Motion of System of Particles and Rigid Body

1. The moment of inertia of a body about a given axis is 1.2kg×m2.Initially, the body is at rest. In order to produce a rotational KE of 1500 joule, an angular acceleration of 25rad/sec2must be applied about that axis for a duration of

   (a) 4 s (b) 2 s (c) 8 s (d) 10 s

Answer: (b)

$K_R = \frac{1}{2}I\omega^2 = \frac{1}{2}I(\alpha t)^2 = \frac{1}{2}I\alpha^2 t^2$

$1500 = \frac{1}{2} \times 1.2 \times (25)^2 t^2$

or t2=4ort=2s

2. A stick of length l is held vertically with one end on the floor and is then allowed to fall, find the speed of the other end when it hits the floor. Assuming the end on the floor does not slip.

   (a) $\sqrt{3gl}$ (b) $\sqrt{\frac{3g}{l}}$ (c) $\sqrt{2gl}$ (d) $\sqrt{\frac{2g}{l}}$

Answer: (a)

From the conservation of energy

Loss in (PE) = gain in (KE)

$mg\left(\frac{l}{2}\right) = \frac{1}{2}I\omega^2 = \frac{1}{2}\left(\frac{ml^2}{3}\right)\omega^2 \Rightarrow \omega = \sqrt{\frac{3g}{l}}$

So $v = \omega l = \sqrt{3gl}$

3. A ring of mass 100 kg and diameter 2m is rotating at the rate of $\left(\frac{300}{\pi}\right)$ rpm. Then

(a) moment of inertia is 100kg–m2

(b) kinetic energy is 5 kJ

(c) if a retarding torque of 200 N-m starts acting then it will come at rest after 5 sec.

(d) all of these

Answer: (d)

Moment of inertia $= MR^2$

k.E of rotation $= \frac{1}{2} I\omega^2$

Torque $= I\alpha$ where $\alpha = \frac{\omega_0}{t}$

4. Two particles A and B, initially at rest, move towards each other under a mutual force of attraction. At the instant when the speed of A is V and the speed of B is 2V, the speed of the centre of mass of the system is

(a) zero (b) V (c) 1.5 V (d) 3 V

Answer: (a)

Since the system is free from external force.

$\therefore a_{cm} = 0$ and initially they are at rest.

$\therefore v_{cm} = 0$

5. A square plate is kept in yz-plane. Then according to perpendicular axis theorem

(a) $I_z=I_x+I_y$ (b) $I_x=I_y+I_z$ (c) $I_y=I_x+I_z$ (d) All

Answer: (b)

For a mass distribution in y-z plane

$I_x=I_y+I_z$

6. What must be the relation between length 'L' and radius 'R' of the cylinder if its moment of inertia about its axis is equal to that about the equatorial axis?

(a) L = R (b) L = 2R (c) L = 3R (d) $L=\sqrt{3}R$

Answer: (d)

$$\frac{mR^2}{2} = M\left(\frac{L^2}{12} + \frac{R^2}{4}\right)$$

or $\frac{R^2}{2} = \frac{L^2}{12} + \frac{R^2}{4}$

or $L=\sqrt{3}R$

7. A particle performs uniform circular motion with angular momentum 'L'. If the frequency of particles motion is halved and its KE is doubled then the angular momentum becomes

(a) $\frac{L}{4}$ (b) 4L (c) 2L (d) L/2

Answer: (b)

$K.E. = \frac{1}{2}I\omega^2 = \frac{1}{2}(I\omega)(\omega)$

or $K.E. = \frac{1}{2}L\omega$

or $L = \frac{2(2K.E.)}{(\omega / 2)}$

Now $L' = \frac{2(2K.E.)}{(\omega / 2)} = 4L$

8. The angular speed of rotating rigid body is increased from 4ω to 5ω. The percentage increase in its K.E. is

(a) 20% (b) 25% (c) 125% (d) 56%

Answer: (d)

$K.E. = \frac{1}{2}I\omega^2 \Rightarrow K.E. \propto \omega^2$

$\% \text{ increase K.E.} = \frac{KEf - KEi}{KEi} \times 100 = \frac{5^2 - 4^2}{4^2} \times 100 = \frac{9}{16} \times 100 = 56\%$

