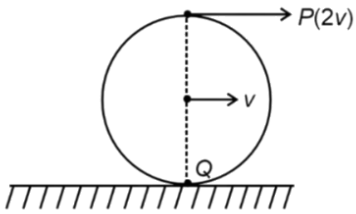
S1. Ans. (a)

In the case of pure rolling.



The topmost point will have velocity 2v while point Q i.e. lowest point will have zero velocity. Hence point P moves faster than point Q.

S2. Ans. (d)

Moment of inertia of rod $I = \frac{m\ell^2}{12}$

$\Rightarrow 2400 = 400\frac{\ell^2}{12}$

$\Rightarrow 72 = \ell^2$

$\Rightarrow \ell = \sqrt{72} = 8.48cm \simeq 8.5\ cm.$

S3. Ans. (a)

The angular acceleration direction is given along angular velocity or opposite to angular velocity depending upon whether angular velocity magnitude is increasing or decreasing and this direction remains along the axis of circular motion.

S4. (None)

Radius of gyration of a solid surface,

$K_S = \sqrt{\frac{2}{5}}R$

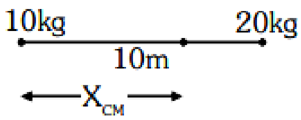
Radius of gyration of a hollow surface,

$K_H = \sqrt{\frac{2}{3}}R$

$\Rightarrow \frac{K_S}{K_H} = \sqrt{\frac{3}{5}} = \frac{\sqrt{3}}{\sqrt{5}}$

S5. Ans. (a)

$X_{CM} = \frac{20 \times 10}{20 + 10} = \frac{20}{3}m$



S6. Ans. (a)

$\omega = \omega_0 + \alpha t$

$\alpha = \frac{\omega - \omega_0}{t}$

$= \frac{(3120 - 1200)}{16\ s} rpm$

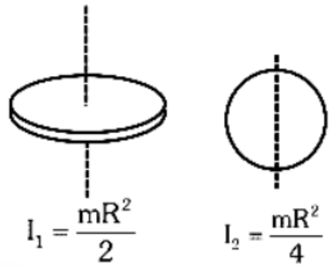
$= \frac{1920}{16} \times \frac{2\pi}{60} rad/s^2$

$= 4\pi\ rad/s^2$

S7. Ans. (a)

$k = \sqrt{\frac{I}{m}}$

$\Rightarrow \frac{k_1}{k_2} = \sqrt{\frac{I_1}{I_2}} = \sqrt{\frac{mR^2/2}{mR^2/4}} = \sqrt{2} : 1$



S8. Ans. (c)

Hint: By balancing torque

2g × 20 = 0.5g × 60 + mg × 120

$m = \frac{0.5}{6} kg = \frac{1}{12}$ kg

S9. Ans. (b)

Hint: $\vec{F} = 3\hat{j}N, \vec{r} = 2\hat{k}$

$\vec{\tau} = \vec{r} \times \vec{F} = 2\hat{k} \times 3\hat{j} = 6(\hat{k} \times \hat{j})$

$= 6(-\hat{i})$

$\vec{\tau} = -6\hat{i}Nm$

S10. Ans. (b)

Hint: For two bodies system

$x_{cm} = \frac{m_1x_2+m_2x_2}{m_1+m_2}$

$= \frac{5\times0+100\times10}{5+10} = \frac{200}{3} = 66.66$ cm

S11. Ans. (d)

Hint: $\omega_0 = \frac{360}{60}$ rps $= 12\pi$ rads^{-1}

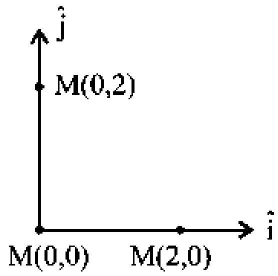
$\omega_0 = \frac{1200}{60}$ rps $= 4\pi$ rads^{-1}

$\omega = \omega_0 + \alpha t$

$\Rightarrow \alpha = \frac{\omega - \omega_0}{t} = \frac{28\pi}{14} = 2\pi$ rad s^{-2}

S12. Ans. (b)

Hint:



$X_{cm} = \frac{M\times0+M\times2+M\times0}{3M} = \frac{2}{5}$

$Y_{cm} = \frac{M\times0+M\times2+M\times0}{3M} = \frac{2}{3}$

Position vector $= \frac{2}{3}\hat{i} + \frac{2}{3}\hat{j} = \frac{2}{3}\ (\hat{i}+\hat{j})$

