COM, Collision and Rotational dynamics

1. Three point particles of mass 1 kg, 1.5 kg and 2.5 kg are placed at three corners of a right triangle of sides 4.0 cm, 3.0 cm and 5.0 cm as shown in the figure. The centre of mass of the system is at the point:

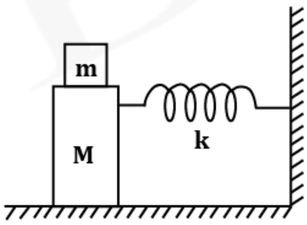
   A. 0.9 cm right and 2.0 cm above 1 kg mass

   B. 2.0 cm right and 0.9 cm above 1 kg mass

   C. 1.5 cm right and 1.2 cm above 1 kg mass

   D. 0.6 cm right and 2.0 cm above 1 kg mass

2. In the given figure, a mass M is attached to a horizontal spring, which is fixed on one side to a rigid support. The spring constant of the spring is k. The mass oscillates on a frictionless surface with time period T and amplitude A. When the mass is in equilibrium position, as shown in the figure, another mass m is gently fixed upon it then the new amplitude of oscillation will be :



   A. $A\sqrt{\dfrac{M}{M+m}}$

   B. $A\sqrt{\dfrac{M}{M-m}}$

   C. $A\sqrt{\dfrac{M-m}{M}}$

   D. $A\sqrt{\dfrac{M+m}{M}}$

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3. Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R.

Assertion A: Body P having mass M moving with speed u has head-on collision elastically with another body Q having mass m initially at rest. If $m << M$, body Q will have a maximum speed equal to $2u$ after collision.

Reason R : During elastic collision, the momentum and kinetic energy are both conserved.

In the light of the above statements, choose the most appropriate answer from the options given below:

A. A is correct but R is not correct.

B. Both A and R are correct but R is NOT the correct explanation of A.

C. A is not correct but R is correct.

D. Both A and R are correct and R is the correct explanation of A.

4. A rubber ball is released from a height of $5\ \mathrm{m}$ above the floor. It bounces back repeatedly, always rising to $\frac{81}{100}$ of the height through which it falls. Find the average speed of the ball.
(Take $g = 10\ \mathrm{m\ s^{-2}}$)

A. $2.50\ \mathrm{m\ s^{-1}}$

B. $3.50\ \mathrm{m\ s^{-1}}$

C. $3.0\ \mathrm{m\ s^{-1}}$

D. $2.0\ \mathrm{m\ s^{-1}}$

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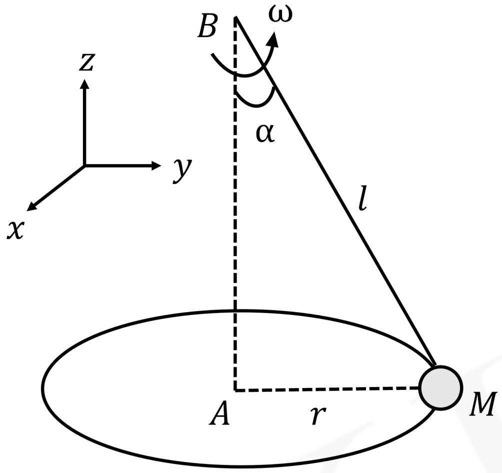
5. A mass M hangs on a massless rod of length l which rotates at a constant angular frequency. The mass M moves with steady speed in a circular path of constant radius. Assume that the system is in steady circular motion with constant angular velocity ω. The angular momentum of M about point A is L_A which lies in the positive $z-$direction and the angular momentum of M about point B is L_B. The correct statement for this system is :



