

System of Particles and Rotational Motion — CBSE Pattern Test 2

Class 11 Physics · 90 minutes · 40 marks · Sections A–D with answer key · Narayan Gurukul Academy

Test 2 — CBSE Pattern (90 minutes, 40 marks)

Class 11 Physics · System of Particles and Rotational Motion · Narayan Gurukul Academy (ClassApna)

General Instructions: (1) This paper has four sections — Section A (1×10), Section B (2×4), Section C (3×4) and Section D (5×2) — total 40 marks. Time allowed: 90 minutes.

(2) All questions are compulsory. No overall choice is given; internal choice, where allowed, is clearly marked.

(3) For MCQ questions choose the single correct option; for VSA answers write a single line.

(4) Take $g = 10 \text{ m/s}^2$. All symbols carry their usual meaning. Use of a calculator is not permitted.

Section A — MCQ & VSA ($10 \times 1 = 10$ marks)

- Angular momentum is conserved when the net external
 - torque is zero
 - force is zero
 - force and torque are zero
 - impulse is zero
- For a rigid body rotating about a fixed axis, angular momentum L equals
 - $I\omega$
 - $mr^2\omega$
 - $\frac{1}{2}I\omega^2$
 - $mv r$
- When an ice skater pulls her arms in while spinning, her angular speed
 - increases
 - decreases
 - stays the same
 - becomes zero
- The relation between torque and angular momentum is
 - $\tau = dL/dt$
 - $\tau = L/t$
 - $\tau = dL \times dt$
 - $\tau = I\alpha^2$
- The moment of inertia of a body depends on
 - the mass distribution about the axis and the axis chosen
 - only on its mass
 - only on its shape
 - its velocity
- The moment of inertia of a uniform ring of mass M and radius R about an axis through its centre and perpendicular to its plane is
 - MR^2
 - $\frac{1}{2}MR^2$
 - $\frac{3}{5}MR^2$
 - $\frac{1}{4}MR^2$
- The parallel axes theorem is written as

(A) $I = I_{CM} + Md^2$

(B) $I = I_{CM} - Md^2$

(C) $I = I_{CM}/d^2$

(D) $I = I_{CM} \times Md^2$

8. The radius of gyration of a body is related to its moment of inertia by

(A) $I = Mk^2$

(B) $I = M/k^2$

(C) $I = k/M$

(D) $I = Mk$

9. Define torque and give its SI unit.

10. State the theorem of parallel axes.

Section B — Short Answer I ($4 \times 2 = 8$ marks)

11. A ring and a disc of the same mass and radius rotate about their central axes. Compare their moments of inertia.

12. Write the moment of inertia of a thin uniform rod of length L about an axis through its centre, perpendicular to its length.

13. Show that internal forces cannot change the motion of the centre of mass.

14. State the law of conservation of angular momentum and give two examples where it applies.

Section C — Short Answer II ($4 \times 3 = 12$ marks)

15. Derive the expression for the position vector of the centre of mass of a system of n particles and show it behaves like a point mass under a net external force.

16. Prove that the angular momentum of a particle is conserved when the net torque on it is zero, and relate it to Kepler's second law of equal areas.

17. Find the moment of inertia of a uniform disc of mass M and radius R about a tangent in its plane, using the theorems of moment of inertia.

18. State and prove that the total kinetic energy of a rolling body equals $\frac{1}{2}Mv^2(1 + k^2/R^2)$, where k is its radius of gyration.

Section D — Long Answers ($2 \times 5 = 10$ marks)

19. Derive the total kinetic energy of a rolling body as $\frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$. A solid sphere, a disc and a ring of the same mass and radius start from rest and roll down the same incline — compare their speeds at the bottom and say which reaches first.

20. Explain the equilibrium conditions of a rigid body (translational and rotational), and derive the work–energy theorem for rotation using torque and angular displacement.

Answer Key (Marking Scheme)

Q1 — (A) torque is zero. Q2 — (A) $I\omega$. Q3 — (A) increases. Q4 — (A) $\tau = dL/dt$.

Q5 — (A) the mass distribution about the axis and the axis chosen. Q6 — (A) MR^2 . Q7 — (A) $I = I_{CM} + Md^2$. Q8 — (A) $I = Mk^2$.

Q9 — Torque $\tau = r \times F$ (magnitude $Fr \sin \theta$); SI unit N m.

Q10 — $I = I_{CM} + Md^2$, where M is the mass and d the distance between the parallel axes.

Q11 — $I_{\text{ring}} = MR^2 = 2 \times \frac{1}{2}MR^2 = 2 \times I_{\text{disc}}$; the ring has twice the moment of inertia.

Q12 — $I = ML^2/12$ about the centre, perpendicular to the length.

Q13 — Internal forces occur in action–reaction pairs that cancel, so they cannot change the net external force or the acceleration of the CM.

Q14 — $L = I\omega$ is constant when no external torque acts; e.g. an ice skater pulling in her arms, a diver tucking for a faster spin.

Q15 — $r_{\text{CM}} = \sum m_i r_i / \sum m_i$; summing equations of motion, $\sum F_{\text{ext}} = M a_{\text{CM}}$, so the CM moves as if the total mass were there.

Q16 — $\tau = dL/dt$; $\tau = 0 \Rightarrow \dot{\Phi} = \text{constant}$; Kepler II (equal areas in equal times) follows from constant areal velocity under a central force.

Q17 — About a diameter $I = MR^2/4$; parallel axes gives $I_{\text{tangent}} = MR^2/4 + MR^2 = 5MR^2/4$.

Q18 — $K = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}Mv^2 + \frac{1}{2}Mk^2(v^2/R^2) = \frac{1}{2}Mv^2(1 + k^2/R^2)$.

Q19 — From energy: $v = \sqrt{2gh/(1 + k^2/R^2)}$. Sphere $k^2/R^2 = 2/5 \rightarrow v = \sqrt{10gh/7}$; disc $k^2/R^2 = \frac{1}{2} \rightarrow v = \sqrt{4gh/3}$; ring $k^2/R^2 = 1 \rightarrow v = \sqrt{gh}$. The sphere reaches first, the ring last.

Q20 — Equilibrium requires $\sum F = 0$ and $\sum \tau = 0$; for rotation $W = \int \tau d\theta = \tau\theta$ (constant torque) $= \Delta(\frac{1}{2}I\omega^2)$, the rotational work–energy theorem.