PRACTICE EXERCISES

SINGLE CORRECT CHOICE TYPE QUESTIONS

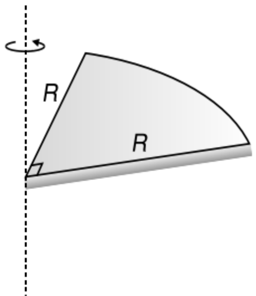
This section contains Single Correct Choice Type Questions. Each question has four choices (A), (B), (C) and (D), out of which ONLY ONE is correct.

1. Three identical rods, each of length l, are joined to form a rigid equilateral triangle. Its radius of gyration about an axis passing through a corner and perpendicular to the plane of the triangle is

(A) $\frac{l}{2}$ (B) $\sqrt{\frac{3}{2}}l$

(C) $\frac{l}{\sqrt{2}}$ (D) $\frac{l}{\sqrt{3}}$

2. One quarter sector is cut from a uniform disc of radius R. This sector has mass M. It is made to rotate about a line perpendicular to its plane and passing through the center of the original disc. Its moment of inertia about the axis of rotation is



(A) $\frac{MR^2}{2}$ (B) $\frac{MR^2}{4}$

(C) $\frac{MR^2}{8}$ (D) $\sqrt{2}MR^2$

3. Two particles of equal mass m at A and B are connected by a rigid light rod AB, lying on a smooth horizontal table. An impulse J is applied at A in the plane of the table and perpendicular at AB. Then the velocity of particle at A is

(A) ZERO (B) $\frac{J}{2m}$

(C) $\frac{J}{m}$ (D) $\frac{2J}{m}$

4. Two point masses of 0.3 kg and 0.7 kg are fixed at the ends of a rod of length 1.4 m and of negligible mass. The rod is set rotating about an axis perpendicular to its length with a uniform angular speed. The point on the rod through which the axis should pass in order that the work required for rotation of the rod is minimum, is located at a distance of

(A) 0.42 m from mass of 0.3 kg
(B) 0.70 m from mass of 0.7 kg
(C) 0.98 m from mass of 0.3 kg
(D) 0.98 m from mass of 0.7 kg

5. A spherical body of radius R is allowed to roll without slipping down an incline to reach the bottom with a speed v_0. The incline is then made smooth by waxing and the body is allowed to slide without rolling now to reach the bottom with a speed $\frac{5}{4}v_0$. The radius of gyration of the body about an axis passing through its centre is

(A) $\frac{2}{5}R$ (B) $\frac{3}{4}R$

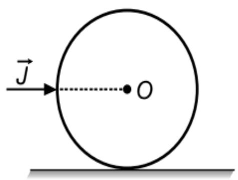
(C) $\frac{4}{3}R$ (D) $\frac{5}{2}R$

6. A uniform disc of radius R lies in x-y plane with its centre at origin. Its moment of inertia about the axis $x = 2R$ and $y = 0$ is equal to the moment of inertia about the axis $y = d$ and $z = 0$, then d equals

(A) $\frac{4R}{3}$ (B) $\frac{R\sqrt{17}}{2}$

(C) $R\sqrt{13}$ (D) $\frac{R\sqrt{15}}{2}$

7. An impulse J is applied on a ring of mass m along a line passing through its centre O. The ring is placed on a rough horizontal surface. The linear velocity of centre of ring once it starts rolling without slipping is

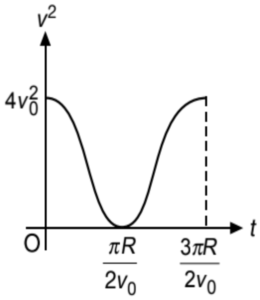


(A) $\frac{J}{m}$ (B) $\frac{J}{2m}$

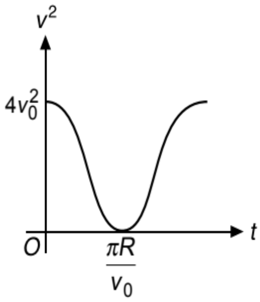
(C) $\frac{J}{4m}$ (D) $\frac{J}{3m}$

8. A wheel is rolling without sliding on a horizontal surface. The centre of the wheel moves with a constant speed v_0. Consider a point P on the rim which is at the top at time $t = 0$. The square of speed of point P is plotted against time t. The correct plot is (R is radius of the wheel)

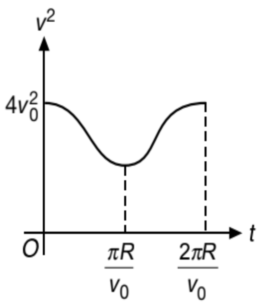
(A)



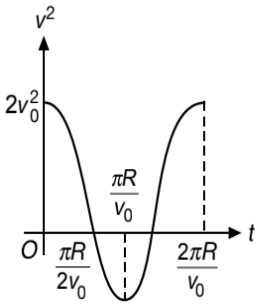
(B)



(C)



(D)



9. A thin uniform rod of mass m moves translationally with acceleration a due to two antiparallel forces of lever arm l. One force is of magnitude F and acts at one extreme end. The length of the rod is

(A) $l\left(1+\frac{F}{ma}\right)$ (B) $2l\left(1+\frac{F}{ma}\right)$

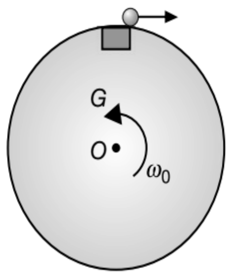
(C) $\frac{l}{2}\left(1+\frac{F}{ma}\right)$ (D) $\frac{mal}{ma+F}$

10. A ladder of length l and mass m is placed against a smooth vertical wall, but the ground is not smooth. Coefficient of friction between the ground and the ladder is μ. The angle θ at which the ladder will stay in equilibrium is

(A) $\theta = \tan^{-1}(\mu)$ (B) $\theta = \tan^{-1}(2\mu)$

(C) $\theta = \tan^{-1}\left(\frac{\mu}{2}\right)$ (D) $\theta = \tan^{-1}\left(\frac{1}{2\mu}\right)$

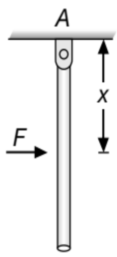
11. A horizontal turn table in the form of a disc of radius r carries a gun at G and rotates with angular velocity ω_0 about a vertical axis passing through the centre O. The increase in angular velocity of the system if the gun fires a bullet of mass m with a tangential velocity v with respect to the gun is (moment of inertia of gun + table about O is I_0)



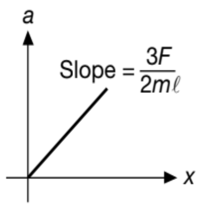
(A) $\frac{v}{2r}$ (B) $\frac{mvr}{2I_0}$

(C) $\frac{2mvr}{I_0}$ (D) $\frac{mvr}{I_0 + mr^2}$

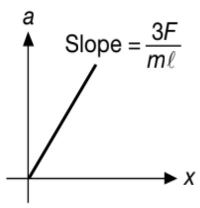
12. A rod of mass m and length l is hinged at one of its end A as shown in figure. A force F is applied at a distance x from A. The acceleration of centre of mass (a) varies with x as



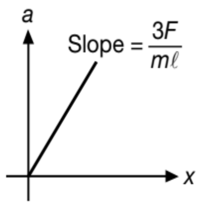
(A)



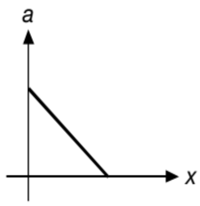
(B)



(C)



(D)



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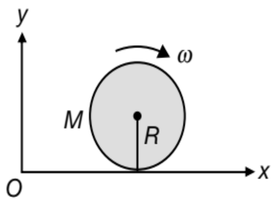
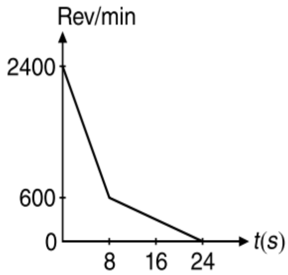
13. A disc of mass M and radius R is rolling with angular speed ω on a horizontal plane as shown in figure. The magnitude of angular momentum of the disc about the origin O is



(A) $\left(\frac{1}{2}\right)MR^2\omega$ (B) $MR^2\omega$

(C) $\left(\frac{3}{2}\right)MR^2\omega$ (D) $2MR^2\omega$

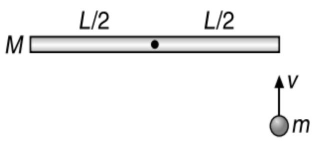
14. A table fan, rotating at a speed of 2400 rpm is switched off and the resulting variation of the rpm with time is shown in the figure. The total number of revolutions of the fan before it comes to rest is



(A) 420 (B) 280

(C) 190 (D) 380

15. A stick of length L and mass M lies on a frictionless horizontal surface on which it is free to move in any way. A ball of mass m moving with speed v collides elastically with the stick as shown in Figure. If after the collision ball comes to rest, then what should be the mass of the ball?



(A) $m = 2M$ (B) $m = M$

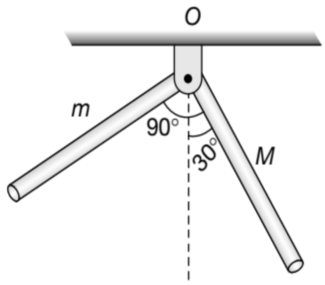
(C) $m = \frac{M}{2}$ (D) $m = \frac{M}{4}$

16. Let I be the moment of inertia of a uniform square plate about an axis AB that passes through its centre and is parallel to two of its sides. CD is a line in the plane of the plate that passes through the centre of the plate and makes an angle θ with AB. The moment of inertia of the plate about the axis CD is then equal to

(A) I (B) $I\sin^2\theta$

(C) $I\cos^2\theta$ (D) $I\cos^2\left(\frac{\theta}{2}\right)$

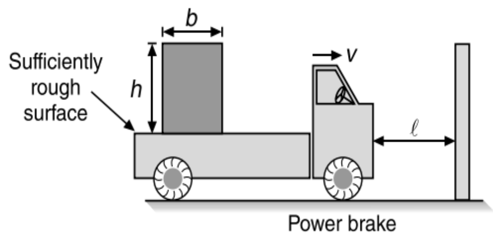
17. Two uniform rods of equal length but different masses are rigidly joined to form an L-shaped body, which is then pivoted as shown. If in equilibrium the body is in the shown configuration, ratio $\frac{M}{m}$ will be



(A) $\sqrt{2}$ (B) 2

(C) $\sqrt{3}$ (D) 3

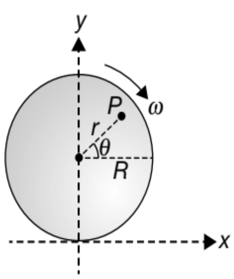
18. The minimum value of l so that truck can avoid hitting the dead end, without toppling the block kept on it is



(A) $\frac{2hv^2}{bg}$ (B) $\frac{bv^2}{2hg}$

(C) $\frac{2bv^2}{hg}$ (D) $\frac{hv^2}{2bg}$

19. A disc of radius R, having angular velocity ω rolls without slipping along positive x-axis. The velocity of point P at the instant shown in figure is



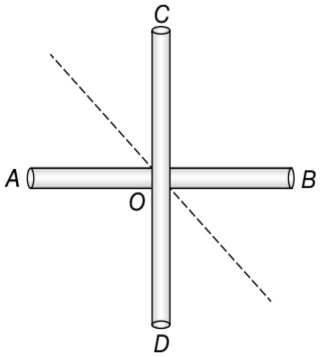
(A) $\vec{v}_P = \omega\left[(r\sin\theta)\hat{i} + (r\cos\theta)\hat{j}\right]$

(B) $\vec{v}_P = \omega\left[(r\sin\theta)\hat{i} - (r\cos\theta)\hat{j}\right]$

(C) $\vec{v}_P = \omega\left[(R + r\sin\theta)\hat{i} - (r\cos\theta)\hat{j}\right]$

(D) $\vec{v}_P = \omega\left[(R + r\sin\theta)\hat{i} + (r\cos\theta)\hat{j}\right]$

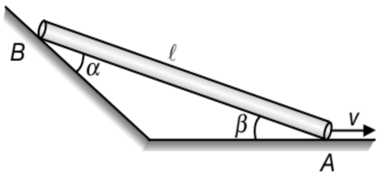
20. AB and CD are two identical rods each of length l and mass m joined to form a cross. The moment of inertia of these two rods about a bisector of the angle between the rods is



(A) $\frac{ml^2}{6}$ (B) $\frac{ml^2}{3}$

(C) $\frac{ml^2}{12}$ (D) $\frac{2ml^2}{3}$

21. A rod of length l slides down along the inclined wall as shown in figure. At the instant shown in figure the speed of end A is v, then the speed of B will be



(A) $\frac{v\sin\alpha}{\sin\beta}$ (B) $\frac{v\sin\beta}{\sin\alpha}$

(C) $\frac{v\cos\alpha}{\cos\beta}$ (D) $\frac{v\cos\beta}{\cos\alpha}$

22. A solid sphere and a hollow sphere of equal mass and radius are placed over a rough horizontal surface after rotating them about their respective centre of mass with same angular velocity ω_0. Once the pure rolling starts let v_1 and v_2 be the linear speeds of their centres of mass. Then

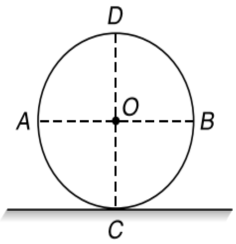
(A) $v_1 = v_2$

(B) $v_1 > v_2$

(C) $v_1 < v_2$

(D) data is insufficient

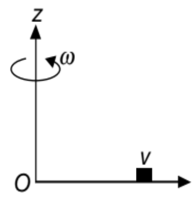
23. A uniform ring of mass M and radius R is in uniform pure rolling motion on a horizontal surface. The velocity of the centre of ring is v_0. The kinetic energy of the segment ACB is



(A) $\frac{Mv_0^2}{2} - \frac{Mv_0^2}{\pi}$ (B) $\frac{Mv_0^2}{2} + \frac{Mv_0^2}{\pi}$

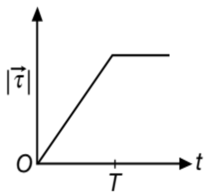
(C) $\frac{Mv_0^2}{2}$ (D) Mv_0^2

24. A thin uniform rod, pivoted at O, is rotating in the horizontal plane with constant angular speed ω, as shown in the figure.

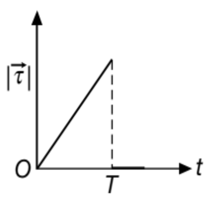


At time $t = 0$, a small insect starts from O and moves with constant speed v with respect to the rod towards the other end. It reaches the end of the rod at $t = T$ and stops. The angular speed of the system remains ω throughout. The magnitude of the torque $(|\vec{\tau}|)$ on the system about O, as a function of time is best represented by which plot?

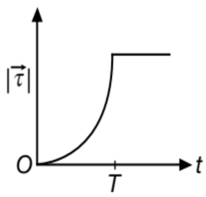
(A)



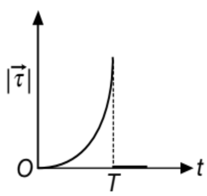
(B)



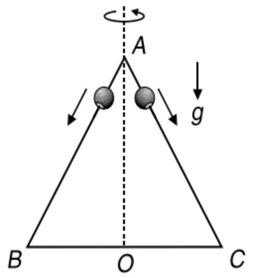
(C)



(D)



25. An equilateral triangle ABC formed from a uniform wire has two small identical beads initially located at A. The triangle is set rotating about the vertical axis AO. Then the beads are released from rest simultaneously and allowed to slide down, one along AB and the other along AC as shown. Neglecting frictional effects, the quantities that are conserved as beads slide down are



(A) angular velocity and total energy (kinetic and potential).
(B) total angular momentum and total energy.
(C) angular velocity and moment of inertia about the axis of rotation.
(D) total angular momentum and moment of inertia about the axis of rotation.

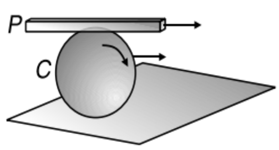
26. A uniform rod of length $2a$ and mass m lies at rest on a smooth horizontal table. A perfectly elastic particle having same mass as the rod moving with speed u on the table in a direction perpendicular to the rod, strikes one end of the rod. The final kinetic energy of the rod is

(A) $\frac{4}{13}mu^2$ (B) $\frac{1}{4}mu^2$
(C) $\frac{4}{25}mu^2$ (D) $\frac{8}{25}mu^2$

27. A uniform horizontal circular platform of mass 200 kg is rotating at 10 rpm about a vertical axis passing through its centre. A boy of mass 50 kg is standing on its edge. If the boy moves to the centre of the platform, the frequency of rotation would be

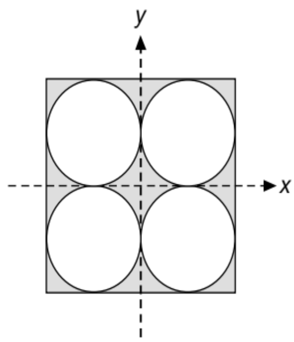
(A) 7.5 rpm (B) 12.5 rpm
(C) 15 rpm (D) 20 rpm

28. A plank P is placed on a hollow cylinder C, which rolls on a horizontal surface as shown. No slippage is there at any of the surfaces in contact. Both have equal mass say M (each) and if v is the velocity of centre of mass of the cylinder C, then the ratio of the kinetic energy of plank P to the cylinder C is



(A) 1 : 1 (B) 2 : 1
(C) 3 : 8 (D) 8 : 11

29. Four holes of radius R are cut from a thin square plate of side $4R$ and mass M. The moment of inertia of the remaining portion about z-axis is



(A) $\frac{\pi}{12}MR^2$ (B) $\left(\frac{4}{3}-\frac{\pi}{4}\right)MR^2$
(C) $\left(\frac{8}{3}-\frac{10\pi}{16}\right)MR^2$ (D) $\left(\frac{4}{3}-\frac{\pi}{6}\right)MR^2$

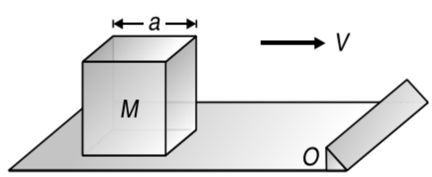
30. A flat rail road car is accelerating along the positive x-axis with an acceleration a_p. A sphere is placed over the car. The friction between car and sphere is not sufficient to support pure rolling of sphere. The correct statement is

(A) The sphere will slip and force of friction on sphere is along $-x$ direction
(B) The sphere will slip and force of friction on sphere is along $+x$ direction
(C) Acceleration of sphere is along $-x$ direction
(D) None of the above

31. A hollow straight tube of length $2l$ and mass m can turn freely about its centre on a smooth horizontal table. Another smooth uniform rod of same length and mass is fitted into the tube so that their centres coincide. The system is set in motion with an initial angular velocity ω_0. The angular velocity of the tube at the instant when the rod slips out of the tube

(A) $\frac{\omega_0}{4}$ (B) $\frac{\omega_0}{5}$
(C) $\frac{\omega_0}{7}$ (D) $\frac{\omega_0}{2}$

32. A cubical block of side a is moving with velocity v on a horizontal smooth plane as shown in figure. It hits a ridge at point O. If the moment of inertia of the block about an axis passing through centre of gravity is $\frac{1}{6}ma^2$, then the angular speed of the block after it hits O is



(A) $\frac{3v}{4a}$ (B) $\frac{3v}{2a}$

(C) $\sqrt{\frac{3}{2}\frac{v}{a}}$ (D) ZERO

33. In a simple pendulum, the breaking strength of the string is double the weight of the bob. The bob is released from rest when the string is horizontal. The string breaks when it makes an angle θ with the vertical

(A) $\theta = \cos^{-1}\left(\frac{1}{3}\right)$

(B) $\theta = \cos^{-1}\left(\frac{2}{3}\right)$

(C) $\theta = 60°$

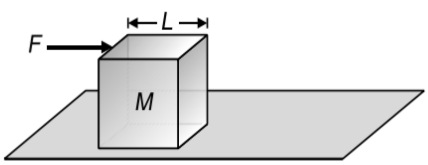
(D) $\theta = 0$

34. Two men each of mass m stand on the rim of a horizontal circular disc, diametrically opposite to each other. The disc has a mass M and is free to rotate about a vertical axis passing through its centre of mass. Each man starts simultaneously along the rim clockwise and reaches its original starting position on the disc. The angle turned through by the disc with respect to the ground (in radian) is

(A) $\frac{\pi m}{M+m}$ (B) $\frac{2\pi m}{4m+M}$

(C) $\frac{4\pi m}{2M+m}$ (D) $\frac{8\pi m}{4m+M}$

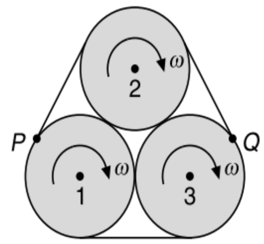
35. A cubical block of side L rests on a rough horizontal surface with coefficient of friction μ. A horizontal force F is applied on the block as shown. If the coefficient of friction is sufficiently high so that the block does not slide before toppling, the minimum force required to topple the block is



(A) infinitesimal (B) $\frac{mg}{4}$

(C) $\frac{mg}{2}$ (D) $mg(1-\mu)$

36. Three identical cylinders of radius R are in contact. Each cylinder is rotating with angular velocity ω. A thin belt is moving without sliding on the cylinders. If P and Q are two points of belt which are in contact with the cylinder, then the magnitude of velocity of point P with respect to Q.



(A) $2R\omega$ (B) $R\omega$

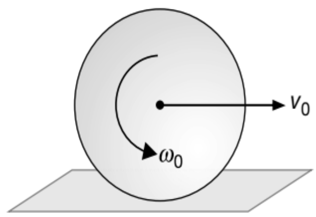
(C) $\frac{R\omega}{2}$ (D) $\sqrt{3}R\omega$

37. A balance is made of a rigid rod free to rotate about a point not at the centre of the rod. When an unknown mass m is placed in the left hand pan, it is balanced by a mass m_1 placed in the right hand pan, and similarly when the mass m is placed in the right pan, it is balanced by a mass m_2 in the left hand pan. Neglecting the masses of the pans, m is

(A) $\frac{1}{2}(m_1+m_2)$ (B) $\sqrt{m_1 m_2}$

(C) $\frac{1}{2}\sqrt{m_1^2+m_2^2}$ (D) $\sqrt{\frac{m_1^2+m_2^2}{2}}$

38. A uniform sphere of radius R is placed on a rough horizontal surface and given a linear velocity v_0 and angular velocity ω_0 as shown. For the sphere to come to rest after moving some distance to the right, we have



(A) $v_0 = R\omega_0$ (B) $5v_0 = 2R\omega_0$

(C) $2v_0 = 5R\omega_0$ (D) $2v_0 = R\omega_0$

39. A stone of mass 16 kg is attached to a string 144 m long and is whirled in a horizontal circle. The maximum tension the string can stand is 16 N. The maximum velocity of revolution that can be given to the stone without breaking the string is

(A) 20 ms^{-1} (B) 16 ms^{-1}

(C) 14 ms^{-1} (D) 12 ms^{-1}

40. At some instant, a particle is moving along a straight line $2x-3y=2$ and its co-ordinates on that line are $(4, 2)$. Now at another instant the same particle is moving along a straight line $3x+4y=7$ and its co-ordinate are $(1, 1)$. The co-ordinates of the axis about which it is in pure rotation are

(A) $\left(\frac{8}{9}, \frac{16}{9}\right)$ (B) $\left(\frac{5}{17}, \frac{6}{17}\right)$

(C) $\left(\frac{30}{17}, \frac{35}{17}\right)$ (D) $\left(\frac{50}{17}, \frac{61}{17}\right)$

41. 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 $\frac{\omega_0}{2}$ after n rotations. How many more rotations will it make before coming to rest?