A. L_A and L_B are both constant in magnitude and direction.

B. L_B is constant, both in magnitude and direction.

C. L_A is constant, both in magnitude and direction.

D. L_A is constant in direction with varying magnitude.

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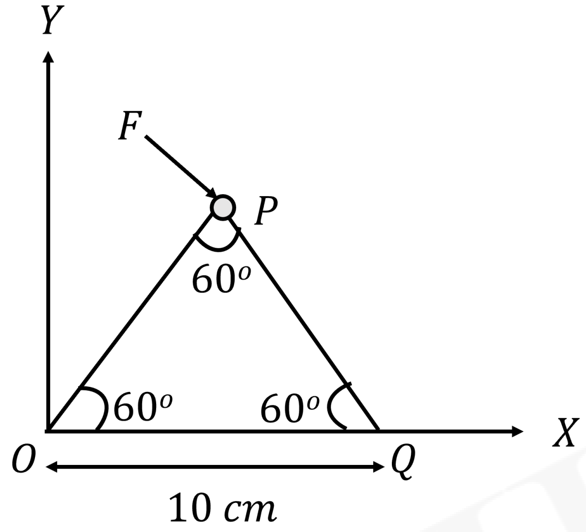
6. A triangular plate is shown in the figure. A force $\overrightarrow{F} = 4\hat{i} - 3\hat{j}$ is applied at point P. The torque acting at point P with respect to point O and point Q respectively are :



A. $15 - 20\sqrt{3}\ ;\ 15 + 20\sqrt{3}$

B. $15 + 20\sqrt{3}\ ;\ 15 - 20\sqrt{3}$

C. $-15 + 20\sqrt{3}\ ;\ 15 + 20\sqrt{3}$

D. $-15 - 20\sqrt{3}\ ;\ 15 - 20\sqrt{3}$

7. A thin circular ring of mass M and radius r is rotating about its axis with an angular speed ω. Two particles having mass m each are now attached at diametrically opposite points. The angular speed of the ring will become:

A. $\omega \frac{M}{M+2m}$

B. $\omega \frac{M}{M+m}$

C. $\omega \frac{M+2m}{M}$

D. $\omega \frac{M-2m}{M+2m}$

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8. An object of mass m_1 collides elastically with another object of mass m_2, which is at rest. After the collision, the objects move with equal speeds in opposite directions. The ratio of the masses, $m_2 : m_1$ is -

   A. $2 : 1$

   B. $1 : 1$

   C. $1 : 2$

   D. $3 : 1$

9. A uniform sphere of mass $500\ \mathrm{g}$ rolls without slipping on a plane horizontal surface with its centre moving at a speed of $5.00\ \mathrm{cm/s}$. Its kinetic energy is

   A. $8.75 \times 10^{-4}\ \mathrm{J}$

   B. $8.75 \times 10^{-3}\ \mathrm{J}$

   C. $6.25 \times 10^{-4}\ \mathrm{J}$

   D. $1.13 \times 10^{-3}\ \mathrm{J}$

10. A particle of mass m is dropped from a height h above the ground. At the same time another particle of the same mass is thrown vertically upwards from the ground with a speed of $\sqrt{2\,gh}$. If they collide head-on completely inelastically, the time taken for the combined mass to reach the ground, in units of $\sqrt{\frac{h}{g}}$ is

    A. $\sqrt{\frac{1}{2}}$

    B. $\sqrt{\frac{3}{4}}$

    C. $\frac{1}{2}$

    D. $\sqrt{\frac{3}{2}}$

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11. Mass per unit area of a circular disc of radius $'a'$ depends on the distance r from its centre, as $\sigma(r) = A + Br$. The moment of inertia of the disc about the axis, perpendicular to the plane and passing through its centre, is:

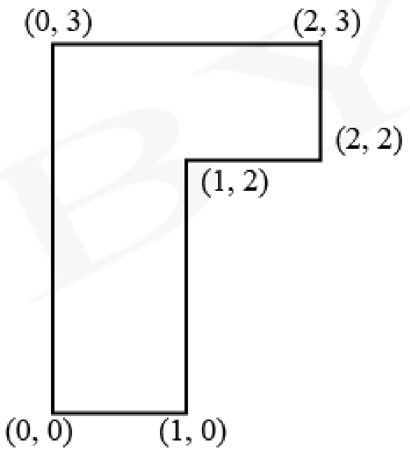
A. $2\pi a^4\left(\frac{A}{4}+\frac{aB}{5}\right)$

