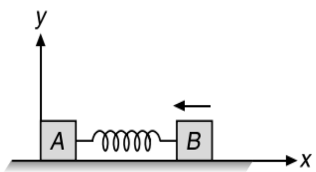


COLUMN-I	COLUMN-II
(A) When the velocity of 3 kg block is $\frac{2}{3}\text{ ms}^{-1}$	(p) velocity of centre of mass is $\frac{2}{3}\text{ ms}^{-1}$
(B) When the velocity of 6 kg block is $\frac{2}{3}\text{ ms}^{-1}$	(q) deformation of the spring is zero
(C) When the speed of 3 kg block is minimum	(r) deformation of the spring is maximum
(D) When the speed of 6 kg block is maximum	(s) both the blocks are at rest with respect to each other

6. A particle of mass m, kinetic energy K and momentum p collides head on elastically with another particle of mass $2m$ at rest. Match the quantities in **COLUMN-I** (quantities after collision) to their respective values in **COLUMN-II**.

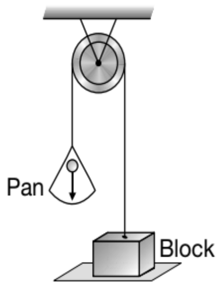
COLUMN-I	COLUMN-II
(A) Momentum of first particle (multiple of p)	(p) $\frac{4}{3}$
(B) Momentum of second particle (multiple of p)	(q) $\frac{1}{9}$
(C) Kinetic energy of first particle (multiple of K)	(r) $-\frac{1}{3}$
(D) Kinetic energy of second particle (multiple of K)	(s) $\frac{8}{9}$

7. Two identical blocks A and B lying on a smooth horizontal surface (along the x-axis) are connected by a spring as shown in Figure. The block A is not connected to the wall (along the y-axis). When the block B is moved to the left and released, then match arguments in **COLUMN-I** to the results in **COLUMN-II**.



COLUMN-I	COLUMN-II
(A) Acceleration of centre of mass of two blocks	(p) remains constant
(B) Velocity of centre of mass of two blocks	(q) first increases then becomes constant
(C) x-coordinate of centre of mass of two blocks	(r) first decreases then become zero
(D) y-coordinate of centre of mass of two blocks	(s) continuously increases

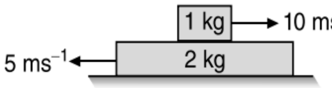
8. A pan of mass $m = 1.5\text{ kg}$ and a block of mass $M = 3\text{ kg}$ are connected with each other by a flexible, light and inextensible string, passing over a small, light and frictionless pulley. Initially the block is resting over a horizontal floor as shown in Figure.



At $t = 0$, an inelastic ball of mass $m_0 = 0.5\text{ kg}$ collides with the pan with velocity $v_0 = 16\text{ ms}^{-1}$ (vertically downward). Take $g = 10\text{ ms}^{-2}$, match the quantities in **COLUMN-I** with the respective values in **COLUMN-II**.

COLUMN-I	COLUMN-II
(A) velocity of pan in ms^{-1} just after collision	(p) 0.64
(B) acceleration in ms^{-2} of pan just after collision	(q) 1.6
(C) maximum height rise in m of block	(r) 2
(D) time in s at which block strikes the floor	(s) 9.8

9. A 1 kg block is lying on a 2 kg platform which lies on a smooth horizontal surface. Friction is present between the block and the platform. At some instant the block has a horizontal velocity of 10 ms^{-1} towards right and the platform has a horizontal velocity of $5\ \text{ms}^{-1}$ towards left. Match the contents of **COLUMN-I** with their respective answers in **COLUMN-II**.

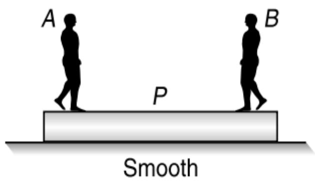


COLUMN-I	COLUMN-II
(A) Velocity of centre of mass	(p) constant
(B) Momentum of centre of mass	(q) first decreases then become zero
(C) Momentum of block	(r) is ZERO
(D) Kinetic energy platform	(s) keeps changing all the time

10. For a system of particles, if the net force is zero, then match the quantities of **COLUMN-I** with their best matches in **COLUMN-II**.

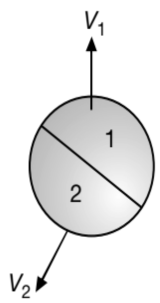
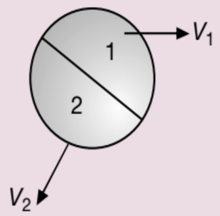
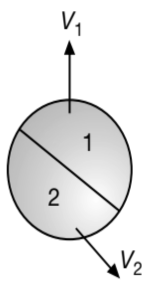
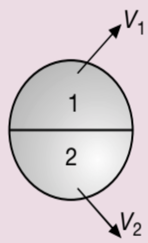
COLUMN-I	COLUMN-II
(A) Acceleration of centre of mass	(p) Constant
(B) Velocity of centre of mass	(q) Zero
(C) Momentum of centre of mass	(r) May be zero
(D) Velocity of an individual particle of the system	(s) May be constant
	(t) None of these

11. Two boys A and B having masses 30 kg and 60 kg are standing on a plank P of mass 30 kg lying on the smooth horizontal surface as shown in Figure. Match the displacement of plank of **COLUMN II** with the conditions given in **COLUMN I**. Note that the displacements mentioned in two columns are with respect to ground.

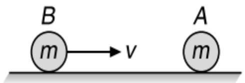


COLUMN-I	COLUMN-II
(A) A moves x towards right	(p) x, towards right
(B) B moves x towards left	(q) $2x$, towards left
(C) A moves x towards right and B moves x towards left	(r) $3x$, towards left
(D) A and B both move x towards right	(s) $\frac{x}{3}$, towards left

12. A body is initially moving towards right explodes into two pieces 1 and 2. Match the direction of motion of the pieces shown in **COLUMN-I** to the possible mass relationships in **COLUMN-II**.

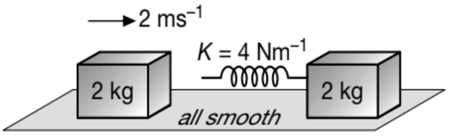
COLUMN-I	COLUMN-II
(A) 	(p) $m_1 > m_2$
(B) 	(q) $m_1 = m_2$
(C) 	(r) $m_1 < m_2$
(D) 	(s) Impossible for any masses

13. Two identical balls A and B are kept on a smooth table as shown. The ball B moving with a speed v collides with the ball A at rest. For different conditions mentioned in **COLUMN-I**, give the corresponding match for the speed of ball A after collision given in **COLUMN II**.



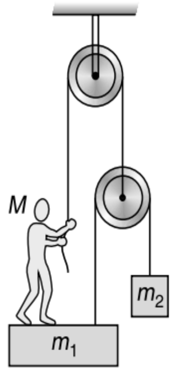
COLUMN-I	COLUMN-II
(A) Elastic collision	(p) $\frac{3v}{4}$
(B) Perfectly inelastic collision	(q) $\frac{5v}{8}$
(C) Inelastic collision with $e=\frac{1}{2}$	(r) v
(D) Inelastic collision with $e=\frac{1}{4}$	(s) $\frac{v}{2}$

14. In the arrangement shown in figure, match the quantities in **COLUMN-I** with the respective values in **COLUMN-II**.



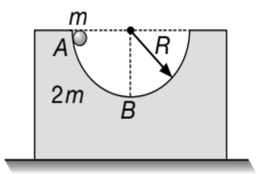
COLUMN-I	COLUMN-II
(A) Velocity of centre of mass (in ms^{-1})	(p) 2
(B) Velocity of combined mass, (in ms^{-1}) when compression in the spring is maximum	(q) 1
(C) Maximum compression (in m) in the spring	(r) 4
(D) Maximum potential energy, in joule stored in the spring	(s) 0.5
	(t) None of these

15. A man of mass M is standing on a platform of mass $m_1=10$ kg connected to a mass $m_2=20$ kg. The man is holding a string passing over a system of ideal pulleys as shown in Figure. Taking $g=10\ ms^{-2}$, match the quantities given in **COLUMN-I** with their respective values in SI system in **COLUMN-II**.



COLUMN-I	COLUMN-II
(A) Weight of man for equilibrium	(p) 100 N
(B) Force exerted by man on string so that the centre of mass of system accelerates upwards	(q) 150 N
(C) Force exerted by man on string so that the centre of mass of system accelerates downwards	(r) 500 N
(D) Force exerted by platform on man in equilibrium is	(s) 600 N

16. In the system shown in figure, mass m is released from rest from position A. Suppose potential energy of m at point A with respect to point B is E. Size of m is negligible and all surfaces are smooth. When mass m reaches at point B.

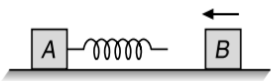


COLUMN-I	COLUMN-II
(A) Kinetic energy of m	(p) $\frac{E}{3}$
(B) Kinetic energy of $2m$	(q) $\frac{2E}{3}$
(C) Momentum of m	(r) $\sqrt{\frac{4mE}{3}}$
(D) Momentum of $2m$	(s) $\sqrt{\frac{2mE}{3}}$

17. Match the quantities in **COLUMN-I** with the respective quantities in **COLUMN-II**.

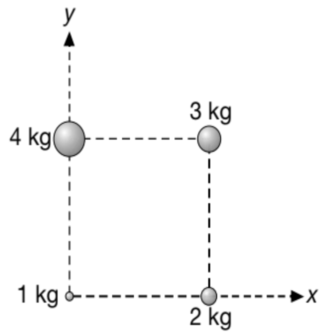
COLUMN-I	COLUMN-II
(A) In the absence of external force	(p) Inside the body
(B) If a man walks on a platform, which is placed on frictionless horizontal surface then	(q) The state of centre of mass will remain unchanged
(C) Centre of mass of a body can be	(r) The linear momentum of system remains conserved
(D) Centre of mass of solid cube is	(s) Outside a body

18. Consider two identical blocks A and B each of mass 0.5 kg. A light elastic spring is connected to block A as shown in Figure. The block B is moving towards A with a kinetic energy of 4 J. Match the momenta in **COLUMN-I** to their respective values in SI system in **COLUMN-II**. Assume friction to be absent everywhere.



