

System of Particles and Rotational Motion — NEET Physics PYQ (2005-2021)

Class 11 Physics · 49 real NEET & AIPMT questions, year-tagged · answers checked by RankUp

NEET 2021

1. From a circular ring of mass 'M' and radius 'R' an arc corresponding to a 90° sector is removed. The moment of inertia of the remaining part of the ring about an axis passing through the centre of the ring and perpendicular to the plane of the ring is 'K' times ' MR^2 '. Then the value of 'K' is :

- (A) $3/4$
- (B) $7/8$
- (C) $1/4$
- (D) $1/8$

NEET 2020 · Q148

2. Two particles of mass 5 kg and 10 kg respectively are attached to the two ends of a rigid rod of length 1 m with negligible mass. The centre of mass of the system from the 5 kg particle is nearly at a distance of :

- (A) 33 cm
- (B) 50 cm
- (C) 67 cm
- (D) 80 cm

NEET 2020 · Q149

3. Find the torque about the origin when a force of $3\hat{j}$ N acts on a particle whose position vector is $2\hat{k}$ m.

- (A) $6\hat{i}$ N m
- (B) $6\hat{j}$ N m
- (C) $-6\hat{i}$ N m
- (D) $6\hat{k}$ N m

NEET 2019 · Q9

4. A disc of radius 2 m and mass 100 kg rolls on a horizontal floor. Its centre of mass has speed of 20 cm/s. How much work is needed to stop it?

- (A) 3 J
- (B) 30 kJ
- (C) 2 J
- (D) 1 J

NEET 2019 · Q21

5. A solid cylinder of mass 2 kg and radius 4 cm is rotating about its axis at the rate of 3 rpm. The torque required to stop after 2π revolutions is:

- (A) 2×10^{-6} N m
- (B) 2×10^{-3} N m
- (C) 12×10^{-4} N m
- (D) 2×10^6 N m

NEET 2018 · Q31

6. Three objects, A : (a solid sphere), B : (a thin circular disk) and C : (a circular ring), each have the same mass M and radius R. They all spin with the same angular speed ω about their own symmetry axes. The amounts of work (W) required to bring them to rest, would satisfy the relation

- (A) $W_B > W_A > W_C$
- (B) $W_A > W_B > W_C$
- (C) $W_C > W_B > W_A$
- (D) $W_A > W_C > W_B$

NEET 2018 · Q36

7. The moment of the force, $\mathbf{F} = 4\hat{i} + 5\hat{j} - 6\hat{k}$ at $(2, 0, -3)$, about the point $(2, -2, -2)$, is given by

- (A) $-7\hat{i} - 8\hat{j} - 4\hat{k}$
- (B) $-4\hat{i} - \hat{j} - 8\hat{k}$
- (C) $-8\hat{i} - 4\hat{j} - 7\hat{k}$
- (D) $-7\hat{i} - 4\hat{j} - 8\hat{k}$

NEET 2018 · Q38

8. A solid sphere is rotating freely about its symmetry axis in free space. The radius of the sphere is increased keeping its mass same. Which of the following physical quantities would remain constant for the sphere?

- (A) Rotational kinetic energy
- (B) Moment of inertia
- (C) Angular velocity
- (D) Angular momentum

NEET 2018 · Q41

9. A solid sphere is in rolling motion. In rolling motion a body possesses translational kinetic energy (K_t) as well as rotational kinetic energy (K_r) simultaneously. The ratio $K_t : (K_t + K_r)$ for the sphere is

- (A) 10 : 7
- (B) 5 : 7
- (C) 7 : 10
- (D) 2 : 5

NEET 2017 · Q141

10. A rope is wound around a hollow cylinder of mass 3 kg and radius 40 cm. What is the angular acceleration of the cylinder if the rope is pulled with a force of 30 N?

- (A) 25 m/s²
- (B) 0.25 rad/s²
- (C) 25 rad/s²
- (D) 5 m/s²

NEET 2017 (Gujarati paper) · Q142

11. A thin uniform rod of mass 'M' and length 'L' is rotating about a perpendicular axis passing through its centre with a constant angular velocity ' ω '. Two objects each of mass $M/3$ are attached gently to the two ends of the rod. The rod will now rotate with an angular velocity of:

- (A) $(1/7)\omega$
- (B) $(1/6)\omega$
- (C) $(1/2)\omega$
- (D) $(1/3)\omega$

NEET 2017 (Gujarati paper) · Q176

12. The rotational kinetic energy of a solid sphere of mass 3 kg and radius 0.2 m rolling down an inclined plane of height 7 m is:

- (A) 60 J
- (B) 36 J
- (C) 70 J
- (D) 42 J

NEET 2016 Phase 2 · Q8

13. Two rotating bodies A and B of masses m and $2m$ with moments of inertia I_A and I_B ($I_B > I_A$) have equal kinetic energy of rotation. If L_A and L_B be their angular momenta respectively, then

- (A) $L_A = L_B/2$
- (B) $L_A = 2L_B$
- (C) $L_B > L_A$
- (D) $L_A > L_B$

NEET 2016 Phase 2 · Q9

14. A solid sphere of mass m and radius R is rotating about its diameter. A solid cylinder of the same mass and same radius is also rotating about its geometrical axis with an angular speed twice that of the sphere. The ratio of their kinetic energies of rotation ($E_{\text{sphere}}/E_{\text{cylinder}}$) will be

- (A) 2 : 3
- (B) 1 : 5
- (C) 1 : 4
- (D) 3 : 1

NEET 2016 Phase 2 · Q10

15. A light rod of length l has two masses m_1 and m_2 attached to its two ends. The moment of inertia of the system about an axis perpendicular to the rod and passing through the centre of mass is

- (A) $(m_1 m_2 / (m_1 + m_2)) l^2$
- (B) $((m_1 + m_2) / (m_1 m_2)) l^2$
- (C) $(m_1 + m_2) l^2$
- (D) $\sqrt{(m_1 m_2)} l^2$

NEET 2016 Phase 1 · Q1

16. From a disc of radius R and mass M , a circular hole of diameter R , whose rim passes through the centre is cut. What is the moment of inertia of the remaining part of the disc about a perpendicular axis, passing through the centre?

- (A) $15 MR^2/32$
- (B) $13 MR^2/32$
- (C) $11 MR^2/32$
- (D) $9 MR^2/32$

NEET 2016 Phase 1 · Q19

17. A uniform circular disc of radius 50 cm at rest is free to turn about an axis which is perpendicular to its plane and passes through its centre. It is subjected to a torque which produces a constant angular acceleration of 2.0 rad s^{-2} . Its net acceleration in ms^{-2} at the end of 2.0 s is approximately:

- (A) 8.0
- (B) 7.0
- (C) 6.0
- (D) 3.0

NEET 2016 Phase 1 · Q21

18. A disk and a sphere of same radius but different masses roll off on two inclined planes of the same altitude and length. Which one of the two objects gets to the bottom of the plane first?

- (A) Disk
- (B) Sphere
- (C) Both reach at the same time
- (D) Depends on their masses

AIPMT 2015

19. A rod of weight W is supported by two parallel knife edges A and B and is in equilibrium in a horizontal position. The knives are at a distance d from each other. The centre of mass of the rod is at distance x from A. The normal reaction on A is:

- (A) $W(d - x)/d$
- (B) Wx/d
- (C) Wd/x
- (D) $W(d - x)/x$

AIPMT 2014

20. The ratio of the accelerations for a solid sphere (mass ' m ' and radius ' R ') rolling down an incline of angle ' θ ' without slipping and slipping down the incline without rolling is:

- (A) 2 : 3
- (B) 2 : 5
- (C) 7 : 5
- (D) 5 : 7

AIPMT 2014

21. A solid cylinder of mass 50 kg and radius 0.5 m is free to rotate about the horizontal axis. A massless string is wound round the cylinder with one end attached to it and other hanging freely. Tension in the string required to produce an angular acceleration of 2 revolutions s^{-2} is:

- (A) 50 N
- (B) 78.5 N
- (C) 157 N
- (D) 25 N

NEET 2013

22. A rod PQ of mass M and length L is hinged at end P. The rod is kept horizontal by a massless string tied to point Q (the string is vertical). When the string is cut, the initial angular acceleration of the rod is

- (A) $3g/(2L)$
- (B) g/L
- (C) $2g/L$
- (D) $2g/(3L)$

NEET 2013

23. A small object of uniform density rolls up a curved surface with an initial velocity v . It reaches up to a maximum height of $3v^2/(4g)$ with respect to the initial position.