B. $2\pi a^4\left(\frac{aA}{4}+\frac{B}{5}\right)$

C. $\pi a^4\left(\frac{A}{4}+\frac{aB}{5}\right)$

D. $2\pi a^4\left(\frac{A}{4}+\frac{B}{5}\right)$

12. The coordinates of centre of mass of a uniform flag shaped lamina (thin flat plate) of mass $4\ \mathrm{kg}$. (The coordinates of the same are shown in figure) are:



A. $1.25\ \mathrm{m}, 1.50\ \mathrm{m}$

B. $0.75\ \mathrm{m}, 1.75\ \mathrm{m}$

C. $0.75\ \mathrm{m}, 0.75\ \mathrm{m}$

D. $1\ \mathrm{m}, 1.75\ \mathrm{m}$

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13. Consider a uniform rod of mass $M = 4m$ and length L pivoted about its centre. A mass m moving with a velocity V making an angle $\theta = \frac{\pi}{4}$ to the rod's long axis collides with one end of the rod, and sticks to it. The angular speed of the rod-mass system just after the collision is:

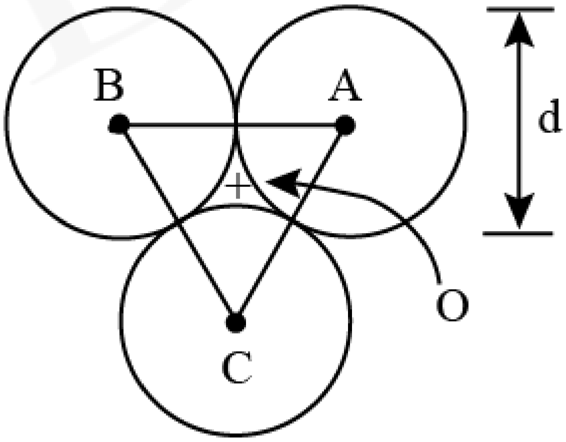
A. $\frac{3}{7\sqrt{2}}\frac{V}{L}$

B. $\frac{3}{7}\frac{V}{L}$

C. $\frac{3\sqrt{2}}{7}\frac{V}{L}$

D. $\frac{4}{7}\frac{V}{L}$

14. Three solid spheres each of mass m and diameter d are stuck together such that the lines connecting the centres form an equilateral triangle of side of length d. The ratio $\frac{I_0}{I_A}$ of moment of inertia I_0 of the system about an axis passing the centroid and about centre of any of the spheres I_A and perpendicular to the plane of the triangle, is:



A. $\frac{13}{23}$

B. $\frac{15}{13}$

C. $\frac{23}{13}$

D. $\frac{13}{15}$

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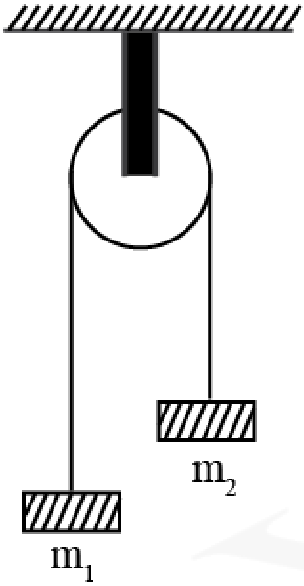
15. A uniformly thick wheel, with moment of inertia I and radius R, is free to rotate about its centre of mass (see fig.). A massless string is wrapped over its rim and two blocks of masses m_1 and $m_2 > m_2$ are attached to the ends of the string. The system is released from rest. The angular speed of the wheel, when m_1 descents through a distance h, is