9. Two loops P and Q are made from a uniform wire. The radii of P and Q are r_1 and r_2 respectively, and their moments of inertia are I_1 and I_2 respectively. If $I_2 = 4I_1$, then $\frac{r_2}{r_1}$ equals

(a) $4^{2/3}$ (b) $4^{1/3}$ (c) $4^{-2/3}$ (d) $4^{-1/3}$

Answer: (b)

$I = MR^2 = (2\pi R A d)R^2$

or $I \propto R^3$

or $R \propto I^{1/3}$

or $\frac{R_2}{R_1} = \left(\frac{I_2}{I_1}\right)^{1/3} = \left(\frac{4}{1}\right)^{1/3}$

10. A loop of radius 3 meter and weighs 150 kg. It rolls along a horizontal floor so that its centre of mass has a speed of 15 cm/sec. How much work has to be done to stop it

(a) 3.375 J (b) 7.375 J (c) 5.375 J (d) 9.375 J

Answer: (a)

Required work = Total K.E.

$$= \frac{1}{2}mv^2\left(1+\frac{k^2}{R^2}\right) = \frac{1}{2}Mv^2\left(1+\frac{k^2}{R^2}\right) = \frac{1}{2}\times150\times(0.15)^2(1+1) = 3.375J$$

11. The moment of inertia of a body is I and its coefficient of linear expansion is α if temperature of body rises by a small amount ΔT. Then change in moment of inertia about the same axis

(a) $\alpha I \Delta T$ (b) $2\alpha I \Delta T$ (c) $4\alpha I \Delta T$ (d) $\frac{\alpha I \Delta T}{2}$

Answer: (b)

Let $I=mr^2$

$$\frac{\Delta I}{I} = \frac{2\Delta r}{r} = 2\alpha\Delta T$$

or $\boxed{\Delta I = 2\alpha I \Delta T}$

12. A sphere of mass 2 kg and radius 5 cm rolls without slipping along a horizontal plane. The velocity of its centre of mass is 10 cm/s. The kinetic energy of the sphere is

(a) 0.07 J (b) 0.014 J (c) 0.025 J (d) 1.25 J

Answer: (b)

$$T = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$$

$I = \frac{2}{5}mr^2$ and $v = \omega r$ as it is rolling without slipping.

$\therefore I = \frac{7}{10}mv^2 = \frac{7}{10} \times 2 \times 0.1^2 = 0.014J$

13. A flywheel has moment of inertia $4 kg-m^2$ and has kinetic energy of 200 J. Calculate the number of revolutions is makes before coming to rest if a constant opposing couple of 5N-m is applied to the flywheel

(a) 12.8 rev (b) 24 rev (c) 6.4 rev (d) 16 rev

Answer: (c)

$W = \Delta KE$ or $\tau(\theta) = \frac{1}{2}I\omega^2$

$\tau(2\pi n) = \frac{1}{2}I\omega^2$

14. Two points of a rod move with velocities 3v and v perpendicular to the rod and in the same direction, separated by a distance 'r'. Then the angular velocity of the rod is

(a) $\frac{3v}{r}$ (b) $\frac{4v}{r}$ (c) $\frac{5v}{r}$ (d) $\frac{2v}{r}$

Answer: (d)

$\omega_{rod} = \omega_{point} = \left(\frac{v_{rel.}}{r}\right)$; v_{re} being the velocity of one point w.r.t other

$= \frac{3v - v}{r}$ and 'r' being the distance between them $\frac{2v}{r}$

15. The moment of inertia of a solid sphere of radius R about its diameter is same as the that of disc of radius 2R about its diameter. The ratio of their masses is

(a) 5 : 2 (b) 5 : 8 (c) 4 : 1 (d) 2 : 1

Answer: (a)

$\frac{2}{5}M_sR^2 = \frac{M_d(2R)^2}{4}$

or $\frac{M_s}{M_d} = \frac{5}{2}$

16. The moment of inertia of a disc about an axis passing through its centre and normal to its plane is I. The disc is now folded along a diameter such that the two halves are mutually perpendicular. Its moment of inertia about this diameter will now be

(a) I (b) I/$\sqrt{2}$ (c) I/2 (d) I/4

Answer: (c)

$I = \frac{1}{2}mR^2$ For a diameter; $I' = \frac{I}{2}$

17. The radius of a wheel is R and its radius of gyration about its axis passing through its center and perpendicular to its plane is K. If the wheel is rolling without slipping the ratio of its rotational kinetic energy to its translational kinetic energy is