(A) $\frac{n}{2}$ (B) $\frac{n}{3}$

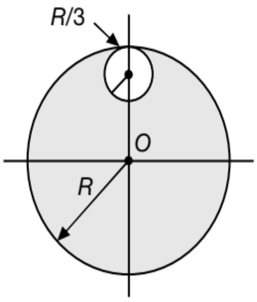
(C) n (D) $2n$

42. A wire of mass m and length l is bent in the form of a quarter circle. The moment of inertia of this wire about an axis passing through the centre of the quarter circle and perpendicular to the plane of the quarter circle is $\left(\text{Take } \pi^2 = 10\right)$

(A) $\frac{3ml^2}{5}$ (B) ml^2

(C) $\frac{ml^2}{5}$ (D) $\frac{2ml^2}{5}$

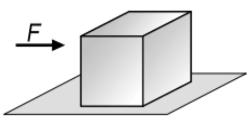
43. A small disc of radius $\frac{R}{3}$ is removed from a circular disc of radius R and mass $9M$. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through O is



(A) $4MR^2$ (B) $\frac{40}{9}MR^2$

(C) $10MR^2$ (D) $\frac{37}{9}MR^2$

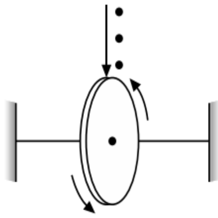
44. A force F is applied on the top of a cube as shown in figure. The coefficient of friction between the cube and the ground is μ. If F is gradually increased, the cube will topple before sliding if



(A) $\mu > 1$ (B) $\mu < \frac{1}{2}$

(C) $\mu < 1$ (D) $\mu > \frac{1}{2}$

45. A disc of mass m_0 rotates freely about a fixed horizontal axis through its centre. A thin cotton pad is fixed to its rim, which can absorb water. The mass of water dripping onto the pad is μ per second. The time after which the angular velocity of the disc gets reduced to half of its initial value is



(A) $\frac{2m_0}{\mu}$ (B) $\frac{m_0}{2\mu}$

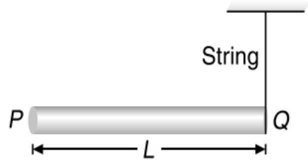
(C) $\frac{m_0}{\mu}$ (D) $\frac{3m_0}{\mu}$

46. Three point masses each of mass m, are placed at the corners of an equilateral triangle of side l. The moment of inertia of this system about an axis along one side of the triangle is

(A) ml^2 (B) $\frac{3}{4}ml^2$

(C) $3ml^2$ (D) $\frac{3}{2}ml^2$

47. A uniform rod PQ of length L is hinged at one end P. The rod is kept in the horizontal position by a massless string tied to point Q as shown in the figure. If the string is cut, the initial angular acceleration of the rod will be

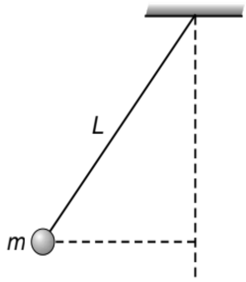


(A) $\frac{g}{L}$ (B) $\frac{2g}{L}$

(C) $\frac{2g}{3L}$ (D) $\frac{3g}{2L}$

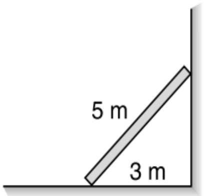
48. A ball of mass $m = 0.5$ kg is attached to the end of a string having length $L = 0.5$ m. The ball is rotated on a horizontal circular path about vertical axis. The maximum tension that the string can bear is 324 N.

The maximum possible value of angular velocity of ball, in rads^{-1} is



(A) 9 (B) 18
(C) 27 (D) 36

49. A uniform ladder of length 5 m is placed against the wall as shown in the Figure.



If coefficient of friction μ is the same for both the walls, the minimum value of μ for the ladder not to slip is

(A) $\mu = \frac{1}{2}$ (B) $\mu = \frac{1}{3}$

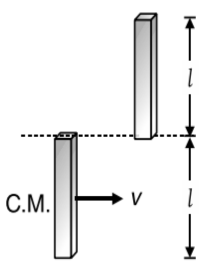
(C) $\mu = \frac{1}{4}$ (D) $\mu = \frac{1}{5}$

50. A thin circular ring of mass M is rotating about its axis with a constant angular velocity ω. The two objects, each of mass m, are attached gently to the opposite ends of a diameter of the ring. The ring now rotates with an angular velocity

(A) $\frac{\omega M}{M+m}$ (B) $\frac{\omega(M-2m)}{M+2m}$

(C) $\frac{\omega M}{M+2m}$ (D) $\frac{\omega(M+2m)}{M}$

51. A bar of mass m, length l is in pure translatory motion with its centre of mass velocity v. It collides with and sticks to another identical bar at rest as shown in figure. Assuming that after collision it becomes one composite bar of length $2l$, the angular velocity of the composite bar will be



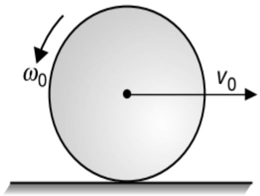
(A) $\frac{3}{4}\frac{v}{l}$, anticlockwise

(B) $\frac{4}{3}\frac{v}{l}$, anticlockwise

(C) $\frac{3}{4}\frac{v}{l}$, clockwise

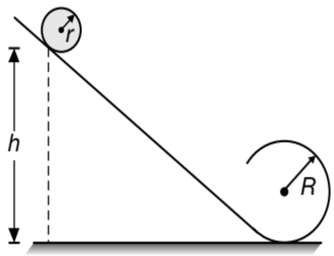
(D) $\frac{4}{3}\frac{v}{l}$, clockwise

52. A uniform circular disc of radius r placed on a rough horizontal plane has initial velocity v_0 and an angular velocity ω_0 as shown. The disc comes to rest after moving some distance in the direction of motion. Then



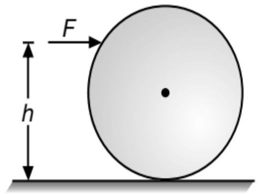
(A) the friction force acts in the forward direction
(B) the point of contact of disc with ground has zero velocity
(C) v_0 must be equal to $\frac{r\omega_0}{2}$ in magnitude
(D) v_0 must be equal to $2r\omega_0$ in magnitude

53. A solid sphere of radius r rolls without slipping from rest from a height h of an inclined track at the bottom of which there is a loop of radius R much larger than the radius of sphere, as shown in figure. The minimum value of h for the sphere to complete the loop is



(A) $2.1R$ (B) $2.3R$
(C) $2.5R$ (D) $2.7R$

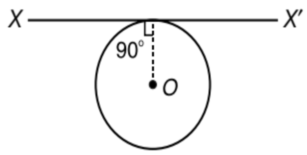
54. A solid sphere of radius R is resting on a smooth horizontal surface. A constant force F is applied at a height h from the bottom. Choose the correct alternative



(A) Sphere will always slide whatever be the value of h
(B) Sphere will roll without slipping when $h \geq 1.4R$
(C) Sphere will roll without slipping if $h = 1.4R$
(D) None of the above

55. A wire of length l and mass m is first bent in a circle, then in a square and then in an equilateral triangle. The moment of inertia in these three cases about an axis perpendicular to their planes and passing through their centres of mass are I_1, I_2 and I_3 respectively. Then maximum of them is
(A) I_1 (B) I_2
(C) I_3 (D) data insufficient

56. A thin wire of length L and uniform linear mass density ρ is bent into a circular loop with centre at O as shown. The moment of inertia of the loop about the axis XX' is



(A) $\frac{\rho L^3}{8\pi^2}$ (B) $\frac{\rho L^3}{16\pi^2}$
(C) $\frac{5\rho L^3}{16\pi^2}$ (D) $\frac{3\rho L^3}{8\pi^2}$

57. A playground merry-go-round is at rest, pivoted about a frictionless axis. A child of mass m runs along the path tangential to the rim with speed v and jumps on to merry-go-round. If R be the radius of merry-go-round and I is the moment of inertia, then the angular velocity of the merry-go-round and the child is
(A) $\frac{mvR}{mR^2 + I}$ (B) $\frac{mvR}{I}$
(C) $\frac{mR^2 + I}{mvR}$ (D) $\frac{I}{mvR}$

58. 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) $\frac{M\omega^2 L}{2}$ (B) $M\omega^2 L$
(C) $\frac{M\omega^2 L}{4}$ (D) $\frac{M\omega^2 L^2}{2}$

59. A solid sphere, a ring and a disc all having same mass and radius are placed at the top of an incline and released. The coefficient of friction between the objects and the incline is same but not sufficient to allow pure rolling. The least time will be taken in reaching the bottom by
(A) the solid sphere
(B) the ring
(C) the disc
(D) All will take the same time

60. In PROBLEM 59, the least value of kinetic energy at the bottom of the incline will be achieved by
(A) the ring
(B) the disc
(C) the solid sphere
(D) All will achieve the same kinetic energy

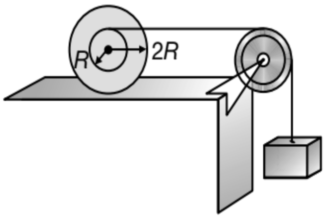
61. The string of a pendulum, having bob of mass m, is displaced through 90° from the vertical and then released. The minimum strength of the string in order to withstand the tension as the pendulum passes through the mean position is
(A) mg (B) $3mg$
(C) $5mg$ (D) $6mg$

62. Two men A and B are carrying a uniform bar of length L on their shoulders. The bar is held horizontally such that A gets $\left(\frac{1}{4}\right)$th load. If A is at one end of the bar, the distance of B from that end is
(A) $\frac{L}{3}$ (B) $\frac{L}{2}$
(C) $\frac{2L}{3}$ (D) $\frac{3L}{4}$

63. A body having moment of inertia about its axis of rotation equal to $3\ \text{kgm}^2$ is rotating with angular velocity equal to $3\ \text{rads}^{-1}$. The kinetic energy of this body is the same as that of a body of mass 27 kg moving with a speed of
(A) $1\ \text{ms}^{-1}$ (B) $0.5\ \text{ms}^{-1}$
(C) $1.5\ \text{ms}^{-1}$ (D) $2.0\ \text{ms}^{-1}$

64. 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) $2L$

65. In the figure shown, the spherical body and block each have a mass m. The moment of inertia of the spherical body about centre of mass is $2mR^2$. The spherical body rolls without slipping on the horizontal surface. The ratio of kinetic energy of the spherical body to that of block is



(A) $\frac{1}{3}$ (B) $\frac{1}{2}$

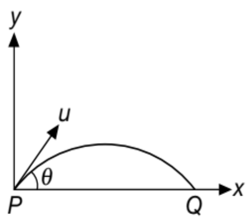
(C) $\frac{2}{3}$ (D) $\frac{3}{4}$

66. A stone of mass m, tied to the end of a string, is whirled around in a horizontal circle (Neglect the force due to gravity). The length of the string is reduced gradually, keeping the angular momentum of the stone about the centre of the circle constant. Then, the tension in the string is given by $T = Ar^n$, where A is a constant, r is the instantaneous radius of the circle, then n is

(A) 1 (B) –1

(C) –2 (D) –3

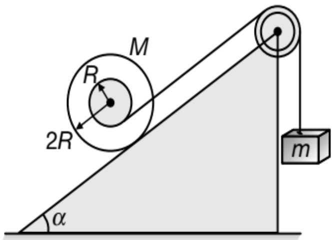
67. Average torque on a projectile of mass m, initial speed u and angle of projection θ is launched between initial and final positions P and Q as shown in figure. The average torque on the projectile about the point of projection is



(A) $mu^2 \cos\theta$ (B) $mu^2 \sin\theta$

(C) $\frac{mu^2 \sin(2\theta)}{2}$ (D) $\frac{mu^2 \cos\theta}{2}$

68. A spool of mass M and radius $2R$ lies on an inclined plane as shown in figure. A light thread is wound around the connecting tube of the spool and its free end carries a weight of mass m. The value of m so that system is in equilibrium is



(A) $2M\sin\alpha$ (B) $M\sin\alpha$

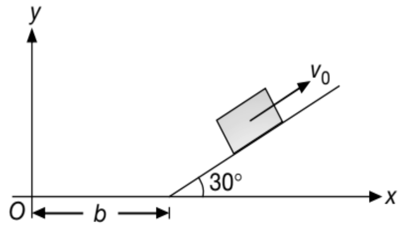
(C) $2M\tan\alpha$ (D) $M\cos\alpha$

69. Two discs have same mass and thickness. Their materials are of densities d_1 and d_2. The ratio of their moments of inertia about and axis passing through the centre and perpendicular to the plane

(A) $d_1 : d_2$ (B) $d_2 : d_1$

(C) $1 : d_1 d_2$ (D) $d_1 d_2 : 1$

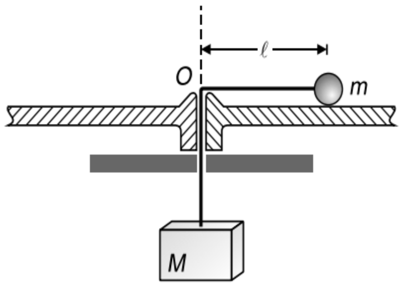
70. A cube of mass m and side a is moving along a plane with constant speed v_0 as shown in figure. The magnitude of angular momentum of the cube about z-axis would be



(A) $\frac{mv_0 b}{2}$ (B) $\frac{\sqrt{3}mv_0 b}{2}$

(C) $mv_0\left(b - \frac{a}{2}\right)$ (D) None of these

71. Two masses m and M are connected by a light string that passes through a smooth hole O at the centre of a table. Mass m lies on the table and M hangs vertically. m is moved round in a horizontal circle with O as the centre. If l is the length of the string from O to m then the frequency with which m should revolve so that M remains stationary is



(A) $\frac{1}{2\pi}\sqrt{\frac{Mg}{ml}}$ (B) $\frac{1}{\pi}\sqrt{\frac{Mg}{ml}}$

(C) $\frac{1}{2\pi}\sqrt{\frac{Ml}{mg}}$ (D) $\frac{1}{\pi}\sqrt{\frac{Ml}{mg}}$

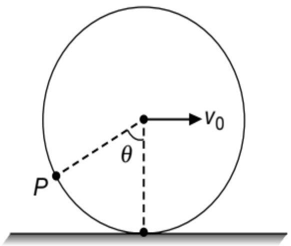
72. A cord is wound round the circumference of wheel of radius r. The axis of the wheel is horizontal and moment of inertia about its axis is I. A weight mg is attached to the end of the cord and is allowed to fall from rest. The angular velocity of the wheel, when the weight has fallen through a distance h, is

iCON

(A) $\sqrt{\dfrac{2gh}{I+mr}}$ (B) $\sqrt{\dfrac{2mgh}{I+mr^2}}$

(C) $\sqrt{\dfrac{2mgh}{I+2mr^2}}$ (D) $\sqrt{2gh}$

73. A hoop rolls without slipping on a horizontal ground having centre of mass speed v_0. The speed of a particle P on the circumference of the hoop at angle θ is



(A) $v_0 \sin\theta$ (B) $v_0 \cos\theta$

(C) $2v_0 \sin\left(\dfrac{\theta}{2}\right)$ (D) $2v_0 \cos\left(\dfrac{\theta}{2}\right)$

74. Two rings each of mass m and radius r are placed such that their centres are at a common point and their planes are normal to each other. The moment of inertia of the system about an axis passing through the centre and perpendicular to plane of one of the ring is

(A) $2mr^2$ (B) mr^2

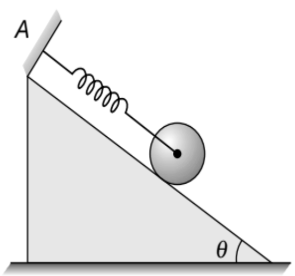
(C) $\dfrac{1}{2}mr^2$ (D) $\dfrac{3}{2}mr^2$

75. A particle of mass 2 kg located at the position $\left(\hat{i}+\hat{j}\right)$ m has a velocity $2\left(\hat{i}-\hat{j}+\hat{k}\right)$ ms^{-1}. Its angular momentum about z-axis in kgm^{2}s^{-1} is

(A) ZERO (B) +8

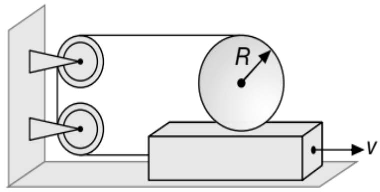
(C) –4 (D) –8

76. A uniform cylinder of mass M and radius R, rolls without slipping down an incline making an angle θ with horizontal. The cylinder is connected to a spring of force constant k at the centre, the other side of which is connected to a fixed support at A. The cylinder is released when the spring is unstretched. The force of friction (f) is



(A) always down the incline.
(B) always up the incline.
(C) initially up the incline and then becomes zero.
(D) initially up the incline and then becomes down the incline.

77. In the figure shown, the plank is being pulled to the right with a constant speed v. If the cylinder does not slip then



(A) the speed of the centre of mass of the cylinder is $2v$
(B) the speed of the centre of mass of the cylinder is v
(C) the angular velocity of the cylinder is $\dfrac{v}{R}$
(D) the angular velocity of the cylinder is zero

78. A cylinder is released from rest from the top of an incline plane of inclination 60° where friction coefficient varies with distance x as $\mu = \dfrac{2-3x}{\sqrt{3}}$. Find the distance travelled by the cylinder on incline before it starts slipping

(A) $\dfrac{1}{3}$ m (B) $\dfrac{1}{\sqrt{3}}$ m

(C) 3 m (D) $\sqrt{3}$ m

79. A smooth sphere A is moving on a frictionless horizontal plane with angular speed ω and centre of mass velocity v. It collides elastically and head on with an identical sphere B at rest. Neglect friction everywhere. After the collision, their angular speeds are ω_A and ω_B. Then

(A) $\omega_A < \omega_B$ (B) $\omega_A = \omega_B$

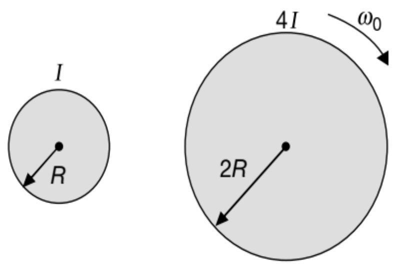
(C) $\omega_A = \omega$ (D) $\omega = \omega_B$

80. Masses of 1 g, 2 g, 3 g, ... 100 g are suspended from the 1 cm, 2 cm, 3 cm, ... 100 cm marks of a light metre scale. The system will be supported in equilibrium at

(A) 60 cm (B) 67 cm

(C) 55 cm (D) 72 cm

81. Two cylinders having radii $2R$ and R and moment of inertias $4I$ and I about their central axes are supported by axles perpendicular to their planes. The large cylinder is initially rotating clockwise with angular velocity ω_0. The small cylinder is moved to the right until it touches the large cylinder and is made to rotate by the frictional force between the two. Eventually slipping ceases and the two cylinders rotate at constant rates in opposite directions. During this process



(A) angular momentum of system is conserved
(B) kinetic energy is conserved
(C) neither the angular momentum nor the kinetic energy is conserved
(D) both the angular momentum and kinetic energy are conserved

82. A uniform rod AB of mass m and length l is at rest on a smooth horizontal surface. An impulse J is applied to the end B perpendicular to the rod in horizontal direction. The speed of particle P at a distance $\frac{l}{6}$ from the centre towards A of the rod after time $t = \frac{\pi ml}{12J}$ is

(A) $\frac{J}{m}$ (B) $\frac{2J}{m}$
(C) $\frac{J\sqrt{2}}{m}$ (D) $\frac{J}{\sqrt{2}m}$

83. A circular platform of radius 2 m and moment of inertia 200 kgm^2 is mounted on a vertical frictionless axle. It is initially at rest. A 70 kg man stands on the edge of the platform and begins to walk along the edge at speed O relative to the ground. The angular velocity of the platform is

(A) 0.4 $rads^{-1}$ (B) CD
(C) $2ma^2$ (D) O

84. In PROBLEM 83, when the man has walked once around the platform, so that he is at his original position on it, then his angular displacement relative to ground is

(A) $\frac{6\pi}{5}$ (B) $\frac{5\pi}{6}$
(C) $\frac{4\pi}{5}$ (D) $\frac{5\pi}{4}$

85. A ring of radius R is first rotated with an angular velocity ω_0 and then carefully placed on a rough horizontal surface. The coefficient of friction between the surface and the ring is μ. The time after which its angular speed is reduced to half is

(A) $\frac{\omega_0 \mu R}{2g}$ (B) $\frac{\omega_0 g}{2\mu R}$
(C) $\frac{2\omega_0 R}{\mu g}$ (D) $\frac{\omega_0 R}{2\mu g}$

86. A uniform thin bar of mass $\frac{\omega_0}{8}$ and length $\frac{3v}{4a}$ is bent to make a regular hexagon. Its moment of inertia about an axis passing through the centre of mass and normal to the plane of hexagon is

(A) $\frac{12}{5}mL^2$ (B) $6mL^2$
(C) $20mL^2$ (D) $30mL^2$

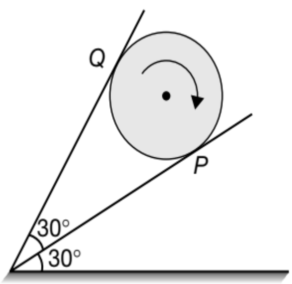
87. A uniform disc of radius R lies in x-y plane with its centre at the origin. Its moment of inertia about z-axis is equal to its moment of inertia about line $y = x + c$. Then c equals

(A) $\frac{R}{\sqrt{2}}$ (B) $-\frac{R}{2}$
(C) $+\frac{R}{4}$ (D) $-R$

88. Four spheres each of mass M and diameter $2r$, are placed with their centres on four corners of a square of side $a(>2r)$. The moment of inertia of the system about one side of square

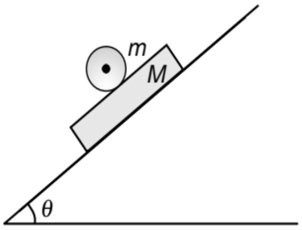
(A) $\frac{2}{5}M(5r^2+4a^2)$ (B) $\frac{2}{5}M(5r^2+2a^2)$
(C) $\frac{2}{5}M(2r^2+5a^2)$ (D) $\frac{2}{5}M(4r^2+5a^2)$

89. A sphere is rotating between two rough inclined plane as shown in figure. The coefficient of friction between each plane and the sphere is $\frac{1}{3}$. If f_1 and f_2 be the friction forces at P and Q. Then $\frac{f_1}{f_2}$ is



(A) $\frac{1}{2}+\sqrt{3}$ (B) $2+\frac{1}{\sqrt{3}}$
(C) $1+\frac{4}{\sqrt{3}}$ (D) $1+2\sqrt{3}$

90. A plank of mass M is placed on a smooth inclined, plane and a sphere of mass m is then placed on the plank. Assuming sufficient friction to be present between the sphere and plank the frictional force on sphere when the plank and sphere are released from rest is



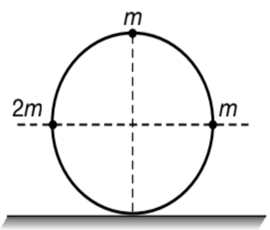
(A) ZERO (B) horizontal
(C) up the incline (D) down the incline

91. A thin rod of mass m and length $2l$ is made to rotate about an axis passing through its centre and perpendicular to it. If its angular velocity changes from 0 to ω in time t, the torque acting on it is

(A) $\frac{ml^2\omega}{12t}$ (B) $\frac{ml^2\omega}{3t}$

(C) $\frac{ml^2\omega}{t}$ (D) $\frac{4ml^2\omega}{3t}$

92. A ring of mass m and radius R has three particles attached to the ring as shown in the figure. The centre of the ring has a speed v_0. Assume slipping to be absent, the kinetic energy of the system is



(A) $4mv_0^2$ (B) $6mv_0^2$

(C) $8mv_0^2$ (D) $12mv_0^2$

93. Two cones A and B are made of two different materials, the density of A being greater than that of B. The height of B is greater than that of A but their base areas and masses are the same. The correct statement about the moment of inertia of the two cones about their axis is

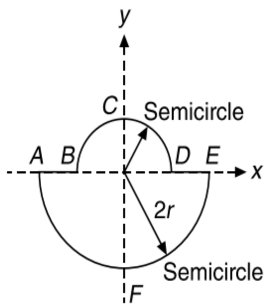
(A) A will have larger moment of inertia than B
(B) B will have larger moment of inertia than A
(C) in such a situation, it is dependent up on the height of the cone, the mass of the cone and radius of the base
(D) the moment of inertia of the two will be the same as it is not dependent on height of the cone but depends only upon the mass and the base area

94. A child is standing with folded hands at the centre of a platform rotating about its central axis. The kinetic energy of the system is K. The child now stretches his arms so that the moment of inertia of the system doubles. The kinetic energy of the system now is

(A) $2K$ (B) $\frac{K}{2}$

(C) $\frac{K}{4}$ (D) $4K$

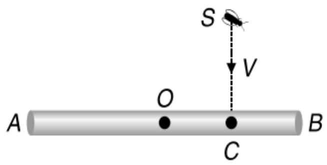
95. A uniform thin rod is bent in the form of closed loop $ABCDEFA$ as shown in Figure. The ratio of moment of inertia of the loop about x-axis to that about y-axis is



(A) >1 (B) <1

(C) $=1$ (D) $=\frac{1}{2}$

96. A homogeneous rod AB of length L and mass M is pivoted at the centre O in such a way that it can rotate freely in a vertical plane. The rod AB is initially in horizontal position. An insect S of same mass falls vertically with a speed V at the point C, midway between points O and B. Immediately after the insect falls, the angular velocity of the system is



(A) $\frac{7}{12}\frac{V}{L}$ (B) $\frac{12}{7}\frac{V}{L}$

(C) $\frac{3}{2}\frac{V}{L}$ (D) $\frac{2}{3}\frac{V}{L}$

97. A circular loop of wire of mass m and radius r is making n revolutions per second about a point on its rim. Its rotational kinetic energy is

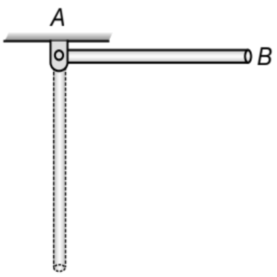
(A) $\pi^2mr^2n^2$

(B) $2\pi^2mr^2n^2$

(C) $4\pi^2mr^2n^2$

(D) $8\pi^2mr^2n^2$

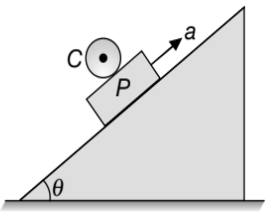
98. One end of a uniform rod of length l and mass m is hinged at A. It is released from rest from horizontal position AB as shown in figure. The force exerted by the rod on the hinge when it becomes vertical is



(A) $\frac{3}{2}mg$ (B) $\frac{5}{2}mg$

(C) $3\,mg$ (D) $5\,mg$

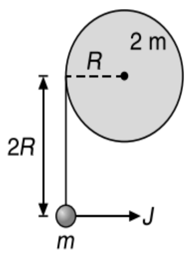
99. The acceleration a of the plank P required to keep the centre C of a cylinder which rolls without slipping on the plank in a fixed position during the motion is



(A) $\frac{g}{2}\sin\theta$ (B) $g\sin\theta$

(C) $2g\sin\theta$ (D) $\sqrt{2g}\sin\theta$

100. A uniform circular disc of mass $2m$ and radius R is placed freely on a horizontal smooth surface. A particle of mass m is connected to the circumference of the disc with a massless string. Now an impulse J is applied on the particle in the direction as shown in Figure.



