Class 11 Physics Chapter 6: System of Particles and Rotational Motion

Multiple Choice Questions I

1. For which of the following does the centre of mass lie outside the body?

Options:

a) a pencil

b) a shotput

c) a dice

d) a bangle

Answer: d) a bangle

Explanation: The centre of mass is the point where the entire mass of the body can be considered to be concentrated. For objects with uniform density and symmetric shapes (pencil, shotput, dice), the centre of mass lies within the body. However, for a bangle (ring-shaped object), the centre of mass lies at the geometric center of the ring, which is an empty space - hence outside the actual material of the body.

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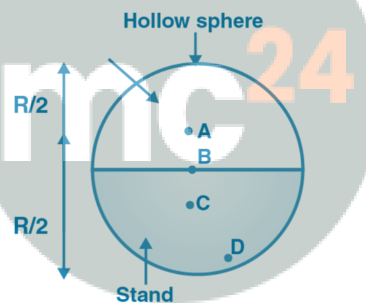
2. Which of the following points is the likely position of the centre of mass of the system shown in the figure?

[Figure shows a hollow sphere half-filled with liquid, with points A, B, C, D marked]



Options:

a) A

b) B

c) C

d) D

Answer: c) C

Explanation: For a hollow sphere that is half-filled with liquid, the centre of mass will be shifted towards the liquid-filled portion. Point C is located in the lower half where the liquid is present, making it the most likely position for the centre of mass. The system is not uniformly distributed, so the centre of mass shifts away from the geometric center towards the denser region.

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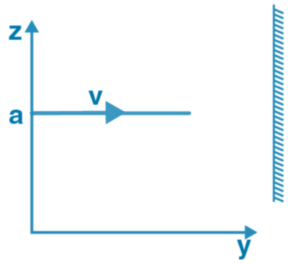
3. A particle of mass m is moving in yz-plane with a uniform velocity v with its trajectory

running parallel to +ve y-axis and intersecting z-axis at z = a. The change in its angular momentum about the origin as it bounces elastically from a wall at y = constant is:

Options:



a) **mv**a$\hat{e}_x$

b) **2mv**a$\hat{e}_x$

c) y**mv**a$\hat{e}_x$

d) 2y**mv**a$\hat{e}_x$

Answer: b) 2mva$\hat{e}_x$

Explanation: Initial angular momentum: $\mathbf{L}_i$ = **r** × **p** = **r** × m**v** After elastic collision with wall at y = constant, the y-component of velocity reverses while z-component remains same. Initial: $\mathbf{L}_i$ = ma**v**($\hat{e}_x$) Final: **L**f = -ma**v**($\hat{e}_x$) Change in angular momentum: Δ**L** = **L**f - $\mathbf{L}_i$ = -ma**v**($\hat{e}_x$) - ma**v**($\hat{e}_x$) = -2ma**v**($\hat{e}_x$) Magnitude of change = 2ma**v**($\hat{e}_x$)

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4. When a disc rotates with uniform angular velocity, which of the following is not true?

Options:

a) the sense of rotation remains same

b) the orientation of the axis of rotation remains same

c) the speed of rotation is non-zero and remains same

d) the angular acceleration is non-zero and remains same

Answer: d) the angular acceleration is non-zero and remains same

Explanation: For uniform angular velocity (constant ω):

- Angular acceleration α = dω/dt = 0 (since ω is constant)
- The sense of rotation remains same ✓
- The axis orientation remains same ✓
- The angular speed remains constant and non-zero ✓
- Statement (d) is incorrect because angular acceleration is zero for uniform angular velocity, not non-zero.

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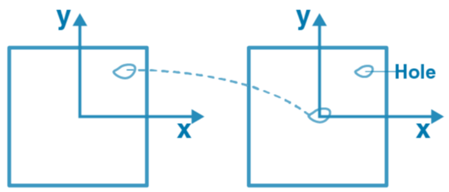
5. A uniform square plate has a small piece Q of an irregular shape removed and glued to the centre of the plate leaving a hole behind. The moment of inertia about the z-axis is then:



Options:

a) increased

b) decreased

c) the same

d) changed in unpredicted manner

Answer: b) decreased

Explanation: Moment of inertia $I = \Sigma m_i r_i^2$ When piece Q is moved from its original position (at some distance from center) to the center:

- At original position: contributed $mQ \cdot rQ^2$ to total moment of inertia
- At center: contributes $mQ \cdot (0)^2 = 0$ to total moment of inertia Since $rQ > 0$, the moment of inertia decreases when the mass is moved closer to the axis.