COLUMN-I	COLUMN-II
(A) Initial momentum of B	(p) 0
(B) Momentum of centre of mass of two blocks	(q) 1
(C) Momentum of A at maximum compression	(r) 2
(D) Momentum of B when spring is relaxed after compression	(s) 4

19. Four point masses are placed at four corners of a square of side 4 m as shown. Match the quantities in **COLUMN-I** to their respective values in **COLUMN-II**.



COLUMN-I	COLUMN-II
(A) x co-ordinate of centre of mass of 4 kg and 2 kg	(p) $\frac{7}{2}$ m
(B) x co-ordinate of centre of mass of 4 kg, 2 kg and 3 kg	(q) $\frac{4}{3}$ m
(C) y co-ordinate of centre of mass of 1 kg, 4 kg and 3 kg	(r) 3 m
(D) y co-ordinate of centre of mass of 1 kg and 3 kg	(s) $\frac{20}{9}$ m

INTEGER/NUMERICAL ANSWER TYPE QUESTIONS

In this section, the answer to each question is a numerical value obtained after doing series of calculations based on the data given in the question(s).

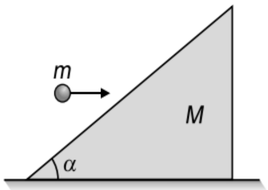
1. After perfectly inelastic collision between two identical particles moving with same speed in different directions, the speed of the particles becomes half the initial speed. The angle between the two colliding bodies just before impact is ϕ. Find $\frac{\phi}{20}$, in degree.

2. Block A has a mass of 3 kg and is sliding on a rough horizontal surface with a velocity $v_A = 2\ \text{ms}^{-1}$ when it makes a direct collision with block B, which has a mass of 2 kg and is originally at rest. If the collision is perfectly elastic, calculate the distance, in cm, between the blocks when they stop sliding. The coefficient of kinetic friction between the blocks and the plane is $\mu_k = 0.4$ and given $g = 10\ \text{ms}^{-2}$.

3. The maximum tension that an inextensible rope of mass density $0.2\ \text{kgm}^{-1}$ can bear is 40 N. Length of rope is 2 m. Calculate the maximum angular velocity,

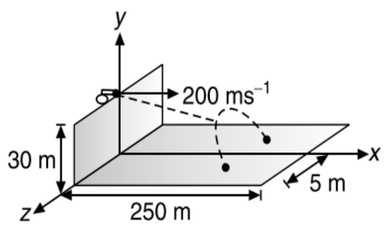
in $rads^{-1}$, with which it can be rotated horizontally in a circular path on a frictionless table.

4. 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 and take $M = 2m$, $v_0 = 10\ ms^{-1}$, $\tan\alpha = 2$, $g = 10\ ms^{-2}$. Calculate the coefficient of restitution for the impact.

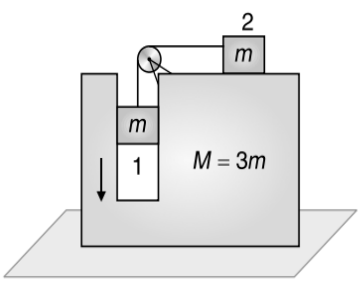


5. Two particles A and B of equal masses lie close together on a horizontal table and are connected by a light inextensible string of length l. A is projected vertically upwards with a velocity $\sqrt{10gl}$. The velocity with which it reaches the table again is $\sqrt{xgl}$. Find x.

6. Two $20\ kg$ cannon balls are chained together and fired horizontally with a velocity of $200\ ms^{-1}$ from the top of a $30\ m$ wall. The chain breaks during the flight of the cannon balls and one of them strikes the ground at $t = 2\ s$, at a distance of $250\ m$ from the foot of the wall and $5\ m$ to the right of the line of fire. The position of the other cannon ball at that instant is $(x_2, y_2, z_2)\ m$. Calculate $x_2 + y_2 + z_2$. Neglect the resistance of air.



7. A wedge having a vertical slot in it is placed on smooth horizontal surface. Two blocks are arranged as shown in Figure.



The system is released from rest. The speed of the wedge when block 1 comes down a distance h is $\sqrt{\frac{2gh}{\alpha}}$. Calculate α.

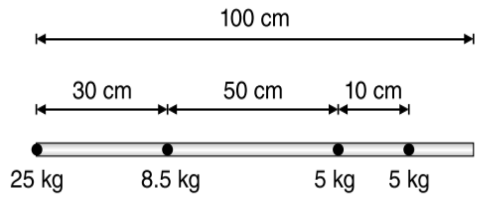
8. A system consists of two particles. At $t = 0$, one particle is at the origin and the other particle having a mass of $600\ kg$, is on the y-axis at $y = 80\ m$. At $t = 0$ the centre of mass of the system is on the y-axis at $y = 24\ m$ and has a velocity given by $(6\ ms^{-3})t^2\hat{j}$.

(a) Find the total mass of the system in kg.

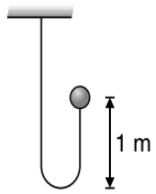
(b) Find the acceleration of the centre of mass, in ms^{-2}, at time $t = 2$ s.

(c) Find the net external force, in N, acting on the system at $t = 3$ s.

9. A rod of mass $10\ kg$ of length $100\ cm$ with point masses tied to it at different positions as shown in Figure. Find the location of a point on the rod from its left end at which if the rod is placed over a knife edge, it will be in equilibrium about that knife edge.

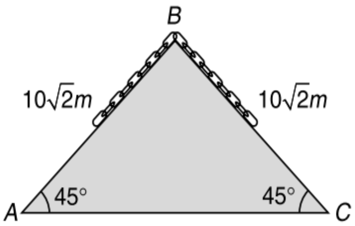


10. A ball of mass $1\ kg$ is attached to an inextensible string. The ball is released from the position shown in Figure. The impulse imparted by the string to the ball immediately after the string becomes taut is $\sqrt{\alpha}\ kgms^{-1}$. Calculate α.

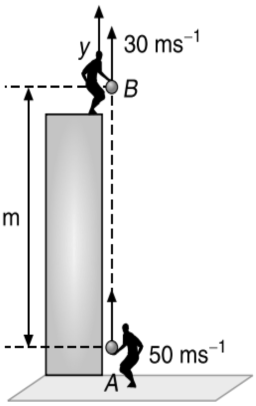


11. A ball of mass m is just disturbed from the top of a fixed smooth circular tube of radius a in a vertical plane and falls impinging on a ball of mass $2m$ at the bottom. If the coefficient of restitution between the balls is $\frac{1}{2}$ then the heights to which the balls m and $2m$ rise after the second impact are $\frac{a}{x}$ and $\frac{a}{y}$. Then find x and y.

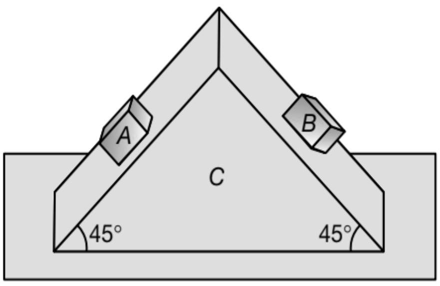
12. A flexible chain of length $L = 20\sqrt{2}\ m$ and weight $W = 10\ kg$ is initially placed at rest on a smooth frictionless wedge surface ABC. It is given a slight push on one-side so that it will start sliding on that side. Calculate the speed of the chain, in ms^{-1}, when its one end will leave the vertex of the wedge. Take $g = 10\ \text{ms}^{-2}$



13. Two balls A and B of equal masses are projected upward simultaneously, one from the ground with speed $50\ \text{ms}^{-1}$ and other from a lower of height $40\ \text{m}$ above the first ball with initial speed $30\ \text{ms}^{-1}$. Calculate the maximum height attained by their centre of mass in metre.

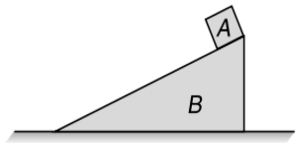


14. Two blocks A and B of equal mass are released on two sides of a fixed wedge C as shown in Figure.

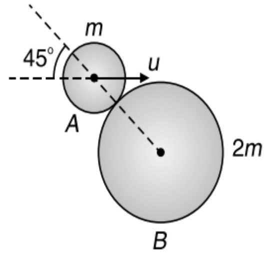


Calculate the acceleration of centre of mass of blocks A and B, in ms^{-2}. Neglect friction.

15. A block A (mass $= 4M$) is placed on the top of a wedge block B of base length $12\ \text{m}$ (mass $= 20M$) as shown in Figure. When the system is released from rest. Find the distance moved by the block B (in metre) till the block A reaches ground. Assume all surfaces are frictionless.



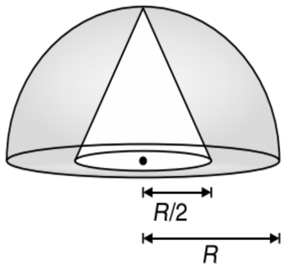
16. Disc A of mass m collides with stationary disc B of mass $2m$ as shown in Figure.