(a) $\frac{K^2}{R^2}$ (b) $\frac{R^2}{K^2}$ (c) $\frac{R^2}{R^2+K^2}$ (d) $\frac{K^2}{R^2+K^2}$

Answer: (a)

$$\frac{K.E._{rot.}}{K.E_{trans.}} = \frac{\frac{1}{2}mv^2\frac{k^2}{R^2}}{\frac{1}{2}mv^2} = \frac{k^2}{R^2}$$

18. A particle is moved in a circle with a constant angular velocity. Its angular momentum is L. If the radius of the circle is halved keeping the angular velocity same, the angular momentum of the particle will become

(a) $\frac{L}{4}$ (b) $\frac{L}{2}$ (c) L (d) 2L

Answer: (a)

$$L = I\omega$$

$$\therefore \frac{L_2}{L_1} = \frac{I_2}{I_1} \quad [\because \omega = \text{const.}]$$

$$\text{or } \frac{L_2}{L_1} = \frac{m\left(\frac{r}{2}\right)^2}{mr^2} = \frac{1}{4}$$

$$\Rightarrow L_2 = \frac{L_1}{4}$$

19. A sphere of mass 10 kg and radius 0.5 m rotates about a tangent. The moment of inertia of the sphere about the tangent is

(a) $5 kgm^2$ (b) $2.7 kgm^2$ (c) $3.5 kgm^2$ (d) $4.5 kgm^2$

Answer: (c)

$$I_{tangent} = \frac{2}{5}Mr^2 + Mr^2 = \frac{7Mr^2}{5} = \frac{7}{5} \times 10 \times 0.5 \times 0.5 = 3.5 kgm^2$$

20. A solid cylinder of mass M and radius R rolls from rest down a plane inclined at an angle θ to the horizontal. The velocity of the centre of mass of the cylinder after it has rolled down a distance d is

(a) $\sqrt{\frac{2}{3}gd\tan\theta}$ (b) $\sqrt{gd\tan\theta}$ (c) $\sqrt{\frac{3}{4}gd\sin\theta}$ (d) $\sqrt{\frac{4}{3}gd\sin\theta}$

Answer: (d)

$$v = \sqrt{2ad} = \sqrt{2\frac{g\sin\theta}{1+\frac{K^2}{R^2}}.d}$$

Here $\frac{K^2}{R^2} = \frac{1}{2}$

$$v = \sqrt{\frac{4gd\sin\theta}{3}}$$

21. The ratio of the time taken by a solid sphere and that taken by a disc of the same mass and radius to roll down a smooth inclined plane from rest from the same height

(a) 15:14 (b) $\sqrt{15:14}$ (c) 14:15 (d) $\sqrt{14:15}$

Answer: (d)

$$t = \sqrt{\frac{2s}{g\sin\theta}\left(1+\frac{K^2}{R^2}\right)}$$

$$\frac{t_1}{t_2} = \sqrt{\frac{1+\frac{2}{5}}{1+\frac{1}{2}}} = \sqrt{\frac{14}{15}}$$

22. A force $\vec{F} = a\hat{i} + 3\hat{j} + 3\hat{k}$ is acting at a point $\vec{r} = 2\hat{i} - 6\hat{j} - 12\hat{k}$. The value of 'a' for which angular momentum is conserved is

(a) 0 (b) 1 (c) −1 (d) 2

Answer: (c)

Angular momentum will be conserved if $\tau = 0$

i.e. $\vec{r} \times \vec{F} = 0$

$$\frac{a}{2} = \frac{3}{-6} = \frac{6}{-12}$$

$\therefore a = -1$

23. When a mass is rotated in a plane about is fixed point, its angular momentum is directed along the

(a) radius (b) tangent to orbit

(c) axis of rotation (d) incline at an angle of 45°to plane of rotation

Answer: (c)

Angular momentum is directed along the axis of rotation.

