Blue Print (As per PU Board)

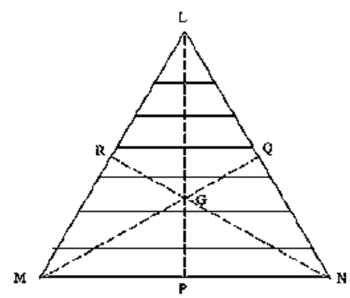
Topic	1 mark questions	2 marks questions	3 marks questions	5 marks questions	Total Marks
System of Particles & Rigid Body	–	–	1	1	8

One mark questions

1. **What is a Rigid body?**
   Answer: A Rigid body is one for which the distances between different particles of the body do not change even though there are forces on them.
2. **What is centre of mass of a system of particles?**
   Answer: Centre of mass of a system of particles is the point where the entire mass of the system can be assumed to be concentrated.
3. **Is moment inertia a vector or a scalar?**
   Answer: Scalar

Two marks questions

4. **How do you find the centre of mass of a triangular lamina.**
   Answer: Subdivide the lamina (LMN) into narrow strips each parallel to the base MN as shown in the figure. By symmetry each strip has its centre of mass at mid-point. Join the midpoint of all the strips, we get a median LP. Therefore the centre of mass of the triangle as a whole must lie on the median LP. Similarly it must lie on the median MQ and NR. This means that the centre of mass lies on the point of concurrence of the median, i.e. on the centroid G of the triangle. Thus centroid of the triangle itself is the centre of mass of the triangular lamina.



5. **Write the expression for the position vector of the centre of mass of a system consisting of three objects in terms of their masses and position vectors.**
   Answer: A $R = \frac{\Sigma m_i r_i}{M}$

   $\therefore R = \frac{m_1 r_1 + m_2 r_1 + m_3 r_3}{m_1 + m_2 + m_3}$

6. **Define torque. Is it a vector or a scalar?**
   Answer: The moment of a force or torque acting on the particle with respect to the origin is defined on the vector product of position vector and the force acting on the particle $\tau = r \times F$.
   It is a vector.

Three marks questions

7. **Write three Kinematic equations of rotational motion of a body with a uniform angular acceleration and explain the terms.**
   Answer: $\omega = \omega_0 + \alpha\, t$

   $\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha\, t^2$

$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$

ω_0 is the initial angular velocity, ω_0 - angular velocity after `t' seconds, $\alpha -$ angular acceleration, θ_0 - initial angular displacement, θ - angular displacement in 't' seconds.

8. **The angular speed of a motor wheel is increased from 1200rpm to 3120 rpm in 16 seconds. What is its angular acceleration, assuming the acceleration to be uniform?**

Answer: We shall use $\omega = \omega_0 + \alpha t$

ω_0 initial angular speed in rad/s

$= 2\pi \times$ angular speed in rev/s

$= \frac{2\pi \times \text{angular speed in rev/min}}{i.60\text{s}/\text{min}}$

$= \frac{2\pi \times 1200}{60} = \text{rad}/\text{s} = 40\pi\,\text{rad}/\text{s}$

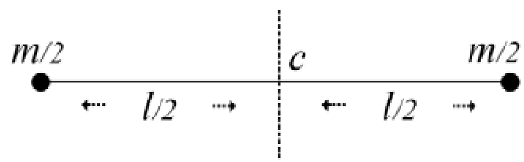
Similarly $\omega =$ final angular speed in rad/s

$= \frac{2\pi \times 3120}{60}\, rad/s = 2\pi \times 52\, rad/s$

$ii. = 104\pi\, rad/s$

$\therefore$ angular acceleration $\alpha = \frac{\omega - \omega_0}{t} = \frac{104\pi - 40\pi}{16} = \frac{64\pi}{16} = 4\pi\ rad/s^2$

9. **Obtain an expression for M.I. of a rotating pair of small masses attached to the two ends of a rigid mass less rod of length l rotating about and axis through the centre of mass perpendicular to the rod.**

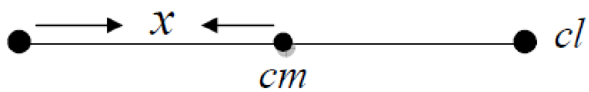


Answer: A From the figure each mass $\frac{m}{2}$ is at distance $\frac{l}{2}$ from the axis. The momentum is therefore $\left(\frac{m}{2}\right)\left(\frac{l}{2}\right)^2 + \left(\frac{m}{2}\right)\left(\frac{l}{2}\right)^2$

Therefore for the pair of masses, rotating about the axis through the centre of mass perpendicular to the rod $I = \frac{ml^2}{4}$.