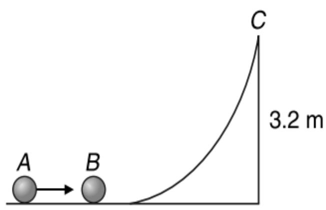
The value of coefficient of restitution for which the two discs move in perpendicular direction after collision is e. Calculate $\frac{1}{e}$.

17. In an elastic head-on collision of bodies of mass m and $(x^2 - 9x + 21)m$, the second body is at rest and the maximum transfer of momentum takes place. Find the value(s) of x.

18. From a hemisphere of radius R, a cone of base radius $\frac{R}{2}$ and height R is removed as shown in Figure. Calculate the height of centre of mass of the remaining object in cm if $R = 28\ \text{cm}$.

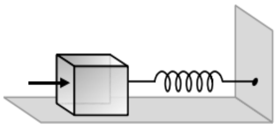


19. Two identical balls A and B lie on a smooth horizontal surface, which gradually merges into a curve to a height $3.2\ \text{m}$. Ball A is given a velocity of $10\ \text{ms}^{-1}$, to collide head-on with ball B, which then takes up the curved path. Calculate the minimum coefficient of restitution, e, for the collision between A and B so that ball B reaches the highest point C of the curve.

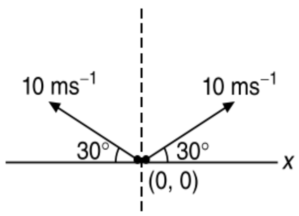


20. A balloon having mass m is filled with gas and is held in hands of a boy. Then suddenly it get released and gas starts coming out of it with a constant rate. The velocities of the ejected gases is also constant 2 ms^{-1} with respect to the balloon. Find out the velocity of the balloon, in ms^{-1}, when the mass of gas is reduced to half. Take $\ln(2)\approx 0.7$

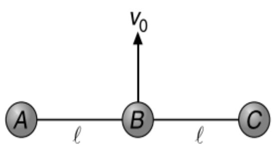
21. A block of mass 0.18 kg is attached to a spring of force constant 2 Nm^{-1}. The coefficient of friction between the block and the floor is 0.1. Initially the block is at rest and the spring is un-stretched. An impulse is given to the block as shown in the figure. The block slides a distance of 0.06 m and comes to rest for the first time. The initial velocity of the block in ms^{-1} is $V=\frac{N}{10}$. Find the value of N.



22. Two particles A and B of equal mass are projected simultaneously with speed of 10 ms^{-1} each as shown in Figure. Find the co-ordinate of centre of mass at $t=10\text{ s}$ is (x,y) m. Calculate $x-y$. Take $g=10\text{ ms}^{-2}$.

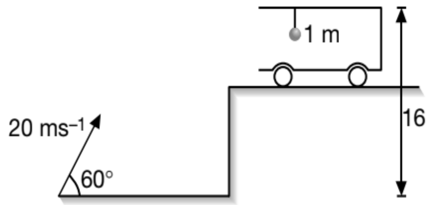


23. Three identical balls each of mass $m=0.5\text{ kg}$ are connected with each other as shown in Figure and rest over a smooth horizontal table. At moment $t=0$, ball B is imparted a horizontal velocity $v_0=9\text{ ms}^{-1}$. Calculate velocity of A just before it collides with ball C.

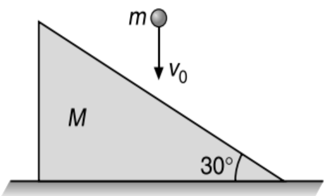


24. Rahul having mass 50 kg and Mohit having mass 60 kg are sitting at the two extremes of a 4 m long floating platform having mass 40 kg standing still in water. To discuss a problem, they come to the middle of the platform. Neglecting friction with water, how far does the platform move in the water during the process (in centimetre).

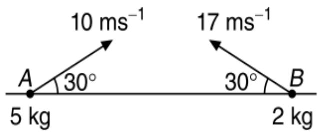
25. A shell of mass 1 kg is projected with velocity 20 ms^{-1} at an angle $60°$ with horizontal. It collides inelastically with a ball of mass 1 kg which is suspended through a thread of length 1 m. The other end of the thread is attached to the ceiling of a trolley of mass 18 kg as shown in figure. Initially the trolley is stationary and it is free to move along horizontal rails without any friction. The maximum deflection of the thread with vertical is θ, such that $\cos\theta=\frac{1}{*}$, where $*$ is not readable. Taking $g=10\text{ ms}^{-2}$, find $*$.



26. A ball of mass $m=1\text{ kg}$ falling vertically with a velocity $v_0=2\text{ ms}^{-1}$ strikes a wedge of mass $M=2\text{ kg}$ kept on a smooth, horizontal surface as shown in figure. The coefficient of restitution between the ball and the wedge is $e=\frac{1}{2}$. The velocity of the wedge and the ball immediately after collision is $\frac{\alpha}{\sqrt{3}}\text{ ms}^{-1}$. Calculate α.

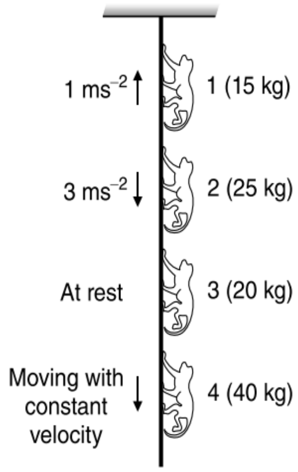


27. Two particles A and B of mass 5 kg and 2 kg are projected simultaneously from same ground level as shown in Figure. Find the maximum height (in cm) reached by the centre of mass. Assume that only gravitational force of attraction by the earth is present and take $g=10\text{ ms}^{-2}$.



28. A sphere A is of mass m and another sphere B of identical size but of mass $2m$, move towards each other with velocity $\hat{i}+2\hat{j}$ and $-\hat{i}+3\hat{j}$ respectively. They collide when their line of centres is parallel to $\hat{i}-\hat{j}$. Taking $e=\frac{1}{2}$ the velocities of A and B after impact are $\frac{1}{\alpha}(-x_1\hat{i}+y_1\hat{j})$ and $\frac{1}{\beta}(-x_2\hat{i}+y_2\hat{j})$. Find α, β, x_1, x_2, y_1 and y_2.

29. A light rope supporting four monkeys, is hanging from roof as shown in Figure.



Monkey 1 of mass 15 kg is going upwards with an acceleration 1 ms^{-2}, monkey 2 of mass 25 kg is going downwards with acceleration 3 ms^{-2}, monkey 3 of mass 20 kg is at rest and monkey 4 of mass 40 kg is moving downward with constant speed. Calculate the force exerted by ceiling on the rope in newton. Take $g = 9.8\text{ ms}^{-2}$

30. A gun is mounted on a railroad car. The mass of the car with all of its components is $80m$ and mass of each shell to be fired is $5m$. If the muzzle velocity of the shells is 100 ms^{-1} horizontally, then calculate the recoil speed of the car after second shot (in ms^{-1}). Consider car to be at rest initially.

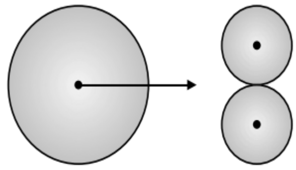
31. A 4 g bullet travelling horizontally with a velocity of magnitude 600 ms^{-1} is fired into a wooden block with a mass of 1 kg, initially at rest on a level surface. The bullet passes through the block and emerges with speed 100 ms^{-1}. The block slides a distance of 0.4 m along the surface from its initial position.

(a) The coefficient of kinetic friction between the block and surface is $\mu_k = \frac{1}{*}$, where $*$ is not readable. Find $*$.

(b) What is the decrease in kinetic energy of the bullet, in joule?

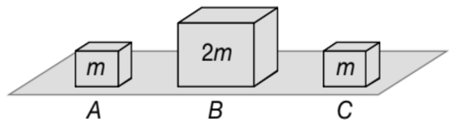
(c) What is the kinetic energy of the block, in joule, at the instant after the bullet passed through it? Neglect friction during collision of bullet with the block. Take $g = 10\text{ ms}^{-2}$.

32. Two equal discs are in contact on a table. A third disc of same mass but of double radius strikes them symmetrically and remains at rest after impact. Find the coefficient of restitution.



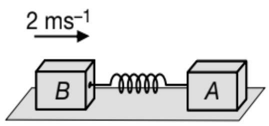
33. A space shuttle of mass M, moving at 4000 kph relative to earth ejects a capsule backward of mass $\frac{M}{5}$. If speed of ejection of capsule is 120 kmph relative to state of shuttle before ejection, find the final velocity of the shuttle in kmph.

34. Three objects A, B and C are kept in a straight line on a frictionless horizontal surface. These have masses m, $2m$ and m, respectively. The object A moves towards B with a speed 9 ms^{-1} and makes an elastic collision with it. Thereafter, B makes completely inelastic collision with C. All motions occur on the same straight line. Find the final speed (in ms^{-1}) of the object C.

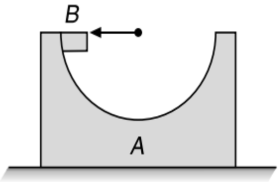


35. Two balls A and B having different but unknown masses, collide elastically. A is initially at rest when B has a speed v. After collision B as a speed $\frac{v}{2}$ and moves at right angles to its original motion.
The direction in which ball A moves after collision is $\tan^{-1}\left(\frac{1}{\alpha}\right)$. Calculate α. If the speed of A is $\sqrt{\beta}v$. Calculate β.

