

System of Particles and Rotational Motion — Assignment 2

Class 11 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Centre of Mass

2 Mark Questions

1. Two bodies of masses 2 kg and 8 kg are placed at the ends of a light rod 1 m long. Find the position of their centre of mass from the 8 kg mass.

3 Mark Questions

1. Three particles of masses 1 kg, 2 kg and 3 kg are placed at the vertices of an equilateral triangle of side 1 m. Find the position of the centre of mass.

Torque and Translational Equilibrium

2 Mark Questions

1. A force of 10 N acts at the end of a rod of length 0.5 m, perpendicular to it. Find the torque about the pivot at the other end.

3 Mark Questions

1. A uniform rod of weight 40 N and length 2 m is pivoted at one end and held horizontal by a force at the other end. Find the force needed to balance the rod.

Angular Momentum and Its Conservation

2 Mark Questions

1. A diver curls into a tight ball during a dive then straightens out on entry. Explain the change in angular speed using angular momentum conservation.

3 Mark Questions

1. A man stands at the centre of a rotating platform and holds weights with arms stretched out. Explain what happens when he pulls the weights in, using conservation of angular momentum.

Moment of Inertia and Theorems

2 Mark Questions

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

3 Mark Questions

1. 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.

Rotational Kinetic Energy and Rolling

2 Mark Questions

1. A flywheel of moment of inertia 2 kg m^2 rotates at 300 rpm. Find its rotational kinetic energy.

3 Mark Questions

1. A solid sphere rolls down an inclined plane of height h starting from rest. Obtain the velocity of its centre of mass at the bottom.

Part B — Integrated problems (multi-topic)

- Two bodies of masses 2 kg and 8 kg are placed at the ends of a light rod 1 m long. Find the position of the centre of mass from the 8 kg mass. Two equal and opposite forces of 10 N act on a body with their lines of action 0.5 m apart — what torque do they produce, and what kind of motion results?
- A uniform rod of weight 40 N and length 2 m is pivoted at one end and held horizontal by a force at the other end. Find the force needed to balance the rod. An extra 10 N is then applied at the far end perpendicular to the rod — find the additional torque about the pivot.
- A flywheel of moment of inertia 2 kg m^2 rotates at 300 rpm. Find its rotational kinetic energy. A man standing on a rotating platform pulls the weights in his hands, halving his moment of inertia — what happens to his angular speed and his rotational kinetic energy?
- A ring and a disc of the same mass and radius rotate about their central axes. Compare their moments of inertia. Using the theorems of moment of inertia, find the moment of inertia of a uniform disc of mass M and radius R about a tangent in its plane.
- A solid sphere rolls down an inclined plane of height h starting from rest. Obtain the velocity of its centre of mass at the bottom, and compare it with the velocities of a disc and a ring of the same mass and radius. Which reaches the bottom first?

Answer Key

Centre of Mass

2M(2): x_{CM} from the 8 kg mass = $(2 \times 1)/(2 + 8) = 0.2 \text{ m}$. 3M(1): $x_{\text{CM}} = (1 \times 0 + 2 \times 1 + 3 \times 0.5)/6 = 3.5/6 \approx 0.58 \text{ m}$; $y_{\text{CM}} = (3 \times \sqrt{3}/2)/6 = \sqrt{3}/4 \approx 0.43 \text{ m}$.

Torque and Translational Equilibrium

2M(0): $\tau = F \times d = 10 \times 0.5 = 5 \text{ N m}$. 3M(0): $F \times 2 = 40 \times 1$, so $F = 20 \text{ N}$.

Angular Momentum and Its Conservation

2M(1): $L = I\omega$ conserved — curled position (small I) gives high ω ; straightening (large I) lowers it. 3M(1): pulling the weights in reduces I ; $L = I\omega$ stays constant so ω increases; letting them out increases I and ω falls.

Moment of Inertia and Theorems

2M(1): $I_{\text{ring}} = MR^2$, $I_{\text{disc}} = \frac{1}{2}MR^2$ — the ring has twice the moment of inertia. 3M(1): about a diameter $I = MR^2/4$; tangent in its plane: parallel axes $I = MR^2/4 + MR^2 = 5MR^2/4$.

Rotational Kinetic Energy and Rolling

2M(0): $\omega = 300 \times 2\pi/60 = 10\pi \approx 31.4 \text{ rad/s}$; $KE = \frac{1}{2} \times 2 \times (10\pi)^2 = 100\pi^2 \approx 987 \text{ J}$. 3M(0): $mgh = \frac{1}{2}mv^2 + \frac{1}{2}(2/5mR^2)(v^2/R^2) = (7/10)mv^2$, so $v = \sqrt{(10gh/7)}$.

Integrated problems

1: CM is 0.2 m from the 8 kg mass (0.8 m from the 2 kg). A couple of moment $\tau = F \times d = 10 \times 0.5 = 5 \text{ N m}$ produces pure rotation only. 2: $F = 20 \text{ N}$; extra torque $= 10 \times 2 = 20 \text{ N m}$. 3: $KE = 100\pi^2 \approx 987 \text{ J}$; halving I doubles ω and doubles K ($K = L^2/2I$ with L constant). 4: $I_{\text{ring}} = MR^2 = 2 \times I_{\text{disc}}$; $I_{\text{disc(tangent in plane)}} = MR^2/4 + MR^2 = 5MR^2/4$. 5: sphere $v = \sqrt{(10gh/7)}$, disc $v = \sqrt{(4gh/3)}$, ring $v = \sqrt{(gh)}$ — sphere is fastest, ring slowest.