

System of Particles and Rotational Motion

Class 11 Physics · 24 NEET MCQs with answers & explanations

System of Particles and Rotational Motion covers centre of mass, torque, angular momentum, moment of inertia, rolling motion and the parallel/perpendicular axis theorems. NEET tests moment of inertia values, torque calculations, angular momentum conservation and rolling problems. This is one of Physics' toughest and highest-scoring chapters.

Key Rotational Concepts

Concept	Key Fact
Torque	$\tau = r \times F = I\alpha$; rotational analogue of force
Moment of inertia	Ring: MR^2 ; Disc: $\frac{1}{2}MR^2$; Solid sphere: $\frac{2}{5}MR^2$; Hollow sphere: $\frac{2}{3}MR^2$
Angular momentum	$L = I\omega$; conserved when net external torque = 0
Parallel axis theorem	$I = I_{cm} + Md^2$; shifts axis parallel to CM axis
Perpendicular axis theorem	$I_z = I_x + I_y$; for planar bodies only
Rolling	$v_{cm} = R\omega$ (pure rolling); $KE = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

Questions

Q1. A particle of mass 2 kg is located at coordinates (2 m, 3 m). The centre of mass of this single-particle system is at:

- (A) (2 m, 3 m)
- (B) (3 m, 2 m)
- (C) (1 m, 1.5 m)
- (D) Origin

Q2. Linear momentum of a body is defined as:

- (A) Product of mass and acceleration
- (B) Product of mass and velocity
- (C) Product of force and time
- (D) Product of mass and displacement

Q3. A rigid body is said to be in equilibrium when:

- (A) Only the net force is zero
- (B) Only the net torque is zero
- (C) The body is at rest
- (D) Both the net force and the net torque are zero

Q4. The moment of force (torque) about a point is defined as:

- (A) Product of force and displacement
- (B) Product of mass and acceleration
- (C) Vector product of position vector and force
- (D) Scalar product of velocity and force

Q5. Moment of inertia of a body depends upon:

- (A) Only its total mass
- (B) Only its shape
- (C) Only the axis of rotation
- (D) Mass distribution and the axis of rotation

Q6. Two particles of masses 2 kg and 3 kg are placed at $x = 0$ m and $x = 10$ m respectively. The x-coordinate of the centre of mass is:

- (A) 0 m
- (B) 4 m
- (C) 6 m
- (D) 10 m

Q7. The rotational analogue of Newton's second law is:

- (A) $F = ma$
- (B) $\tau = mv$
- (C) $\tau = I\alpha$
- (D) $L = I\omega$

Q8. For pure rolling without slipping, the relation between linear speed v of the centre of mass and angular speed ω is:

- (A) $v = \omega/R$
- (B) $v = R^2\omega$
- (C) $v = R\omega$
- (D) $v = \omega^2R$

Q9. The perpendicular axis theorem is applicable only to:

- (A) Plane laminae
- (B) Three-dimensional solid bodies
- (C) Hollow spheres
- (D) All rigid bodies

Q10. The rotational kinetic energy of a rigid body rotating with angular speed ω is:

- (A) $I\omega^2$
- (B) $I\omega^2/4$
- (C) $\frac{1}{2}I\omega^2$
- (D) $I\omega$

Q11. The standard moment of inertia of a thin ring of mass M and radius R about an axis through its centre perpendicular to its plane is:

- (A) $MR^2/2$
- (B) $2MR^2/5$
- (C) MR^2
- (D) $2MR^2/3$

Q12. The angular displacement of a rotating body is measured in:

- (A) Radian per second
- (B) Degree per second
- (C) Radian
- (D) Revolution per second

Q13. According to Newton's second law for a system of particles, the acceleration of the centre of mass depends on:

- (A) Internal forces only
- (B) Net external force on the system
- (C) Both internal and external forces equally
- (D) The number of particles in the system

Q14. The angular momentum of a particle about a point is defined as:

- (A) Product of force and displacement
- (B) Product of mass and velocity
- (C) Vector product of position vector and linear momentum
- (D) Product of moment of inertia and angular acceleration

Q15. The radius of gyration k of a body is defined by the relation:

- (A) $I = Mk$
- (B) $I = Mk^2$
- (C) $I = M^2k$
- (D) $I = k^2/M$

Q16. For two equal masses placed at $x = -4$ m and $x = +8$ m, the centre of mass is located at:

- (A) -4 m
- (B) 0 m
- (C) 1 m
- (D) 2 m

Q17. A particle of mass 2 kg is at $x = 2$ m and another of mass 6 kg is at $x = 8$ m. Which statement correctly describes the location of the centre of mass?