A. $\left[\dfrac{2(m_1 - m_2)gh}{(m_1 + m_2)R^2 + I}\right]^{1/2}$

B. $\left[\dfrac{2(m_1 + m_2)gh}{(m_1 + m_2)R^2 + I}\right]^{1/2}$

C. $\left[\dfrac{(m_1 - m_2)}{(m_1 + m_2)R^2 + I}\right]^{1/2} gh$

D. $\left[\dfrac{(m_1 + m_2)}{(m_1 + m_2)R^2 + I}\right]^{1/2} gh$

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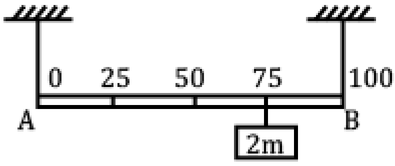
16. 

Shown in the figure is a rigid and uniform one meter long rod AB held in horizontal position by two strings tied to its ends and attached to the ceiling. The rod is of mass m and has another weight of mass $2m$ hung at a distance of $75\ \mathrm{cm}$ from A. The tension in the string at A is :

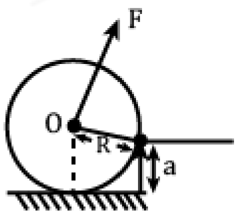
A. $0.5mg$

B. $2mg$

C. $0.75mg$

D. $1mg$

17. A uniform cylinder of mass M and radius R is to be pulled over a step of height a $(a < R)$ by applying a force F at its centre O perpendicular to the plane through the axes of the cylinder on the edge of the step (see figure). The minimum value of F required is :



A. $Mg\sqrt{1-\left(\frac{R-a}{R}\right)^2}$

B. $Mg\sqrt{\left(\frac{R}{R-a}\right)^2-1}$

C. $Mg\frac{a}{R}$

D. $Mg\sqrt{1-\frac{a^2}{R^2}}$

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18. Moment of inertia of a cylinder of mass M, length L and radius R about an axis passing through its centre and perpendicular to the axis of the cylinder is $I = M\left(\frac{R^2}{4} + \frac{L^2}{12}\right)$. If such a cylinder to be made for a given mass of a material, the ratio $\frac{L}{R}$ for it to have minimum possible I is-

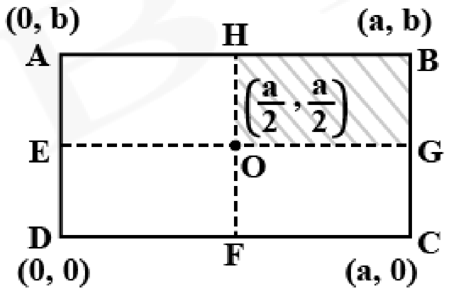
A. $\frac{2}{3}$

B. $\frac{3}{2}$

C. $\sqrt{\frac{3}{2}}$

D. $\sqrt{\frac{2}{3}}$

19. 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. $\left(\frac{3a}{4}, \frac{3b}{4}\right)$

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

C. $\left(\frac{2a}{3}, \frac{2b}{3}\right)$

D. $\left(\frac{5a}{12}, \frac{5b}{12}\right)$

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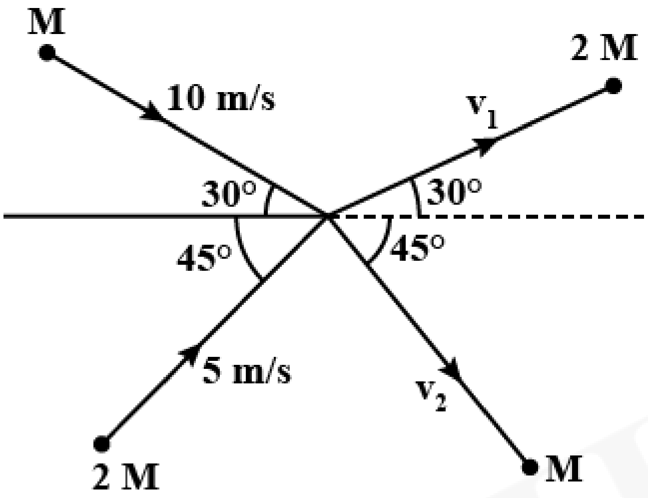
20. Two particles, of masses M and $2M$, moving, as shown, with speeds of $10 \mathrm{~m/s}$ and $5 \mathrm{~m/s}$, collide elastically at the origin. After the collision, they move along the indicated directions with speeds v_1 and v_2, respectively. The values of v_1 and v_2 are nearly