If $J = 10$ Ns, $m = \sqrt{10}$ kg and $R = 25$ cm, then acceleration of centre of mass of the disc just after application of impulse is

(A) $1\ ms^{-2}$ (B) $2\ ms^{-2}$

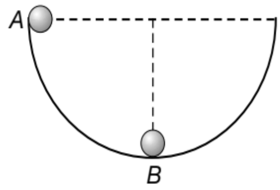
(C) $3\ ms^{-2}$ (D) $4\ ms^{-2}$

101. A solid sphere of mass 2 kg rolls up a 30° incline with an initial speed of $10\ ms^{-1}$. The maximum height reached by the sphere is ($g = 10\ ms^{-2}$)

(A) 3.5 m (B) 7.0 m

(C) 10.5 m (D) 14.0 m

102. A small ball of mass m, radius r is released from rest from a point A to roll inside a hemispherical shell of radius R as shown in figure. The angular velocity of centre of the ball in position B about the centre of the shell is



(A) $2\sqrt{\frac{g}{5(R-r)}}$ (B) $\sqrt{\frac{10g}{7(R-r)}}$

(C) $\sqrt{\frac{2g}{5(R-r)}}$ (D) $\sqrt{\frac{5g}{2(R-r)}}$

103. In PROBLEM 102, the normal force between the ball and the shell in position $\frac{d\vec{L}}{dt}$ is

(A) mg (B) $\frac{10}{7}mg$

(C) $\frac{12}{7}mg$ (D) $\frac{17}{7}mg$

104. An inclined plane makes an angle of 60^o with horizontal. A disc rolling down this inclined plane without slipping has a linear acceleration equal to

(A) $\frac{g}{3}$ (B) $\frac{3g}{4}$

(C) $\frac{g}{\sqrt{3}}$ (D) $\frac{g}{2}$

105. Locus of all the points in a plane on which the moment of inertia of a rigid body is same throughout is

(A) a straight line (B) a circle

(C) a parabola (D) an ellipse

106. A rigid spherical body is spinning around an axis without any external torque. Due to temperature its volume increases by 3%. Then percentage change in its angular speed is

(A) –2% (B) –1%

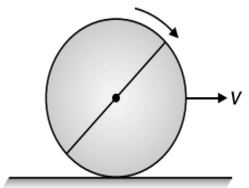
(C) –3% (D) 1%

107. A uniform rod AB of mass m and length $2a$ is falling with velocity v without rotation in gravity free space with AB horizontal. Suddenly the end A gets hit by an obstacle when the speed of the rod is v. Assume the end A to hinge about the obstacle, the angular speed with which the rod begins to rotate is

(A) $\frac{v}{2a}$ (B) $\frac{4v}{3a}$

(C) $\frac{v}{3a}$ (D) $\frac{3v}{4a}$

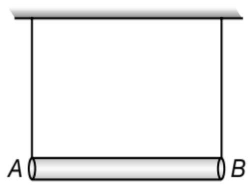
108. A ring of mass m is rolling without slipping with linear velocity v as shown in figure. A rod of identical mass is fixed along one of its diameter. The total kinetic energy of the system is



(A) $\frac{7}{5}mv^2$ (B) $\frac{2}{3}mv^2$

(C) $\frac{4}{3}mv^2$ (D) $\frac{5}{3}mv^2$

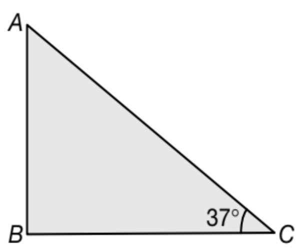
109. A uniform rod of mass m and length l is suspended by means of two light inextensible strings as shown in figure. Tension in one string immediately after the other string is cut is



(A) $\frac{mg}{4}$ (B) $\frac{mg}{2}$

(C) mg (D) $2mg$

110. ABC is a right angled triangular plate of uniform thickness. I_1, I_2 and I_3 are moments of inertia about AB, BC and AC respectively. Given that $\sin(37°) = \frac{3}{5}$, then which of the following relation is correct?



(A) $I_2 > I_1 > I_3$

(B) $I_3 > I_1 > I_2$

(C) $I_3 < I_2 < I_1$

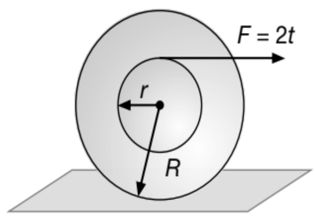
(D) $I_1 = I_2 = I_3$

111. A solid sphere and a solid cylinder of same mass are rolled down on two inclined planes of heights h_1 and h_2 respectively. At the bottom of the plane the two objects have same linear velocities, then $h_1 : h_2$ is

(A) $2:3$ (B) $7:5$

(C) $14:15$ (D) $15:14$

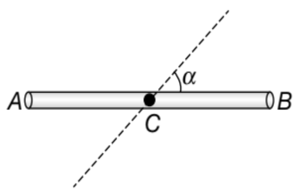
112. A time varying force $F = 2t$ is applied on a spool as shown in figure. The angular momentum of the spool at time t about bottommost point is



(A) $\frac{r^2t^2}{R}$ (B) $\frac{(R+r)^2}{r}t^2$

(C) $(R+r)t^2$ (D) $\frac{R^2t^2}{r}$

113. The moment of inertia of a uniform rod of length $2l$ and mass m about an axis passing through its centre and inclined at an angle α is



(A) $\frac{ml^2}{3}\sin^2\alpha$ (B) $\frac{ml^2}{12}\sin^2\alpha$

(C) $\frac{K}{4}$ (D) v_c

114. A rod of length l is given two velocities v_1 and v_2 in opposite directions at its two ends at right angles to the length. The distance of the instantaneous axis of rotation from v_1 is

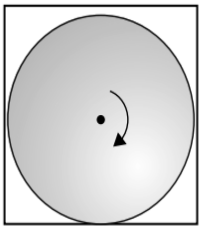
(A) ZERO (B) $\frac{l}{2}$

(C) $\left(\frac{v_1}{v_1+v_2}\right)l$ (D) $\left(\frac{v_2}{v_1+v_2}\right)l$

115. If the radius of the earth suddenly contracts to $\frac{1}{n^{th}}$ of its present radius without any change in its mass, the duration of the day will approximately become

(A) $\frac{24}{n}$ hour (B) $\frac{24}{n^2}$ hour
(C) $24n$ hour (D) $24n^2$ hour

116. A solid sphere of mass 5 kg and radius 1 m after rotating with angular speed $\omega_0 = 40$ rads^{-1} is placed between two smooth walls on a rough ground. Distance between the walls is slightly greater than the diameter of the sphere. If the coefficient of friction between the sphere and the ground is $\mu = 0.1$, then the sphere will stop rotating after time



(A) 8 s (B) 12 s
(C) 16 s (D) 20 s

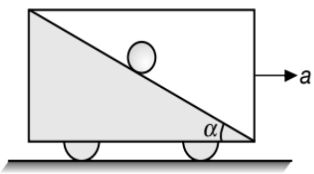
117. A wheel rotates with constant acceleration of 2.0 rads^{-2}. If the wheel starts from rest, the number of revolutions it makes in the first ten second will be approximately

(A) 8 (B) 16
(C) 24 (D) 32

118. 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 $\frac{I_2}{I_1} = 4$, then $\frac{R_2}{R_1}$ is

(A) $4^{2/3}$ (B) $4^{1/3}$
(C) $4^{-2/3}$ (D) $4^{-1/3}$

119. In the arrangement shown, a smooth inclined plane of inclination θ is fixed in a car and a sphere is set in pure rolling on the incline. The value of a (the acceleration of car in horizontal direction) for which the sphere will continue pure rolling is

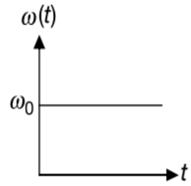


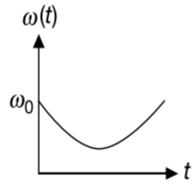
(A) $g\cos\theta$ (B) $g\sin\theta$
(C) $g\cot\theta$ (D) $g\tan\theta$

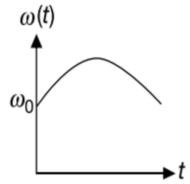
120. A homogeneous cylinder of mass M and radius R is pulled on a horizontal plane by a horizontal force F acting through its centre of mass. Assuming the cylinder to roll without slipping, the angular acceleration of the cylinder is

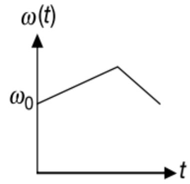
(A) $\frac{3F}{2MR}$ (B) $\frac{2F}{3MR}$
(C) $\frac{F}{2MR}$ (D) $\frac{3F}{4MR}$

121. Moment of inertia I of a solid sphere about an axis parallel to a diameter and at a distance x from it varies as

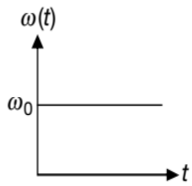
(A)


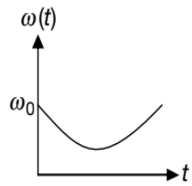
(B)


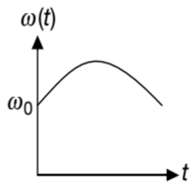
(C)


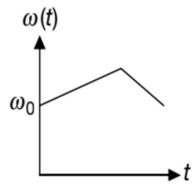
(D)


122. A circular platform is free to rotate in a horizontal plane about a vertical axis passing through its centre. A tortoise is sitting at the edge of the platform. Now the platform is given an angular velocity ω_0. When the tortoise move along a chord of the platform with a constant velocity (with respect to the platform). The angular velocity of the platform $\omega(t)$ will vary with time t as

(A)


(B)


(C)


(D)


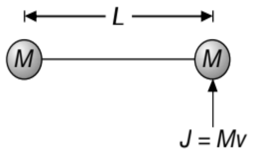
123. A particle of mass 5 g is moving with a uniform speed of $3\sqrt{2}$ cms^{-1} in the xy-plane along the line $y = x + 4$. Magnitude of its angular momentum about origin in gcms^{-2} is

(A) ZERO (B) 30
(C) $30\sqrt{2}$ (D) 60

124. When a mass is rotated in a plane about a fixed point, its angular momentum is directed along the
(A) radius
(B) tangent to orbit
(C) axis of rotation
(D) line at an angle of 45° to plane of rotation

125. A uniform thin wire of length $\omega = \frac{v}{5a}$ and mass m is bent to form of a rectangular frame $ABCD$ with $\frac{AB}{BC} = 2$. The moment of inertia of this wire frame about the smaller side is
(A) $\frac{6}{81}ml^2$
(B) $\frac{6}{217}ml^2$
(C) $\frac{7}{81}ml^2$
(D) $\frac{7}{162}ml^2$

126. Consider a body, shown in figure, consisting of two identical balls, each of mass M connected by a light rigid rod. If an impulse $J = Mv$ is imparted to the body at one of its end, the its angular velocity is



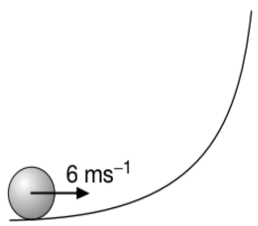
(A) $\frac{v}{L}$
(B) $\frac{2v}{L}$
(C) $\frac{v}{3L}$
(D) $\frac{v}{4L}$

127. A cylinder rolls up an inclined plane, reaches some height and then rolls down (without slipping throughout these motions). The directions of the frictional force acting on the cylinder are
(A) up the incline while ascending and down the incline while descending
(B) up the incline while ascending as well as descending
(C) down the incline while ascending and up the incline while descending
(D) down the incline while ascending as well as descending

128. A thin uniform circular disc of mass M and radius R is rotating in a horizontal plane about an axis passing through its centre and perpendicular to its plane with an angular velocity ω. Another disc of same dimensions but of mass $\frac{1}{4}M$ is placed gently on the first disc co-axially. The angular velocity of the system is
(A) $\sqrt{2}\omega$
(B) $\frac{4}{5}\omega$
(C) $\frac{3}{4}\omega$
(D) $\frac{1}{3}\omega$

129. A uniform ring of mass m and radius R is released from top of an inclined plane. The plane makes an angle θ with horizontal. The coefficient of friction between the ring and the plane is μ. Initially, the point of contact of ring and plane is P. Angular momentum of the ring about point P as a function of time t is
(A) $mgRt\sin\theta - \mu mgRt\cos\theta$
(B) $mgRt\sin\theta$
(C) $mgRt\sin\theta + \mu mgRt\cos\theta$
(D) $mgRt(1-\mu^2)\sin\theta$

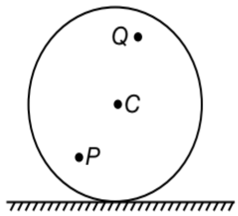
130. A disc of radius 0.1 m rolls without sliding on a horizontal surface with a velocity of 6 ms^{-1}. It then ascends a smooth continuous track as shown in figure. Taking $g = 10$ ms^{-2}, the height upto which it will ascend is



(A) 0.9 m
(B) 1.8 m
(C) 2.4 m
(D) 2.7 m

131. Two equal and opposite forces act on a rigid body at a certain distance. Then
(A) the body is in equilibrium
(B) the body will rotate about its centre of mass
(C) the body may rotate about any point other than its centre of mass
(D) the body cannot rotate about its centre of mass

132. A disc is rolling (without slipping) on a horizontal surface. C is its centre and Q and P are two points equidistant from C. Let v_P, v_Q and v_C be the magnitude of velocities of points P, Q and C respectively, then



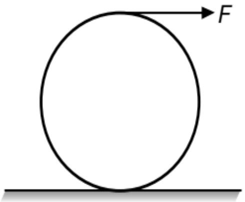
(A) $v_Q > v_C > v_P$
(B) $v_Q < v_C < v_P$
(C) $v_Q = v_P$, $v_C = \frac{1}{2}v_P$
(D) $v_Q < v_C > v_P$

133. Two particles A and B are moving with constant velocities $\vec{v}_1 = 1\text{ ms}^{-1}\hat{j}$ and $\vec{v}_2 = 2\text{ ms}^{-1}\hat{i}$ respectively in XY plane. At time $t = 0$, the particle A is at co-ordinates $(0, 0)$ m and B is at $(0, -4)$ m. The angular velocity of B with respect to A at $t = 2$ s is

(A) $\frac{1}{2}$ rads^{-1} (B) 1 rads^{-1}

(C) 2 rads^{-1} (D) 4 rads^{-1}

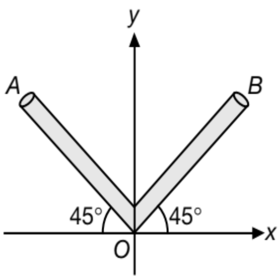
134. A force F is applied at the top of a ring of mass M and radius R placed on a rough horizontal surface as shown in figure. Friction is sufficient to prevent slipping. The friction force acting on the ring is



(A) $\frac{F}{2}$ towards right (B) $\frac{F}{3}$ towards left

(C) $\frac{2F}{3}$ towards right (D) ZERO

135. Two rods OA and OB of equal length and mass are lying in xy plane as shown in figure. Let I_x, I_y and I_z be the moment of inertias of both the rods about x, y and z-axis respectively. Then



(A) $I_x = I_y > I_z$ (B) $I_x = I_y < I_z$

(C) $I_x > I_y > I_z$ (D) $I_z > I_y > I_x$

136. A carpet of mass M made of inextensible material is rolled along its length in the form of a cylinder of radius R and is kept on a rough floor. The carpet starts unrolling without sliding on the floor when a negligibly small push is given to it. The horizontal velocity of the axis of cylindrical part of the carpet when its radius reduces to $\frac{R}{2}$ is

(A) $\sqrt{gR}$ (B) $\sqrt{\frac{7}{3}gR}$

(C) $\sqrt{\frac{8}{3}gR}$ (D) $\sqrt{\frac{14}{3}gR}$

137. A long horizontal rod has a bead which can slide along its length and is initially placed at a distance L from one end A of the rod. The rod is set in angular motion about A with a constant angular acceleration α. If the coefficient of friction between the rod and the bead is μ, and gravity is neglected, then the time after which the bead starts slipping is

(A) $\sqrt{\frac{\mu}{\alpha}}$ (B) $\frac{\mu}{\sqrt{\alpha}}$

(C) $\frac{1}{\sqrt{\mu\alpha}}$ (D) infinitesimal

138. A solid sphere rolls down two different inclined planes of same height but of different inclinations. In both cases

(A) the speed and time of descend will be same

(B) the speed will be same but time of descend will be different

(C) the speed will be different but time of descend will be same

(D) speed and time of descend both are different

139. The linear velocity of a particle moving with angular velocity $\vec{\omega} = 2\hat{k}$ at position vector $\vec{r} = 2\hat{i} + 2\hat{j}$ is

(A) $4(\hat{i} - \hat{j})$ (B) $4(\hat{j} - \hat{i})$

(C) $4\hat{i}$ (D) $-4\hat{i}$

140. A particle undergoes uniform circular motion. About which point on the plane of the circle, will the angular momentum of the particle remain conserved?

(A) Centre of circle

(B) On the circumference of the circle

(C) Inside the circle

(D) Outside the circle

141. A force $\vec{F} = a\hat{i} + 3\hat{j} + 6\hat{k}$ 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

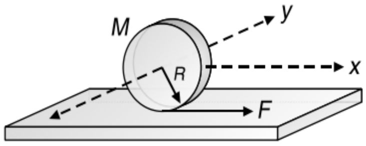
(C) –1 (D) 2

142. A solid cylinder of mass 50 kg and radius 0.5 mis free to rotate about its axis which is horizontal. A string is wound around the cylinder with one end attached to it and other hanging freely. The tension in the string required to produce an angular acceleration of 2 revs^{-2} in the cylinder is

(A) 78.5 N (B) 157 N

(C) 314 N (D) 628 N

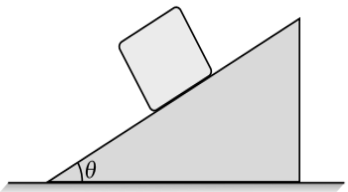
143. A uniform cylindrical disc of radius R and mass M is pulled over a horizontal frictionless surface by a constant force. The force is applied by means of a string wound around the disc as shown in the figure. If it starts from rest at $t=0$, the linear and angular displacements respectively at time t are



(A) $\left(\frac{F}{M}\right)t^2, \left(\frac{F}{M}\right)t^2$ (B) $\left(\frac{F}{2M}\right)t, \left(\frac{F}{2MR}\right)t^2$

(C) $\left(\frac{F}{M}\right)t^2, \left(\frac{F}{MR}\right)t^2$ (D) $\left(\frac{2F}{M}\right)t^2, \left(\frac{2F}{MR}\right)t^2$

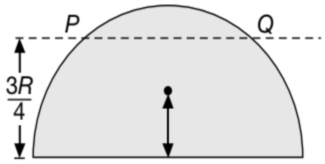
144. A cube is placed on a rough inclined plane of inclination θ as shown in figure. The coefficient of friction between the cube and the plane is μ. If the angle θ is gradually increased, the cube slides before toppling when



(A) $\mu<1$ (B) $\mu<\frac{1}{2}$

(C) $\mu>1$ (D) $\mu>\frac{1}{2}$

145. Assuming the centre of mass of a hemisphere to lie at a height $\frac{3R}{8}$ from the base, the radius of gyration of a solid hemisphere of mass M and radius R about an axis parallel to the diameter at a distance $\frac{3}{4}R$ from this plane is given by



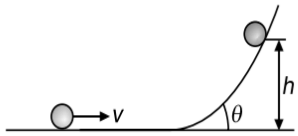
(A) $\frac{3R}{\sqrt{10}}$ (B) $\frac{5R}{4}$

(C) $\frac{5R}{8}$ (D) $\sqrt{\frac{2}{5}}R$

146. A particle moves in a circular path with decreasing speed. Choose the correct statement

(A) Angular momentum remains constant
(B) Acceleration $(\vec{a})$ is towards the centre
(C) Particle moves in a spiral path with decreasing radius
(D) The direction of angular momentum remains constant

147. A sphere of mass M and radius R moves on a horizontal surface with a velocity V and then climbs up an inclined plane up to a height h where it stops. The height upto which it rises will be

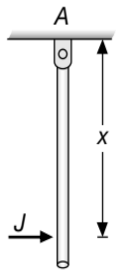


(A) directly proportional to the square of the velocity and inversely proportional to the angle of the inclination
(B) directly proportional to the velocity and inversely proportional to its mass
(C) directly proportional to the square of and the angle of the velocity and independent of mass the inclination
(D) directly proportional to its velocity and inversely proportional to the angle of the inclination

148. The moment of inertia of the body about an axis is $1.2\ \text{kgm}^2$. Initially the body is at rest. In order to produce a rotational kinetic energy of $1500\ \text{J}$, an angular acceleration of $25\ \text{rads}^{-2}$ must be applied about the axis for the duration of

(A) 2 s (B) 4 s
(C) 8 s (D) 10 s

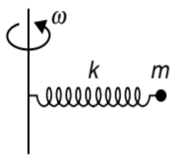
149. A uniform rod of length l is pivoted at point A. It is struck by a horizontal force which delivers an impulse J at a distance x from point A as shown in figure. The impulse delivered by pivot is zero when x equals



(A) $\frac{l}{2}$ (B) $\frac{l}{3}$

(C) $\frac{2l}{3}$ (D) $\frac{3l}{4}$

150. A particle of mass m is fixed to one end of a light spring of force constant k and unstretched length l. The system is rotated about the other end of the spring with an angular velocity ω, in gravity free space. The increase in length of the spring will be



(A) $\frac{ml\omega^2}{k}$ (B) $\frac{ml\omega^2}{k - m\omega^2}$

(C) $\frac{ml\omega^2}{k + m\omega^2}$ (D) None of these

151. A uniform cube of side a and mass m rests on a rough horizontal surface. A horizontal force F is applied normal to one face at a point that lies directly above the centre of the face at a height $\frac{a}{4}$ above the centre. The minimum value of F for which the cube begins to topple above an edge without sliding is

(A) $\frac{1}{4}mg$ (B) $\frac{1}{2}mg$

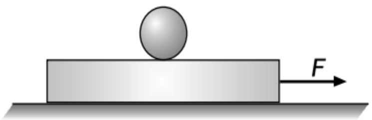
(C) $\frac{2}{3}mg$ (D) $2mg$

152. The ratio of moment of inertia of the ring about an axis passing through its rim and perpendicular to its plane and that about its diameter is

(A) $1:4$ (B) $4:1$

(C) $1:2$ (D) $2:1$

153. A plank with a uniform sphere placed on it resting on a smooth horizontal plane. Plank is pulled to right by a constant force F. If sphere does not slip over the plank. Which of the following is incorrect?