36. Two blocks A and B each of mass $m = 1\text{ kg}$ are lying on a smooth horizontal surface as shown in figure. A spring of force constant $k = 200\text{ Nm}^{-1}$ is fixed at one end of block A. Block B collides with block A with velocity $v_0 = 2\text{ ms}^{-1}$. Find the maximum compression, in cm, of the spring.



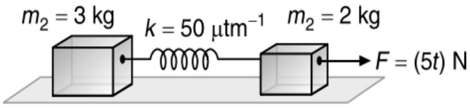
37. A block A of mass $6m$ having a smooth semi-circular groove of radius a placed on a smooth horizontal surface as shown in Figure.



A block B of mass m is released from a position in grove where its radius is horizontal. If the speed of bigger block when smaller block reaches its bottommost position is $\sqrt{\frac{ga}{*}}$ where $*$ is not readable. Calculate $*$.

38. A particle of mass m having collided a stationary particle of mass $M = 5\text{ m}$ deviated by an angle $\frac{\pi}{2}$ whereas the particle M recoiled at an angle $\theta = 30°$ to the direction of the initial motion of the particle m. Find the percentage change in kinetic energy of this system after collision.

39. On a spring block system, a time varying force $F = (5t)\text{ N}$ is applied on 2 kg mass as shown in Figure.



After 10 s, the velocity of 3 kg mass is 30 ms^{-1}. Calculate velocity of 2 kg mass at this instant in ms^{-1}.

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1. **[Online September 2020]**
A particle of mass m with an initial velocity $u\hat{i}$ collides perfectly elastically with a mass $3m$ at rest. It moves with a velocity $v\hat{j}$ after collision, then, v is given by

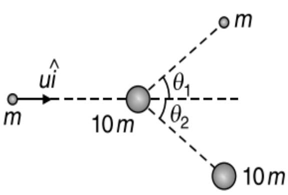
(A) $v = \sqrt{\frac{2}{3}}u$

(B) $v = \frac{1}{\sqrt{6}}u$

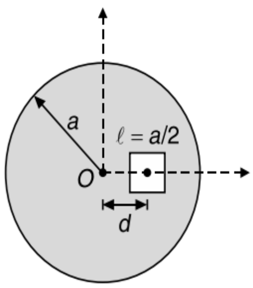
(C) $v = \frac{u}{\sqrt{3}}$

(D) $v = \frac{u}{\sqrt{2}}$

2. **[Online September 2020]**
A particle of mass m is moving long the x-axis with initial velocity $u\hat{i}$. It collides elastically with a particle of mass $10m$ at rest and then moves with half its initial kinetic energy (see figure). If $\sin\theta_1 = \sqrt{n}\sin\theta_2$ then value of n is ……



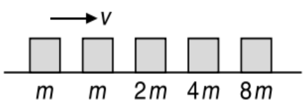
3. **[Online September 2020]**
A square shaped hole of side $l = \frac{a}{2}$ is carved out at a distance $d = \frac{a}{2}$ from the center O of a uniform circular disk of radius a. If the distance of the center of mass of the remaining portion from O is $-\frac{a}{X}$, value of X (to the nearest integer) is ……



4. **[Online September 2020]**
A block of mass 1.9 kg is at rest at the edge of a table, of height 1 m. A bullet of mass 0.1 kg collides with the block and sticks to it. If the velocity of the bullet is 20 ms^{-1} in the horizontal direction just before the collision then the kinetic energy just before the combined system strikes the floor, is [Take $g = 10\text{ ms}^{-2}$. Assume there is no rotational motion and loss of energy after the collision is negligible]

(A) 21 J (B) 23 J
(C) 19 J (D) 20 J

5. **[Online September 2020]**
Blocks of masses m, $2m$, $4m$ and $8m$ are arranged in a line on a frictionless floor. Another block of mass m, moving with speed v along the same line (see figure) collides with mass m in perfectly inelastic manner. All the subsequent collisions are also perfectly inelastic. By the time the last block of mass $8m$ starts moving the total energy loss is $p\%$ of the original energy. Value of p is close to



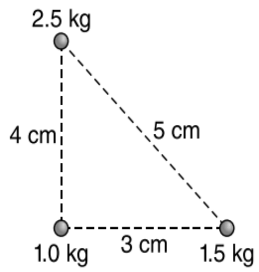
(A) 77 (B) 37
(C) 87 (D) 94

6. **[Online September 2020]**
Two bodies of the same mass are moving with the same speed, but in different directions in a plane. They have a completely inelastic collision and move together thereafter with a final speed which is half of their initial speed. The angle between the initial velocities of the two bodies (in degree) is

7. **[Online September 2020]**
Particle A of mass m_1 moving with velocity $(\sqrt{3}\hat{i}+\hat{j})\ \text{ms}^{-1}$ collides with another particle B of mass m_2 which is at rest initially. Let $\vec{V}_1$ and $\vec{V}_2$ be the velocities of particle A and B after collision respectively. If $m_1 = 2m_2$ and after collision $\vec{V}_1 = (\hat{i}+\sqrt{3}\hat{j})\ \text{ms}^{-1}$, the angle between $\vec{V}_1$ and $\vec{V}_2$ is
(A) 60° (B) 15°
(C) –45° (D) 105°

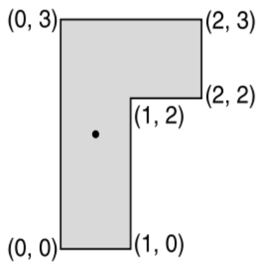
8. **[Online September 2020]**
The center of mass of a solid hemisphere of radius 8 cm is x cm from the center of the flat surface. Then value of x is ......

9. **[Online January 2020]**
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 Figure. The center of mass of the system is at a point



(A) 1.5 cm right and 1.2 cm above 1 kg mass
(B) 0.9 cm right and 2.0 cm above 1 kg mass
(C) 0.6 cm right and 2.0 cm above 1 kg mass
(D) 2.0 cm right and 0.9 cm above 1 kg mass

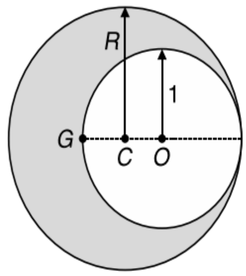
10. **[Online January 2020]**
The coordinates of center of mass of a uniform flag shaped lamina (thin flat plate) of mass 4 kg. (The coordinates of the same are shown in Figure) are



(A) (1.25 m, 1.50 m) (B) (1 m, 1.75 m)
(C) (0.75 m, 0.75 m) (D) (0.75 m, 1.75 m)

11. **[Online January 2020]**
A body A, of mass $m = 0.1$ kg has an initial velocity of $3\hat{i}\ \text{ms}^{-1}$. It collides elastically with another body, B of the same mass which has an initial velocity of $5\hat{j}\ \text{ms}^{-1}$. 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 ......

12. **[Online January 2020]**
A spherical cavity (centered at O) of radius 1 is cut out of a uniform sphere of radius R (centered at C) as shown in Figure. The center of mass of remaining (shaded) part of sphere is at G, i.e., on the surface of the cavity. R can be determined by the equation



(A) $(R^2 - R + 1)(2 - R) = 1$
(B) $(R^2 + R - 1)(2 - R) = 1$
(C) $(R^2 + R + 1)(2 - R) = 1$
(D) $(R^2 - R - 1)(2 - R) = 1$

13. **[Online January 2020]**
Two particles of equal mass m have respective initial velocities $u\hat{i}$ and $u\left(\frac{\hat{i}+\hat{j}}{2}\right)$. They collide completely inelastically. The energy lost in the process is
(A) $\frac{3}{4}mu^2$ (B) $\frac{1}{8}mu^2$
(C) $\sqrt{\frac{2}{3}}mu^2$ (D) $\frac{1}{3}mu^2$

14. **[Online January 2020]**
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 center of mass of the rod is at
(A) $\frac{4}{3}\left(\frac{a+b}{2a+3b}\right)L$ (B) $\frac{3}{2}\left(\frac{a+b}{2a+b}\right)L$
(C) $\frac{3}{2}\left(\frac{2a+b}{3a+b}\right)L$ (D) $\frac{3}{4}\left(\frac{2a+b}{3a+b}\right)L$

15. [Online January 2020]

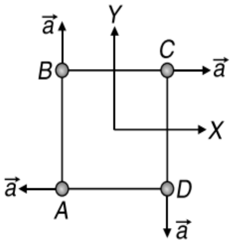
A particle of mass m is projected with a speed u from the ground at an angle $\theta = \frac{\pi}{3}$ w.r.t. horizontal (x-axis). When it has reached its maximum height, it collides completely inelastically with another particle of the same mass and velocity $u\hat{i}$. The horizontal distance covered by the combined mass before reaching the ground is

(A) $\frac{3\sqrt{2}}{4}\frac{u^2}{g}$ (B) $2\sqrt{2}\frac{u^2}{g}$

(C) $\frac{3\sqrt{3}}{8}\frac{u^2}{g}$ (D) $\frac{5}{8}\frac{u^2}{g}$

16. [Online April 2019]

Four particles A, B, C and D with masses $m_A = m$, $m_B = 2m$, $m_C = 3m$ and $m_D = 4m$ are at the corners of a square. They have accelerations of equal magnitude with directions as shown. The acceleration of the centre of mass of the particles is



(A) ZERO (B) $a(\hat{i}+\hat{j})$

(C) $\frac{a}{5}(\hat{i}+\hat{j})$ (D) $\frac{a}{5}(\hat{i}-\hat{j})$

17. [Online April 2019]