S13. Ans. (a)

Hint: Work needed = change in kinetic energy Final KE = 0

Initial KE $= \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{3}{4}mv^2$

$$\left(\begin{matrix}\because I = \frac{1}{2}\ mr^2 \\ \text{and } \omega = \frac{v}{r}\end{matrix}\right)$$

$= \frac{3}{4} \times 100 \times (20 \times 10^{-2})^2 = 3J$

$|\Delta KE| = 3J$

S14. Ans. (a)

Hint: $\theta = 2\pi$ revolution

$= 2\pi \times 2\pi = 4\pi^2 rad$

$\omega_i = 2\pi f = 2\pi \times \frac{3}{60} rad/s \left(\because f = \frac{3}{60} s^{-1}\right)$

$\omega_f = 0$

Work energy theorem.

$W = \frac{1}{2}I\left(\omega_f^2 - \omega_i^2\right)$

$\Rightarrow -\tau\theta = \frac{1}{2} \times \frac{1}{2} mt^2\left(0^2 - \omega_i^2\right)$

$\Rightarrow -\tau = \frac{\frac{1}{2}\times\frac{1}{2}\times2\left(4\times10^{-2}\right)^2\left(-3\times\frac{2\pi}{60}\right)^2}{4\pi^2}$

$\Rightarrow \tau = 2 \times 10^{-6} Nm$

S15. Ans. (b)

Hint: $\frac{K_f}{K_T+K_R} = \frac{\frac{1}{2}mv^2}{\frac{1}{2}mv^2+\frac{1}{2}I\omega^2}$

$\Rightarrow \frac{\frac{1}{2}mv^2}{\frac{1}{2}mv^2+\frac{1}{2}\times\frac{2}{5}mR^2\left(\frac{v^2}{R^2}\right)} = \frac{5}{7}$

S16. Ans. (d)

Hint: As $\tau_{ext} = 0$ Angular momentum will remain conserved

S17. Ans. (c)

Hint: From work energy theorem, to stop the system

$W_{ext} = \frac{1}{2}I\omega^2 \Rightarrow W_{ext} \propto I$

$I_C > I_B > I_A \Rightarrow W_C > W_B > W_A$

S18. Ans. (d)

Hint: $\vec{\tau} = \vec{r} \times \vec{F}$

$\vec{\tau} = \left(0\hat{i} + 2\hat{j} - \hat{k}\right) \times \left(4\hat{i} + 5\hat{j} - 6\hat{k}\right)$

$\vec{\tau} = -7\hat{i} - 4\hat{j} - 8\hat{k}$

S19. Ans. (d)

Hint: Centre of mass may lie on centre of gravity net torque of gravitational pull is zero about centre of mass.

Mechanical advantage $= \frac{\text{Load}}{\text{Effort}} > 1$

Load > Effort

S20. Ans. (b)

Hint: Hollow cylinder is equivalent to ring

$I_{ring} = MR^2$

$\tau = I\alpha$ ....(1)

$\tau = FR$ ....(2)

$I\alpha = FR$

$mR^2\alpha = FR \Rightarrow MR\alpha = F$

$\alpha = \frac{F}{MR} \Rightarrow \frac{30}{3\times40\times10^{-2}} \Rightarrow \alpha = 25\ rad/s^2$

S21. Ans. (a)

Hint: External torque = zero By conservation of angular momentum

$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega$

$I_1 = I_2 = I$

$\omega = \frac{\omega_1 + \omega_2}{2}$

$KE_1 = \frac{1}{2}I\omega_1^2 + \frac{1}{2}I\omega_2^2$

$KE_2 = \frac{1}{2}(2I)\omega^2$

$KE_2 = I\left[\frac{\omega_1+\omega_2}{2}\right]^2$

$\Delta KE = \frac{1}{2}I[\omega_1 - \omega_2]^2$

S22. Ans. (a)

Hint: External torque is zero Angular momentum conserved

$I_1\omega_1 = I_2\omega_2$

$\frac{ML^2}{12}\omega = \left[\frac{ML^2}{12} + \frac{M}{3}\left[\frac{L}{2}\right]^2 + \frac{M}{3}\left[\frac{L}{2}\right]^2\right]\omega^2$

$\omega_2 = \frac{\omega}{3}$

S23. Ans. (b)