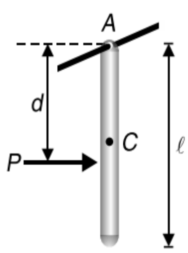
(A) Acceleration of the centre of sphere is less than that of the plank

(B) Work done by friction acting on the sphere is equal to its total kinetic energy

(C) Total kinetic energy of the system is equal to work done by the force F

(D) None of the above

154. The uniform bar of length l and mass m is suspended from a very thin axle that passes through a hole near the top end A of the bar as shown. An impulsive blow having magnitude P is applied at right angles to the bar in order to start the bar rotating about A without breaking the axle. For this



(A) $d = \frac{l}{2}$ (B) $d = \frac{l}{3}$

(C) $d = l$ (D) $d = \frac{2l}{3}$

155. A railway track is banked for a speed v, by making the height of the outer rail h higher than that of the inner rail. The distance between the rails is d. The radius of curvature of the track is r.

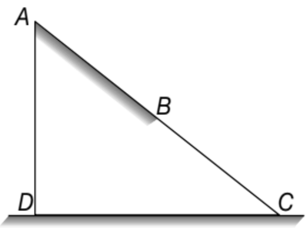
(A) $\frac{h}{d} = \frac{v^2}{rg}$

(B) $\tan\left\{\sin^{-1}\left(\frac{h}{d}\right)\right\} = \frac{v^2}{rg}$

(C) $\tan^{-1}\left(\frac{h}{d}\right) = \frac{v^2}{rg}$

(D) $\frac{h}{r} = \frac{v^2}{dg}$

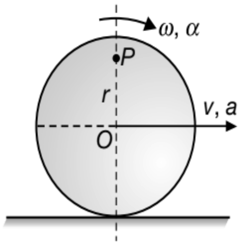
156. Of a wedge shown in figure the portion AB is rough and BC is smooth. A solid cylinder rolls without slipping from A to B. If $AB = BC$, then ratio of translational kinetic energy to rotational kinetic energy, when the cylinder reaches the point C is



(A) $\frac{3}{5}$ (B) $\frac{7}{5}$

(C) $\frac{8}{3}$ (D) 5

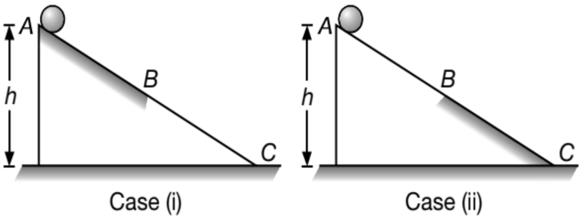
157. A disc of radius R rolls on a horizontal ground with linear acceleration a and angular acceleration α as shown in figure. The magnitude of acceleration of point P shown in figure at an instant when its linear velocity is v and angular velocity is ω will be



(A) $\sqrt{(a + r\alpha)^2 + (r\omega^2)^2}$ (B) $\frac{ar}{R}$

(C) $\sqrt{r^2\alpha^2 + r^2\omega^4}$ (D) $r\alpha$

158. In both the cases, B is mid-point of A and C, while all other factors are same, except that in Case (i) AB is rough and BC is smooth while in Case (ii) AB is smooth and BC is rough. The kinetic energy of the ball on reaching the bottom

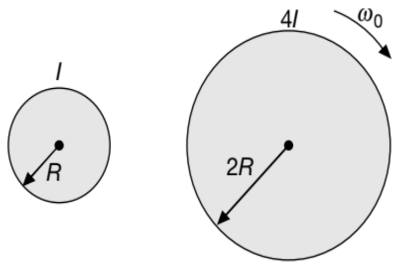


(A) is same in both the cases
(B) is greater in Case (i)
(C) is greater in Case (ii)
(D) None of these

159. A wheel of radius R rolls on the ground with a uniform velocity v. The relative acceleration of topmost point of the wheel with respect to the bottommost point is

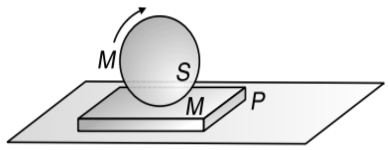
(A) $\frac{v^2}{R}$ (B) $\frac{2v^2}{R}$
(C) $\frac{v^2}{2R}$ (D) $\frac{4v^2}{R}$

160. Two cylinders having radii $2R$ and R and moment of inertias $4I$ and I about their central axes are supported by axles perpendicular to their planes. The large cylinder is initially rotating clockwise with angular velocity ω_0. The small cylinder is moved to the right until it touches the large cylinder and is made to rotate by the frictional force between the two. Eventually slipping ceases and the two cylinders rotate at constant rates in opposite directions. The final angular velocity of the small cylinder is



(A) $\frac{\omega_0}{4}$ (B) ω_0
(C) $\frac{\omega_0}{2}$ (D) $\frac{\omega_0}{8}$

161. A sphere S of mass M is given a finite angular velocity about a horizontal axis through its centre. Now it is gently placed on a plank P of same mass. The coefficient of friction between the two is μ and the plank rests on a smooth horizontal surface as shown. The initial acceleration of the sphere relative to the plank will be



(A) μg (B) $2\mu g$
(C) $\frac{2}{5}\mu g$ (D) ZERO

162. A solid cylinder R is free to rotate about its axis which is horizontal. A string is wound around it and a mass m is attached to its free end. When m falls through a distance h, its speed at that instant is proportional to

(A) R (B) $\frac{1}{R}$
(C) $\frac{1}{R^2}$ (D) None of these

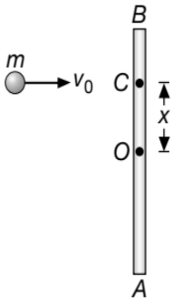
163. A wheel of mass 40 kg and radius of gyration 0.5 m comes to rest from a speed of 1800 rpm in 30 s. Assuming that the retardation is uniform, the value of the retarding torque, in Nm, is

(A) 10π (B) 20π
(C) 30π (D) 40π

164. A solid cylinder of mass M and radius R rolls down the inclined plane from height h without slipping. The speed of its centre of mass when it reaches the bottom is

(A) $\sqrt{2gh}$ (B) $\sqrt{\frac{4}{3}gh}$
(C) $\sqrt{\frac{3}{4}gh}$ (D) $\sqrt{\frac{4g}{h}}$

165. A uniform rod AB of length L having mass m are lying on a smooth table. A small particle of mass m strikes the rod with a velocity v_0 at point C, a distance x from the centre O. The particle comes to rest after collision. The value of x, so that point A of the rod remains stationary just after collision is



(A) $\frac{L}{3}$ (B) $\frac{L}{6}$

(C) $\frac{L}{4}$ (D) $\frac{L}{12}$

166. A wheel of radius r rolls without slipping with a speed v on a horizontal road. When it is at a point A on the road, a small blob of mud separates from the wheel at its highest point and lands at point B on the road

(A) $AB = v\sqrt{\frac{r}{g}}$ (B) $AB = 2v\sqrt{\frac{r}{g}}$

(C) $AB = 4v\sqrt{\frac{r}{g}}$ (D) $AB = 8v\sqrt{\frac{r}{g}}$

167. A mass M is moving with a constant velocity parallel to the x-axis. Its angular momentum with respect to the origin

(A) is zero (B) remains constant

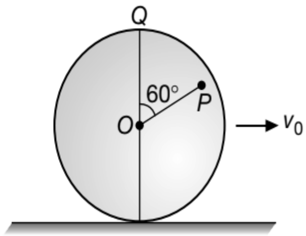
(C) increases (D) decreases

168. A billiard ball of mass m and radius r, hit by a cue at a height h above the centre, acquires a linear velocity v_0. The angular velocity ω_0 acquired by the ball is

(A) $\frac{2v_0h}{5r^2}$ (B) $\frac{5v_0h}{2r^2}$

(C) $\frac{2v_0r^2}{5h}$ (D) $\frac{5v_0r^2}{2h}$

169. A disc of radius r rolls without slipping on a rough horizontal floor. If velocity of its centre of mass is v_0, then velocity of point P at distance $\frac{r}{2}$ such that $\angle POQ = 60°$ as shown in the figure is



(A) v_0 (B) $\frac{v_0}{2}$

(C) $\frac{v_0\sqrt{7}}{2}$ (D) $\frac{v_0\sqrt{3}}{2}$

170. A particle is projected with velocity v at an angle of ϕ with horizontal. The average angular velocity of the particle from the point of projection to impact equals

(A) $\frac{g\cos\phi}{\phi v}$ (B) $\frac{g}{v\sin\phi}$

(C) $\frac{g}{v\phi}$ (D) $\frac{g\phi}{v\sin\phi}$

171. A uniform stick of length F_3 and mass m lies on a smooth table. It rotates with angular velocity ω about an axis perpendicular to the table and passes through one end of the stick. The angular momentum of the stick about the end is

(A) $ml^2\omega$ (B) F_2

(C) $I_1 + I_2$ (D) $\frac{ml^2\omega}{6}$

MULTIPLE CORRECT CHOICE TYPE QUESTIONS

This section contains Multiple Correct Choice Type Questions. Each question has four choices (A), (B), (C) and (D), out of which ONE OR MORE is/are correct.

1. The moment of inertia of a solid cylinder of mass M, length $2R$ and radius R about an axis passing through the centre of mass and perpendicular to the axis of the cylinder is I_1 and about an axis passing through one end of the cylinder and perpendicular to the axis of cylinder is I_2

(A) $I_2 - I_1 = MR^2$ (B) $I_2 > I_1$

(C) $\frac{I_2}{I_1} = \frac{19}{12}$ (D) $I_1 - I_2 = MR^2$

2. The torque $\vec{\tau}$ on a body about a given point is found to be $\vec{A} \times \vec{L}$ where $\vec{A}$ is a constant vector and $\vec{L}$ is angular momentum of the body about that point. From this it follows that

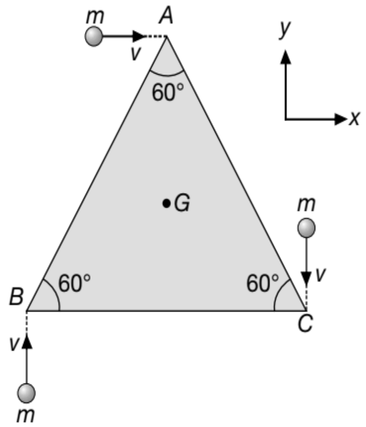
(A) $\frac{d\vec{L}}{dt}$ is perpendicular to $\vec{L}$ at all instants of time.

(B) the component of $\vec{L}$ in the direction of $\vec{A}$ does not change with time.

(C) the magnitude of $\vec{L}$ does not change with time.

(D) $\vec{L}$ does not change with time.

3. A triangular wedge ABC of mass m and sides $2a$ lies on a smooth horizontal plane as shown. Three point masses of mass m each strike the wedge at A, B and C with speeds v as shown. After the collision, the particles come to rest. Select the correct alternative(s).



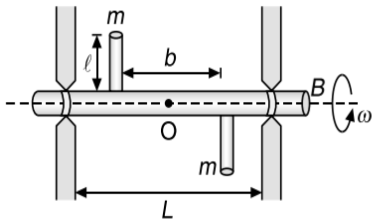
(A) The centre of mass of ABC remains stationary after collision

(B) The centre of mass of ABC moves with a velocity v along x-axis after collision

(C) The triangular wedge rotates with an angular velocity $\omega = \frac{2\sqrt{3}mva}{I}$ about its centre of mass (here, I is the moment of inertia of triangular wedge about its centroid axis perpendicular to its plane)

(D) A point lying at a distance of $\left(\frac{I}{2\sqrt{3}ma}\right)$ from G on perpendicular bisector of BC (below G) is at rest just after collision

4. Figure shows a horizontal rod AB which is free to rotate about two smooth bearing system. Two identical uniform rods each of mass m are attached to rod AB. All the dimensions are given in the Figure. The system is rotating with constant angular velocity ω in such a way that the upper rod is coming outward from the plane of the paper in the position shown. Gravity can be assumed to be absent in the experiment, then choose the correct option(s).



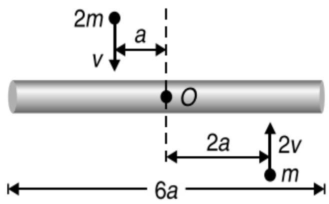
(A) The hinge reaction at A on the rod AB is downward

(B) The hinge reaction at B on the rod AB is upward

(C) The hinge reaction at B on the rod AB is downward

(D) The angular momentum of the system about point O is not along the rod AB.

5. A uniform bar of length $6a$ and mass $8m$ lies on a smooth horizontal table. Two point masses m and $2m$ moving in the same horizontal plane with speeds $2v$ and v, respectively, strike the bar as shown in the figure and stick to it after collision. Denoting angular velocity (about the centre of mass), total energy and the centre of mass velocity by ω, E and V_c respectively, we have after collision



(A) $V_c = 0$ (B) $\omega = \frac{3v}{5a}$

(C) $\omega = \frac{v}{5a}$ (D) $E = \frac{3mv^2}{5}$

6. A particle of mass m is travelling with a constant velocity $\vec{v} = v_0\hat{i}$ along the line $y = b$, $z = 0$. If dA be the area swept out by the position vector from origin to the particle in time dt and L be the magnitude of angular momentum of particle about origin at any time t. Then

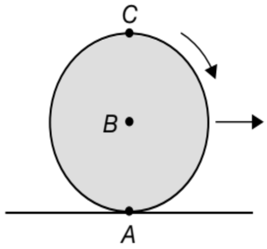
(A) $L \neq$ constant

(B) $L =$ constant

(C) $\frac{dA}{dt} = \frac{2L}{m}$

(D) $\frac{dA}{dt} = \frac{L}{2m}$

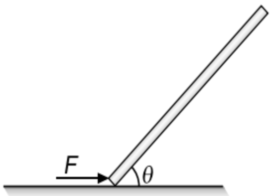
7. A sphere is rolling without slipping on a fixed horizontal plane surface. In the figure, A is the point of contact, B is the centre of the sphere and C is its topmost point. Then,



(A) $\vec{V}_C - \vec{V}_A = 2(\vec{V}_B - \vec{V}_C)$ (B) $\vec{V}_C - \vec{V}_B = \vec{V}_B - \vec{V}_A$

(C) $|\vec{V}_C - \vec{V}_A| = 2|\vec{V}_B - \vec{V}_C|$ (D) $|\vec{V}_C - \vec{V}_A| = 4|\vec{V}_B|$

8. A rod of length l is balanced in a vertical plane by applying a horizontal force F to its end lying on the surface as shown in Figure.



The linear mass density of the rod varies with distance r from the end lying on the surface as $\lambda(r) = \left(\frac{\lambda_0}{l^2}\right)r$, where λ_0 is a positive constant. If the applied force equals 4/3 times the weight of the rod and the rod only translates, then select the correct option(s).

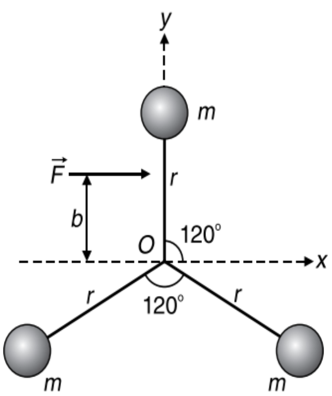
(A) $\theta = 37°$

(B) Acceleration of rod is $\frac{4g}{3}$

(C) normal force is $\frac{\lambda_0 g}{2}$

(D) normal force is $\lambda_0 g$

9. Each of the three balls has a mass m and is welded to the rigid equiangular from of negligible mass. The assembly rests on a smooth horizontal surface. A force F is suddenly applied to one bar as shown.



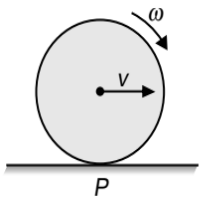
(A) Acceleration of point O is $\vec{a} = \frac{1}{3}\frac{\vec{F}}{m}\hat{i}$.

(B) Acceleration of point O is $\vec{a} = \frac{\vec{F}}{m}\hat{i}$.

(C) The magnitude of angular acceleration of the frame is $\alpha = \frac{1}{3}\frac{Fb}{mr^2}$.

(D) The magnitude of angular acceleration of the frame is $\alpha = \frac{Fb}{mr^2}$.

10. A body of mass m, radius R rolls on a horizontal surface with linear velocity v as shown in Figure.



If L_1 and L_2 be the magnitudes of the respective angular momenta of the body about centre of mass and the point of contact P. Then

(A) $L_2 = 2L_1$, for all cases

(B) $L_2 = 2L_1$, if radius of gyration $K = R$

(C) $L_2 > 2L_1$, if radius of gyration $K < R$

(D) $L_2 > 2L_1$, if radius of gyration $K > R$

11. A and B are two solid spheres of equal masses. A rolls down an incline plane without slipping from a height of 3 m. B falls vertically from the same height. Then on reaching the ground

(A) A can do more work than B

(B) B can do more work than A

(C) both perform equal work

(D) both will have different linear speeds

12. A solid body rotates about a stationary axis so that its angular velocity depends upon the rotation angle ϕ as $\omega = \omega_0 - a\phi$, where a and ω_0 are positive constants. Initially that is at $t = 0$, $\phi = 0$.

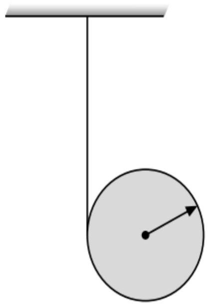
(A) $\phi = \frac{\omega_0}{a}(1 - e^{-at})$

(B) $\phi = \frac{\omega_0}{a}(1 + e^{at})$

(C) $\omega = \omega_0 e^{-at}$

(D) $\omega = \omega_0 e^{at}$

13. A string is wrapped over a uniform cylinder, as shown in Figure (side view). When cylinder is released, string unwraps without any slipping and cylinder comes down. Select the correct statements(s).



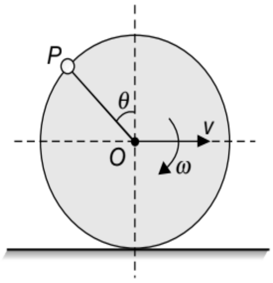
(A) Work done by tension force on the cylinder is zero.
(B) Work done by tension is negative
(C) Ratio of rotational kinetic energy and translational kinetic energy is $\frac{1}{2}$
(D) Ratio of rotational kinetic energy to translational kinetic energy is 2

14. The density of a rod AB increases linearly from A to B. Its midpoint is O and its centre of mass is at C. Four axes pass through A, B, O and C, all perpendicular to the length of the rod. The moments of inertia of the rod about these axes are I_A, I_B, I_O and I_C respectively

(A) $I_A > I_B$ (B) $I_A < I_B$
(C) $I_O > I_C$ (D) $I_O < I_C$

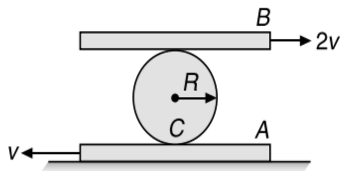
15. A thin uniform rod of mass m and length l is free to rotate about its upper end. When it is at rest, it receives an impulse J at its lowest point, normal to its length. Immediately after impact
(A) the angular momentum of the rod is Jl
(B) the angular velocity of the rod is $\frac{3J}{ml}$
(C) the kinetic energy of the rod is $\frac{3J^2}{2m}$
(D) the linear velocity of the midpoint of the rod is $\frac{3J}{2m}$

16. A disc of radius R rolls on a horizontal surface with linear velocity v and angular velocity ω. A point P on the circumference of the disc at angle θ shown has a vertical velocity. Then,



(A) $\theta = \pi + \sin^{-1}\left(\frac{v}{R\omega}\right)$ (B) $\theta = \frac{\pi}{2} - \sin^{-1}\left(\frac{v}{R\omega}\right)$
(C) $\theta = \pi - \cos^{-1}\left(\frac{v}{R\omega}\right)$ (D) $\theta = \pi + \cos^{-1}\left(\frac{v}{R\omega}\right)$

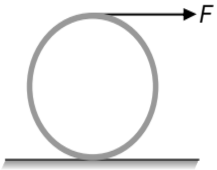
17. A cylinder C of mass $8m$ is rolling without sliding over two horizontal planks A and B having masses $2m$ and m, moving with uniform velocities $-v\hat{i}$ and $2v\hat{i}$ respectively. Select the correct option(s).