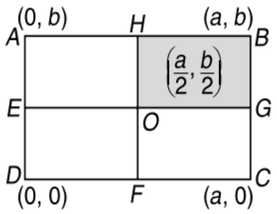
A body of mass m_1 moving with an unknown velocity of $v_1\hat{i}$, undergoes a collinear collision with a body of mass m_2 moving with a velocity $v_2\hat{i}$. After collision, m_1 and m_2 move with velocities of $v_3\hat{i}$ and $v_4\hat{i}$, respectively. If $m_2 = 0.5\ \text{m}_1$ and $v_3 = 0.5\ \text{v}_1$, then v_1 is

(A) $v_4 - \frac{v_2}{4}$ (B) $v_4 - v_2$

(C) $v_4 + v_2$ (D) $v_4 - \frac{v_2}{2}$

18. [Online April 2019]

A uniform rectangular thin sheet $ABCD$ of mass M has length a and breadth b, as shown in the figure. If the shaded portion $HBGO$ is cut-off, the coordinates of the centre of mass of the remaining portion will be



(A) $\left(\frac{2a}{3}, \frac{2b}{3}\right)$ (B) $\left(\frac{5a}{12}, \frac{5b}{12}\right)$

(C) $\left(\frac{3a}{4}, \frac{3b}{4}\right)$ (D) $\left(\frac{5a}{3}, \frac{5b}{3}\right)$

19. [Online April 2019]

A body of mass 2 kg makes an elastic collision with a second body at rest and continues to move in the original direction but with one fourth of its original speed. What is the mass of the second body?

(A) 1.5 kg (B) 1.8 kg

(C) 1.0 kg (D) 1.2 kg

20. [Online April 2019]

A wedge of mass $M = 4m$ lies on a frictionless plane. A particle of mass m approaches the wedge with speed v. There is no friction between the particle and the plane or between the particle and the wedge. The maximum height climbed by the particle on the wedge is given by

(A) $\frac{v^2}{g}$ (B) $\frac{2v^2}{5g}$

(C) $\frac{2v^2}{7g}$ (D) $\frac{v^2}{2g}$

21. [Online April 2019]

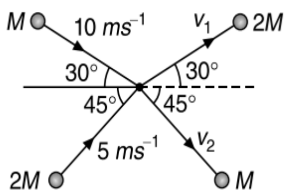
A particle of mass m is moving with speed $2v$ and collides with a mass $2m$ moving with speed v in the same direction. After collision, the first mass is stopped completely while the second one splits into two particles each of mass m, which move at angle $45°$ with respect to the original direction. The speed of each of the moving particle will be

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

(C) $\sqrt{2}v$ (D) $2\sqrt{2}v$

22. [Online April 2019]

Two particles, of masses M and $2M$, moving, as shown, with speeds of 10 ms^{-1} and 5 ms^{-1}, collide elastically at the origin. After the collision, they move along the indicated directions with speeds v_1 and v_2, respectively. The values of v_1 and v_2 are nearly



(A) 3.2 ms^{-1} and 12.6 ms^{-1}

(B) 3.2 ms^{-1} and 6.3 ms^{-1}

(C) 6.5 ms^{-1} and 3.2 ms^{-1}

(D) 6.5 ms^{-1} and 6.3 ms^{-1}

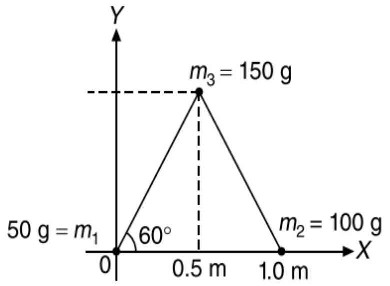
23. [Online April 2019]

A man $(\text{mass} = 50 \text{ kg})$ and his son $(\text{mass} = 20 \text{ kg})$ are standing on a frictionless surface facing each other. The man pushed his son so that he starts moving at a speed of 0.70 ms^{-1} with respect to the man. The speed of the man with respect to the surface is

(A) 0.20 ms^{-1} (B) 0.14 ms^{-1}
(C) 0.47 ms^{-1} (D) 0.28 ms^{-1}

24. [Online April 2019]

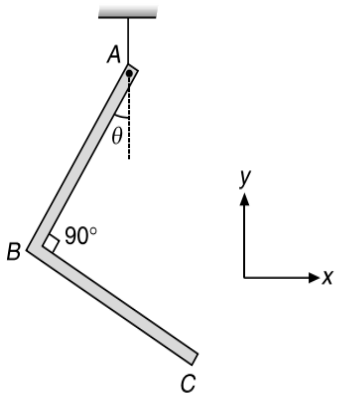
Three particles of masses, 50 g, 100 g and 150 g are placed at the vertices of an equilateral triangle of side 1 m (as shown in the figure). The (x, y) coordinates of the centre of mass will be



(A) $\left(\frac{\sqrt{3}}{8} \text{ m}, \frac{7}{12} \text{ m}\right)$ (B) $\left(\frac{\sqrt{3}}{4} \text{ m}, \frac{5}{12} \text{ m}\right)$
(C) $\left(\frac{7}{12} \text{ m}, \frac{\sqrt{3}}{8} \text{ m}\right)$ (D) $\left(\frac{7}{12} \text{ m}, \frac{\sqrt{3}}{4} \text{ m}\right)$

25. [Online January 2019]

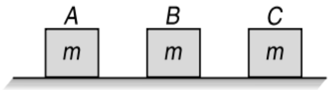
An L-shaped object, made of thin rods of uniform mass density, is suspended with a string as shown in figure. If $AB = BC$, and the angle made by AB with downward vertical is θ, then



(A) $\tan\theta = \frac{1}{2}$ (B) $\tan\theta = \frac{2}{\sqrt{3}}$
(C) $\tan\theta = \frac{1}{3}$ (D) $\tan\theta = \frac{1}{2\sqrt{3}}$

26. [Online January 2019]

Three blocks A, B and C are lying on a smooth horizontal surface, as shown in the figure. A and B have equal masses, m while C has mass M. Block A is given an initial speed v towards B due to which it collides with B perfectly inelastically. The combined mass collides with C, also perfectly inelastically $\frac{5}{6}$th of the initial kinetic energy is lost in whole process. What is value of $\frac{M}{m}$?



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

27. [Online January 2019]

A piece of wood of mass 0.03 kg is dropped from the top of a 100 m height building. At the same time, a bullet of mass 0.02 kg is fired vertically upwards, with a velocity 100 ms^{-1}, from the ground. The bullet gets embedded in the wood. Then the maximum height to which the combined system reaches above the top of the building before falling below is $(g = 10 \text{ ms}^{-2})$

(A) 30 m (B) 40 m
(C) 20 m (D) 10 m

28. [Online January 2019]

A body of mass 1 kg falls freely from a height of 100 m, on a platform of mass 3 kg which is mounted on a spring having spring constant $k = 1.25 \times 10^6 \text{ Nm}^{-1}$. The body sticks to the platform and the spring's maximum compression is found to be x. Given that $g = 10 \text{ ms}^{-2}$, the value of x will be close to

(A) 80 cm (B) 8 cm
(C) 4 cm (D) 40 cm

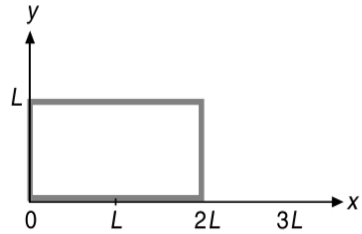
29. [Online January 2019]

A simple pendulum, made of a string of length l and a bob of mass m, is released from a small angle θ_0. It strikes a block of mass M, kept on a horizontal surface at its lowest point of oscillations, elastically. It bounces back and goes up to an angle θ_1. Then M is given by

(A) $m\left(\frac{\theta_0 + \theta_1}{\theta_0 - \theta_1}\right)$ (B) $\frac{m}{2}\left(\frac{\theta_0 - \theta_1}{\theta_0 + \theta_1}\right)$
(C) $\frac{m}{2}\left(\frac{\theta_0 + \theta_1}{\theta_0 - \theta_1}\right)$ (D) $m\left(\frac{\theta_0 - \theta_1}{\theta_0 + \theta_1}\right)$

30. [Online January 2019]

The position vector of the center of mass $\vec{r}_{cm}$ of an asymmetric uniform bar of negligible area of cross-section as shown in Figure is



(A) $\vec{r}_{cm} = \frac{5}{8}L\hat{x} + \frac{13}{8}L\hat{y}$ (B) $\vec{r}_{cm} = \frac{3}{8}L\hat{x} + \frac{11}{8}L\hat{y}$

(C) $\vec{r}_{cm} = \frac{13}{8}L\hat{x} + \frac{5}{8}L\hat{y}$ (D) $\vec{r}_{cm} = \frac{11}{8}L\hat{x} + \frac{3}{8}L\hat{y}$

31. [2018]

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

(A) $\frac{v_0}{4}$ (B) $\sqrt{2}v_0$

(C) $\frac{v_0}{2}$ (D) $\frac{v_0}{\sqrt{2}}$

32. [Online 2018]

A proton of mass m collides elastically with a particle of unknown mass at rest. After the collision, the proton and the unknown particle are seen moving at an angle of $90°$ with respect to each other. The mass of unknown particle is

(A) m (B) $2m$

(C) $\frac{m}{\sqrt{3}}$ (D) $\frac{m}{2}$

33. [Online 2017]

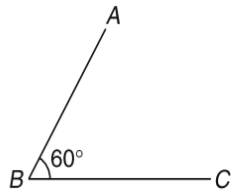
An object is dropped from a height h from the ground. Every time it hits the ground it looses 50% of its kinetic energy. The total distance covered at $t \to \infty$ is

(A) $2h$ (B) $\frac{8}{3}h$

(C) $\frac{5}{3}h$ (D) ∞

34. [Online 2016]

In the figure shown ABC is a uniform wire. If centre of mass of wire lies vertically below point A, then $\frac{BC}{AB}$ is close to



(A) 1.85 (B) 1.5

(C) 1.37 (D) 3

35. [2015]

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

(A) h (B) $\frac{3h}{4}$

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

36. [Online 2015]

A uniform thin rod AB of length L has linear mass density $\mu(x) = a + \frac{bx}{L}$, where x is measured from A. If the CM of the rod lies at a distance of $\frac{7L}{12}$ from A, then a and b are related as

(A) $a = b$ (B) $a = 2b$

(C) $2a = b$ (D) $3a = 2b$

37. [2015]

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

(A) 44% (B) 50%

(C) 56% (D) 62%

38. [2010]

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

Statement-2: Principle of conservation of momentum holds true for all kinds of collisions.