A. $6.5 \mathrm{~m/s}$ and $6.3 \mathrm{~m/s}$

B. $3.2 \mathrm{~m/s}$ and $6.3 \mathrm{~m/s}$

C. $6.5 \mathrm{~m/s}$ and $3.2 \mathrm{~m/s}$

D. $3.2 \mathrm{~m/s}$ and $12.6 \mathrm{~m/s}$

21. A piece of wood of mass $0.03 \mathrm{~kg}$ is dropped from the top of a $100 \mathrm{~m}$ height building. At the same time, a bullet of mass $0.02 \mathrm{~kg}$ is fired vertically upward, with a velocity $100 \mathrm{~ms}^{-1}$, 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: $(g=10 \mathrm{~ms}^{-2})$

A. $20 \mathrm{~m}$

B. $30 \mathrm{~m}$

C. $40 \mathrm{~m}$

D. $10 \mathrm{~m}$

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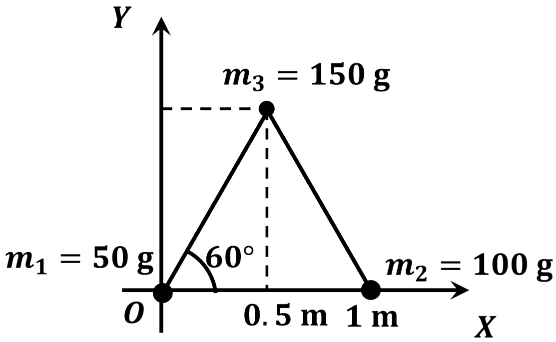
22. Three particles of masses $50 \mathrm{~g}, 100 \mathrm{~g}$ and $150 \mathrm{~g}$ are placed at the vertices of an equilateral triangle of side $1 \mathrm{~m}$ (asshown in the figure). The (x, y) coordinates of the centre of mass will be :



A. $\left(\frac{\sqrt{3}}{4} \mathrm{~m}, \frac{5}{12} \mathrm{~m}\right)$

B. $\left(\frac{7}{12} \mathrm{~m}, \frac{\sqrt{3}}{8} \mathrm{~m}\right)$

C. $\left(\frac{7}{12} \mathrm{~m}, \frac{\sqrt{3}}{4} \mathrm{~m}\right)$

D. $\left(\frac{\sqrt{3}}{8} \mathrm{~m}, \frac{7}{12} \mathrm{~m}\right)$

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

A. $a=2 b$

B. $2 a=b$

C. $a=b$

D. $3 a=2 b$

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24. A boy of mass $20 \mathrm{~kg}$ is standing on a $80 \mathrm{~kg}$ free to move long cart. There is negligible friction between cart and ground. Initially, the boy is standing $25 \mathrm{~m}$ from a wall. If he walks $10 \mathrm{~m}$ on the cart towards the wall, then the final distance of the boy from the wall will be