(A) The instantaneous axis of rotation is located at a distance of $\frac{4R}{3}$ below the topmost contact point.
(B) Angular velocity of the cylinder is $\frac{3v}{2R}$
(C) Translational kinetic energy of the system is $4mv^2$
(D) Kinetic energy of the system is $\frac{9}{2}mv^2$

18. A uniform disc is rotating at a constant speed in a vertical plane about a fixed horizontal axis passing through the centre of the disc. A piece of the disc from its rim detaches itself from the disc at the instant when it is at horizontal level with the centre of the disc and moving upward. Then about the fixed axis, the angular speed of the
(A) remaining disc decreases
(B) remaining disc increases
(C) remaining disc stays constant
(D) broken away piece decreases initially and later increases

19. A constant force F is applied at the top of a ring of mass M and radius is R as shown. The angular momentum of particle about point of contact at time t



(A) is constant
(B) increases linearly with time
(C) is $2FRt$
(D) decreases linearly with time

20. A particle moves in a circle of radius r with angular velocity $\vec{\omega}$. At some instant its velocity is $\vec{v}$ and radius vector with respect to centre of the circle is $\vec{r}$. At this particular instant centripetal acceleration $\vec{a}_c$ of the particle is

(A) $\vec{v}\times\vec{\omega}$ (B) $\vec{\omega}\times\vec{v}$
(C) $\vec{v}\times(\vec{r}\times\vec{\omega})$ (D) $\vec{\omega}\times(\vec{\omega}\times\vec{r})$

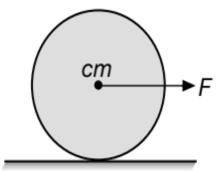
21. A disc rolls without slipping in the absence any external force on a

(A) rough inclined plane
(B) smooth inclined plane
(C) rough horizontal surface
(D) smooth horizontal surface

22. A pan containing a layer of uniform thickness of ice is placed on a circular turntable with its centre coinciding with the centre of the turntable. The turntable is now rotated at a constant angular velocity about a vertical axis passing through its centre and the driving torque is withdrawn. There is no friction between the table and the pivot. The pan rotates with the table. As the ice melts

(A) the angular velocity of system increases
(B) the angular velocity of system decreases
(C) the angular velocity remains unchanged
(D) the moment of inertia of system increases

23. A solid cylinder of mass M and radius R is rolled horizontally on a rough surface as shown in the figure. Choose the correct alternative(s)



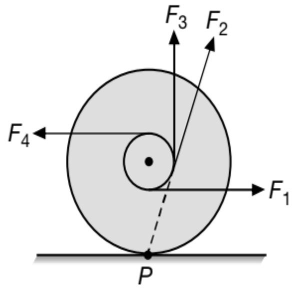
(A) The acceleration of the centre of mass is $\frac{F}{M}$

(B) The acceleration of the centre of mass is $\frac{2}{3}\frac{F}{M}$

(C) The friction force on the cylinder acts backward

(D) The magnitude of the friction force is $\frac{F}{3}$

24. A spool of wire rests on a horizontal surface as shown in figure. As the wire is pulled, the spool does not slip at contact point P. On separate trials, each one of the forces F_1, F_2, F_3 and F_4 is applied to the spool. For each one of these forces the spool



(A) will rotate anticlockwise if F_1 is applied
(B) will rotate anticlockwise if F_3 is applied
(C) will rotate clockwise if F_4 is applied
(D) will not rotate if F_2 is applied

25. A rod of length l is standing vertically on a frictionless surface. It is disturbed slightly from this position. Let ω and α be the angular speed and angular acceleration of the rod when the rod turns through an angle θ with the vertical. If the speed of the centre of mass is v and the value of acceleration of centre of mass of the rod is a, then

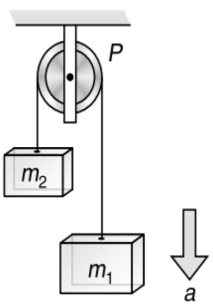
(A) $a=\frac{l\alpha}{2}\sin\theta+\frac{l\omega^2}{2}\cos\theta$

(B) $a=\frac{l\omega^2}{2}\sin\theta+\frac{l\alpha}{2}\cos\theta$

(C) $v=\frac{l\omega}{2}\cos\theta$

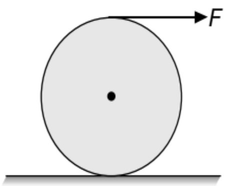
(D) $v=\frac{l\omega}{2}\sin\theta$

26. In the figure the blocks have unequal masses m_1 and $m_2\,(m_1>m_2)$. m_1 has a downward acceleration a. The pulley P has a radius R, and some mass. The string does not slip on the pulley



(A) the two sections of the string have unequal tensions
(B) the two blocks have accelerations of equal magnitude
(C) the angular acceleration of P is $\frac{a}{R}$
(D) $a < \left(\frac{m_1 - m_2}{m_1 + m_2}\right)g$

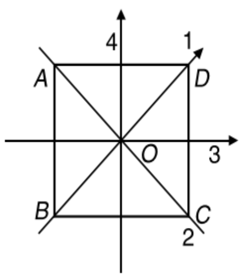
27. A solid sphere of radius R is rolled by a force F acting at the top of the sphere as shown in the figure. There is no slipping and initially sphere is in the rest position then



(A) work done by force F when the centre of mass moves a distance S is $2FS$
(B) speed of centre of mass (CM) when CM moves a distance S is $\sqrt{\frac{20FS}{7M}}$
(C) work done by the force F when CM moves a distance S is FS
(D) speed of the CM when CM moves a distance S is $\sqrt{\frac{4FS}{M}}$

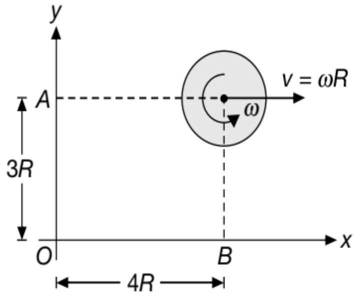
28. If a circular concentric hole is made in a disc, then about an axis passing through the centre of the disc and perpendicular to its plane the
(A) radius of gyration increases
(B) radius of gyration decreases
(C) moment of inertia increases
(D) moment of inertia decreases

29. The moment of inertia of a thin square plate $ABCD$ of uniform thickness about an axis passing through the centre O and perpendicular to the plate is



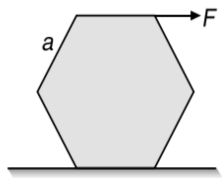
(A) $I_1 + I_2$ (B) $I_3 + I_4$
(C) $I_1 + I_3$ (D) $I_1 + I_2 + I_3 + I_4$

30. A disc of mass M and radius R moves in the x-y plane as shown in the figure. The angular momentum of the disc at the instant shown is



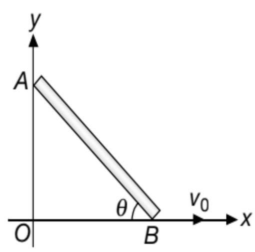
(A) $\frac{5MR^2\omega}{2}$ about O (B) $\frac{7MR^2\omega}{2}$ about O
(C) $\frac{MR^2\omega}{2}$ about A (D) $4MR^2\omega$ about A

31. A horizontal force F acts on one side of a hexagonal body that lies on a horizontal rough surface as shown in Figure. Select the correct statement(s).



(A) For toppling, the minimum value of coefficient of friction is $\frac{1}{2\sqrt{3}}$.
(B) For toppling, the minimum value of coefficient of friction is $\frac{2}{\sqrt{3}}$.
(C) If $\mu = 2\mu_{\min}$ and applied force $F = \frac{mg}{\sqrt{3}}$, then angular acceleration of the body is $\frac{6g}{17a}$.
(D) If $\mu = 2\mu_{\min}$ and applied force $F = \frac{mg}{\sqrt{3}}$, then angular acceleration of the body is $\frac{6g}{5a}$.

32. The end B of the rod AB which makes angle θ with the floor is being pulled with a constant velocity v_0 as shown. The length of the rod is l. At the instant when $\theta = 37°$, the



(A) velocity of end A is constant

(B) velocity of end A is $\frac{4}{3}v_0$ downwards

(C) angular velocity of rod is constant

(D) angular velocity of rod is $\frac{5}{3}\frac{v_0}{l}$

33. Four particles each of mass m are placed at four corners of a square $ABCD$ of side a. If the point O happens to be the centre of the square, then the moment of inertia of all four particles about an axis passing through

(A) A and B is $2ma^2$

(B) A and C is ma^2

(C) O and perpendicular to plane of square is $2ma^2$

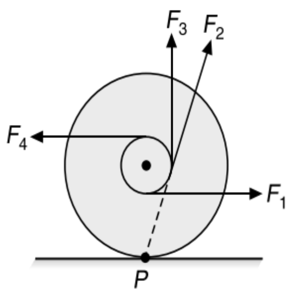
(D) O and parallel to CD is ma^2

34. In pure rolling, the fraction of total energy associated with rotation is α for a ring and β for a solid sphere. Then

(A) $\alpha = \frac{1}{2}$ (B) $\alpha = \frac{1}{4}$

(C) $\beta = \frac{2}{5}$ (D) $\beta = \frac{2}{7}$

35. A spool of wire rests on a horizontal surface as shown in Figure.



As the wire is pulled, the spool does not slip at contact point P. On separate trials, each one of the forces F_1, F_2, F_3 and F_4 is applied to the spool. The direction of friction force is

(A) towards left if F_1 is applied

(B) towards left if F_2 is applied

(C) towards right if F_3 is applied

(D) may be right or left or friction may be zero if F_4 is applied

36. A student holds the axle of a spinning bicycle wheel while seated on a pivoted stool. The student and the stool are initially at rest while the wheel is spinning in a horizontal plane with an angular momentum $\vec{L}_0$ pointing upward. The wheel is inverted about its centre by $180°$.

(A) The angular momentum of the system is conserved.

(B) The angular momentum of the system is not conserved.

(C) The final angular momentum of student plus stool will be $2\vec{L}_0$.

(D) The final angular momentum of student plus stool will be zero.

37. Which of the following statement(s) is/are correct for a spherical body rolling without slipping on a rough horizontal surface at rest?

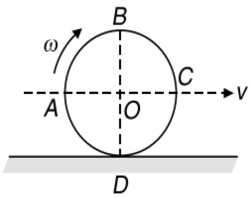
(A) The speed of some of the point(s) is (are) zero

(B) The acceleration of a point in contact with ground is zero

(C) Work done by friction may or may not be zero

(D) Friction force may or may not be zero

38. A ring rolls without slipping on a horizontal surface. At any instant, its position is as shown in the figure



(A) section ABC has greater kinetic energy than section ADC

(B) section BC has greater kinetic energy than section CD

(C) section BC has the same kinetic energy as section DA

(D) the section AB, BC, CD and DA have the same kinetic energy

39. A particle of mass m is projected with velocity v making an angle of $45°$ with the horizontal. The magnitude of angular momentum of the projectile about point of projection when the particle is at maximum height h is

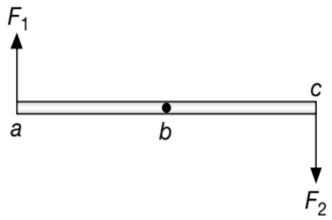
(A) ZERO

(B) $\frac{mv^3}{4\sqrt{2}g}$

(C) $\frac{mv^3}{\sqrt{2}g}$

(D) $m\sqrt{2gh^3}$

40. Two forces F_1 and F_2 are acting on a rod *abc* as shown in figure. Select the correct statement(s).



(A) If $F_1 \neq F_2$, then $\tau_a \neq \tau_b \neq \tau_c$

(B) If $F_1 \neq F_2$, then $\tau_a = \tau_c \neq \tau_b$

(C) If $F_1 = F_2$, then $\tau_a = \tau_b = \tau_c$ (for both the forces)

(D) If $F_1 = F_2$, then $\tau_a = \tau_c \neq \tau_b$

41. A horizontal disc rotates freely about a vertical axis through its centre. A ring, having the same mass and radius as the disc, is now gently placed on the disc. After some time, the two rotate with a common angular velocity

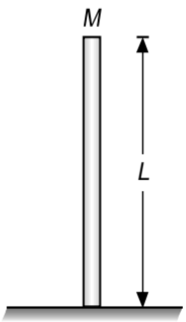
(A) some friction exists between the disc and the ring.

(B) the angular momentum of the 'disc plus ring' is conserved.

(C) the final common angular velocity is $\frac{2}{3}$ times initial angular velocity of the disc.

(D) $\frac{2}{3}$ times the initial kinetic energy changes to heat.

42. A uniform rod of mass M and length L is held vertically on a smooth horizontal surface. When the rod is released, choose the correct alternative(s).



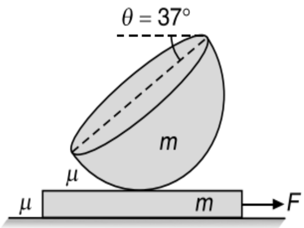
(A) The centre of mass of the rod accelerates in the vertical direction

(B) Initially, the magnitude of the normal reaction is Mg

(C) When the rod becomes just horizontal, the magnitude of the normal reaction becomes $\frac{Mg}{2}$

(D) When the rod becomes just horizontal, the magnitude of the normal reaction becomes $\frac{Mg}{4}$

43. A force F is applied on the plank such that the hollow hemispherical shell of mass $m = 5$ kg is in equilibrium as shown in Figure.



The coefficient of friction μ between hemispherical shell and plank is same as between plank and ground. Friction is just sufficient to prevent the slipping. Taking $g = 10\ ms^{-2}$, select the correct statement(s).

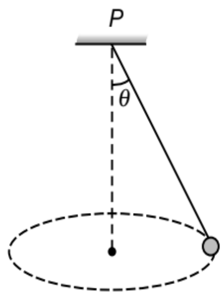
(A) Minimum coefficient of friction to prevent slipping is $\mu_{min} = \frac{1}{4}$

(B) Minimum coefficient of friction to prevent slipping is $\mu_{min} = \frac{1}{2}$

(C) Acceleration of plank is $10\ ms^{-2}$

(D) Magnitude of applied force is 100 N

44. A particle of mass 2 kg is attached to a string of length 1 m, moves in a horizontal circle just like a conical pendulum. The string makes an angle $\theta = 30^o$ with the vertical. Select the correct alternative(s) $\left(g = 10\ ms^{-2}\right)$.



(A) The vertical component of angular momentum of mass about the point of support P is approximately $1.7\ kgm^2s^{-1}$.

(B) The horizontal component of angular momentum of mass about the point of support P is approximately $2.9\ kgm^2s^{-1}$.

(C) Magnitude of $\frac{d\vec{L}}{dt}$, where $\vec{L}$ is the angular momentum of mass about point of support P, is approximately $10\ kgm^2s^{-2}$.

(D) $\vec{\tau} = \frac{d\vec{L}}{dt}$ will not hold good in this case.

REASONING BASED QUESTIONS

This section contains Reasoning type questions, each having four choices (A), (B), (C) and (D) out of which ONLY ONE is correct. Each question contains STATEMENT 1 and STATEMENT 2. You have to mark your answer as

Bubble (A) If both statements are TRUE and STATEMENT 2 is the correct explanation of STATEMENT 1.
Bubble (B) If both statements are TRUE but STATEMENT 2 is not the correct explanation of STATEMENT 1.
Bubble (C) If STATEMENT 1 is TRUE and STATEMENT 2 is FALSE.
Bubble (D) If STATEMENT 1 is FALSE but STATEMENT 2 is TRUE.

1. **Statement-1:** If earth shrink (without change in mass) to half it's present size. Length of the day would become 6 hours.
Statement-2: As size of earth changes its moment of inertia changes.

2. **Statement-1:** A ring moving down on a smooth inclined plane will be in slipping motion.
Statement-2: Work done by friction in pure rolling motion is zero.

3. **Statement-1:** A non-uniform sphere is placed such that its centre is at the origin of coordinate system. If I_x and I_y be moment of inertia about x-axis and y-axis respectively then moment of inertia about z-axis is $I_x + I_y$.
Statement-2: According to perpendicular axis theory $I_z = I_x + I_y$ when object is lying in x-y plane.

4. **Statement-1:** A sphere is performing pure rolling on a rough horizontal surface with constant angular velocity. Frictional force acting on the sphere is zero.
Statement-2: Velocity of contact point is zero.

5. **Statement-1:** If momentum of system is zero than kinetic energy must be zero.
Statement-2: If kinetic energy of system is zero than momentum must be zero.

6. **Statement-1:** A ladders is more likely to slip when a person is near the top than when he is near the bottom.
Statement-2: The friction between the ladder and floor decreases as he climbs up.

7. **Statement-1:** If rod is thrown upward with initial angular velocity and velocity of centre of mass then its momentum changes but angular velocity remains same.
Statement-2: Torque on rod about centre of mass due to gravitational force is zero.

8. **Statement-1:** The mass of a body cannot be considered to be concentrated at the centre of mass of the body for the purpose of computing its moment of inertia.
Statement-2: For then the moment of inertia of every-body about an axis passing through its centre of mass would be zero.

9. **Statement-1:** A disc is rolling on a rough horizontal surface. The instantaneous speed of the point of contact during perfect rolling is zero with respect to ground.
Statement-2: The force of friction can help in achieving pure rolling condition.

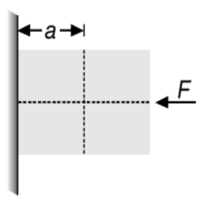
10. **Statement-1:** A solid sphere rolling on a rough horizontal surface. Acceleration of contact point is zero.
Statement-2: A solid sphere can roll on the smooth surface.

11. **Statement-1:** A disc is rolling on an inclined plane without slipping. The velocity of centre of mass is V. These other points on the disc lie on a circular arc having same speed as centre of mass.
Statement-2: When a disc is rolling on an inclined plane. The magnitude of velocities of all the point from the contact point is same, having distance equal to radius r.

12. **Statement-1:** The velocity of a body at the bottom of an inclined place of given height, is more when it slides down the plane, compared to, when it rolling down the same plane.
Statement-2: In rolling down, a body acquires both, kinetic energy of translation and rotation.

13. **Statement-1:** The force of friction in the case of a disc rolling without slipping down on inclined plane is $\frac{1}{3} g \sin\alpha$.
Statement-2: When the disc rolls without slipping, friction is required because for rolling condition velocity of point of contact is zero.

14. **Statement-1:** A horizontal force F is applied such that the block remains stationary because N will produce torque.
Statement-2: The torque produced by friction force is equal and opposite the torque produce due to normal reaction (N).



15. **Statement-1:** When a diver dives, the rotational kinetic energy of diver increases, during several somersaults.
Statement-2: When diver pulls his limbs, the moment of inertia decreases and on account of conservation of angular momentum his angular speed increases.

LINKED COMPREHENSION TYPE QUESTIONS

This section contains Linked Comprehension Type Questions or Paragraph based Questions. Each set consists of a Paragraph followed by questions. Each question has four choices (A), (B), (C) and (D), out of which only one is correct. (For the sake of competitiveness there may be a few questions that may have more than one correct options)

Comprehension I

A uniform rod AB of mass $3m$ and length $4l$, which is free to turn in a vertical plane about a smooth horizontal axis through A, is released from rest from the horizontal position. When the rod first becomes vertical, a point C of the rod, where $AC = 3l$, strikes a fixed peg. In Situation-I, for an impulse J_1 exerted by the peg on the rod, the rod is brought to rest by the peg. However, in Situation- II, for an impulse J_2 exerted by the peg on the rod, the rod rebounds and next comes to instantaneous rest when inclined to the downward vertical at an angle of $\frac{\pi}{3}$ radian. Based on above information, answer the following questions.

1. The value of J_1 in Situation-I is

(A) $m\sqrt{3gl}$ (B) $\frac{m}{8}\sqrt{3gl}$

(C) $8m\sqrt{\frac{gl}{3}}$ (D) $3m\sqrt{\frac{gl}{8}}$

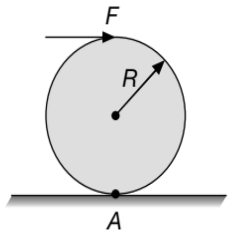
2. The value of J_2 in Situation-II is

(A) $m\sqrt{\frac{gl}{3}}$ (B) $4m\left(\sqrt{2}+1\right)\sqrt{\frac{2gl}{3}}$

(C) $2m\left(\sqrt{2}+1\right)\sqrt{\frac{gl}{3}}$ (D) $4m\sqrt{\frac{gl}{3}}$

Comprehension 2

When a body is hinged at a point and a force is acting on the body, in such a way that the line of action of force is at some distance from the hinged point, the body will start rotating about the hinged point. The angular acceleration of the body can be calculated by finding the torque of that force about the hinged point. A disc of mass m and radius R is hinged at point A at its bottom and is free to rotate in the vertical plane. A force of magnitude F is acting on the ring at the top most point. Based on above information, answer the following questions.



3. Tangential acceleration of centre of mass is

(A) $\frac{3F}{4m}$ (B) $\frac{F}{m}$

(C) $\frac{2F}{3m}$ (D) $\frac{4F}{3m}$

4. The component of reaction at hinge in vertical direction is

(A) $\frac{4}{3}mg$ (B) mg

(C) $\frac{mg}{2}$ (D) $\frac{2}{3}mg$

5. Component of reaction at hinge in horizontal direction is

(A) $\frac{F}{4}$ (B) F

(C) $\frac{F}{3}$ (D) $\frac{F}{2}$

Comprehension 3

A uniform rod AB of mass $3m$ and length $2l$ is lying at rest on a smooth horizontal table with a smooth vertical axis through the end A. A particle of mass $2m$ moves with speed $2u$ across the table and strikes the rod at its midpoint C. In Situation-I, the particle strikes the rod normally, the impact is perfectly elastic such that the speed of the particle after impact is v_1. In Situation-II, the particle strikes the rod such that its path before impact is inclined at $60°$ to AC, the impact is still perfectly elastic such that the speed of the particle after impact is v_2. Based on above information, answer the following questions.

6. The value of v_1 in Situation-I is

(A) u (B) $\frac{u}{2}$

(C) $\frac{2u}{3}$ (D) $\frac{u}{4}$

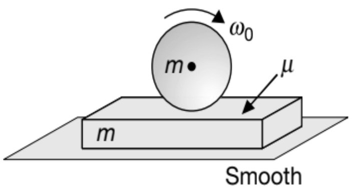
7. The value of v_2 in Situation-II is

(A) $\frac{u}{\sqrt{3}}$ (B) $\frac{2u}{\sqrt{3}}$

(C) $\frac{u}{\sqrt{2}}$ (D) $\frac{3u}{\sqrt{2}}$

Comprehension 4

A long horizontal plank of mass m is lying on a smooth horizontal surface. A sphere of same mass m and radius r is spinned about its own axis with angular velocity ω_0 and gently placed on the plank. The coefficient of friction between the plank and the sphere is μ. After some time, the pure rolling of the sphere on the plank starts. Based on above information, answer the following questions.



8. The time t at which the pure rolling begins is

(A) $\frac{r\omega_0}{9\mu g}$ (B) $\frac{2r\omega_0}{9\mu g}$

(C) $\frac{r\omega_0}{3\mu g}$ (D) $\frac{2r\omega_0}{\mu g}$

9. The velocity of the sphere, after the pure rolling begins is

(A) $\frac{2}{9}r\omega_0$ (B) $\frac{r\omega_0}{9}$

(C) $\frac{r\omega_0}{3}$ (D) $\frac{2}{3}r\omega_0$

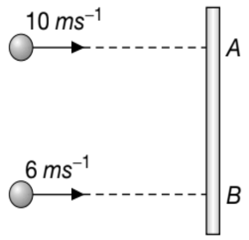
10. The displacement of the plank, till the sphere starts pure rolling is

(A) $\frac{r^2\omega_0^2}{81\mu g}$ (B) $\frac{2}{27}\left(\frac{r^2\omega_0^2}{\mu g}\right)$

(C) $\frac{4}{81}\left(\frac{r^2\omega_0^2}{\mu g}\right)$ (D) $\frac{2}{81}\left(\frac{r^2\omega_0^2}{\mu g}\right)$

Comprehension 5

A thin uniform bar lies on a frictionless horizontal surface and is free to move in any way on the surface. Its mass is 0.16 kg and length is $\sqrt{3}$ m. Two particles, each of mass 0.08 kg are moving on the same surface and towards the bar in a direction perpendicular to the bar one with a velocity of 10 ms^{-1}, and the other with 6 ms^{-1}, as shown in figure. The first particle strikes the bar at points A and the other point B. Points A and B are at a distance of 0.5 m from the centre of the bar. The particles strike the bar at the same instant of time and stick to the bar on collision. Based on above information, answer the following questions.



11. The velocity of the centre of mass of system, just after impact is

(A) 1 ms^{-1} (B) 2 ms^{-1}

(C) 3 ms^{-1} (D) 4 ms^{-1}

12. The angular velocity of the system, just after impact is

(A) 8 $rads^{-1}$ (B) 4 $rads^{-1}$

(C) 2 $rads^{-1}$ (D) 1 $rads^{-1}$

13. The loss of kinetic energy of the system in the above collision process is

(A) 1.72 J (B) 2.72 J

(C) 3.36 J (D) 4.36 J

Comprehension 6

A uniform disk of mass M and radius R is pivoted so that it can rotate freely about a horizontal axis through its centre and perpendicular to the plane of the disk. A small particle of mass m, the half of the mass of the disc, is attached to the rim of the disk at the top directly above the pivot. The system is given a gentle start and the disk begins to rotate about O. Based on above information, answer the following questions.

14. The angular velocity of the disk when the particle is at its lowest point is

(A) $\sqrt{\frac{g}{R}}$ (B) $\sqrt{\frac{3g}{R}}$

(C) $\sqrt{\frac{2g}{R}}$ (D) $\sqrt{\frac{g}{2R}}$

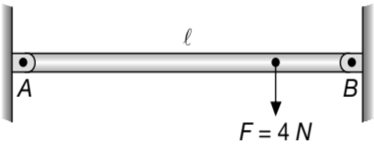
15. At the lowest point, the force that must be exerted by the disc on the particle to keep it on the disk is

(A) $\frac{Mg}{2}$ (B) $\frac{2Mg}{3}$

(C) $\frac{Mg}{3}$ (D) $\frac{3Mg}{2}$

Comprehension 7

A uniform rod of mass 2 kg and length l is suspended by two smooth hinges A and B as shown in figure. A force $F = 4$ N is applied downwards at a distance $\frac{l}{4}$ from hinge B. Due to the application of this force F, the hinge B breaks. At this instant, applied force F is also removed. The rod starts to rotate downward about hinge A. Take $g = 10\text{ ms}^{-2}$. Based on above information, answer the following questions.



16. The reaction at hinge A, before hinge B breaks, is
(A) 10 N (B) 11 N
(C) 12 N (D) 24 N

17. The reaction at hinge A, just after hinge B breaks is
(A) 35 N (B) 25 N
(C) 15 N (D) 5 N

18. The acceleration of the end point of rod having small mass dm when the rod becomes vertical is
(A) 100 ms^{-2} (B) 20 ms^{-2}
(C) 30 ms^{-2} (D) 40 ms^{-2}

Comprehension 8

A vertically oriented uniform heavy rod of mass M and length L can rotate about its upper end hinged to a rigid support. A fast moving light ball of mass m strikes the lower end of the rod with velocity u and sticks to it, as a result of which the rod swings through an angle θ. Based on above information, answer the following questions.