(A) Statement-1 is true, Statement-2 is false.

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

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

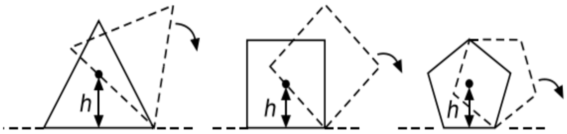
(D) Statement-1 is false, Statement-2 is true.

ARCHIVE: JEE ADVANCED

Single Correct Choice Type Problems

(In this section each question has four choices (A), (B), (C) and (D), out of which ONLY ONE is correct)

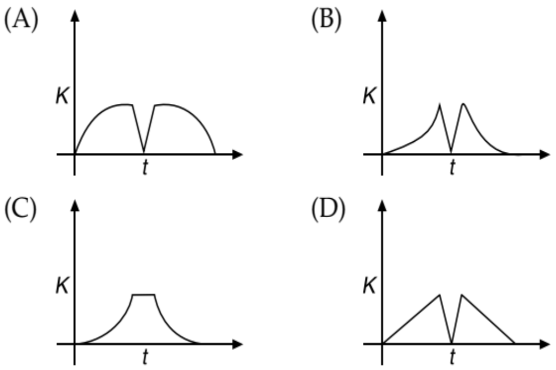
1. **[JEE (Advanced) 2017]**
Consider regular polygons with number of sides $n = 3$, 4, 5.......as shown in the figure. The centre of mass of all the polygons is at height h from the ground. They roll on a horizontal surface about the leading vertex without slipping and sliding as depicted. The maximum increase in height of the locus of the centre of mass for each polygon is Δ. Then, Δ depends on n and h as



(A) $\Delta = h\sin^2\left(\frac{\pi}{n}\right)$ (B) $\Delta = h\sin\left(\frac{2\pi}{n}\right)$

(C) $\Delta = h\tan^2\left(\frac{\pi}{2n}\right)$ (D) $\Delta = h\left(\frac{1}{\cos\left(\frac{\pi}{n}\right)} - 1\right)$

2. **[JEE (Advanced) 2014]**
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.



3. **[JEE (Advanced) 2013]**
A pulse of light of duration 100 ns is absorbed completely by a small object initially at rest. Power of the pulse is 30 mV and the speed of light is $3\times10^8\text{ ms}^{-1}$. The final momentum of the object is

(A) $0.3\times10^{-17}\text{ kgms}^{-1}$ (B) $1.0\times10^{-17}\text{ kgms}^{-1}$

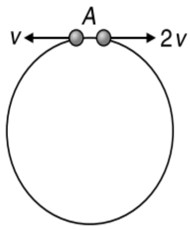
(C) $3.0\times10^{-17}\text{ kgms}^{-1}$ (D) $9.0\times10^{-17}\text{ kgms}^{-1}$

4. **[JEE (Advanced) 2013]**
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

(A) $\frac{\pi}{4}$ (B) $\frac{\pi}{4}+\alpha$

(C) $\frac{\pi}{4}-\alpha$ (D) $\frac{\pi}{2}$

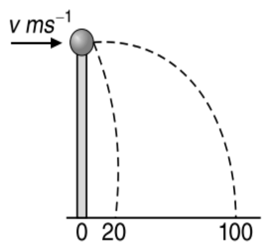
5. **[JEE (Advanced) 2009]**
Two small particles of equal masses start moving in opposite directions from a point A in a horizontal circular orbit. Their tangential velocities are v and $2v$ respectively, as shown in the figure. Between collisions, the particles move with constant speeds. After making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



(A) 4 (B) 3

(C) 2 (D) 1

6. **[IIT-JEE 2011]**
A ball of mass 0.2 kg rests on a vertical post of height 5 m. A bullet of mass 0.01 kg, travelling with a velocity $v\text{ ms}^{-1}$ 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

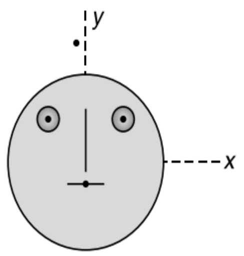


(A) 250 ms^{-1} (B) $250\sqrt{2}\text{ ms}^{-1}$

(C) 400 ms^{-1} (D) 500 ms^{-1}

7. [IIT-JEE 2009]

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



(A) $\frac{a}{10}$ (B) $\frac{a}{8}$

(C) $\frac{a}{12}$ (D) $\frac{a}{3}$

8. [IIT-JEE 2009]

If the resultant of all the external forces acting on a system of particles is zero, then from an inertial frame, one can surely say that

(A) linear momentum of the system does not change in time

(B) kinetic energy of the system does not change in time

(C) angular momentum of the system does not change in time

(D) potential energy of the system does not change in time

9. [IIT-JEE 2007]

A particle moves in the x-y plane under the influence of a force such that its linear momentum is $\vec{p}(t) = A\left[\hat{i}\cos(kt) - \hat{j}\sin(kt)\right]$, where, A and k are constants. The angle between the force the momentum is

(A) 0° (B) 30°

(C) 45° (D) 90°

10. [IIT-JEE 2002]

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

(A) 30 ms^{-1} (B) 20 ms^{-1}

(C) 10 ms^{-1} (D) 5 ms^{-1}

11. [IIT-JEE 2001]

Two particles of masses m_1 and m_2 in projectile motion have velocities v_1 and v_2 respectively at time $t = 0$. They collide at time t_0. Their velocities become $\vec{v}_1'$ and $\vec{v}_2'$ at time $2t_0$, while still moving in air. The value of $\left|(m_1\vec{v}_1' + m_2\vec{v}_2') - (m_1\vec{v}_1 + m_2\vec{v}_2)\right|$ is

(A) ZERO (B) $(m_1 + m_2)gt_0$

(C) $2(m_1 + m_2)gt_0$ (D) $\frac{1}{2}(m_1 + m_2)gt_0$

12. [IIT-JEE 1997]

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

(A) $y = -5\text{ cm}$ (B) $y = +20\text{ cm}$

(C) $y = +5\text{ cm}$ (D) $y = -20\text{ cm}$

13. [IIT-JEE 1986]

A shell is fired from a canon with a velocity v at an angle θ with the horizontal. At the highest point it explodes into two pieces of equal masses. One of the pieces retraces its path to the canon. 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) $v\cos\theta$

14. [IIT-JEE 1986]

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

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

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

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

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

15. [IIT-JEE 1982]

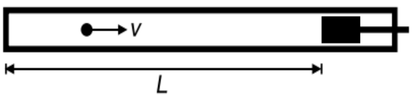
Two particles A and B, initially at rest, move towards each other under a mutual force of attraction. At the instant when the speed of A is V and the speed of B is $2V$, the speed of the centre of mass of the system is

(A) ZERO (B) V
(C) $1.5V$ (D) $3V$

Multiple Correct Choice Type Problems

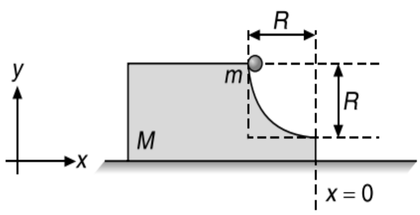
(In this section each question has four choices (A), (B), (C) and (D), out of which ONE OR MORE is/are correct)

1. [JEE (Advanced) 2019]
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 $V \ll \frac{dL}{L} v_0$, where dL is the infinitesimal displacement of the piston. Which of the following statement(s) is/are correct?



(A) If the piston moves inward by dL, the particle speed increases by $2v\frac{dL}{L}$
(B) The particle's kinetic energy increases by a factor of 4 when the piston is moved inward from L_0 to $\frac{1}{2}L_0$
(C) After each collision with the piston, the particle speed increases by $2V$
(D) The rate at which the particle strikes the piston $\frac{v}{L}$

2. [JEE (Advanced) 2017]
A block of mass M has a circular cut with a frictionless surface as shown. The block rests on the horizontal frictionless surfaced 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 it slides down. When the mass loses contact with the block, its position is x and the velocity is v. At that instant, which of the following option is/are correct?