24. The highest moment of inertia if all the objects have same mass and same radius is of

(a) a ring about its axis perpendicular to the plane of the ring

(b) a solid sphere about one of its diameters

(c) a spherical shell about one of its diameters

(d) a disc about its axis perpendicular to the plane of the disc

Answer: (a)

$I_{ring} = mr^2$

$I_{solid sphere} = \frac{2}{5} mr^2$

$I_{spherical shell} = \frac{2}{3} mr^2$

and $I_{disc} = \frac{mr^2}{2}$

25. A solid sphere of mass M and radius R rolls on a horizontal surface without slipping. The ratio of rotational kinetic energy to total kinetic energy is

(a) 1:2 (b) 2:5 (c) 2:7 (d) 7:10

Answer: (c)

$$\frac{KE_{Rot.}}{KE_{Total}} = \frac{\frac{1}{2} mv^2 \frac{K^2}{R^2}}{\frac{1}{2} mv^2 \left(1 + \frac{K^2}{R^2}\right)} = \frac{K^2/R^2}{1 + \frac{K^2}{R^2}} = \frac{2/5}{1+2/5}$$

26. A meter stick is held vertically with one end on the floor and is then allowed to fall. The speed of the other end when it hits the floor assuming that the end of the stick does not slip and $g = 9.8 m/s^2$

(a) 3.2 m/s (b) 5.4 m/s (c) 7.8 m/s (d) 9.2 m/s

Answer: (b)

loss in P.E. = gain in KE

$$mg\left(\frac{L}{2}\right) = \frac{1}{2} I \left(\frac{v}{L}\right)^2$$

27. If L, m denote the angular momentum and mass of a particle and P its linear momentum. Which of the following can represent the kinetic energy of the particle moving in a circle of radius R?

(a) $\frac{L^2}{2m}$ (b) $\frac{P^2}{m}$ (c) $\frac{L^2}{2mR^2}$ (d) $\frac{1}{2}mP^2$

Answer: (c)

$$KE = \frac{1}{2}I\omega^2 = \frac{1}{2}\frac{I^2\omega^2}{I} = \frac{L^2}{2(mR^2)}$$

28. A disc is rotating with an angular velocity ω_0. A constant retarding torque is applied on it to stop the disc. The angular velocity becomes $(\omega_0/2)$ after n rotations. How many more rotations will it make before coming to rest?

(a) n (b) 2n (c) n/2 (d) n/3

Answer: (d)

From third equation, $\omega^2 = \omega_0^2 - 2\alpha\theta$

$\Rightarrow (\omega_0/2)^2 = \omega_0^2 - 2\alpha(2n\pi)$

$\Rightarrow 4\pi n\alpha = 3/4\,\omega_0^2$ ...(1)

Let no. of rotations before coming to rest $= n'$

$\Rightarrow 0 = \left(\frac{\omega_0}{2}\right)^2 - 2\alpha(2\pi n') \Rightarrow 4\pi n'\alpha = \frac{\omega_0^2}{4}$ ...(2)

from (1)/(2) $n/n' = 3 \Rightarrow n' = n/3$

29. The angular velocity of a body changes from ω_1 to ω_2 without an external torque by changing moment of inertia. The ratio of initial radius of gyration to the final radius of gyration is

(a) $\omega_2 : \omega_1$ (b) $\omega_2^2 : \omega_1^2$ (c) $\sqrt{\omega_2} : \sqrt{\omega_1}$ (d) $\omega_1 : \omega_2$

Answer: (c)

Conservation of angular momentum gives

$I_1\omega_2 = I_2\omega_2$

$\Rightarrow mR_1^2\omega_1 = mR_2^2\omega_2 \Rightarrow \frac{R_1}{R_2} = \sqrt{\frac{\omega_2}{\omega_1}}$

30. Angular momentum of the particle rotating with a central force is constant due to

(a) constant torque (b) constant force

(c) constant linear momentum (d) zero torque

Answer: (d)

Torque of central force w.r.t. CM is zero

∴ Angular momentum is constant

31. The moment of inertia of a uniform disc about an axis passing through its centre and perpendicular to its plane is $1 kgm^2$. It is rotating with an angular velocity 100 rad/sec. Another identical disc is gently placed on it so that their centres coincide. Now these two discs together continue to rotate about the same axis. Then the loss in kinetic energy in kilojoule is

(a) 2.5 (b) 3.0 (c) 3.5 (d) 4.0

Answer: (a)