19. The angular velocity of the system just after impact is
(A) $\frac{mu}{3ML}$ (B) $\frac{Mu}{3mL}$
(C) $\frac{3mu}{ML}$ (D) $\frac{3Mu}{mL}$

20. The velocity, u of the ball is
(A) $\frac{M}{m}\sqrt{\frac{gL}{3}}\sin\left(\frac{\theta}{2}\right)$ (B) $\frac{m}{M}\sqrt{\frac{2}{3}gL}\sin\left(\frac{\theta}{2}\right)$
(C) $\frac{M}{m}\sqrt{\frac{2}{3}gL}\sin\left(\frac{\theta}{2}\right)$ (D) $\frac{m}{M}\sqrt{gL}\sin\left(\frac{\theta}{2}\right)$

21. The momentum change in the ball-rod system during the impact
(A) $m\sqrt{\frac{gL}{6}}\sin\left(\frac{\theta}{2}\right)$ (B) $m\sqrt{gL}\sin\left(\frac{\theta}{2}\right)$
(C) $m\sqrt{gL}\cos\left(\frac{\theta}{2}\right)$ (D) $M\sqrt{\frac{gL}{6}}\sin\left(\frac{\theta}{2}\right)$

22. The distance x from the upper end of the rod where the ball must strike the rod such that the momentum of the ball + rod system remains constant during the impact is
(A) $\frac{L}{3}$ (B) $\frac{L}{6}$
(C) $\frac{2L}{3}$ (D) $\frac{L}{2}$

Comprehension 9

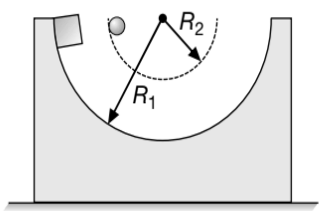
Moment of inertia of a straight wire about an axis perpendicular to the wire and passing through one of its end is I. This wire is now framed into a circle (a ring) of single turn. The moment of inertia of this ring about an axis passing through centre and normal to its plane is I_1. Now the same wire is bent into a ring of two turns and the moment of inertia about an axis passing through the ring normal to its plane is I_2. Based on above information, answer the following questions.

23. The value of I_1 is
(A) $\left(\frac{3}{\pi^2}\right)I$ (B) $\left(\frac{3}{4\pi^2}\right)I$
(C) $\left(\frac{\pi^2}{3}\right)I$ (D) $\left(\frac{4\pi^2}{3}\right)I$

24. The value of I_2 is
(A) $\left(\frac{\pi^2}{3}\right)I$ (B) $\left(\frac{\pi^2}{12}\right)I$
(C) $\left(\frac{3}{16\pi^2}\right)I$ (D) $\left(\frac{3}{8\pi^2}\right)I$

Comprehension 10

A fixed wedge has two semi-circular tracks of radius R_1 and R_2, such that $R_1 = 2R_2$. The track of radius R_1 is frictionless. A small block of mass m is held on the top of the larger track. A spherical ball of radius $r(\ll R_2)$ is held on the top of the other track. Both the block and the ball are released simultaneously. Friction in the track containing the ball is large enough to avoid slipping of the ball. Based on above information, answer the following questions.



25. Out of the block and the ball,
(A) the block reaches the bottom of the track first.
(B) the ball reaches the bottom of the track first.

(C) both reach the bottom of the track simultaneously.
(D) it is difficult to arrive at a conclusion, because some vital information is not provided in the paragraph.

26. Assuming the block and the ball to reach the bottom of their respective tracks simultaneously, then the ratio $\frac{R_1}{R_2}$ is

(A) $\frac{1}{5}$ (B) $\frac{5}{7}$
(C) $\frac{7}{5}$ (D) $\frac{9}{5}$

Comprehension 11

The angular momentum of a flywheel having a moment of inertia of 0.4 kgm^2 decreases from 3 kgm^2s^{-1} to 2 kgm^2s^{-1} in a period of 2 second. Based on above information, answer the following questions.

27. The average torque acting on the flywheel during this period is
(A) 10 Nm (B) 2.5 Nm
(C) 0.5 Nm (D) 5 Nm

28. If the angular acceleration is uniform, the number of revolutions the flywheel would have turned in that interval is
(A) 2 (B) 4
(C) 12 (D) 6

29. The work done is
(A) 3.125 Nm
(B) 12.5 Nm
(C) 62.5 Nm
(D) 6.25 Nm

Comprehension 12

A rod of mass m and length l in placed on a smooth horizontal table. A particle of same mass m strikes the rod with velocity v_0 in a direction perpendicular to the rod at distance $x\left(<\frac{l}{2}\right)$ from its centre and sticks to the rod. Let ω be the angular speed of system just after collision, then based on above information, answer the following questions.

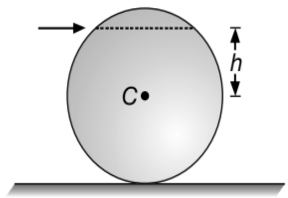
30. When x is increased from 0 to $\frac{l}{2}$, the angular speed ω
(A) will first decrease and then increase
(B) will first increase and then decrease
(C) will continuously increase
(D) will continuously decrease

31. Assume that the particle is still sticking to the rod, the maximum possible value of impulse obtained by varying x, that can be imparted to the particle during collision is

(A) $\frac{mv_0}{2}$ (B) $\frac{2mv_0}{3}$
(C) $\frac{3mv_0}{4}$ (D) $\frac{4mv_0}{5}$

Comprehension 13

A solid sphere is kept over a smooth surface as shown in figure. It is hit by a cue at height h above the centre C. In case 1, $h = \frac{R}{4}$ and in case 2, $h = \frac{R}{2}$. Suppose in case 1 the sphere acquires a total kinetic energy K_1 and in case 2 total kinetic energy is K_2.



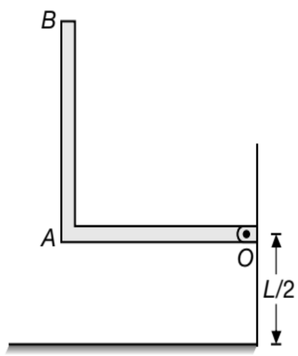
Assuming that in both the cases the sphere is hit by the same impulse, answer the following questions.

32. The appropriate comparison relation between K_1 and K_2 is
(A) $K_1 = K_2$ (B) $K_1 > K_2$
(C) $K_1 < K_2$ (D) data insufficient

33. If the surface is rough, then after hitting the sphere, in which case the force of friction is in forward direction.
(A) In case 1 (B) In case 2
(C) In both the cases (D) In none of the cases

Comprehension 14

An L shaped frame is free to rotate in a vertical plane about a horizontal axis passing through a smooth hinge O. Each side of the frame has a length L and mass m. The frame is let to fall with one side horizontal and the other vertical. Based on above information, answer the following questions.



34. The angular acceleration of the frame just after it is allowed to fall is

(A) $\frac{4g}{3L}$ (B) $\frac{9g}{8L}$

(C) $\frac{g}{2L}$ (D) $\frac{3g}{2L}$

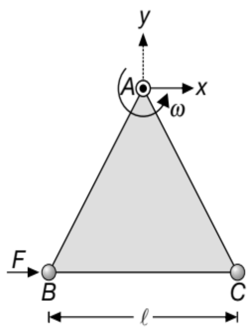
35. The speed of the end A with which it strikes the ground is

(A) $1.1\sqrt{gL}$ (B) $2\sqrt{gL}$

(C) $3.2\sqrt{gL}$ (D) $\sqrt{gL}$

Comprehension 15

Three particles A, B and C, each of mass m, are connected to each other by three massless rigid rods to form a rigid, equilateral triangular body of side l. This body is placed on a horizontal frictionless table $(x\text{-}y \text{ plane})$ and is hinged to it at the point A so that it can move without friction about the vertical axis through A (see figure). The body is set into rotational motion on the table about A with a constant angular velocity ω. At time T, when the side BC is parallel to the x-axis, a force F is applied on B along BC (as shown). Based on above information, answer the following questions.



36. The magnitude of the horizontal force exerted by the hinge on the body is

(A) $ml\omega^2$ (B) $\frac{ml\omega^2}{\sqrt{3}}$

(C) $\sqrt{3}ml\omega^2$ (D) $\frac{ml\omega^2}{3}$

37. The x-component of force exerted by the hinge on the body immediately after time T is

(A) $\frac{F}{2}$, along x-axis

(B) $\frac{F}{2}$, along negative x-axis

(C) $\frac{F}{4}$, along x-axis

(D) $\frac{F}{4}$, along negative x-axis

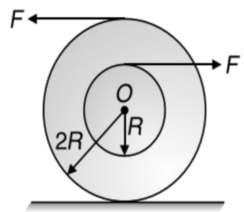
38. The y-component of the force exerted by the hinge on the body immediately after time T is

(A) $ml\omega^2$ (B) $\frac{ml\omega^2}{\sqrt{3}}$

(C) $\sqrt{3}ml\omega^2$ (D) $\frac{ml\omega^2}{3}$

Comprehension 16

In the arrangement shown, $F = 10$ N, $R = 1$ m, $M = 2$ kg and moment of inertia of the body about an axis passing through O and perpendicular to plane of body is $I = 4$ kgm^2. O is the centre of mass of the body. If the ground is smooth, the kinetic energy of the body at $t = 2$ s is K_1. However, when the ground is sufficiently rough the kinetic energy of the body at $t = 6$ s is K_2. Based on above information, answer the following questions.



39. The value K_1 equals

(A) 25 J (B) 50 J

(C) 75 J (D) 100 J

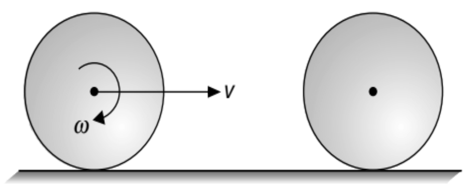
40. The value K_2 equals

(A) 10.33 J (B) 250 J

(C) 16.67 J (D) 150 J

Comprehension 17

A solid sphere of mass m, radius R is rolling without slipping on rough horizontal surface as shown in figure. It collides elastically with another identical sphere at rest. There is no friction between the two spheres.



Based on above information, answer the following questions.

41. Linear velocity of first sphere after it again starts rolling without slipping is

(A) $\frac{2}{5}R\omega$ (B) $\frac{2}{7}R\omega$

(C) $\frac{7}{10}R\omega$ (D) $\frac{7}{5}R\omega$

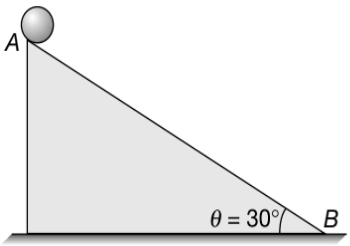
42. The net angular impulse imparted to the second sphere by the external forces is

(A) $\frac{2}{7}mvR$ (B) $\frac{5}{7}mvR$

(C) $\frac{2}{5}mvR$ (D) $\frac{7}{10}mvR$

Comprehension 18

On an inclined plane AB of length 5 m, a body is released from the point A. Assuming friction to be sufficient enough for pure rolling to take place, answer the following questions.



43. The maximum time which a body (that is capable of rolling) can take to reach the bottom is

(A) 8 s (B) 6 s

(C) 4 s (D) 2 s

44. If four bodies like ring, disc, solid sphere and hollow sphere (all having identical mass, radius and coefficient of friction) are taken and the angle θ is now gradually increased, then the body that will be the first to start slipping is

(A) Ring (B) Disc

(C) Solid sphere (D) Hollow sphere

Comprehension 19

A thin rod AB of mass M, length a has a variable mass per unit length $\frac{\rho_0(a+x)}{a}$, where x is the distance measured from the end A of the rod and ρ_0 is a constant. The rod is freely pivoted at A and is hanging in equilibrium when it is struck by a horizontal impulse of magnitude J at the point B. Based on above information, answer the following questions.

45. The total mass M of the rod is

(A) $2a\rho_0$ (B) $a\rho_0$

(C) $\frac{a\rho_0}{3}$ (D) $\frac{3a\rho_0}{2}$

46. The centre of mass of the rod is at the point at distance from the end A given by

(A) $\frac{a}{9}$ (B) $\frac{a}{3}$

(C) $\frac{5a}{9}$ (D) $\frac{2a}{3}$

47. The moment of inertia of the rod about an axis passing through A and perpendicular to AB is

(A) $\frac{7Ma^2}{18}$ (B) $\frac{5Ma^2}{18}$

(C) $\frac{1Ma^2}{12}$ (D) $\frac{1Ma^2}{18}$

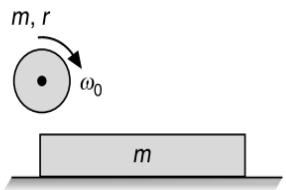
48. If on the application of impulse, the end B passes through a point vertically above A, then the minimum value of J is

(A) $\frac{M}{7}\sqrt{90ag}$ (B) $\frac{M}{9}\sqrt{70ag}$

(C) $\frac{M}{7}\sqrt{30ag}$ (D) $\frac{M}{5}\sqrt{80ag}$

Comprehension 20

In the diagram shown, a plank of mass m is lying at rest on a smooth horizontal surface. A disc of same mass m and radius r is rotated to an angular speed ω_0 and then gently placed on the plank. It is found that finally slipping ceases and 50% of the total kinetic energy of the system is lost. Assume that the plank is long enough and the coefficient of friction between disc and plank is μ. Based on above information, answer the following questions.



49. The final velocity of the plank is

(A) $\frac{r\omega_0}{4}$ (B) $\frac{r\omega_0}{\sqrt{10}}$

(C) $\frac{r\omega_0}{2}$ (D) $\frac{r\omega_0}{2\sqrt{10}}$

50. Time when slipping ceases is

(A) $\frac{r\omega_0}{2\mu g}$ (B) $\frac{r\omega_0}{\sqrt{10}\mu g}$

(C) $\frac{r\omega_0}{4\mu g}$ (D) $\frac{r\omega_0}{2\sqrt{10}\mu g}$

51. Magnitude of the change in angular momentum of the disc about center of mass of the disc is

(A) $\frac{3}{4}mr^2\omega_0$ (B) $\frac{3}{8}mr^2\omega_0$

(C) ZERO (D) $\frac{1}{2}mr^2\omega_0$

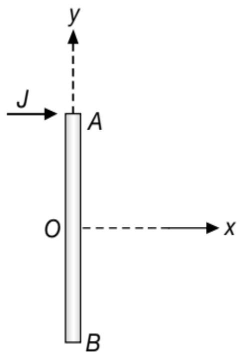
52. Distance moved by the plank from the placing of disc on the plank till the slipping ceases between disc and plank is

(A) $\dfrac{r^2\omega_0^{\,2}}{16\mu g}$ (B) $\dfrac{r^2\omega_0^{\,2}}{8\mu g}$

(C) $\dfrac{r^2\omega_0^{\,2}}{32\mu g}$ (D) $\dfrac{r^2\omega_0^{\,2}}{200\mu g}$

Comprehension 21

A rod AB of length 2 m and mass 2 kg is lying on smooth horizontal x-y plane with its centre at origin O as shown figure. An impulse J of magnitude 10 Ns is applied perpendicular to AB at A. Based on above information, answer the following questions.



53. The distance of point P from centre of the rod which is at rest just after the impact is

(A) $\dfrac{1}{4}$ m (B) $\dfrac{1}{2}$ m

(C) $\dfrac{1}{3}$ m (D) $\dfrac{2}{3}$ m

54. Co-ordinates of point A of the rod after time $t = \dfrac{\pi}{45}$ s will be

(A) $\left[\dfrac{1}{2}m, \dfrac{1}{2}m\right]$

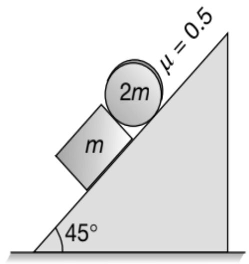
(B) $\left[\left(\dfrac{3}{4}m, \dfrac{3}{2}m\right)\right]$

(C) $\left[\left(\dfrac{\pi}{6}+\dfrac{1}{2}\right)m, \dfrac{1}{2}m\right]$

(D) $\left[\left(\dfrac{\pi}{9}+\dfrac{\sqrt{3}}{2}\right)m, \dfrac{1}{2}m\right]$

Comprehension 22

On a rough inclined plane of inclination $45°$, a block of mass m and a cylinder of mass $2m$ are released. The coefficient of friction between all the surfaces of contact is 0.5. Based on above information, answer the following questions.



55. The acceleration of the block and the cylinder when both move separately is

(A) $\dfrac{g}{2\sqrt{2}}, \dfrac{g}{3\sqrt{3}}$ (B) $\dfrac{g}{\sqrt{2}}, \dfrac{g}{\sqrt{3}}$

(C) $\dfrac{\sqrt{2}g}{3}, \dfrac{g}{2\sqrt{2}}$ (D) $\dfrac{g}{2\sqrt{2}}, \dfrac{\sqrt{2}g}{3}$

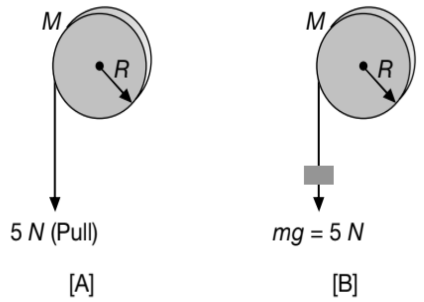
56. The acceleration of the block and the cylinder when both move together is

(A) $\dfrac{5g}{3\sqrt{2}}$ (B) $\dfrac{3g}{5\sqrt{2}}$

(C) $\dfrac{5g}{\sqrt{2}}$ (D) $\dfrac{3g}{\sqrt{2}}$

Comprehension 23

A uniform disc of mass $M = 2.5$ kg and radius $R = 0.2$ m is mounted on an axle supported on fixed frictionless bearings. A light cord wrapped around the rim is pulled with a force 5 N. On the same system of pulley and string instead of pulling it down, a body of weight 5 N is suspended. If the first process is termed A and the second B.



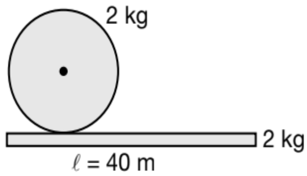
Based on above information, answer the following questions.

57. The tangential acceleration will be
(A) equal in the processes A and B
(B) greater in process A than in B
(C) greater in process B than in A
(D) independent of the two processes

58. The mechanical energy is conserved
(A) in both A and B
(B) in B only
(C) in A only
(D) neither in A nor in B

Comprehension 24

A plank of length 40 m and mass 2 kg is kept on a horizontal frictionless surface. A cylinder of mass 2 kg is placed on the plank. The coefficient of friction between the two surfaces is $\mu = 0.1$. Plank is suddenly given a velocity $v = 10\ ms^{-1}$ towards left. Based on above information, answer the following questions.



59. Initially the acceleration of point of contact with respect to the plank is

(A) $2\ ms^{-2}$ (B) $1\ ms^{-2}$
(C) $4\ ms^{-2}$ (D) $6\ ms^{-2}$

60. The time after which pure rolling starts is

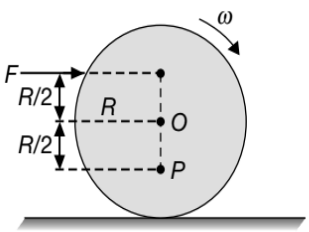
(A) 2 s (B) 2.5 s
(C) 3.5 s (D) 4.5 s

61. The time after which the plank and cylinder separates

(A) 6.75 s (B) 4 s
(C) 3.25 s (D) 5.25 s

Comprehension 25

A disc of mass 10 kg and radius 1 m is set into pure rolling on a rough horizontal surface as shown in the figure. At a particular instant, point P (figure) which is at a distance $\frac{R}{2}$ from the centre O is found to have a speed of $2\ ms^{-1}$ and acceleration of $10\ ms^{-2}$. Based on above information, answer the following questions.



62. Acceleration of the centre of mass of the disc is

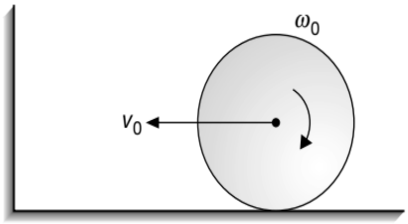
(A) $4\ ms^{-2}$ (B) $8\ ms^{-2}$
(C) $12\ ms^{-2}$ (D) $20\ ms^{-2}$

63. If a horizontal force F, applied at $\frac{R}{2}$ from the centre (as shown in the figure) causes this motion, the value of F is

(A) ZERO (B) 60 N
(C) 120 N (D) 200 N

Comprehension 26

A solid sphere of radius 1 m and mass 2 kg has linear velocity $v_0 = 4\ ms^{-1}$ and angular velocity $\omega_0 = 9\ rads^{-1}$ as shown. The ground on which it is moving, is smooth. It collides elastically with a rough wall of coefficient of friction μ. Based on above information, answer the following questions.



64. If the sphere after colliding with the wall rolls without slipping in opposite direction, then

(A) $\mu = \frac{1}{4}$ (B) $\mu = \frac{1}{3}$
(C) $\mu = \frac{1}{2}$ (D) $\mu = \frac{2}{3}$

65. The net linear impulse imparted by the wall on the sphere during impact is

(A) $\sqrt{32}$ Ns (B) $4\sqrt{5}$ Ns
(C) $4\sqrt{17}$ Ns (D) $15\sqrt{2}$ Ns

Comprehension 27

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. Based on above information, answer the following questions.

66. 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) $\frac{K^2}{R^2+K^2}$

67. The ratio of the rotational kinetic energy to total kinetic energy is

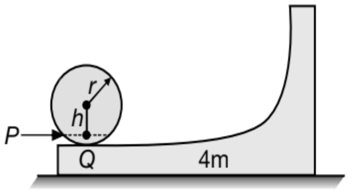
(A) $\frac{K^2}{R^2+K^2}$ (B) $\frac{R^2}{R^2+K^2}$
(C) $\frac{1}{R^2+K^2}$ (D) None of these

68. The ratio of the translational kinetic energy to the total kinetic energy is

(A) $\frac{K^2}{R^2+K^2}$ (B) $\frac{R^2}{R^2+K^2}$
(C) $\frac{1}{R^2+K^2}$ (D) None of these

Comprehension 28

A wedge of mass $4m$ is placed at rest on a smooth horizontal surface. A uniform solid sphere of mass m and radius r is placed at rest on the flat portion of the wedge at the point Q as shown in the figure. A sharp horizontal impulse P is given to the sphere at a point below $h = 0.4r$ from the center of the sphere. The radius of curvature of the curved portion of the wedge is R. Coefficient of friction to the left side of point Q is μ and to the right side of point Q is zero. Based on above information, answer the following questions.



69. The maximum height to which the center of mass of the sphere will climb on the curved portion of the wedge is

(A) $\frac{2P^2}{5m^2g}$ (B) $\frac{P^2}{5m^2g}$

(C) $\frac{P^2}{2m^2g}$ (D) None of these

70. Kinetic energy of the system when sphere is at the highest point is

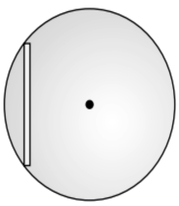
(A) $\frac{P^2}{10m}$ (B) $\frac{P^2}{5m}$

(C) $\frac{3P^2}{10m}$ (D) $\frac{3P^2}{5m}$

Comprehension 29

A rod of mass 4 kg, length 2 m is kept vertically inside a smooth spherical shell of radius 2 m. The rod starts slipping inside the shell. Based on above information, answer the following questions.

71. Angular speed of the rod $\left(\text{in rad s}^{-1}\right)$ in the position when it becomes horizontal is



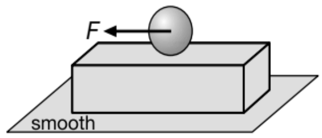
(A) 3.2 (B) 4.6
(C) 6.8 (D) 7.2

72. Velocity of centre of mass of the rod $\left(\text{in ms}^{-1}\right)$ at this instant is approximately

(A) 4.7 (B) 5.5
(C) 6.2 (D) 10.2

Comprehension 30

A disc of mass m and radius R is placed over a plank of same mass m. There is sufficient friction between disc and plank to prevent slipping. A force F is applied at the centre of the disc. Based on above information, answer the following questions.



73. Acceleration of the plank is

(A) $\frac{F}{4m}$ (B) $\frac{3F}{4m}$

(C) $\frac{F}{2m}$ (D) $\frac{3F}{2m}$

74. Acceleration of the disc is

(A) $\frac{F}{4m}$ (B) $\frac{F}{2m}$

(C) $\frac{3F}{4m}$ (D) F

75. The angular acceleration of the disc is

(A) $\frac{F}{mR}$ (B) $\frac{F}{2mR}$

(C) $\frac{3F}{2mR}$ (D) $\frac{3F}{mR}$

76. Force of friction between the disc and the plank is

(A) $\frac{F}{4}$ (B) $\frac{F}{3}$

(C) $\frac{F}{2}$ (D) $\frac{2F}{3}$

Comprehension 31

A uniform rod AB of mass $3m$ and length $2l$ is free to turn in a vertical plane about a smooth horizontal axis through A. A particle of mass m is attached to the rod at B. When the rod is hanging in equilibrium, it is set moving with an angular velocity $\omega_0 = \sqrt{\frac{kg}{l}}$, where k is a positive real number. Based on above information, answer the following questions.