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6. In problem 5, the center of mass of the plate is now in which quadrant of the x-y plane?

Options:

a) I

b) II

c) III

d) IV

Answer: c) III

Explanation: Originally, the plate was symmetric with center of mass at origin. After removing piece Q and placing it at center, there's now a hole where Q was removed. The center of mass shifts away from the hole towards the opposite side. If Q was removed from quadrant I, the center of mass shifts towards quadrant III.

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7. The density of a non-uniform rod of length 1 m is given by $\rho(x) = a(1 + bx^2)$ where a and b are constants and $0 \le x \le 1$. The centre of mass of the rod will be at:

Options:

a) $3(2 + b)/(4(3 + b))$

b) $4(2 + b)/(3(3 + b))$

c) $3(3 + b)/(4(2 + b))$

d) $4(3 + b)/(3(2 + b))$

Answer: a) $3(2 + b)/(4(3 + b))$

Explanation: For center of mass: $\bar{x} = \int_0^1 x \cdot \rho(x)dx \,/\, \int_0^1 \rho(x)dx$

Mass element: $dm = \rho(x)dx = a(1 + bx^2)dx$

Total mass: $M = \int_0^1 a(1 + bx^2)dx = a[x + bx^3/3]_0^1 = a(1 + b/3) = a(3 + b)/3$

Numerator: $\int_0^1 x \cdot a(1 + bx^2)dx = a\int_0^1(x + bx^3)dx = a[x^2/2 + bx^4/4]_0^1 = a(1/2 + b/4) = a(2 + b)/4$
Therefore: $\bar{x} = [a(2 + b)/4] / [a(3 + b)/3] = 3(2 + b)/(4(3 + b))$

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8. A merry-go-round, made of a ring-like platform of radius R and mass M, is revolving with angular speed ω. A person of mass M is standing on it. At one instant, the person jumps off radially away from the centre. The speed of the round afterwards is:

Options:

a) 2ω

b) ω

c) ω/2

d) 0

Answer: a) 2ω

Explanation: Initial angular momentum: $L_i = I_{platform} \cdot \omega + I_{person} \cdot \omega = MR^2\omega + MR^2\omega = 2MR^2\omega$

When person jumps radially outward, no torque about center, so angular momentum conserved. Final angular momentum: $L_f = I_{platform} \cdot \omega_f = MR^2 \cdot \omega_f$

Conservation: $2MR^2\omega = MR^2\omega_f$ Therefore: $\omega_f = 2\omega$

Multiple Choice Questions II

9. Choose the correct alternatives:

Options: a) for a general rotational motion, angular momentum **L** and angular velocity **ω** need not be parallel

b) for a rotational motion about a fixed axis, angular momentum **L** and angular velocity **ω** are always parallel

c) for a general translational motion, momentum **p** and velocity **v** are always parallel

d) for a general translational motion, acceleration **a** and velocity **v** are always parallel

Answer: a) and c)

Explanation:

- (a) TRUE: For asymmetric objects, **L** = **I**·**ω** where **I** is a tensor, so **L** and **ω** may not be parallel
- (b) TRUE: For fixed axis rotation, **L** and **ω** are always parallel
- (c) TRUE: **p** = m**v**, so they're always parallel for constant mass
- (d) FALSE: **a** and **v** can be in different directions (e.g., circular motion)

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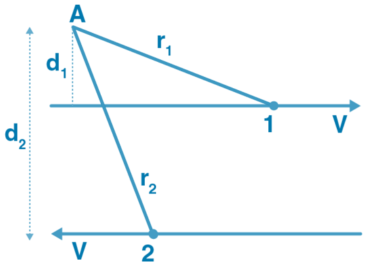
10. Figure shows two identical particles 1 and 2, each of mass m, moving in opposite directions with same speed v along parallel lines. At a particular instant, r_1 and r_2 are their respective position vectors drawn from point A. Choose the correct options:

Options:



a) angular momentum l_1 of particle 1 about A is $l_1 = mvd_1$

b) angular momentum l_2 of particle 2 about A is $l_2 = mvd_2$

c) total angular momentum of the system about A is $l = mv(r_1 + r_2)$

d) total angular momentum of the system about A is $l = mv(d_2 - d_1)\otimes$ represents a unit vector coming out of the page

Answer: a) and b)

Explanation: Angular momentum $\mathbf{L} = \mathbf{r} \times \mathbf{p} = \mathbf{r} \times m\mathbf{v}$ For each particle: $|\mathbf{L}| = mvr \sin\theta = mv \cdot d$ (where d is perpendicular distance)

- (a) Correct: $l_1 = mvd_1$
- (b) Correct: $l_2 = mvd_2$
- (c) & (d) Incorrect: Total angular momentum depends on vector sum, not simple addition of magnitudes

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11. The net external torque on a system of particles about an axis is zero. Which of the following are compatible with it?

Options:

a) the forces may be acting radially from a point on the axis

b) the forces may be acting on the axis of rotation

c) the forces may be acting parallel to the axis of rotation

d) the torque caused by some forces may be equal and opposite to that caused by other forces

Answer: All four options (a, b, c, d)

Explanation: For zero net torque: $\Sigma\tau = \Sigma(\mathbf{r} \times \mathbf{F}) = 0$ This occurs when:

- (a) Radial forces: $\mathbf{r} \times \mathbf{F} = 0$ since $\mathbf{r} \parallel \mathbf{F}$
- (b) Forces on axis: $r = 0$, so $\mathbf{r} \times \mathbf{F} = 0$
- (c) Forces parallel to axis: $\mathbf{r} \perp$ axis, $\mathbf{F} \parallel$ axis, so $\mathbf{r} \times \mathbf{F} \perp$ axis (contributes zero torque about axis)
- (d) Equal and opposite torques: $\Sigma\tau = \tau_1 + \tau_2 + \ldots = 0$

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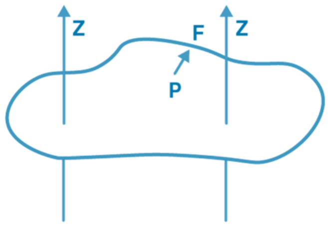
12. Figure shows a lamina in x-y plane. Two axes z and z' pass perpendicular to its plane. A force F acts in the plane of lamina at point P. Which of the following are true?

Options:



a) torque τ caused by **F** about z-axis is along $-\hat{k}$

b) torque τ' caused by **F** about z' axis is along $-\hat{k}$

c) torque τ caused by **F** about z-axis is greater in magnitude than that about z' axis

d) total torque is given by τ = τ + τ'

Answer: b) and c)

Explanation:

- (b) Correct: τ' about z' axis is along $-\hat{k}$ direction
- (c) Correct: |τ| > |τ'| because lever arm for z-axis is greater than for z'-axis
- (a) & (d) are incorrect based on the geometry and vector directions shown

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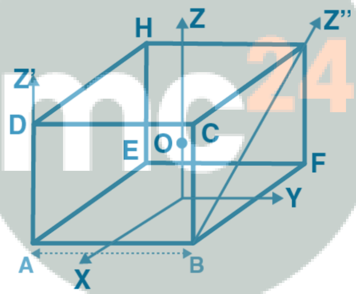
13. With reference to the figure of a cube of edge a and mass m, state whether the following are true or false:

Options:



a) the moment of inertia of cube about z-axis is Iz = Ix + Iy

b) the moment of inertia of cube about z' is $I'z = Iz + ma^2/2$

c) the moment of inertia of cube about z'' is $Iz + ma^2/2$

d) Ix = Iy

Answer: b) and d)

Explanation: For a uniform cube:

- (d) TRUE: By symmetry, $Ix = Iy = ma^2/6$
- (b) TRUE: Using parallel axis theorem: $I'z = Iz + Ma^2$ where a is the distance between axes
- (a) FALSE: For a cube, Iz ≠ Ix + Iy (this would be true for a flat plate, not a 3D cube)
- (c) Needs verification based on axis position