Five marks questions

10. **In the** Hcl **molecule, the separation between the nuclei of the two atoms is about** $1.27\,A°\left(IA° = 10^{-10}\,\text{m}\right)$ **Find the approximate location of the CM of the molecule, given that a chlorine atom is about 35.5 times as massive as a hydrogen atom and nearly all the mass of and atom is concentrated in its nucleus.**



Answer: Let us consider hydrogen nucleus as the origin for measuring distance. If `m' is the mass of the hydrogen atom, then mass of the chlorine atom = 35.5m Distance of the centre of moss of Hcl molecule from the origin is given by

$x = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$

Here $x_1 = 0,\ x_2 = 1.27 \times 10^{-10}$ metre

$\therefore\ x = \dfrac{m \times o + 35.5m \times 1.27 \times 10^{-10}}{m + 35.5\text{m}}$

$\therefore\ x = \dfrac{35.5 \times 1.27 \times 10^{-10}}{36.5} = 1.23 \times 10^{-10m} = 1.235 A°$

11. **(a) A child stands at the centre of a turn table with his arm outstretched. The turn table is set rotating with an angular speed of 40 rev/min. how much is the angular speed of the child, if he folds his hand back and thereby reduces his moment of inertia to $\frac{2}{5}$ times the initial value? Assume that the turntable rotates without friction.**
(b) Show that the child's new K.E. of rotation is more than the initial K.E. of rotation. How do you account for this increase in Kinetic Energy?

Answer: Given $I_{\text{final}} = \frac{2}{5}$ Initial, $40 rev\ \text{min}^{-1}$ using the principle of conservation of angular momentum

We get $I_i \omega_i = I_F \omega_F$

Or $\omega_F = \dfrac{I_i \omega_i}{I_F} = \dfrac{I_i \times 40}{\frac{2}{5} I_i} = 100\ \ rev\ \text{min}^{-1}$

(b) $\dfrac{\text{Final K.E. of rotation}}{\text{initia K.E. of rotation}} = \dfrac{\frac{1}{2} I_F \omega_F^2}{\frac{1}{2} I_i \omega_i^2}$

$= \left(\dfrac{I_F}{l_i}\right)\left(\dfrac{\omega_F}{\omega_i}\right)^2 = \dfrac{2}{5} \times \left(\dfrac{100}{40}\right)^2 = 2.5$

$\therefore$ Final kinetic $= 2.5 \times$ initial K.E.

Final K.E. is more than initial K.E. because the child uses his internal energy when the folds his hands.

12. **A man stands on a rotating plat form, with his arms stretched horizontally holding a 5 kg weight in each hand. The angular speed of the platform is 30 revolutions per minute. The man then brings his arms close to his body with the distance of each weight form the axis changing from 90cm to 20cm. The moment of inertia of the man together with the platform may be taken to be constant and equal to $76\ \text{k gm}^2$.**
(a) What is his new angular speed? (neglect friction)
(b) Is kinetic energy conserved in the process? If not, from where does the change come from? given $\omega_i = 30$ rpm.

Answer: (a) Initial = inertia of the man together with the platform + moment inertia of the out stretched weight.

$= 7.6 + 2\left(MR^2\right) = 7.6 \times 2 \times 5 (0.9)^2$

$= 7.6 \times 10 \times 0.81 = 15.7\ \text{kgm}^2$

$\text{I}_{\text{Final}} = 7.6 + 2 \times \left(\text{MR}^2\right)$

$= 7.6 \times 2 \times 5 \times (0.2)^2 = 8.0\ \text{kgm}^2$

Using the principle of conservation of angular momentum

$I_1 \omega_1 = I_2 \omega_2$

$\omega_2 = \dfrac{I_1 \omega_1}{I_2} = \dfrac{15.7 \times 30}{8} = 58.88\ \text{rpm}$

(b) Kinetic energy is not conserved. As the moment of inertia decreases, the K.E. of rotation increases. This change comes from the work done by the man in bringing his arms close to his body.