The object is

- (A) Ring
- (B) Solid sphere
- (C) Hollow sphere
- (D) Disc

AIPMT 2012 Mains

24. Three masses are placed on the x-axis : 300 g at origin, 500g at $x = 40$ cm and 400g at $x = 70$ cm. The distance of the centre of mass from the origin is :

- (A) 40 cm
- (B) 45 cm
- (C) 50 cm
- (D) 30 cm

AIPMT 2012 Prelims

25. A solid cylinder of mass 3 kg is rolling on a horizontal surface with velocity 4 m s⁻¹. It collides with a horizontal spring of force constant 200 N m⁻¹. The maximum compression produced in the spring will be

- (A) 0.2 m
- (B) 0.5 m
- (C) 0.6 m
- (D) 0.7 m

AIPMT 2012 Prelims

26. When a mass is rotating in a plane about a fixed point, its angular momentum is directed along:

- (A) the tangent to the orbit
- (B) a line perpendicular to the plane of rotation
- (C) the line making an angle of 45° to the plane of rotation
- (D) the radius

AIPMT 2012 Prelims

27. Two persons of masses 55 kg and 65 kg respectively, are at the opposite ends of a boat. The length of the boat is 3.0 m and weighs 100 kg. The 55 kg man walks up to the 65 kg man and sits with him. If the boat is in still water the centre of mass of the system shifts by

- (A) 0.75 m
- (B) 3.0 m
- (C) 2.3 m
- (D) zero

AIPMT 2011 Mains

28. A small mass attached to a string rotates on a frictionless table top (the string passes through a hole at the centre of the table). If the tension in the string is increased by pulling the string causing the radius of the circular motion to decrease by a factor of 2, the kinetic energy of the mass will

- (A) Increase by a factor of 4
- (B) Decrease by a factor of 2
- (C) Remain constant
- (D) Increase by a factor of 2

AIPMT 2011 Prelims

29. The moment of inertia of a thin uniform rod of mass M and length L about an axis passing through its midpoint and perpendicular to its length is I₀. Its moment of inertia about an axis passing through one of its ends and perpendicular to its length is

- (A) I₀ + ML²
- (B) I₀ + ML²/2
- (C) I₀ + ML²/4
- (D) I₀ + 2ML²

AIPMT 2011 Prelims

30. The instantaneous angular position of a point on a rotating wheel is given by the equation $\theta(t) = 2t^3 - 6t^2$. The torque on the wheel becomes zero at

- (A) t = 2 s
- (B) t = 1 s
- (C) t = 0.2 s
- (D) t = 0.25 s

31. From a circular disc of radius R and mass $9M$, a small disc of mass M and radius $R/3$ is removed concentrically. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through its centre is

- (A) $(40/9) MR^2$
- (B) MR^2
- (C) $4 MR^2$
- (D) $(4/9) MR^2$

32. A solid cylinder and a hollow cylinder, both of the same mass and same external diameter are released from the same height at the same time on a inclined plane. Both roll down without slipping. Which one will reach the bottom first?

- (A) Both together only when angle of inclination of plane is 45°
- (B) Both together
- (C) Hollow cylinder
- (D) Solid cylinder

33. (a) Centre of gravity (C.G.) of a body is the point at which the weight of the body acts

(b) Centre of mass coincides with the centre of gravity if the earth is assumed to have infinitely large radius

(c) To evaluate the gravitational field intensity due to any body at an external point, the entire mass of the body can be considered to be concentrated at its C.G.

(d) The radius of gyration of any body rotating about an axis is the length of the perpendicular dropped from the C.G. of the body to the axis

Which one of the following pairs of statements is correct?

- (A) (d) and (a)
- (B) (a) and (b)
- (C) (b) and (c)
- (D) (c) and (d)

34. A thin circular ring of mass M and radius r is rotating about its axis with constant angular velocity ω . Two objects each of mass m are attached gently to the opposite ends of a diameter of the ring. The ring now rotates with angular velocity given by

- (A) $(M + 2m)\omega/(2m)$
- (B) $2M\omega/(M + 2m)$
- (C) $(M + 2m)\omega/M$
- (D) $M\omega/(M + 2m)$

35. A man of 50 kg mass is standing in a gravity free space at a height of 10 m above the floor. He throws a stone of 0.5 kg mass downwards with a speed 2 m/s. When the stone reaches the floor, the distance of the man above the floor will be

- (A) 20 m
- (B) 9.9 m
- (C) 10.1 m
- (D) 10 m

36. Two particles which are initially at rest, move towards each other under the action of their internal attraction. If their speeds are v and $2v$ at any instant, then the speed of centre of mass of the system will be

- (A) v
- (B) $2v$
- (C) Zero
- (D) $1.5 v$

37. A thin circular ring of mass M and radius R is rotating in a horizontal plane about an axis vertical to its plane with a constant angular velocity ω . If two objects each of mass m be attached gently to the opposite ends of a diameter of the ring, the ring will then rotate with an angular velocity:

- (A) $\omega M/(M + 2m)$
- (B) $\omega(M + 2m)/M$
- (C) $\omega M/(M + m)$
- (D) $\omega(M - 2m)/(M + 2m)$

38. If $\mathbf{F}$ is the force acting on a particle having position vector $\mathbf{r}$ and $\mathbf{\tau}$ be the torque of this force about the origin, then:

- (A) $\mathbf{r} \cdot \mathbf{\tau} > 0$ and $\mathbf{F} \cdot \mathbf{\tau} < 0$
- (B) $\mathbf{r} \cdot \mathbf{\tau} = 0$ and $\mathbf{F} \cdot \mathbf{\tau} = 0$
- (C) $\mathbf{r} \cdot \mathbf{\tau} = 0$ and $\mathbf{F} \cdot \mathbf{\tau} \neq 0$
- (D) $\mathbf{r} \cdot \mathbf{\tau} \neq 0$ and $\mathbf{F} \cdot \mathbf{\tau} = 0$

39. Four identical thin rods each of mass M and length l , form a square frame. Moment of inertia of this frame about an axis through the centre of the square and perpendicular to its plane is :

- (A) $(2/3) MI^2$
- (B) $(13/3) MI^2$
- (C) $(1/3) MI^2$
- (D) $(4/3) MI^2$

40. Two bodies of mass 1 kg and 3 kg have position vectors $\hat{i} + 2\hat{j} + \hat{k}$ and $-3\hat{i} - 2\hat{j} + \hat{k}$, respectively. The centre of mass of this system has a position vector:

- (A) $-2\hat{i} - \hat{j} + \hat{k}$
- (B) $2\hat{i} - \hat{j} - 2\hat{k}$
- (C) $-\hat{i} + \hat{j} + \hat{k}$
- (D) $-2\hat{i} + 2\hat{k}$

41. The ratio of the radii of gyration of a circular disc to that of a circular ring, each of same mass and radius, around their respective axes is

- (A) $\sqrt{2} : \sqrt{3}$
- (B) $\sqrt{3} : \sqrt{2}$
- (C) $1 : \sqrt{2}$
- (D) $\sqrt{2} : 1$

42. A thin rod of length L and mass M is bent at its midpoint into two halves so that the angle between them is 90° . The moment of inertia of the bent rod about an axis passing through the bending point and perpendicular to the plane defined by the two halves of the rod is

- (A) $\sqrt{2} ML^2/24$
- (B) $ML^2/24$
- (C) $ML^2/12$
- (D) $ML^2/6$

43. A wheel has angular acceleration of 3.0 rad/sec^2 and an initial angular speed of 2.00 rad/sec . In a time of 2 sec it has rotated through an angle (in radian) of

- (A) 10
- (B) 12
- (C) 4
- (D) 6

44. A uniform rod AB of length l , and mass m is free to rotate about point A. The rod is released from rest in the horizontal position. Given that the moment of inertia of the rod about A is $ml^2/3$, the initial angular acceleration of the rod will be

- (A) $mg/l/2$
- (B) $(3/2)gl$
- (C) $3g/(2l)$
- (D) $2g/(3l)$

45. A particle of mass m moves in the XY plane with a velocity v along the straight line AB. If the angular momentum of the particle with respect to origin O is LA when it is at A and LB when it is at B, then

- (A) $LA = LB$
- (B) the relationship between LA and LB depends upon the slope of the line AB
- (C) $LA < LB$
- (D) $LA > LB$

46. A tube of length L is filled completely with an incompressible liquid of mass M and closed at both the ends. The tube is then rotated in a horizontal plane about one of its ends with a uniform angular velocity ω . The force exerted by the liquid at the other end is :

- (A) $ML\omega^2/2$
- (B) $ML^2\omega/2$
- (C) $2ML\omega^2$
- (D) $ML^2\omega^2/2$

47. A uniform rod of length l and mass m is free to rotate in a vertical plane about A. The rod initially in horizontal position is released. The initial angular acceleration of the rod is : (Moment of inertia of rod about A is $ml^2/3$)

- (A) $3g/2l$
- (B) $2l/3g$
- (C) $3g/2l^2$
- (D) $mg(l/2)$

48. Two bodies have their moments of inertia I and $2I$ respectively about their axis of rotation. If their kinetic energies of rotation are equal, their angular momenta will be in the ratio :

- (A) 1 : 4
- (B) $\sqrt{2}$: 1
- (C) 4 : 1
- (D) 1 : $\sqrt{2}$

49. The moment of inertia of a uniform circular disc of radius R and mass M about an axis passing from the edge of the disc and normal to the disc is :

- (A) $(5/2)MR^2$
- (B) MR^2
- (C) $(7/2)MR^2$
- (D) $(3/2)MR^2$

Answer key and explanations

1. Answer: (A) 3/4

Every element of a ring is at distance R from the central perpendicular axis, so $I = (\text{mass}) \times R^2$. Removing a 90° arc leaves $3/4$ of the mass, so $I = (3/4)MR^2$ and $K = 3/4$.