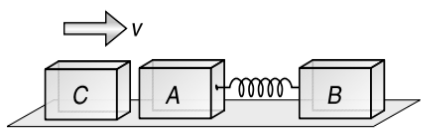


(A) The velocity of the point mass m is $v = \sqrt{\dfrac{2gR}{1+\dfrac{m}{M}}}$
(B) The x component of displacement of the centre of mass of the block M is $-\dfrac{mR}{M+m}$
(C) The position of the point mass is $x = -\sqrt{2}\dfrac{mR}{M+m}$
(D) The velocity of the block M is $V = -\dfrac{m}{M}\sqrt{2gR}$

3. [IIT-JEE 2010]
A point mass of 1 kg 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?
(A) Total momentum of the system is 3 kgms^{-1}
(B) Momentum of 5 kg mass after collision is 4 kgms^{-1}
(C) Kinetic energy of the centre of mass is 0.75 J
(D) Total kinetic energy of the system is 4 J

4. [IIT-JEE 2008]
Two balls, having linear momenta $\vec{p}_1 = p\hat{i}$ and $\vec{p}_2 = -p\hat{i}$, undergo a collision in free space. There is no external force acting on the balls. Let $\vec{p}_1'$ and $\vec{p}_2'$ be their final momenta. The following option figure(s) is (are) not allowed for any non-zero value of p, a_1, a_2, b_1, b_2, c_1 and c_2.
(A) $\vec{p}_1' = a_1\hat{i} + b_1\hat{j} + c_1\hat{k}$, $\vec{p}_2' = a_2\hat{i} + b_2\hat{j}$
(B) $\vec{p}_1' = c_1\hat{k}$, $\vec{p}_2' = c_2\hat{k}$
(C) $\vec{p}_1' = a_1\hat{i} + b_1\hat{j} + c_1\hat{k}$, $\vec{p}_2' = a_2\hat{i} + b_2\hat{j} - c_1\hat{k}$
(D) $\vec{p}_1' = a_1\hat{i} + b_1\hat{j}$, $\vec{p}_2' = a_2\hat{i} + b_1\hat{j}$

5. [IIT-JEE 1993]
Two blocks A and B each of mass m are connected by a massless spring of natural length L and spring constant k. The blocks are initially resting on a smooth horizontal floor with the spring at its natural length, as shown in figure. A third identical block C, also of mass m, moves on the floor with a speed v along the line joining A to B and collides with A. Then



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

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

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

Reasoning Based Questions

This section contains Reasoning type questions, each having four choices (A), (B), (C) and (D) out of which ONLY ONE is correct. Each question contains STATEMENT 1 and STATEMENT 2. You have to mark your answer as

Bubble (A) If both statements are TRUE and STATEMENT 2 is the correct explanation of STATEMENT 1.

Bubble (B) If both statements are TRUE but STATEMENT 2 is not the correct explanation of STATEMENT 1.

Bubble (C) If STATEMENT 1 is TRUE and STATEMENT 2 is FALSE.

Bubble (D) If STATEMENT 1 is FALSE but STATEMENT 2 is TRUE.

1. [IIT-JEE 2007]

Statement-1: If there is no external torque on a body about its centre of mass, then the velocity of the centre of mass remains constant.

Statement-2: The linear momentum of an isolated system remains constant.

2. [IIT-JEE 2007]

Statement-1: In an elastic collision between two bodies, the relative speed of the bodies after collision is equal to the relative speed before the collision.

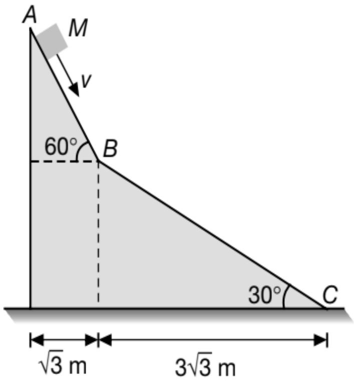
Statement-2: In an elastic collision, the linear momentum of the system is conserved.

Linked Comprehension Type Questions

This section contains Linked Comprehension Type Questions or Paragraph based Questions. Each set consists of a Paragraph followed by questions. Each question has four choices (A), (B), (C) and (D), out of which only one is correct. (For the sake of competitiveness there may be a few questions that may have more than one correct options)

Comprehension

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



1. [IIT-JEE 2008]

The speed of the block at point B immediately after it strikes the second incline is

(A) $\sqrt{60}\ \text{ms}^{-1}$ (B) $\sqrt{45}\ \text{ms}^{-1}$
(C) $\sqrt{30}\ \text{ms}^{-1}$ (D) $\sqrt{15}\ \text{ms}^{-1}$

2. [IIT-JEE 2008]

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

(A) $\sqrt{120}\ \text{ms}^{-1}$ (B) $\sqrt{105}\ \text{ms}^{-1}$
(C) $\sqrt{90}\ \text{ms}^{-1}$ (D) $\sqrt{75}\ \text{ms}^{-1}$

3. [IIT-JEE 2008]

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

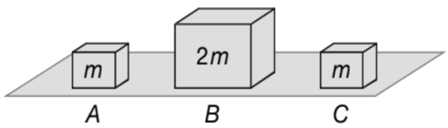
(A) $\sqrt{30}\ \text{ms}^{-1}$ (B) $\sqrt{15}\ \text{ms}^{-1}$
(C) 0 (D) $-\sqrt{15}\ \text{ms}^{-1}$

Integer/Numerical Answer Type Questions

In this section, the answer to each question is a numerical value obtained after series of calculations based on the data provided in the question(s).

1. [IIT-JEE 2009]

Three objects A, B and C are kept in a straight line on a frictionless horizontal surface. These have masses m, $2m$ and m, respectively. The object A moves towards B with a speed $9\ \text{ms}^{-1}$ and makes an elastic collision with it. Thereafter, B makes completely inelastic collision with C. All motions occur on the same straight line. Find the final speed (in ms^{-1}) of the object C.



ANSWER KEYS–TEST YOUR CONCEPTS AND PRACTICE EXERCISES

Test Your Concepts-I (Based on Centre of Mass)

1. $\dfrac{m_1\ell_1+m_2\ell_2}{m_1+m_2}$
2. $\dfrac{m_2x}{m_1}$
3. $\dfrac{1}{2}\left(3\hat{i}+\hat{j}-\hat{k}\right)$ m
4. $\dfrac{6R}{\pi}$
5. $\left(-\dfrac{a}{12},-\dfrac{b}{12}\right)$
6. $\left(\dfrac{2r}{3(4-\pi)},0\right)$
7. 2 kg
8. $\dfrac{(\rho_1+3\rho_2)L}{4(\rho_1+\rho_2)}$
9. $\left[\dfrac{l}{2}\left(\dfrac{4+\sqrt{3}+3\pi}{4+\sqrt{3}+\pi}\right),\dfrac{l}{2}\left(\dfrac{5+2\sqrt{3}+\pi}{4+\sqrt{3}+\pi}\right)\right]$
10. $\dfrac{3\ell}{4}$
11. $\left(\dfrac{L}{8},\dfrac{5L}{8}\right)$
12. $\dfrac{\pi a}{\pi+4}$
13. $\dfrac{R}{2(2\pi-1)}$
14. $\left(\dfrac{\lambda_1+2\lambda_2}{\lambda_1+\lambda_2}\right)\dfrac{L}{3}$

Test Your Concepts-II (Based on Motion of Centre of Mass)

1. $\dfrac{m_1L}{2(m_1+m_2)}$
2. $\sqrt{31}$ ms^{-2}
3. 5 m
4. 45 m, 10 ms^{-1}
5. 13.6 m
6. $l/12$
7. $5l/28$
8. (a) $\left(1.5\hat{i}+2\hat{j}\right)$ ms^{-1}, (b) $\left(-3\hat{i}+4\hat{j}\right)$ m
9. $\dfrac{mR\sin\theta}{m+M}$
10. 1.25 ms^{-1}
11. (a) 0, (b) not accelerate, (c) yes, upwards (d) $\dfrac{ml}{2M}$, upwards
12. (a) 0.3 kg, (b) $2.4\hat{j}$ kgms^{-1}, (c) $8\hat{j}$ ms^{-1}
13. $\dfrac{ML}{m+M}$
14. (a) 40 cm, (b) 2.67 ms^{-1}
15. $\dfrac{ml}{M+m}$
16. $\dfrac{(m_1+m_2)x_1-m_2l}{m_1+m_2+m_0}$
17. $-1.5\hat{i}+2\hat{j}$ ms^{-1}, $\left(-3\hat{i}+4\hat{j}\right)$ m
18. $\dfrac{2nv\cos\left(\dfrac{\theta}{2}\right)}{1+n}$

Test Your Concepts-III (Based on Work Energy Theorem for System of Particles and its Applications from Centre of Mass Reference Frame)

1. 10 J
2. $\sqrt{2gR\left(\dfrac{2}{\pi}+\dfrac{\pi}{2}\right)}$
3. $3v_0^2/g$
4. $2\sqrt{\dfrac{3m}{k}}v_0$
5. $x\sqrt{\dfrac{k}{2m}}$
6. $\dfrac{2(m_1F_2+m_2F_1)}{k(m_1+m_2)}$
7. $-\dfrac{3}{8}mv_0^2$
8. $mgl/18$
9. $2v_0\sqrt{\dfrac{m}{k}}$

Test Your Concepts-IV (Based on Conservation of Linear Momentum)