$\therefore I_1\omega_1 = I_2\omega_2$

$\therefore I \times 100 = (I+I)\omega' \Rightarrow \omega' = 50 rad/s$

$\Delta K = \frac{1}{2} I \omega^2 - \frac{1}{2}(2I)\omega'^2 = \frac{1}{2} \times 1 \times (100)^2 - \frac{1}{2} \times (50)^2 = 2500 J$

32. A disc initial at rest, is rotated about its axis with a uniform angular acceleration. In the first 2s, it rotates an angle θ.In the next 2s, the disc rotate through an angle

(a) θ (b) 2θ (c) 3θ (d) 4θ

Answer: (c)

$\theta_1 = \frac{1}{2}\alpha(2)^2 \quad [\omega_0 = 0]$

$\theta_1 + \theta_2 = \frac{1}{2}\alpha(2+2)^2 \quad [\because \omega_0 = 0]$

$\Rightarrow \theta_2 = 3\theta_1$

33. The torque required to stop a wheel of moment of inertia $5 \times 10^{-3} kgm^2$ from a speed of 20 rad/s in 10 s is

(a) 1 Nm (b) 0.1 Nm (c) 0.01 Nm (d) 0.001 Nm

Answer: (c)

From $\omega = \omega_o + \alpha t$ $\quad 0 = 20 + \alpha \cdot 10 \Rightarrow \alpha = -2 rad/s^2$

From $\tau = I\alpha$ $\quad \tau = 5 \times 10^{-3} \times 2 = 0.01 Nm$

34. For a rigid body made of total N particles each of mass m, the radius of gyration about a given axis equals to

(a) Root mean square values of the distance of the constituent particles from the given axis.

(b) Distance of any of the constituent particles form the given axis.

(c) mean of the distances of the constituent particles form the given axis.

(d) harmonic mean of the distance of consituent particles from the given axis.

Answer: (a)

$$K = \sqrt{\frac{I}{M}} = \sqrt{\frac{m_1 r_1^2 + m_2 r_2^2 + \ldots + m_n r_n^2}{m_1 + m_2 + \ldots + m_n}}$$

If $m_1 = m_2 = \ldots = m_n$

$$k = \sqrt{\frac{r_1^2 + r_2^2 + \ldots + r_n^2}{n}} = r_{rms}$$

35. A disc of mass M and radius R is reshaped in the form of ring of same mass but radius 2R. The radius of gyration goes up by a factor

(a) $\sqrt{2}$ (b) 4 (c) $2\sqrt{2}$ (d) 2

Answer: (c)

$K_{disc} = \frac{R}{\sqrt{2}}$ and $K_{ring} = 2R$

$$\therefore \frac{K_{ring}}{K_{disc}} = \frac{2R}{\frac{R}{\sqrt{2}}} = 2\sqrt{2}$$

36. If the system consists of two identical particles. One particle is at rest and the other particle has an acceleration 'a'. The centre of mass of the system has an acceleration of

(a) 2a (b) a (c) $\frac{a}{2}$ (d) $\frac{a}{4}$

Answer: (c)

$$a_{cm} = \frac{m_1 a_1 + m_2 a_2}{m_1 + m_2} = \frac{m(0) + m(a)}{m + m} = a/2$$

37. A nonzero external force acts on a system of particles. The velocity and the acceleration of the centre of mass are found to be v_o and a_o at an instant t. It is possible that

(a) $v_o = 0, a_o = 0$ (b) $v_o = 0, a_o \neq 0$ (c) $v_o \neq 0, a_o = 0$ (d) $v_o \neq 0, a_o \neq 0$

Answer: (b)

Since $\vec{F}_{ext} \neq 0$

$\vec{a}_{cm} = a_o, \vec{v}_{cm} = v_o$ at any time 't'.

Since $\vec{a}_{cm} = \frac{\vec{F}_{ext}}{M}$ so $a_o \neq 0$

$v_o = 0$ and $a_o \neq 0$

38. Moment of inertia of a uniform circular disc about a diameter is I. Its moment of inertia about an axis perpendicular to its plane and passing through a point on its rim will be

(a) 5I (b) 3I (c) 6I (d) 4I

Answer: (c)

∴ M.I. about diameter, $I_1 = \frac{1}{4} MR^2$

∴ M.I. about tangent perpendicular to plane.