2. Answer: (C) 67 cm

Taking the 5 kg particle at the origin, $x_{\text{cm}} = (5 \times 0 + 10 \times 1)/15 = 0.667 \text{ m} \approx 67 \text{ cm}$. 33 cm is the distance from the heavier particle, since the centre of mass lies closer to the larger mass.

3. Answer: (C) $-6\hat{i} \text{ N m}$

$\tau = \mathbf{r} \times \mathbf{F} = 2\hat{k} \times 3\hat{j} = 6(\hat{k} \times \hat{j}) = -6\hat{i} \text{ N m}$, because $\hat{k} \times \hat{j} = -\hat{i}$. Reversing the order ($\mathbf{F} \times \mathbf{r}$) gives the sign error $+6\hat{i} \text{ N m}$.

4. Answer: (A) 3 J

For a rolling disc $KE = \frac{1}{2}mv^2(1 + k^2/R^2) = \frac{3}{4}mv^2 = 0.75 \times 100 \times (0.2)^2 = 3 \text{ J}$, so 3 J of work must be removed. Counting only translational KE gives 2 J; forgetting to convert cm/s to m/s gives 30 kJ.

5. Answer: (A) $2 \times 10^{-6} \text{ N m}$

$I = \frac{1}{2}MR^2 = \frac{1}{2} \times 2 \times (0.04)^2 = 1.6 \times 10^{-3} \text{ kg m}^2$. $\omega = 3 \times 2\pi/60 = \pi/10 \text{ rad/s}$; $\theta = 2\pi \text{ rev} \times 2\pi = 4\pi^2 \text{ rad}$. $\alpha = \omega^2/2\theta = (\pi^2/100)/(8\pi^2) = 1/800 \text{ rad/s}^2$, so $\tau = I\alpha = 2 \times 10^{-6} \text{ N m}$. Treating 2π revolutions as 2π radians gives a value 2π times too large.

6. Answer: (C) $W_C > W_B > W_A$

Work needed equals the rotational KE $\frac{1}{2}I\omega^2$. $I_{\text{ring}} = MR^2 > I_{\text{disc}} = MR^2/2 > I_{\text{sphere}} = 2MR^2/5$, so $W_C > W_B > W_A$. The sphere needs the least because its mass is closest to the axis.

7. Answer: (D) $-7\hat{i} - 4\hat{j} - 8\hat{k}$

$\vec{r} = (2, 0, -3) - (2, -2, -2) = 2\hat{j} - \hat{k}$. $\vec{\tau} = \vec{r} \times \mathbf{F} = \hat{i}(2 \cdot (-6) - (-1) \cdot 5) - \hat{j}(0 \cdot (-6) - (-1) \cdot 4) + \hat{k}(0 \cdot 5 - 2 \cdot 4) = -7\hat{i} - 4\hat{j} - 8\hat{k}$. The other vectors have the components permuted.

8. Answer: (D) Angular momentum

In free space there is no external torque, so angular momentum $L = I\omega$ is conserved. Increasing the radius raises I , so ω falls and the rotational KE $L^2/2I$ also falls.

9. Answer: (B) 5 : 7

$K_t = \frac{1}{2}mv^2$, $K_r = \frac{1}{2}(2/5 mR^2)(v/R)^2 = (1/5)mv^2$. $K_t : (K_t + K_r) = \frac{1}{2} : (7/10) = 5 : 7$. The ratio 2 : 5 is $K_r : K_t$.

10. Answer: (C) 25 rad/s²

For a hollow cylinder about its axis $I = MR^2 = 3 \times (0.4)^2 = 0.48 \text{ kg m}^2$. Torque $\tau = FR = 30 \times 0.4 = 12 \text{ N m}$, so $\alpha = \tau/I = 12/0.48 = 25 \text{ rad/s}^2$. 25 m/s² has the right number but wrong units for an angular acceleration.

11. Answer: (D) $(1/3)\omega$

$I_1 = ML^2/12$. Each added mass contributes $(M/3)(L/2)^2 = ML^2/12$, so $I_2 = ML^2/12 + 2 \times ML^2/12 = 3ML^2/12$. With no external torque, $I_1\omega = I_2\omega'$, so $\omega' = \omega/3$. Taking each mass at the full length L instead of $L/2$ leads to the wrong value $\omega/9$.