A. $15 \mathrm{~m}$

B. $12.5 \mathrm{~m}$

C. $15.5 \mathrm{~m}$

D. $17 \mathrm{~m}$

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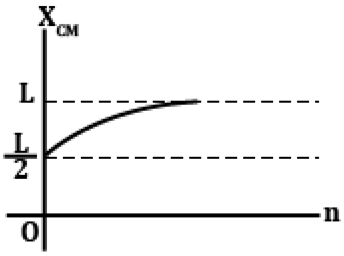
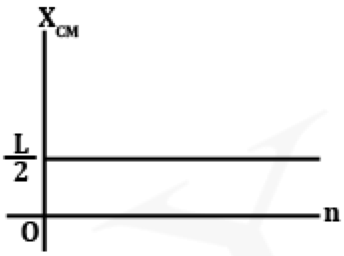
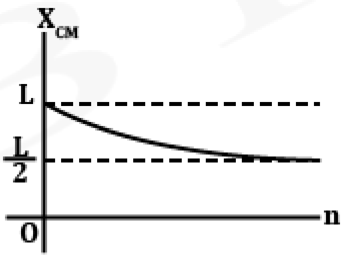
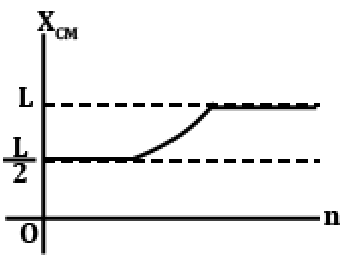
25. A thin rod of length $'L'$ is lying along the x-axis with its ends at $x = 0$ and $x = L$. Its linear density $\left(\frac{\text{mass}}{\text{length}}\right)$ varies with x as $k\left(\frac{x}{L}\right)^n$, where n can be zero or any positive number. If the position x_{cm} of the center of mass of the rod is plotted against $'n'$ which of the following graphs best approximates the dependence of x_{cm} on n?

A.


B.


C.


D.


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26. A circular disc of radius R is removed from a bigger circular disc of radius $2R$ such that the circumferences of the discs coincide. The center of mass of the new disc is $\frac{\alpha}{R}$ from the center of the bigger disc. The value of α is

A. $\frac{1}{4}$

B. $\frac{1}{3}$

C. $\frac{1}{2}$

D. $\frac{1}{6}$

27. A bullet of $4\ \mathrm{g}$ mass is fired from a gun of mass $4\ \mathrm{kg}$. If the bullet moves with the muzzle speed of $50\ \mathrm{ms}^{-1}$, the impulse imparted to the gun and velocity of recoil of gun are :

A. $0.4\ \mathrm{kg\ ms}^{-1}, 0.1\ \mathrm{ms}^{-1}$

B. $0.2\ \mathrm{kg\ ms}^{-1}, 0.05\ \mathrm{ms}^{-1}$

C. $0.2\ \mathrm{kg\ ms}^{-1}, 0.1\ \mathrm{ms}^{-1}$

D. $0.4\ \mathrm{kg\ ms}^{-1}, 0.05\ \mathrm{ms}^{-1}$

28. A body rolls down an inclined plane without slipping. The kinetic energy of rotation is 50% of its translational kinetic energy. The body is :

A. Solid sphere

B. Solid cylinder

C. Hollow cylinder

D. Ring

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29. The moment of inertia of a square plate of side l about the axis passing through one of the corner and perpendicular to the plane of the square plate is given by:

A. $\frac{Ml^2}{12}$

B. $\frac{2}{3}Ml^2$

C. $\frac{Ml^2}{6}$

D. Ml^2

30. Two discs have moments of inertia I_1 and I_2 about their respective axes perpendicular to the plane and passing through the center. They are rotating with angular speeds, ω_1 and ω_2 respectively and are brought into contact face to face with their axes of rotation coaxial. The loss in kinetic energy of the system in the process is given by :

A. $\frac{I_1 I_2}{2(I_1 + I_2)}(\omega_1 - \omega_2)^2$

B. $\frac{I_1 I_2}{(I_1 + I_2)}(\omega_1 - \omega_2)^2$

C. $\frac{(\omega_1 - \omega_2)^2}{2(I_1 + I_2)}$

D. $\frac{(I_1 + I_2)^2 \omega_1 \omega_2}{2(I_1 + I_2)}$

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