- (A) At $x = 2$ m, coinciding with the lighter mass
- (B) Closer to the 6 kg mass, at $x = 6.5$ m
- (C) Exactly midway between the two masses at $x = 5$ m
- (D) At $x = 7$ m, two-thirds of the way from the lighter mass

Q18. A uniform circular ring of radius R has its centre of mass at:

- (A) A point on the circumference of the ring
- (B) The geometric centre of the ring, where no material is present
- (C) A point on any diameter but not at the centre
- (D) A point outside the ring at distance R from the centre

Q19. How many of the following statements about centre of mass are correct? I. Centre of mass may lie outside the body. II. Centre of mass always lies on a particle of the system. III. Centre of mass depends on mass distribution. IV. Repositioning particles within a system generally changes the position of the centre of mass.

- (A) Only 1
- (B) Only 2
- (C) Only 3
- (D) All 4

Q20. For which of the following uniform bodies does the centre of mass lie at a point where NO material of the body is present?

- (A) Uniform solid sphere
- (B) Uniform solid cylinder
- (C) Uniform circular ring
- (D) Uniform square lamina

Q21. A uniform rod of length 2 m has masses 2 kg and 6 kg attached at its two ends. Taking the end with the 2 kg mass as origin, the centre of mass of the system is located at:

- (A) 0.25 m
- (B) 0.75 m
- (C) 1.25 m
- (D) 1.50 m

Q22. All of the following statements about centre of mass are correct EXCEPT:

- (A) Centre of mass always coincides with the geometric centre of every body
- (B) Centre of mass depends on mass distribution
- (C) Centre of mass may lie outside the body
- (D) For a two-particle system, centre of mass lies on the line joining the two particles

Q23. A uniform body possesses an axis of symmetry. Which statement correctly describes the location of its centre of mass?

- (A) At one end of the axis of symmetry
- (B) On the axis of symmetry
- (C) Outside the body, along an extension of the axis
- (D) At the geometric centre only if the body is solid

Q24. Three particles of masses 1 kg, 2 kg and 3 kg are placed at $x = 0$ m, $x = 3$ m and $x = 6$ m respectively. The x-coordinate of the centre of mass is:

- (A) 3 m
- (B) 4 m
- (C) 4.5 m
- (D) 5 m

Answer key

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

Answers with explanations

Q1 — Answer: (A) (2 m, 3 m)

For a single particle, the CM coincides with the particle itself. No averaging is needed; $x_{CM} = 2$ m, $y_{CM} = 3$ m.

Q2 — Answer: (B) Product of mass and velocity

$p = mv$ by definition. Option A is force ($F = ma$). Option C gives impulse for constant force ($J = F\Delta t$) — not momentum itself. Option D has dimensions ML^2T^{-1} , which do not match momentum (MLT^{-1}).

Q3 — Answer: (D) Both the net force and the net torque are zero

Complete equilibrium requires $\Sigma F=0$ (translational) and $\Sigma \tau=0$ (rotational). Option A ignores rotational equilibrium. Option C fails because a body in uniform motion is also in equilibrium.

Q4 — Answer: (C) Vector product of position vector and force

Torque $\tau = r \times F$ is a vector (cross) product of position vector r and force F . Option D is wrong because torque uses cross product not dot product, and involves force not velocity.

Q5 — Answer: (D) Mass distribution and the axis of rotation

$I = \Sigma mr^2$ depends on both how mass is distributed and which axis is chosen. Two bodies with equal mass but different shapes have different moments of inertia.

Q6 — Answer: (C) 6 m

$x_{CM} = (2 \times 0 + 3 \times 10)/5 = 6$ m. Option B (4 m) results from swapping mass weights; option D is the position of the heavier mass alone.

Q7 — Answer: (C) $\tau = I\alpha$

Net torque equals moment of inertia times angular acceleration: $\tau = I\alpha$. Option D ($L = I\omega$) gives angular momentum, not Newton's second law — it is the rotational analogue of $p = mv$, a different relation.