12. Answer: (A) 60 J

Total KE at the bottom = $mgh = 3 \times 10 \times 7 = 210 \text{ J}$ (taking $g = 10 \text{ m s}^{-2}$). For a solid sphere, $K_{\text{rot}}/K_{\text{total}} = (2/5)/(1 + 2/5) = 2/7$, so $K_{\text{rot}} = 210 \times 2/7 = 60 \text{ J}$. 70 J would be one third of the energy, the fraction for a different shape.

13. Answer: (C) $L_B > L_A$

Rotational KE = $L^2/(2I)$, so $L = \sqrt{2IK}$. With equal K, the body with the larger moment of inertia has the larger angular momentum, so $L_B > L_A$. The masses alone do not fix an exact ratio such as 2, since only I enters.

14. Answer: (B) 1 : 5

$E_{\text{sphere}} = \frac{1}{2}(2/5 mR^2)\omega^2 = mR^2\omega^2/5$ and $E_{\text{cylinder}} = \frac{1}{2}(\frac{1}{2}mR^2)(2\omega)^2 = mR^2\omega^2$. The ratio is 1 : 5. Ignoring the doubled angular speed of the cylinder would give 4 : 5.

15. Answer: (A) $(m_1 m_2 / (m_1 + m_2)) l^2$

The distances from the centre of mass are $r_1 = m_2 l / (m_1 + m_2)$ and $r_2 = m_1 l / (m_1 + m_2)$. Then $I = m_1 r_1^2 + m_2 r_2^2 = m_1 m_2 l^2 / (m_1 + m_2)$, the reduced mass times l^2 . $(m_1 + m_2)l^2$ would be the value if both masses were at distance l.

16. Answer: (B) $13 MR^2/32$

The full disc has $I = MR^2/2 = 16MR^2/32$. The removed piece has mass $M/4$ and radius $R/2$, with its centre at $R/2$, so by the parallel axis theorem its $I = (M/4)(R/2)^2/2 + (M/4)(R/2)^2 = 3MR^2/32$. Remaining $I = 16MR^2/32 - 3MR^2/32 = 13MR^2/32$; forgetting the parallel-axis term gives the wrong $15MR^2/32$.

17. Answer: (A) 8.0

At $t = 2 \text{ s}$, $\omega = \alpha t = 4 \text{ rad/s}$. For a point on the rim, centripetal acceleration = $\omega^2 r = 16 \times 0.5 = 8 \text{ m/s}^2$ and tangential acceleration = $\alpha r = 1 \text{ m/s}^2$. Net = $\sqrt{64 + 1} \approx 8.06 \approx 8.0 \text{ m/s}^2$; taking only the tangential part misses the dominant centripetal term.

18. Answer: (B) Sphere

For rolling without slipping, acceleration = $g \sin \theta / (1 + k^2/R^2)$, independent of mass. A solid sphere has $k^2/R^2 = 2/5$, smaller than the disc's $1/2$, so the sphere accelerates more and reaches first. Mass does not matter because it cancels.

19. Answer: (A) $W(d - x)/d$

Take torques about knife edge B: $N_A \times d = W \times (d - x)$, so $N_A = W(d - x)/d$. Wx/d is the reaction at B, the usual mix-up.

20. Answer: (D) 5 : 7

Rolling solid sphere: $a = g \sin \theta / (1 + k^2/R^2) = g \sin \theta / (1 + 2/5) = (5/7)g \sin \theta$. Slipping without rolling: $a = g \sin \theta$. Ratio = 5 : 7, not the inverse 7 : 5.

21. Answer: (C) 157 N

$I = (1/2)MR^2 = (1/2)(50)(0.5)^2 = 6.25 \text{ kg m}^2$ and $\alpha = 2 \text{ rev s}^{-2} = 4\pi \text{ rad s}^{-2}$. $\tau = I\alpha$ gives $T = 6.25 \times 4\pi/0.5 = 50\pi \approx 157 \text{ N}$; using $\alpha = 2 \text{ rad s}^{-2}$ gives the 25 N trap.

22. Answer: (A) $3g/(2L)$

About the hinge P, the weight acts at $L/2$: torque = $Mg(L/2)$. Moment of inertia of a rod about its end = $ML^2/3$. $\alpha = Mg(L/2)/(ML^2/3) = 3g/(2L)$. Using g/L treats the rod as a point mass at the end.