77. For $k = 2$, the height of B above the level of A when the rod first comes to instantaneous rest is

(A) $\frac{3l}{5}$ (B) $\frac{4l}{5}$

(C) $\frac{6l}{5}$ (D) $\frac{8l}{5}$

78. The minimum value of k for which the particle describes complete circle about A is

(A) $\frac{3}{2}$ (B) $\frac{5}{2}$
(C) $\frac{7}{2}$ (D) $\frac{9}{2}$

Comprehension 32

A uniform disc of radius 1 m and mass 2 kg is mounted on an axle supported on fixed frictionless bearings. A light cord is wrapped around the rim of the disc and a mass of 1 kg is tied to the free end. If it is released from rest, the tension in the cord is T. If the applied torque acts for 4 second, the total angular displacement in this interval of time is θ. The work done by the applied torque is W and the increase in rotational kinetic energy is ΔK. Based on above information, answer the following questions.

79. The value of T is
(A) 10 N (B) 5 N
(C) 40 N (D) 15 N

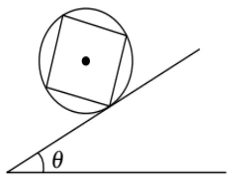
80. θ equals
(A) 40 rad (B) 80 rad
(C) 20 rad (D) 10 rad

81. W has a value given by
(A) 400 J (B) 50 J
(C) 100 J (D) 200 J

82. ΔK equals
(A) 400 J (B) 100 J
(C) 200 J (D) 80 J

Comprehension 33

Four identical rods of mass $M = 6$ kg each are welded at their ends to form a square and then welded to a massive ring having mass $m = 4$ kg having radius $R = 1$ m. If the system is allowed to roll down the incline of inclination $\theta = 30°$. Based on above information, answer the following questions.



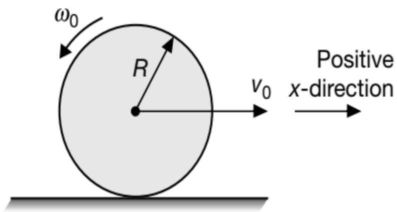
83. The moment of inertia of the system about the centre of ring will be
(A) 10 kgm^2
(B) 20 kgm^2
(C) 40 kgm^2
(D) 60 kgm^2

84. The acceleration of the system will be
(A) $\frac{g}{8}$ (B) $\frac{g}{4}$
(C) $\frac{7g}{24}$ (D) $\frac{g}{2}$

85. The minimum value of friction coefficient to prevent slipping is
(A) $\frac{5}{7}$ (B) $\frac{7}{5\sqrt{3}}$
(C) $\frac{5\sqrt{3}}{7}$ (D) $\frac{5}{12\sqrt{3}}$

Comprehension 34

A disc of mass M and radius R is given a velocity v_0 and an angular velocity ω_0 as shown in the figure. Then it is kept over a rough horizontal surface where coefficient of friction is μ. After some time slipping ceases, based on above information, answer the following questions.



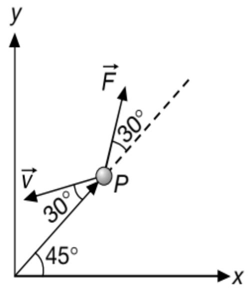
86. If $v_0 = R\omega_0$, then time after which pure rolling starts is
(A) $\frac{v_0}{\mu g}$
(B) $\frac{3v_0}{\mu g}$
(C) $\frac{2}{3}\frac{v_0}{\mu g}$
(D) pure rolling will never start

87. Velocity of centre of disc at the moment when angular velocity of disc becomes zero is
(A) v_0 (B) $\frac{v_0}{2}$
(C) $\frac{v_0}{3}$ (D) $\frac{v_0}{4}$

88. Velocity of centre of mass of disc when pure rolling begins is
(A) v_0 (B) $\frac{v_0}{2}$
(C) $\frac{v_0}{3}$ (D) $\frac{v_0}{4}$

Comprehension 35

A particle P with a mass 2 kg has position vector $r = 3$ m and velocity $V = 4\ \text{ms}^{-1}$ shown. It is accelerated by the force $F = 2$ N. All three vectors lie in the common plane. Based on above information, answer the following questions.



89. The angular momentum vector is

(A) 12 $\text{kgm}^2\text{s}^{-1}$, out of the plane of the figure

(B) 12 $\text{kgm}^2\text{s}^{-1}$, into the plane of the figure

(C) ZERO

(D) 24 $\text{kgm}^2\text{s}^{-1}$, out of the plane of the figure

90. The torque is

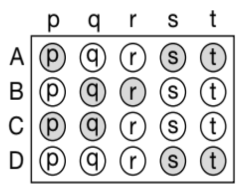
(A) 6 Nm, out of the page (B) 3 Nm, out of the page

(C) 6 Nm, into the page (D) 3 Nm, into the page

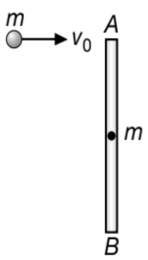
MATRIX MATCH/COLUMN MATCH TYPE QUESTIONS

Each question in this section contains statements given in two columns, which have to be matched. The statements in **COLUMN-I** are labelled A, B, C and D, while the statements in **COLUMN-II** are labelled p, q, r, s (and t). Any given statement in **COLUMN-I** can have correct matching with **ONE OR MORE** statement(s) in **COLUMN-II**. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following examples:

If the correct matches are A $\rightarrow$ p, s and t; B $\rightarrow$ q and r; C $\rightarrow$ p and q; and D $\rightarrow$ s and t; then the correct darkening of bubbles will look like the following:

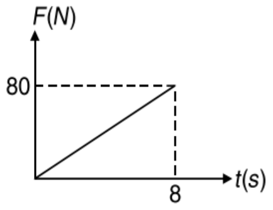


1. A smooth ball of mass m moving with a uniform velocity v_0 strikes a smooth uniform rod AB of equal mass m, lying on a frictionless horizontal table. The ball strikes the rod at one end A, perpendicular to the rod, as shown in Figure. The collision is perfectly elastic. If $K_i, K_f, K_T, J, p_i, L_{cm}, L_i$ denote the initial kinetic energy, final kinetic energy, final kinetic energy of translation of rod, impulse delivered to rod, initial momentum of ball, angular momentum of centre of mass and initial angular momentum of ball about CM of rod, then match the physical quantities pertaining to this situation given in **COLUMN-I** with their values given in **COLUMN-II**.



COLUMN-I	COLUMN-II
(A) $\dfrac{K_f}{K_i}$	(p) $\dfrac{2}{5}$
(B) $\dfrac{J}{p_i}$	(q) $\dfrac{3}{5}$
(C) $\dfrac{L_{cm}}{L_i}$	(r) $\dfrac{9}{25}$
(D) $\dfrac{K_f}{K_T}$	(s) 3

2. A uniform disc of mass 10 kg, radius 1 m is placed on a rough horizontal surface. The coefficient of friction between the disc and the surface is 0.2. A horizontal time varying force is applied at the centre of the disc whose variation with time is shown in graph. Match the contents of **COLUMN-I** with their respective time values in **COLUMN-II**.

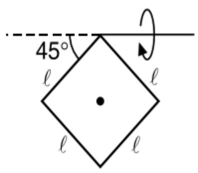
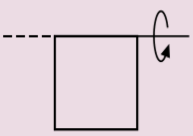
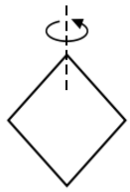
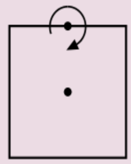


COLUMN-I	COLUMN-II
(A) Disc rolls without slipping	(p) at $t = 7$ s
(B) Disc rolls with slipping	(q) at $t = 3$ s
(C) Disc starts slipping at	(r) at $t = 4$ s
(D) Friction force is 10 N at	(s) at $t = 6$ s

3. Match the following quantities of **COLUMN-I** to their respective match(es) in **COLUMN-II**.

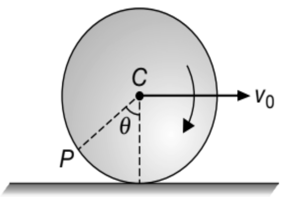
COLUMN-I	COLUMN-II
(A) Axial vector	(p) Rotational K.E.
(B) Scalar	(q) Translational K.E.
(C) Turning ability of force	(r) Angular momentum
(D) A rolling body can have	(s) Torque

4. A square frame is made by using four uniform rods each of mass m, length l. Match the moment of inertia for the frame about axis specified in **COLUMN-I** to their respective values given in **COLUMN-II**.

COLUMN-I (Axis of rotation)	COLUMN-II (Moment of Inertia about axis of rotation)
(A) 	(p) $\frac{2}{3}ml^2$
(B) 	(q) $\frac{5}{3}ml^2$
(C) 	(r) $\frac{7}{3}ml^2$
(D) 	(s) $\frac{8}{3}ml^2$

(Continued)

5. A disc rolls without slipping on the ground such that velocity of centre of mass of the disc is v_0. A point P on circumference of disc at angle θ with the vertical have a speed v_p. Assuming that initially the point P is in contact with the ground, match the following.



COLUMN-I	COLUMN-II
(A) If $\theta = 60°$	(p) $v_P = \sqrt{2}v$
(B) If $\theta = 90°$	(q) $v_P = v$
(C) If $\theta = 120°$	(r) $v_P = 2v$
(D) If $\theta = 180°$	(s) $v_P = \sqrt{3}v$

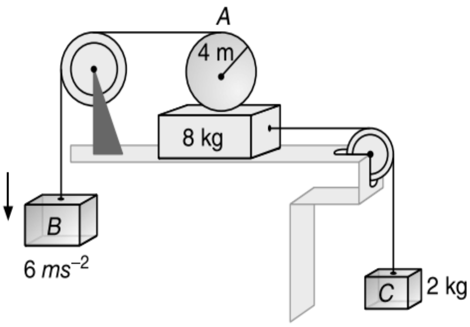
6. Match the moment of inertia of bodies about specified axis with their respective values.

COLUMN-I	COLUMN-II
(A) Moment of inertia of a circular disc of mass M and radius R about a tangent parallel to plane of disc	(p) $\frac{1}{2}MR^2$
(B) Moment of inertia of a solid sphere of mass M and radius R about a tangent.	(q) $\frac{7}{5}MR^2$

(Continued)

COLUMN-I	COLUMN-II
(C) Moment of inertia of a circular disc of mass M and radius R about a tangent perpendicular to plane of disc	(r) $\frac{5}{4}MR^2$
(D) Moment of inertia of a cylinder of mass M and radius R about its axis	(s) $\frac{1}{4}MR^2$
	(t) $\frac{3}{2}MR^2$

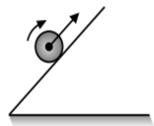
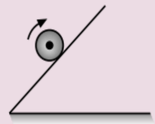
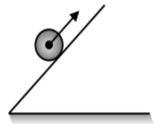
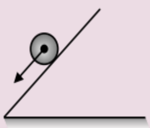
7. The diagram shows a uniform smooth solid cylinder A of radius 4 m rolling without slipping on the 8 kg plank, which in turn is supported by a fixed smooth surface. The blocks B and C both accelerate down with 6 ms^{-2} and 2 ms^{-2} respectively.



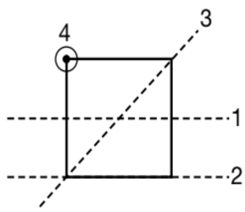
The angular acceleration of the cylinder A is α, the acceleration of centre of mass of cylinder is a, the ratio of mass of cylinder A to the mass of block B is $\frac{m_A}{m_B}$. The length of the unwrapped thread between the cylinder and the block at $t = 0$ is $l_0 = 20$ m and at $t = 2$ s is l (assume the system to be released from rest), match the following

COLUMN-I	COLUMN-II
(A) $\alpha(\text{in rads}^{-2})$	(p) 8
(B) $2a(\text{in ms}^{-2})$	(q) 2
(C) $\frac{m_A}{m_B}$	(r) 4
(D) $(l - l_0)$	(s) 1

8. The inclined surfaces shown in **COLUMN-I** are sufficiently rough and **COLUMN-II** gives direction of frictional forces for situations in **COLUMN-I**. Match the two columns.

COLUMN-I	COLUMN-II
(A)  Rolling upwards	(p) up the incline
(B)  Kept in rotating position	(q) down the incline
(C)  Kept in translational position	(r) maximum friction will act
(D)  Kept in translational position	(s) required value of friction will act

9. Four thin uniform rods of equal length l and mass m each form a square as shown in Figure. Moment of inertia about axes 1, 2, 3 and 4 are say I_1, I_2, I_3 and I_4. Then, match the following



COLUMN-I	COLUMN-II
(A) I_1	(p) $\frac{4}{3}ml^2$
(B) I_2	(q) $\frac{2}{3}ml^2$

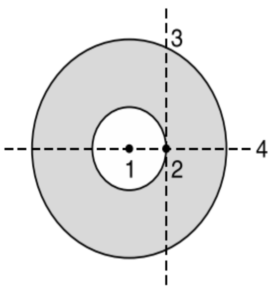
(Continued)

COLUMN-I	COLUMN-II
(C) I_3	(r) $\frac{10}{3}ml^2$
(D) I_4	(s) $\frac{5}{3}ml^2$

10. A uniform disc is acted upon by some forces and it rolls on a horizontal plank without slipping from north to south. The plank, in turn lies on a smooth horizontal surface. Match the following regarding this situation.

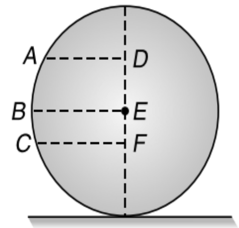
COLUMN-I	COLUMN-II
(A) Frictional force on the disc by the surface	(p) May be directed towards north
(B) Velocity of the lowermost point of the disc	(q) May be directed towards south
(C) Acceleration of centre of mass of the disc	(r) May be zero
(D) Vertical component of the acceleration of centre of mass	(s) Must be zero

11. From a uniform disc of mass M and radius R, a concentric disc of half the radius is cut out. For the remaining annular disc the moment of inertia about axis 1 is I_1 about 2 is I_2 about 3 is I_3 and about 4 is I_4. The axes 1, 2 are perpendicular to the disc and axes 3, 4 are in the plane of the disc. Axes 2, 3 and 4 intersect at a common point. Match the contents of **COLUMN-I** with those in **COLUMN-II**.



COLUMN-I	COLUMN-II
(A) I_1	(p) $\frac{21}{32}MR^2$
(B) I_2	(q) $\frac{I_1}{2}$
(C) (I_3+I_4)	(r) $\frac{15}{32}MR^2$
(D) (I_2-I_3)	(s) $\frac{31}{22}MR^2$

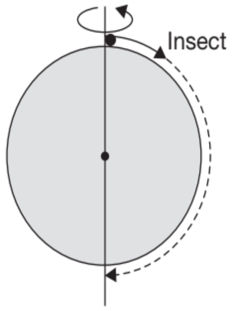
12. A solid sphere is placed on a rough horizontal ground as shown in Figure.



If E is the centre of sphere such that $DE > EF$ and a linear impulse can be applied either at point A, B or C then match the following two columns.

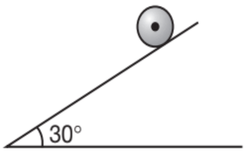
COLUMN-I	COLUMN-II
(A) Sphere will acquire maximum angular speed if impulse is applied at	(p) A
(B) Sphere will acquire maximum linear speed if impulse is applied at	(q) B
(C) Sphere can roll without slipping if impulse is applied at	(r) C
(D) Sphere can roll with forward slipping if impulse is applied at	(s) at any point A, B or C

13. A solid sphere is rotating about an axis as shown in Figure. An insect follows the dotted path on the circumference of sphere as shown. Match the following



COLUMN-I	COLUMN-II
(A) Moment of inertia	(p) will remain constant
(B) Angular velocity	(q) will first increase then decrease
(C) Angular momentum	(r) will first decrease then increase
(D) Rotational kinetic energy	(s) will continuously decrease
	(t) will continuously increase

14. A thin walled cylindrical shell of mass m and radius R is placed on a rough inclined plane so that it rolls without slipping. Match the following table

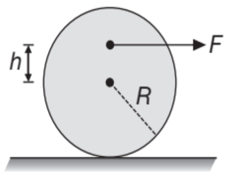
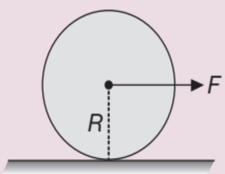
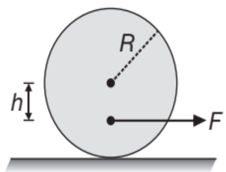
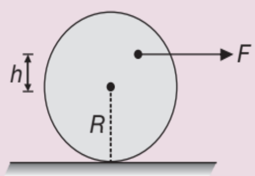


COLUMN-I	COLUMN-II
(A) Linear acceleration of centre of mass	(p) is directly proportional to m
(B) Angular acceleration	(q) is inversely proportional to m
(C) Rotational kinetic energy at any instant	(r) is directly proportional to R^2
(D) Translational kinetic energy at any instant	(s) is inversely proportional to R
	(t) constant

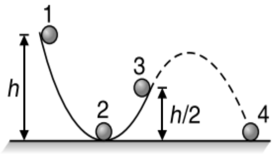
15. A solid sphere, a hollow sphere, a cylinder all of same mass and radius are released from a rough inclined plane on which all of them roll down without slipping. On reaching the bottom of the plane, match the contents of **COLUMN-I** with those of **COLUMN-II**.

COLUMN-I	COLUMN-II
(A) Time taken to reach the bottom	(p) Maximum for solid sphere
(B) Total kinetic energy	(q) Maximum for hollow sphere
(C) Rotational kinetic energy	(r) Maximum for cylinder
(D) Translational kinetic energy	(s) Same for all

16. In each case, there is sufficient friction for regular rigid uniform disc to undergo pure rolling on a rigid horizontal surface. Match the situations in **COLUMN-I** to the quantities in **COLUMN-II**.

COLUMN-I	COLUMN-II
(A) 	(p) The direction of static friction may be forward or may be backward or static friction may be zero
(B) 	(q) The direction of static friction is towards backward
(C) 	(r) The angular acceleration will be clockwise
(D) 	(s) Acceleration of the centre mass will be along direction F

17. A small solid ball rolls down along sufficiently rough surface from point 1 to point 3 as shown in Figure.



From point 3 onwards it moves under the influence of gravity. Match the following two columns.

COLUMN-I	COLUMN-II
(A) Rotational kinetic energy of ball at point 2	(p) $\frac{1}{7}mgh$
(B) Translational kinetic energy of ball at point 3	(q) $\frac{2}{7}mgh$
(C) Rotational kinetic energy of ball at point 4	(r) $\frac{5}{7}mgh$
(D) Translational kinetic energy of ball at point 4	(s) $\frac{5}{14}mgh$

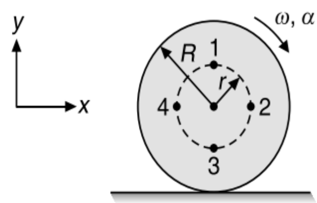
18. A particle moving on the smooth horizontal table strikes the rod AB at an end A perpendicularly and then stops. Match the following.

COLUMN-I	COLUMN-II
(A) Angular momentum of system (particle + rod) about any point is	(p) Conserved for elastic collision
(B) Linear momentum of system (particle + rod) is	(q) Not conserved for elastic collision
(C) Angular momentum of rod about its centre of mass is	(r) Conserved for inelastic collision
(D) Kinetic energy of system (particle + rod), except during collision is	(s) Not conserved for inelastic collision

19. For the following statements, except the gravity and contact force between the contact surfaces, no other force is acting on the body. Match the quantities in **COLUMN-I** to their respective match(es) in **COLUMN-II**.

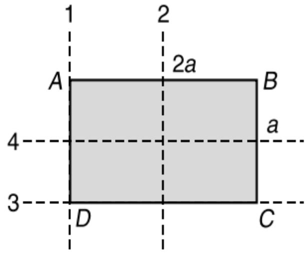
COLUMN-I	COLUMN-II
(A) When a sphere is in pure–rolling on a fixed horizontal surface.	(p) Upward direction
(B) When a cylinder is in pure rolling on a fixed inclined plane in upward direction then friction force acts in	(q) $v_{cm} > R\omega$
(C) When a cylinder is in pure rolling down a fixed incline plane, friction force acts is	(r) $v_{cm} < R\omega$
(D) When a sphere of radius R is rolling with slipping on a fixed horizontal surface, the relation between v_{cm} and ω is	(s) No frictional force acts.

20. A disc of radius R is rolling without slipping with an angular acceleration α on a horizontal plane. Four points are marked at the end of horizontal and vertical diameter of a circle of radius $r(<R)$ on the disc. Let horizontal and vertical directions be chosen as x and y axis as shown in Figure. When angular velocity of the disc is ω, then acceleration of points 1, 2, 3 and 4 are $\vec{a}_1$, $\vec{a}_2$, $\vec{a}_3$ and $\vec{a}_4$ respectively. Match the accelerations given in **COLUMN-I** with their respective vectors given in **COLUMN-II**.



COLUMN-I	COLUMN-II
(A) $\vec{a}_1$	(p) $(R-r)\alpha\hat{i}+(r\omega^2)\hat{j}$
(B) $\vec{a}_2$	(q) $(R+r)\alpha\hat{i}-(r\omega^2)\hat{j}$
(C) $\vec{a}_3$	(r) $(R\alpha-r\omega^2)\hat{i}-(r\alpha)\hat{j}$
(D) $\vec{a}_4$	(s) $(R\alpha+r\omega^2)\hat{i}+(r\alpha)\hat{j}$

21. A rectangular slab $ABCD$ has dimensions $a \times 2a$ as shown in Figure.



Match the radius of gyration about the axis specified in **COLUMN-I** with their respective values in **COLUMN-II**.

COLUMN-I	COLUMN-II
(A) About axis 1	(p) $\frac{a}{\sqrt{12}}$
(B) About axis 2	(q) $\frac{2a}{\sqrt{3}}$
(C) About axis 3	(r) $\frac{a}{\sqrt{2}}$
(D) About axis 4	(s) $\frac{a}{\sqrt{3}}$

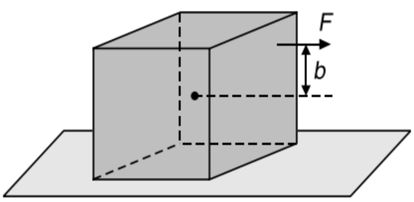
INTEGER/NUMERICAL ANSWER TYPE QUESTIONS

In this section, the answer to each question is a numerical value obtained after doing series of calculations based on the data given in the question(s).

1. A small ball of mass 1 kg is attached to one end of a 1 m long light string and the other end of the string is hung from a point. When the resulting pendulum is 30° from the vertical, calculate the magnitude of torque, in Nm, about the point of suspension. Take $g = 10\text{ ms}^{-2}$.

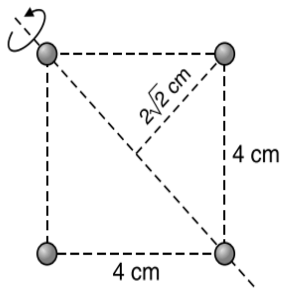
2. A uniform rod is falling without rotation on a smooth horizontal plane. Assuming the collision to be perfectly elastic, the angular velocity of the rod after striking the table is maximum when the rod makes an angle $\cos^{-1}\left(\frac{1}{\sqrt{*}}\right)$ with the horizontal just before striking where $*$ is not readable. Find $*$.

3. Consider a uniform cubical box of side a on a rough floor that is to be moved by applying minimum possible force F at a point b above its center of mass (see figure). If the coefficient of friction is $\mu = 0.4$, the maximum possible value of $100 \times \frac{b}{a}$ for a box not to topple before moving is ......



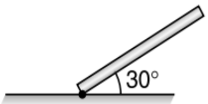
4. A uniform sphere of radius $= \frac{R}{16}$ starts rolling down without slipping from the top of another sphere of radius $R = 1\text{ m}$. Find the angular velocity of the sphere, in rads^{-1}, after it leaves the surface of the larger sphere.