Q8 — Answer: (C) $v = R\omega$

In pure rolling the contact point is instantaneously at rest, requiring $v = R\omega$. Option A inverts the relation (ω/R has units of s^{-1}/m , not m/s). Options B and D are dimensionally wrong for speed.

Q9 — Answer: (A) Plane laminae

$I_z = I_x + I_y$ holds only for plane laminae where every mass element lies in the x-y plane. For 3D bodies, mass is distributed across all three dimensions, violating the theorem's core condition.

Q10 — Answer: (C) $\frac{1}{2}I\omega^2$

$K = \frac{1}{2}I\omega^2$ is the standard formula. Option A ($I\omega^2$) omits the factor $\frac{1}{2}$. Option D ($I\omega$) is angular momentum, not energy.

Q11 — Answer: (C) MR^2

For a ring, every mass element sits at distance R from the central axis, so $I = MR^2$. Compare: disc = $MR^2/2$ (mass spread 0 to R); solid sphere = $2MR^2/5$; hollow sphere = $2MR^2/3$.

Q12 — Answer: (C) Radian

Angular displacement is the angle swept by a rotating body; its SI unit is radian. Radian per second is the unit of angular velocity, not displacement.

Q13 — Answer: (B) Net external force on the system

$F_{ext} = Ma_{CM}$. Internal forces appear in equal and opposite pairs by Newton's third law and cancel when summed over the whole system. Only the net external force determines a_{CM} .

Q14 — Answer: (C) Vector product of position vector and linear momentum

$L = r \times p$, where r is the position vector and p is the linear momentum. Direction is given by the right-hand rule. Option D defines torque ($\tau = I\alpha$), not angular momentum.

Q15 — Answer: (B) $I = Mk^2$

k is defined such that $I = Mk^2$, where M is total mass and I is moment of inertia about the chosen axis. Option A gives wrong dimensions; option C makes k independent of mass distribution incorrectly.

Q16 — Answer: (D) 2 m

For equal masses, $COM = \text{arithmetic mean} = (-4 + 8)/2 = 2$ m. Option B (0 m) is a common error from sign mishandling; option C (1 m) arises from adding without dividing correctly.

Q17 — Answer: (B) Closer to the 6 kg mass, at $x = 6.5$ m

$x_{CM} = (2 \times 2 + 6 \times 8)/8 = 52/8 = 6.5$ m, nearer the heavier mass. Option C ($x = 5$ m) is the arithmetic mean — the classic trap for students who ignore mass weighting.

Q18 — Answer: (B) The geometric centre of the ring, where no material is present

By symmetry, all radial mass contributions cancel. COM lies at the geometric centre — a point with no material. This confirms COM need not coincide with any physical location of mass.

Q19 — Answer: (C) Only 3

Statements I, III and IV are correct — 3 statements. Statement II is false: COM lies at the geometric centre of a uniform ring, where no particle exists. Students selecting D often overlook Statement II.

Q20 — Answer: (C) Uniform circular ring

A ring is hollow at its centre; COM lies at the geometric centre where there is no material. All other options are solid bodies whose COM lies within their material. This is a standard NEET exception-type question.

Q21 — Answer: (D) 1.50 m

$x_{CM} = (2 \times 0 + 6 \times 2) / (2 + 6) = 12/8 = 1.50$ m. Option C (1.25 m) arises from dividing 10 by 8; option B from incorrectly using length/total mass without weighting positions.

Q22 — Answer: (A) Centre of mass always coincides with the geometric centre of every body

Statement A is false. COM coincides with the geometric centre only for uniform, symmetric bodies. For asymmetric or non-uniform mass distributions, COM is displaced from the geometric centre.

Q23 — Answer: (B) On the axis of symmetry

Equal masses are symmetrically distributed on both sides of the axis, so perpendicular components cancel. COM must lie on the axis of symmetry. Option C is a trap: COM lies outside the material for hollow symmetric bodies but still on the axis.

Q24 — Answer: (B) 4 m

$x_{CM} = (1 \times 0 + 2 \times 3 + 3 \times 6) / 6 = 24/6 = 4$ m. Option A (3 m) is the unweighted midpoint; option C (4.5 m) is the arithmetic mean of positions — both ignore mass weighting.

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