1. $\dfrac{m_1 v_r}{m_1+m_2}$
2. $\dfrac{mu}{m+M}$
3. $R\sqrt{\dfrac{2(M+m)}{M}}$
4. $\sqrt{2gh}\tan\theta, m\sqrt{2gh}\sec\theta, mgh(1-\tan^2\theta)$
5. 2.55 ms^{-1}, 24.1 ms^{-1}
6. $\dfrac{5}{3}v_0\cos\theta_0$, along x direction
7. $2m\sin\left(\dfrac{\alpha}{2}\right)\sqrt{\dfrac{g\ell}{(M+m)M}}$
8. (a) $v'=\dfrac{u}{2}$ and $\int Tdt=\dfrac{mu}{2}$ (b) $v'=\dfrac{u\sqrt{13}}{8}$ and $\int Tdt=\dfrac{mu\sqrt{13}}{8}$ (c) $v'=\dfrac{u\sqrt{3}}{4}$ and $\int Tdt=\dfrac{mu\sqrt{3}}{4}$
9. $\dfrac{mv}{m+M}$
10. $\dfrac{v}{2}$
11. (a) $\dfrac{2mu}{M+2m}$, (b) $\dfrac{mu}{M+2m}+\dfrac{mu}{M+m}$
12. $\dfrac{2k^2+2k+1}{k}$
13. $\sqrt{\dfrac{2MgR}{M+m}}$
14. $mv_0\cos\theta, \dfrac{mv_0\sin\theta}{M}$
15. $\dfrac{2m}{M-m}\sqrt{\dfrac{2h}{g}}, \dfrac{Mmgh}{M+m}$
16. $mv_0\operatorname{cosec}\theta, mv_0\cot\theta, v_0\cot\theta, \dfrac{mv_0}{M}, \mu mv_0\cot\theta$
17. 1.5 ms^{-1}, 0.1 m
18. $\dfrac{Mu^2}{2g(M+m)}$

Test Your Concepts-V (Based on Variable Mass Systems)

1. $\dfrac{F}{m_0-\mu t}, \dfrac{F}{\mu}\log_e\left(\dfrac{m_0}{m_0-\mu t}\right)$
2. $\rho A(v+u)^2$
3. (a) (i) 2.5 kgs^{-1}, (ii) 7.5 kgs^{-1} (b) 4.156 kms^{-1}
4. $\dfrac{(m_1-m_0+bt)g+bv_0}{m_0+m_1-bt}$
5. $\lambda v^2+\lambda g(h-y)$
6. $\dfrac{M}{k}-\dfrac{v_0}{g}$
7. $m_0 e^{-\left(\frac{a}{u}\right)t}$
8. $\dfrac{F}{m_0-\mu t}, \dfrac{F}{\mu}\ln\left(\dfrac{m_0}{m_0-\mu t}\right)$
9. $\left(\dfrac{2M_0 g+\mu v_0}{\mu}\right)\log_e\left(\dfrac{2M_0}{2M_0-\mu t}\right)+gt$

Test Your Concepts-VI (Based on Head-On Collisions)

1. $\dfrac{1}{\sqrt{2}}$
2. **64 J**
3. 4 ms^{-1}
4. $0.23d$
5. $v_1=0$ and $v_2=6$ ms^{-1}
6. $\dfrac{\sqrt{2\mu gd}-\sqrt{v_0^2-2\mu gd}}{2}$
7. $\left(\dfrac{1+e}{2}\right)^{n-1}u$
8. $9h$
9. $\sqrt{m_1 m_3}$
10. $\dfrac{m_2 g}{k}\left(\dfrac{m_2+2m_1}{2m_1}\right)$
11. $-2v$, $-v$
12. $x\sqrt{\dfrac{kM}{m(M+m)}}, x\sqrt{\dfrac{km}{M(M+m)}}$

Test Your Concepts-VII (Based on Oblique Collisions)

1. $\dfrac{H^5}{L^4}$
2. $-\dfrac{3}{2}\hat{i}+\hat{j}, \dfrac{27m}{8}, -\left(\dfrac{9m}{2}\right)\hat{i}$
3. $\dfrac{mv_0\cos\theta}{M+m}, \dfrac{mv_0^2}{2}\left(\dfrac{M+m\sin^2\theta}{M+m}\right)$

4. $m\left(-3\hat{i}+4\hat{j}\right)$, $\frac{9}{16}$

5. $\sqrt{u^2+v^2}$

6. $\left[\frac{(1+e)m\sin\theta}{M+m\sin^2\theta}\right]v_0$, $\left(\frac{m\sin^2\theta-Me}{M+m\sin^2\theta}\right)v_0$

7. eL_1

8. $v\cong 8\text{ ms}^{-1}$

9. $e=0$, $e=\tan^2\theta=\tan^2\frac{\pi}{6}=\frac{1}{3}$

10. (a) e^2h_1, (b) e^2h_1

11. $\frac{1}{\left(\frac{u^2\sin(2\alpha)}{ag}-1\right)}$

Single Correct Choice Type Questions

1. B	2. A	3. C	4. B	5. B	6. b	7. D	8. A	9. B	10. B
11. C	12. D	13. A	14. A	15. C	16. B	17. B	18. A	19. C	20. B
21. C	22. C	23. B	24. B	25. D	26. B	27. D	28. A	29. B	30. A
31. C	32. B	33. B	34. C	35. D	36. D	37. B	38. C	39. D	40. A
41. C	42. C	43. C	44. A	45. D	46. A	47. D	48. A	49. C	50. C
51. B	52. C	53. A	54. D	55. D	56. A	57. C	58. C	59. D	60. D
61. C	62. D	63. B	64. C	65. C	66. D	67. A	68. B	69. D	70. C
71. B	72. B	73. A	74. D	75. B	76. D	77. A	78. B	79. C	80. B
81. C	82. B	83. B	84. D	85. D	86. B	87. C	88. C	89. B	90. C
91. A	92. A	93. D	94. B	95. A	96. A	97. B	98. C	99. D	100. C
101. C	102. C	103. C	104. C	105. A	106. B	107. D	108. C	109. C	110. D
111. C	112. C	113. D	114. A	115. D	116. B	117. C	118. D	119. C	120. D
121. A	122. D	123. B	124. C	125. B	126. C	127. B	128. A		

Multiple Correct Choice Type Questions

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

Reasoning Based Questions

1. A	2. D	3. A	4. C	5. D	6. D	7. C	8. D	9. C	10. A

Linked Comprehension Type Questions

1. B	2. A	3. B	4. B	5. C	6. C	7. D	8. D	9. B	10. A
11. C	12. D	13. C	14. B	15. A	16. D	17. C	18. D	19. C	20. C

21. B	**22.** C	**23.** D	**24.** C	**25.** B	**26.** C	**27.** D	**28.** C	**29.** C	**30.** B
31. D	**32.** C	**33.** D	**34.** C	**35.** C	**36.** B, D	**37.** A	**38.** C	**39.** C	**40.** C
41. B	**42.** B	**43.** C	**44.** C	**45.** B	**46.** B	**47.** B	**48.** C	**49.** D	**50.** C
51. B	**52.** C	**53.** A	**54.** B	**55.** D	**56.** D	**57.** C	**58.** A	**59.** C	**60.** C
61. D	**62.** B								

Matrix Match/Column Match Type Questions

1. A → (p)	B → (r)	C → (s)	D → (r)
2. A → (p)	B → (p,	C → (q)	D → (r)
3. A → (q)	B → (q)	C → (p)	D → (s)
4. A → (q)	B → (s)	C → (r)	D → (p)
5. A → (p, r, s)	B → (p, r, s)	C → (p)	D → (p, q)
6. A → (r)	B → (p)	C → (q)	D → (s)
7. A → (r)	B → (q)	C → (s)	D → (p)
8. A → (q)	B → (r)	C → (p)	D → (p)
9. A → (p, r)	B → (p, r)	C → (q)	D → (q)
10. A → (q)	B → (p, r)	C → (p, r)	D → (r, s)
11. A → (s)	B → (p)	C → (p)	D → (r)
12. A → (s)	B → (s)	C → (p, q, r)	D → (p, q, r)
13. A → (r)	B → (s)	C → (p)	D → (q)
14. A → (q)	B → (q)	C → (q)	D → (p)
15. A → (r)	B → (r, s)	C → (p, q)	D → (p)
16. A → (q)	B → (p)	C → (r)	D → (r)
17. A → (q, r)	B → (q, r)	C → (p, s)	D → (p)
18. A → (r)	B → (r)	C → (q)	D → (p)
19. A → (q)	B → (s)	C → (p)	D → (r)

Integer/Numerical Answer Type Questions

1. 6	**2.** 70	**3.** 10	**4.** 0.75	**5.** 4
6. 35	**7.** 45	**8.** (a) 2, (b) 24, (c) 72	**9.** 30	**10.** 40
11. 2, 8	**12.** 10	**13.** 100	**14.** 5	**15.** 2
16. 2	**17.** 4, 5	**18.** 11	**19.** 16	**20.** 1, 4
21. 4	**22.** 450	**23.** 6	**24.** 13	**25.** 8
26. 2	**27.** 180	**28.** 2, 4, 1, 1, 7, 9	**29.** 920	**30.** 13
31. (a) 2, (b) 700, (c) 2	**32.** 0.56	**33.** 4030	**34.** 4	**35.** 2, 0.45
36. 10	**37.** 21	**38.** 40	**39.** 80	

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1. D	**2.** 10.00	**3.** 23.00	**4.** A	**5.** D	**6.** 120.00	**7.** D	**8.** 3	**9.** B	**10.** D
11. 1.00	**12.** C	**13.** B	**14.** D	**15.** C	**16.** D	**17.** B	**18.** B	**19.** D	**20.** B
21. D	**22.** D	**23.** A	**24.** D	**25.** C	**26.** B	**27.** B	**28.** *	**29.** A	**30.** C
31. B	**32.** A	**33.** *	**34.** C	**35.** B	**36.** C	**37.** C	**38.** B		

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Single Correct Choice Type Problems

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

Multiple Correct Choice Type Problems

1. B, C	**2.** A, B	**3.** A, C	**4.** A, D	**5.** B, D

Reasoning Based Questions

1. D	**2.** D

Linked Comprehension Type Questions

1. B	**2.** B	**3.** C

* No given option is correct.