Hint: $mgh = \frac{1}{2}\left[\frac{7}{5}mR^2\right]\omega^2$........(1)

$KE_{rot} = \frac{1}{2}\left[\frac{2}{5}mR^2\right]\omega^2$..............(2)

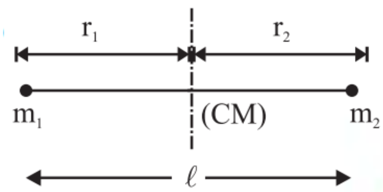
by Eqs. (1) and (2)

$KE_{rot} = \frac{2}{7}mgh$

$= \frac{2}{7} \times 3 \times 10 \times 7 = 60\ J$

S24. Ans. (c)

Hint:



$r_1 = \frac{m_2\ell}{m_1+m_2}, r = \frac{m_1\ell}{m_1+m_2}$

$I_{cm} = m_1r_1^2 + m_2r_2^2 = \frac{m_1m_2}{m_1+m_2}\ell^2$

S25. Ans. (d)

Hint: $K.E_{rotation} = \frac{1}{2}I\omega^2$

$E_{sphere} = \frac{1}{2}I_s\omega^2 = \frac{1}{2} \times \frac{2}{5}Mr^2 \times \omega^2$

$E_{cylinder} = \frac{1}{2}I_c(2\omega)^2 = \frac{1}{2} \times \frac{MR^2}{2} \times 4\omega^2$

$\frac{E_{sphere}}{E_{cylinder}} = \frac{1}{5}$

S26. Ans. (a)

Hint: $K_A = K_B \Rightarrow \frac{L_A^2}{2I_A} = \frac{L_B^2}{2I_B}$

As $I_B > I_A$ So, $L_A^2 < L_B^2 \Rightarrow L_A < L_B \Rightarrow L_B > L_A$

S27. Ans. (c)

Hint: Impulse = $|\overrightarrow{\Delta P}| = |\overrightarrow{m\Delta V}|$

$= m(2V\cos 60°) = mV$

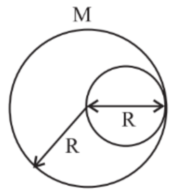
S28. Ans. (a)

Hint: Centripetal acceleration $= \frac{v^2}{R} =$ $a\cos 30°$

$\Rightarrow v = \sqrt{aR\cos 30°} = \sqrt{15 \times 2.5 \times \frac{\sqrt{3}}{2}} = 5.7\ m/s$

S29. Ans. (b)

Hint:



$I_{total\ disc} = \frac{MR^2}{2}$

$M_{Removed} = \frac{M}{4}$ (Mass ∝ area)

$I_{Removed}$ (about same Perpendicular axis)

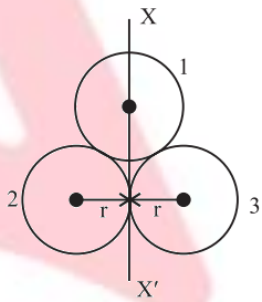
$= \frac{\frac{M}{4}\left(\frac{R}{2}\right)^2}{2} + \frac{M}{4}\left(\frac{R}{2}\right)^2 = \frac{3MR^2}{31}$

$I_{Remaing\ disc} = I_{disc} - I_{Removed}$

$= \frac{MR^2}{2} - \frac{3}{32}MR^2 = \frac{13}{32}MR^2$

S30. Ans. (c)

Hint:



$I_{x_X}' = I_1 + I_2 + I_3$

$\frac{2}{3}mr^2 + \left(\frac{2}{3}mr^2 + mr^2\right) + \left(\frac{2}{3}mr^2 + mr^2\right)$

(Using parallel axis theorem)

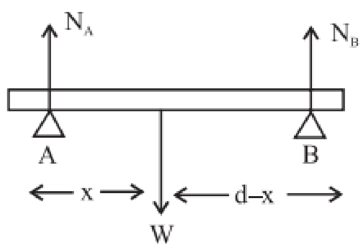
$\Rightarrow I_{xx}' = 2m^2 + 2mt^2 = 4mr^2$

S31. Ans. (c)

Hint: By torque balancing about B

$N_A(d) = W(d - x)$

$\Rightarrow N_A = \frac{W(d-x)}{d}$



S32. Ans. (b)