23. Answer: (D) Disc

Rolling KE = $(1/2)mv^2(1 + k^2/R^2)$ is converted to $mgh = mg \times 3v^2/(4g) = (3/4)mv^2$. So $1 + k^2/R^2 = 3/2$, $k^2/R^2 = 1/2$, which is the value for a disc. A solid sphere ($k^2/R^2 = 2/5$) or a ring ($k^2/R^2 = 1$) would rise to different heights.

24. Answer: (A) 40 cm

$x_{\text{cm}} = (300 \times 0 + 500 \times 40 + 400 \times 70)/(300 + 500 + 400) = 48000/1200 = 40 \text{ cm}$. Forgetting the 300 g mass at the origin in the denominator gives a larger, wrong value.

25. Answer: (C) 0.6 m

A rolling solid cylinder has KE = $\frac{1}{2}mv^2 + \frac{1}{2}(\frac{1}{2}mR^2)(v/R)^2 = \frac{3}{4}mv^2 = \frac{3}{4} \times 3 \times 16 = 36 \text{ J}$. Setting $\frac{1}{2}kx^2 = 36$ gives $x^2 = 72/200 = 0.36$, so $x = 0.6 \text{ m}$. Ignoring rotational KE gives 24 J and $x \approx 0.49 \text{ m}$, which leads to the 0.5 m trap.

26. Answer: (B) a line perpendicular to the plane of rotation

Angular momentum $L = r \times p$, and both r and p lie in the plane of rotation, so L is perpendicular to that plane. The tangent is the direction of linear momentum, and the radius is the direction of r .

27. Answer: (D) zero

The man, the other man and the boat form an isolated system with no external horizontal force (still water, friction-free), so the centre of mass of the system cannot move. The boat moves back as the man walks, but the common centre of mass shifts by zero.

28. Answer: (A) Increase by a factor of 4

The string tension acts towards the hole, so angular momentum $L = mvr$ is conserved. $KE = L^2/(2mr^2)$, so halving r makes KE four times larger. Saying it stays constant ignores the work done by the pulling force.

29. Answer: (C) $I_0 + ML^2/4$

By the parallel axis theorem, $I = I_0 + Md^2$, and the end of the rod is $d = L/2$ from the centre, so $I = I_0 + ML^2/4$. Using the full length L as the shift distance (giving $I_0 + ML^2$) is the usual mistake.

30. Answer: (B) $t = 1$ s

Torque is zero when angular acceleration is zero: $\alpha = d^2\theta/dt^2 = 12t - 12 = 0$, so $t = 1$ s. Setting the angular velocity $6t^2 - 12t$ to zero instead gives $t = 2$ s, which is the trap.

31. Answer: (A) (40/9) MR^2

Full disc: $I_1 = (9M)R^2/2$. Removed disc: $I_2 = M(R/3)^2/2 = MR^2/18$. Remaining $I = 81MR^2/18 - MR^2/18 = 80MR^2/18 = (40/9)MR^2$. Answers like $4MR^2$ come from subtracting $MR^2/2$ instead of using the small disc's own radius $R/3$.

32. Answer: (D) Solid cylinder

For rolling without slipping $a = g \sin \theta / (1 + k^2/R^2)$. The solid cylinder has $k^2/R^2 = 1/2$ and the hollow one 1, so the solid cylinder has the larger acceleration and reaches first at any angle. Masses being equal does not make them arrive together because the mass distribution differs.

33. Answer: (B) (a) and (b)

The weight of a body acts at its centre of gravity, and if g is uniform over the body (earth of infinite radius) the centre of gravity coincides with the centre of mass, so the first two statements are correct. The gravitational field of a body at an external point can be found by concentrating its mass at one point only for spherically symmetric bodies, and the radius of gyration is defined by $I = Mk^2$, not as the distance from the C.G. to the axis.

34. Answer: (D) $M\omega/(M + 2m)$

No external torque acts, so angular momentum is conserved: $Mr^2\omega = (M + 2m)r^2\omega'$, giving $\omega' = M\omega/(M + 2m)$. Adding mass increases the moment of inertia, so the angular velocity must fall; expressions bigger than ω such as $(M + 2m)\omega/M$ are wrong.

35. Answer: (C) 10.1 m

With no external force, momentum is conserved: $0.5 \times 2 = 50 \times v$, so the man moves up at 0.02 m/s. The stone takes $10/2 = 5$ s to reach the floor, in which the man rises $0.02 \times 5 = 0.1$ m, so he is at 10.1 m. Answering 10 m ignores the recoil; 9.9 m takes the recoil in the wrong direction.