$I' = \frac{3}{2}MR^2 = \frac{3}{2}(4I) = 6I$

39. When an ideal diatomic gas is heated at constant pressure, the fraction of the heat energy supplied which increases the internal energy of the gas, is

(a) $\frac{2}{5}$ (b) $\frac{3}{5}$ (c) $\frac{3}{7}$ (d) $\frac{5}{7}$

Answer: (d)

$\Delta U = nC_v\Delta T, (\Delta Q)_p = nC_p\Delta T$

$$\frac{\Delta U}{(\Delta Q)_p} = \frac{C_v}{C_p} = \frac{1}{\gamma} = \frac{5}{7}$$

40. When a ceiling fan is switched off, its angular velocity reduces to 50%while it make 36 rotations. How many more rotations will it make before coming to rest? (Assume uniform angular retardation)

(a) 18 (b) 12 (c) 36 (d) 48

Answer: (b)

$$\left(\frac{\omega_0}{2}\right)^2 = \omega_0^2 - 2\alpha\theta_1 \Rightarrow 2\alpha\theta_1 = \frac{3}{4}\omega_0^2 \quad \text{...(i)}$$

$$0 = \left(\frac{\omega_0}{2}\right)^2 - 2\alpha\theta_2 \Rightarrow 2\alpha\theta_2 = \frac{\omega_0^2}{4} \quad \text{...(ii)}$$

from (i) & (ii) $\frac{\theta_1}{\theta_2} = 3$

$\Rightarrow \theta_2 = \frac{\theta_1}{3} = \frac{36}{3} = 12$ rotation

41. A coin placed on a rotating table just slips if it is placed at a distance 4r from the centre. On doubling the angular velocity of the table, the coin will just slip when at a distance from the centre equal to

(a) 4r (b) 2r (c) r (d) r/4

Answer: (c)

$\therefore \omega = \sqrt{\frac{\mu g}{r}}$ $\therefore \omega \propto \frac{1}{\sqrt{r}} \Rightarrow r \propto \frac{1}{\omega^2}$

Since ωis double thus

$r' = \frac{4r}{4} = r$

42. 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) $\sqrt{2}:1$ (b) $\sqrt{2}:\sqrt{3}$ (c) $\sqrt{3}:\sqrt{2}$ (d) $1:\sqrt{2}$

Answer: (d)

For disc , $K_1 = \sqrt{\frac{I}{M}} = \sqrt{\frac{\frac{1}{2}MR^2}{M}} = \frac{R}{\sqrt{2}}$

For Ring, $K_2 = \sqrt{\frac{I}{M}} = \sqrt{\frac{MR^2}{M}} = R$

$\Rightarrow \frac{K_1}{K_2} = \frac{1}{\sqrt{2}}$

43. Two rings of radius R and nR made up of same material have the ratio of moment of inertia about an axis passing through centre as 1:8.The value of n is

(a) 2 (b) $2\sqrt{2}$ (c) 4 (d) $\frac{1}{2}$

Answer: (a)

For Ring, $I=MR^2(\lambda\times2\pi R)R^2$

$\Rightarrow I=2\pi\lambda R^3$(where, λ=lineardensity)

$\therefore \frac{I_1}{I_2}=\left(\frac{R_1}{R_2}\right)^3 \Rightarrow \frac{1}{8}=\left(\frac{R}{nR}\right)^3 \Rightarrow n=2$

44. A homogeneous disc of mass 2 kg and radius 15 cm is rotating about its axis (which is fixed) with an angular velocity of 4 radian/sec. The linear momentum of the disc is

(a) 1.2 kg m/sec (b) 1.0 kg m/sec

(c) 0.6 kg m/sec (d) none of the above

Answer: (d)

Since, axis of the disc is fixed therefore velocity of centre of mass is zero.

45. A solid homogeneous sphere is moving on a rough horizontal surface, partly rolling and partly sliding. During this kind of motion of this sphere

(A) total kinetic energy is conserved

(B) angular momentum of the sphere about the point of contact with the plane is conserved

(C) only the rotational kinetic energy about the centre of mass is conserved.

(D) angular momentum about the centre of mass is conserved.

Answer: (d)

When sphere partly rolls & partly slides, frictional loss is there. Therefore, total mechanical energy cannot be conserved.

Since, all the forces passes through the instantaneous point of contact, their torque about this point is zero

$\Rightarrow$ Angular momentum about that point (not about the mass centre) remains constant.