Hint: Angular momentum remains constant because of the torque of tension is zero

$\Rightarrow L_i = L_f$

$\Rightarrow mv_0 R = mv\frac{R}{2}$

$\Rightarrow v = 2v_0$

$KE_f = \frac{1}{2}m(2v_0)^2 = 2mv_0^2$

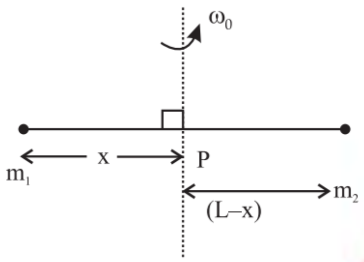
S33. Ans. (b)

Hint: For conservation of angular momentum about origin

$\sum \vec{\tau}_{net} = 0 \Rightarrow \vec{r} \times \vec{F} = 0 \Rightarrow \alpha = -1$

S34. Ans. (a)

Hint:



The position of point P on rod through which the axis should pass so that the work required to set the rod rotating with minimum angular velocity ω_0 is their center of mass so $m_1 x = m_2(L - x)$

$\Rightarrow x = \frac{m_2 L}{m_1 + m_2}$

S35. Ans. (b)

Hint: Velocity of the automobile

$v = 54 \times \frac{5}{18} = 15\ ms^{-1}$

$\omega_0 = \frac{v}{R} = \frac{15}{0.45} = \frac{100}{3}$ rad/s

So angular acceleration

$\alpha = \frac{\Delta\omega}{t} = \frac{\omega_f - \omega_0}{t} = -\frac{100}{45}$ rad/s^2

$\tau = I\alpha = 3 \times \frac{100}{45} = 6.66\ kgm^2/s^2$

S36. Ans. (a)

Hint: For rolling motion without slipping on inclined plane

$a_1 = \frac{g\sin\theta}{1+\frac{K^2}{R^2}}$

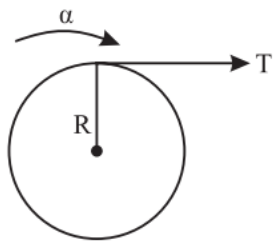
And for slipping motion on inclined plane

$a_2 = g\sin\theta$

Required ratio $= \frac{a_1}{a_2} = \frac{1}{1+\frac{K^2}{R^2}} = \frac{1}{1+\frac{2}{5}} = \frac{5}{7}$

S37. Ans. (d)

Hint:



Here, mass of the cylinder, M = 50 kg

Radius of the cylinder, R = 0.5 m

Angular acceleration, $\alpha = 2$ rev s^{-2}

$= 2 \times 2\pi$ rad s^{-2} $= 4\pi$ rad s^{-2}

Torque $\tau = TR$

Moment of inertia of the solid cylinder about its axis,

$I = \frac{1}{2}MR^2$

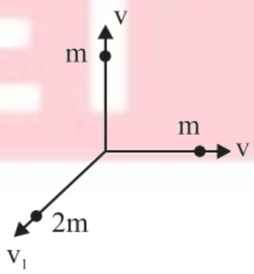
∴ Angular acceleration of the cylinder

$\alpha = \frac{\tau}{I} = \frac{TR}{\frac{1}{2}MR^2}$

$T = \frac{MR\alpha}{2} = \frac{50 \times 0.5 \times 4\pi}{2} = 157$ N

S38. Ans. (b)

Hint:



By conservation of linear momentum

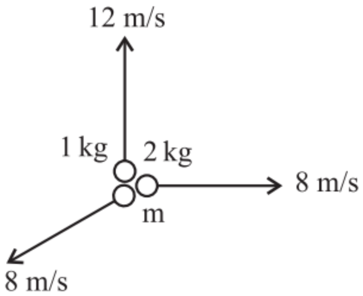
$2m_1 = \sqrt{2}\,mv \Rightarrow v_1 = \frac{v}{\sqrt{2}}$

Total K.E generated $= \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{4}(2m)v^2$

$= mv^2 + \frac{mv^2}{2} = \frac{3}{2}mv^2$

S39. Ans. (c)

Hint:

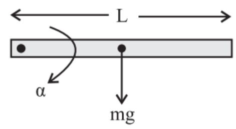


From conservation of momentum

$m(4) = \sqrt{(1 \times 12)^2 + (2 \times 8)^2} \Rightarrow m = 5\text{ kg}$

S40. Ans. (b)

Hint:



$\tau = I\alpha \Rightarrow mg\left(\frac{L}{2}\right) = \left(\frac{ML^3}{3}\right)\alpha \Rightarrow \alpha = \frac{3g}{2L}$