36. Answer: (C) Zero

Only internal forces act, so total momentum stays zero (it was zero initially). Hence the centre of mass stays at rest and its speed is zero, whatever the individual speeds v and $2v$ are.

37. Answer: (A) $\omega M/(M + 2m)$

No external torque acts, so angular momentum is conserved: $MR^2\omega = (MR^2 + 2mR^2)\omega'$. Hence $\omega' = \omega M/(M + 2m)$. The added masses increase the moment of inertia, so the angular velocity must fall, which rules out the expression larger than ω .

38. Answer: (B) $\vec{r} \cdot \vec{\tau} = 0$ and $\vec{F} \cdot \vec{\tau} = 0$

$\vec{\tau} = \vec{r} \times \vec{F}$ is perpendicular to the plane containing $\vec{r}$ and $\vec{F}$. A vector perpendicular to both has zero dot product with each, so $\vec{r} \cdot \vec{\tau} = 0$ and $\vec{F} \cdot \vec{\tau} = 0$.

39. Answer: (D) (4/3) MI^2

Each rod's centre is $l/2$ from the axis: $I = MI^2/12 + M(l/2)^2 = MI^2/3$ (parallel-axis theorem). Four rods give $4MI^2/3$. Forgetting the parallel-axis term would give only $MI^2/3$ for the frame.

40. Answer: (A) $-2\hat{i} - \hat{j} + \hat{k}$

$\vec{r}_{cm} = (m_1\vec{r}_1 + m_2\vec{r}_2)/(m_1 + m_2) = [(\hat{i} + 2\hat{j} + \hat{k}) + 3(-3\hat{i} - 2\hat{j} + \hat{k})]/4 = (-8\hat{i} - 4\hat{j} + 4\hat{k})/4 = -2\hat{i} - \hat{j} + \hat{k}$.

41. Answer: (C) 1 : $\sqrt{2}$

About the central axis, $I(\text{disc}) = MR^2/2$ gives $k = R/\sqrt{2}$, and $I(\text{ring}) = MR^2$ gives $k = R$. So $k(\text{disc}) : k(\text{ring}) = 1 : \sqrt{2}$. $\sqrt{2} : 1$ is the inverted ratio (ring to disc).

42. Answer: (C) $ML^2/12$

Each half has mass $M/2$ and length $L/2$ and rotates about its own end: $I = 2 \times (1/3)(M/2)(L/2)^2 = ML^2/12$. The bend angle does not matter, because each element stays at the same distance from the axis, so the $\sqrt{2}$ factor is a trap.

43. Answer: (A) 10

$\theta = \omega_0 t + \frac{1}{2} \alpha t^2 = 2.0 \times 2 + \frac{1}{2} \times 3.0 \times 4 = 4 + 6 = 10$ rad. 4 rad counts only the initial-speed term.

44. Answer: (C) $3g/(2l)$

Torque of gravity about A is $mg(l/2) = I\alpha = (ml^2/3)\alpha$, so $\alpha = 3g/(2l)$. $mg/l/2$ is the torque itself, not the angular acceleration.

45. Answer: (A) $LA = LB$

$L = mvd$, where d is the perpendicular distance from O to the line AB; this distance is the same for every point on the line, so $LA = LB$. The slope of AB changes d but not the equality between the two points.

46. Answer: (A) $ML\omega^2/2$

The liquid moves in circles about the axis and its centre of mass is at $L/2$, so the net centripetal force needed is $M\omega^2(L/2)$. This force is provided by the closed far end of the tube, so the liquid presses on it with $ML\omega^2/2$. Expressions with L^2 have the wrong dimensions for a force.

47. Answer: (A) $3g/2l$

The weight acts at the centre, $l/2$ from A, giving torque $\tau = mgl/2$. With $I = ml^2/3$, $\alpha = \tau/I = (mgl/2)/(ml^2/3) = 3g/(2l)$. The expression $mg(l/2)$ is the torque itself, not the angular acceleration.

48. Answer: (D) $1 : \sqrt{2}$

$E = L^2/2I$, so $L = \sqrt{2IE}$. For equal E , $L_1/L_2 = \sqrt{I_1/I_2} = 1 : \sqrt{2}$. The body with the larger moment of inertia has the larger angular momentum, not the smaller.

49. Answer: (D) $(3/2)MR^2$

About the central perpendicular axis $I = MR^2/2$. By the parallel-axis theorem, about a parallel axis through the edge $I = MR^2/2 + MR^2 = (3/2)MR^2$. $(5/2)MR^2$ wrongly adds $2MR^2$.

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