5. Four solid spheres each of diameter $\sqrt{5}$ cm and mass 0.5 kg are placed with their centers at the corners of a square of side 4 cm. The moment of inertia of the system about the diagonal of the square is $N \times 10^{-4}\text{ kgm}^2$, find N.

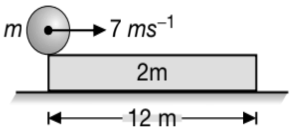


6. A uniform disc of mass 40 kg and radius 0.5 m can turn about a smooth axis through its centre and perpendicular to the disc. A constant torque is applied to the disc for 2 s from rest and the angular velocity at the end of that time is $\frac{240}{\pi}$ revolutions per minute. Find the magnitude of the torque, in Nm. If the torque is then removed and the disc is brought to rest in t second by a constant force of 10 N applied tangentially at a point on the rim of the disc, find t, in seconds.

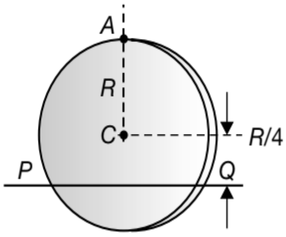
7. One end of a straight uniform 1 m long bar is pivoted on horizontal surface. It is released from rest when it makes an angle 30° from the horizontal (see figure). Its angular speed when it hits the table is given as $\sqrt{n}\text{ s}^{-1}$, where n is an integer. The value of n is ......



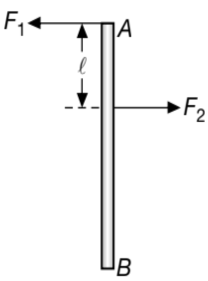
8. A cylinder of mass m is kept on the edge of a plank of mass $2m$ and length 12 metre, which in turn is kept on smooth ground. Coefficient of friction between the plank and the cylinder is 0.1. The cylinder is given an impulse, which imparts it a velocity $7\ \text{ms}^{-1}$ but no angular velocity. Find the time, in second, after which the cylinder falls off the plank. $\left(g = 10\ \text{ms}^{-2}\right)$.



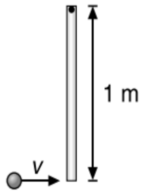
9. A uniform circular disc has radius R and mass m, A particle, also of mass m, is fixed at a point A on the edge of the disc as shown in Figure. The disc can rotate freely about a fixed horizontal chord PQ that is at a distance $\frac{R}{4}$ from the centre C of the disc. The line AC is perpendicular to PQ. Initially the disc is held vertical with the point A at its highest position. It is then allowed to fall so that it starts rotating about PQ. The linear speed of the particle as it reaches its lowest position is $\sqrt{xgR}$. Find x.



10. A thin uniform rod AB of mass $m = 1$ kg moves translationally with acceleration $a = 2\ \text{ms}^{-2}$ due to two anti-parallel forces F_1 and F_2. The distance between the points at which these forces are applied is equal to $l = 20$ cm. Besides, it is known that $F_2 = 5$ N. Find the length of the rod, in metre.

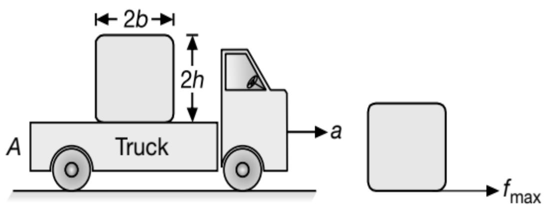


11. A thin rod of mass 0.9 kg and length 1 m is suspended, at rest, from one end so that it can freely oscillate in the vertical plane. A particle of mass 0.1 kg moving in a straight line with velocity $80\ \text{ms}^{-1}$ hits the rod at its bottom most point and sticks to it (see figure). The angular speed (in rads^{-1}) of the rod immediately after the collision will be ......



12. A flywheel whose moment of inertia about its axis of rotation is $16\ \text{kgm}^2$ is rotating freely in its own plane about a smooth axis through its centre. Its angular velocity is $9\ \text{rads}^{-1}$ when a torque is applied to bring it to rest in t_0 second. Find t_0, in seconds, if
(a) the torque is constant and of magnitude of 4 Nm
(b) the magnitude of the torque after t second is given by $8t$

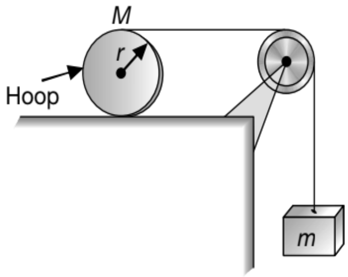
13. A block of mass m height $2h = 2.4$ m and width $2b = 1.2$ m rests on a flat truck which moves horizontally with constant acceleration a as shown in figure. Determine



(a) the value of the acceleration, in ms^{-2}, at which slipping of the block on the truck starts if the coefficient of friction is $\mu = 0.4$.
(b) the value of the acceleration a, in ms^{-2}, at which block topples about A, assuming sufficient friction to prevent slipping.
(c) the shortest distance, in metre, in which the truck can be stopped from a speed of $72\ \text{kmhr}^{-1}$ with constant deceleration so that the block is not disturbed.
Given that $g = 10\ \text{ms}^{-2}$

14. A person of 80 kg mass is standing on the rim of a circular platform of mass 200 kg rotating about its axis as 5 revolutions per minute (rpm). The person now starts moving towards the center of the platform. The rotational speed (in rpm) of the platform when the person reaches its centre is ......

15. For the system shown in figure a hoop of mass $M = 1\text{ kg}$ radius $r = 0.2\text{ m}$ is attached to a block of mass $m = 0.5\text{ kg}$. Calculate.

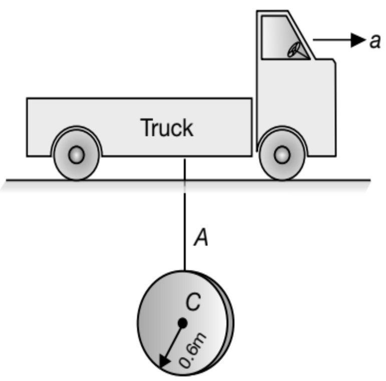


(a) the linear acceleration of hoop, in ms^{-2}.
(b) the angular acceleration of the hoop in rads^{-2}.
(c) the tension in the rope, in newton.

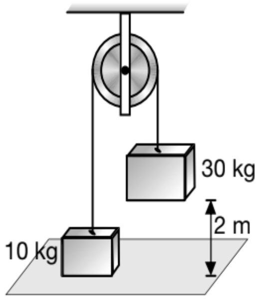
Neglect the mass of small pulley and the friction between the hoop and the horizontal surface. Masses of the pulley and string and friction between the hoop and the horizontal surface are negligible.

16. A ball rolls without sliding over a rough horizontal floor with velocity $v_0 = 7\text{ ms}^{-1}$ towards a smooth vertical wall. If coefficient of restitution between the wall and the ball is $e = 0.7$, calculate velocity v of the ball, in ms^{-1}, along after the collision.

17. A 100 N circular plate of radius 0.6 m is suspended from a pin at A. If the pin is connected to a truck which is given an acceleration $a = 0.9\text{ ms}^{-2}$, determine the horizontal and vertical components of reaction, in newton, at A and the acceleration of the centre of mass (C) of the plate in cms^{-2}. Assume, the plate to be originally at rest. Also find the angular acceleration in rads^{-2} of the plate.



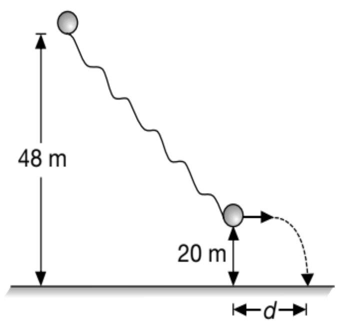
18. The system in figure is released from rest. The 30 kg body is 2 m above the floor and is connected through an ideal string passing over the pulley (a uniform disk with a radius of 10 cm and mass 20 kg) to another body of mass 10 kg. Find



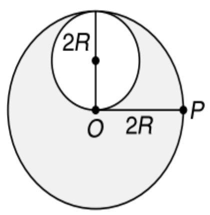
(a) the speed of the 30 kg body, in ms^{-1}, just before it hits the floor and the angular speed of the pulley, in rads^{-1}, at that time
(b) the tension, in newton, in the strings and
(c) the time, in second, it takes for the 30 kg body to reach the floor.

19. A circular disc of mass M and radius R is rotating about its axis with angular speed ω_1. If another stationary disc having radius $\frac{R}{2}$ and same mass M is dropped co-axially on to the rotating disc. Gradually both discs attain constant angular speed ω_2. The energy lost in the process is $p\%$ of the initial energy. Value of p is ……

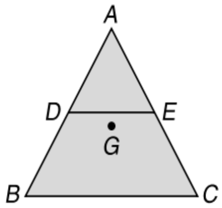
20. A sphere starts from rest at the upper end of the track shown in the accompanying figure. It rolls until it leaves the track at the right end, where the track is horizontal. Calculate the distance d to the right, in metre, of this point at which the sphere strikes the ground. Take $g = 10\text{ ms}^{-2}$.



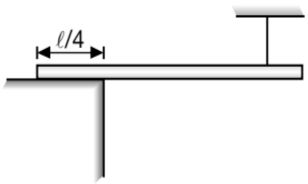
21. A lamina is made by removing a small disc of diameter $2R$ from a bigger disc of uniform mass density and radius $2R$, as shown in the figure. The moment of inertia of this lamina about axes passing through O and P is I_O and I_P, respectively. Both these axes are perpendicular to the plane of the lamina. Find the ratio $\frac{I_P}{I_O}$ to the nearest integer.



22. ABC is a plane lamina of the shape of an equilateral triangle. D, E are mid points of AV and G is the centroid of the lamina. Moment of inertia of the lamina about an axis passing through G and perpendicular to the plane ABC is I_0. If part ADE is removed, the moment of inertia of the remaining part about the same axis is $\frac{NI_0}{16}$ where N is an integer. Value of N is ......

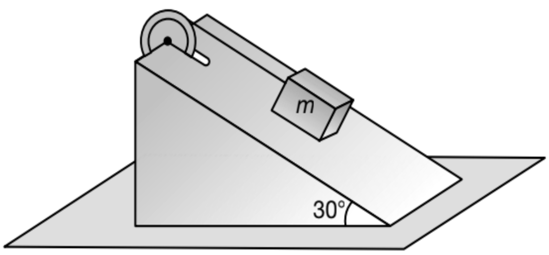


23. One fourth length of a uniform rod of mass m and length l is placed on a rough horizontal surface and it is held stationary in horizontal position by means of a light thread as shown in the figure. The thread is then burnt and the rod starts rotating about the edge. The angle between the rod and the horizontal when it is about to slide on the edge is $\tan\theta = \frac{*\mu}{13}$, where $*$ is not readable and μ is the coefficient of friction between the rod and the surface. Find $*$.

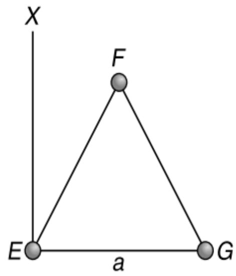


24. A bowling ball is thrown straight down the rough alley. The coefficient of friction between the ball and the alley is 0.75. When the ball starts, its centre of mass has a speed 12 ms^{-1} and it is sliding without rotating. Calculate the distance moved by the ball (in metre) down the alley before it starts rolling without slipping.

25. A block of mass $m = 1$ kg slides down the surface of a smooth incline as shown in figure. The block is tied to a string which is wrapped around a disk capable of rotating about a horizontal axis. The disk has a mass $M = 3$ kg and a radius $R = 0.2$ m. Initially the string is taut. If the mass is released, calculate its acceleration, in ms^{-2}, if $g = 10$ ms^{-2}.



26. A massless equilateral triangle EFG of side a (as shown in Figure) has three particles of mass m situated at its vertices. The moment of inertia of the system about the line EX perpendicular to EG in the plane of EFG is $\frac{N}{20}ma^2$ where N is an integer. The value of N is ......

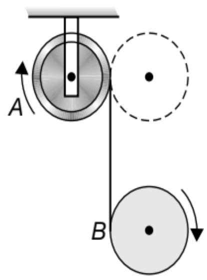


27. A uniform disk of mass $M = 40$ g and radius $R = 0.5$ cm is pivoted so that it can rotate freely about a horizontal axis through its centre and normal to the plane of the disk. A small particle of mass $m = 5$ g is attached to the rim of the disk at the top directly above the pivot. The system is given a gentle start and the disk begins to rotate.

(a) What is the angular velocity of the disk, in $rads^{-1}$, when the particle is at its lowest point?

(b) At this point, what force, in newton, must be exerted on the particle by the disk to keep it on the disk? Take $g = 10$ ms^{-2}

28. Two identical uniform discs A and B each of mass 2 kg and radius 0.5 m are held, as shown in figure with the help of a long massless string which is wrapped around the discs in opposite directions. Disc A is attached to the ceiling in such a way that it can rotate freely about its axis. The disc, B, initially held at same height as A, is then released to fall so that string unwinds from both the discs. Find the angular acceleration, in $rads^{-2}$ linear acceleration of falling disc in ms^{-2} and tension in the string, in newton. Assume that string does not slip and motion is confined in the same vertical plane and take $g = 10$ ms^{-2}.



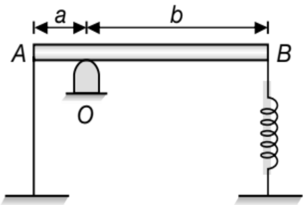
29. A grindstone in the form of a solid cylinder has a radius of 0.2 m and a mass of 30 kg.

(a) What constant torque, in newton metre, will bring it from rest to an angular velocity of 250 $revmin^{-1}$ in 10 s?

(b) Through what angle, in radian, has it turned during that time?

(c) Calculate the work done, in joule, by the torque.

30. A uniform rod AB of mass $m = 2$ kg and length $\ell = 1$ m is placed on a sharp support O such that $a = 0.4$ m and $b = 0.6$ m. A spring of force constant $k = 600\ \text{Nm}^{-1}$ is attached to end B as shown in Figure.



To keep the rod horizontal, its end A is tied with a thread such that the spring is elongated by 1 cm. Calculate reaction of support O, in newton, at the instant thread is burnt.

31. A solid fly wheel of 20 kg mass and 120 mm radius revolves at 600 rpm. Calculate the force (in newton) with which the brake lining should be pressed against the flywheel to stop the flywheel in 3 s, if the coefficient of friction is 0.1.

32. The polar ice caps contain about 3×10^{19} kg of ice. This contributes essentially nothing to the moment of inertia of the earth because it is located at the poles, close to the axis of rotation. Estimate the expected change in the length of the day (in second) if the polar ice caps melt, distributing the water uniformly over the entire surface of the earth if mass and radius of earth are 6×10^{24} kg and 6.4×10^{6} m.

33. A force $\vec{F} = (\hat{i} + 2\hat{j} + 3\hat{k})$ N acts at a point $(4\hat{i} + 3\hat{j} - k)$ m. Then the magnitude of torque about the point $(\hat{i} + 2\hat{j} + \hat{k})$ m will be $\sqrt{x}$ Nm. The value of x is ......

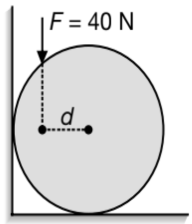
34. A man stands at the centre of a circular platform holding his arms extended horizontally with 4 kg block in each hand. He is set rotating about a vertical axis at 0.5 revs^{-1}. The moment of inertia of the man plus platform is 1.6 kgm^2, assumed constant. The blocks are 90 cm from the axis of rotation. He now pulls the blocks inwards towards his body until they are 15 cm from the axis of rotation. Calculate

(a) his new angular velocity, in rads^{-1}.

(b) the initial and final kinetic energy of the man and platform (in joule).

(c) the work done by the man (in joule) to pull in the blocks.

35. A cylinder of mass $r = 0.1$ m and mass $M = 2$ kg is placed such that it is in contact simultaneously with a vertical and a horizontal surface as shown in Figure. The coefficient of static friction $\mu = \left(\frac{1}{3}\right)$ for both the surfaces. Find the distance d, in cm, from the centre of the cylinder at which a force $F = 40$ N should be applied so that the cylinder just starts rotating in the anticlockwise direction. Take $g = 10\ \text{ms}^{-2}$.



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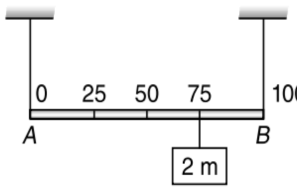
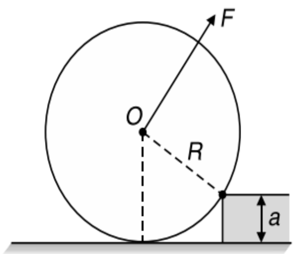
1. **[Online September 2020]**
Shown in Figure is rigid and uniform one meter long rod AB held in horizontal position by two strings tied to its ends and attached to the ceiling. The rod is of mass m and has another weight of mass 2 m hung at a distance of 75 cm from A. The tension in the string at A is



(A) $2mg$ (B) $0.5mg$

(C) $0.75mg$ (D) $1mg$

2. **[Online September 2020]**
A uniform cylinder of mass M and radius R is to be pulled over a step of height $a (a > R)$ by applying a force F at its center O perpendicular to the plane through the axes of the cylinder on the edge of the step (see figure). The minimum value of F required is



(A) $Mg\sqrt{1-\frac{a^2}{R^2}}$ (B) $Mg\sqrt{\left(\frac{R}{R-a}\right)^2-1}$

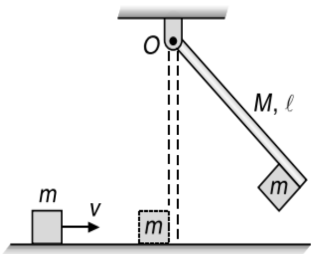
(C) $Mg\frac{a}{R}$ (D) $Mg\sqrt{1\left(\frac{R-a}{R}\right)^2}$

3. [Online September 2020]
Two uniform circular discs are rotating independently in the same direction around their common axis passing through their centers. The moment of inertia and angular velocity of the first disc are 0.1 kgm^2 and 10 rads^{-1} respectively while those for the second one are 0.2 kgm^2 and 5 rads^{-1} respectively. At some instant they get stuck together and start rotating as a single system about their common axis with some angular speed. The kinetic energy of the combined system is

(A) $\frac{10}{3}$ J (B) $\frac{2}{3}$ J

(C) $\frac{5}{3}$ J (D) $\frac{20}{3}$ J

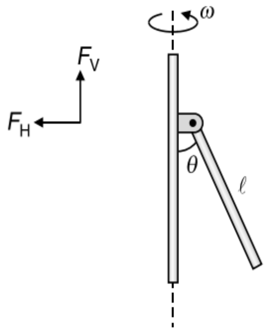
4. [Online September 2020]
A block of mass $m = 1$ kg slides with velocity $v = 6$ ms^{-1} on a frictionless horizontal surface and collides with a uniform vertical rod and sticks to it as shown. The rod is pivoted about O and swings as a result of the collision making angle θ before momentarily coming to rest. If the rod has mass $M = 2$ kg, and length $l = 1$ m, the value of θ is approximately (Take $g = 10$ ms^{-2})



(A) 69° (B) 63°

(C) 55° (D) 49°

5. [Online September 2020]
A uniform rod of mass m, length l is pivoted at one of its ends on a vertical shaft of negligible radius. When the shaft rotates at angular speed ω the rod makes an angle θ it (see figure). To find θ, equate the rate of change of angular momentum (direction going into the paper) $\frac{ml^2}{12}\omega^2\sin\theta\cos\theta$ about the center of mass (CM) to the torque provided by the horizontal and vertical forces F_H and F_V about the CM. The value of θ is then such that



(A) $\cos\theta = \frac{g}{2l\omega^2}$ (B) $\cos\theta = \frac{3g}{2l\omega^2}$

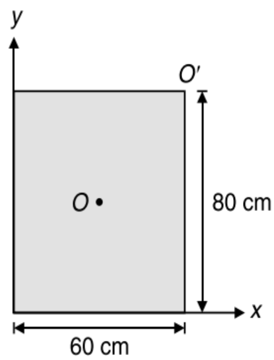
(C) $\cos\theta = \frac{2g}{3l\omega^2}$ (D) $\cos\theta = \frac{g}{l\omega^2}$

6. [Online September 2020]
Consider two uniform discs of the same thickness and different radii $R_1 = R$ and $R_2 = \alpha R$ made of the same material. If the ratio of their moments of inertia I_1 and I_2, respectively, about their axes is $I_1 : I_2 = 1:16$ then the value of α is

(A) $\sqrt{2}$ (B) 2

(C) 4 (D) $2\sqrt{2}$

7. [Online September 2020]
For a uniform rectangular sheet shown in Figure, the ratio of moments of inertia about the axes perpendicular to the sheet and passing through O (the center of mass) and O' (corner point) is



(A) $\frac{1}{2}$ (B) $\frac{2}{3}$

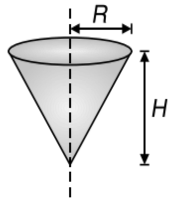
(C) $\frac{1}{8}$ (D) $\frac{1}{4}$

8. [Online September 2020]
A wheel is rotating freely with an angular speed ω on a shaft. The moment of inertia of the wheel is I and the moment of inertia of the shaft is negligible. Another wheel of moment of inertia $3I$ initially at rest is suddenly coupled to the same shaft. The resultant fractional loss in the kinetic energy of the system is

(A) 0 (B) $\frac{1}{4}$

(C) $\frac{3}{4}$ (D) $\frac{5}{6}$

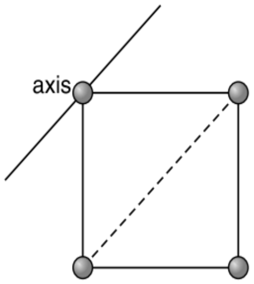
9. **[Online September 2020]**
Shown in Figure is a hollow ice cream cone (it is open at the top). If its mass is M, radius of its top, R and height, H, then its moment of inertia about its axis is



(A) $\frac{MR^2}{2}$ (B) $\frac{MH^2}{3}$

(C) $\frac{MR^2}{3}$ (D) $\frac{M(R^2+H^2)}{4}$

10. **[Online September 2020]**
Four point masses, each of mass m, are fixed at the corners of a square of side l. The square is rotating with angular frequency ω, about an axis passing through one of the corners of the square and parallel to its diagonal, as shown in Figure. The angular momentum of the square about this axis is



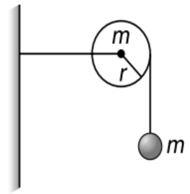
(A) $2ml^2\omega$ (B) $3ml^2\omega$
(C) $ml^2\omega$ (D) $4ml^2\omega$

11. **[Online September 2020]**
The linear mass density of a thin rod AB of length L varies from A to B as $\lambda(x)=\lambda_0\left(1+\frac{x}{L}\right)$, where x is the distance from A. If M is the mass of the rod then its moment of inertia about an axis passing through A and perpendicular to the rod is

(A) $\frac{5}{12}ML^2$ (B) $\frac{3}{7}ML^2$

(C) $\frac{2}{5}ML^2$ (D) $\frac{7}{18}ML^2$

12. **[Online January 2020]**
As shown in Figure, a bob of mass m is tied by a massless string whose other end portion is wound on a fly wheel (disc) of radius r and mass m. When released from rest the bob starts falling vertically. When it has covered a distance of h, the angular speed of the wheel will be



(A) $\frac{1}{r}\sqrt{\frac{2gh}{3}}$ (B) $r\sqrt{\frac{3}{4gh}}$

(C) $\frac{1}{r}\sqrt{\frac{4gh}{3}}$ (D) $r\sqrt{\frac{3}{2gh}}$

13. **[Online January 2020]**
The radius of gyration of a uniform rod of length l, about an axis passing through a point $\frac{l}{4}$ away from the center of the rod, and perpendicular to it, is

(A) $\frac{l}{8}$ (B) $l\sqrt{\frac{7}{48}}$

(C) $l\sqrt{\frac{3}{8}}$ (D) $\frac{l}{4}$

14. **[Online January 2020]**
Mass per unit area of a circular disc of radius a depends on the distance r from its center as $\sigma(r)=A+Br$. The moment of inertia of the disc about the axis, perpendicular to the plane and passing through its center is

(A) $2\pi a^2\left(\frac{A}{4}+\frac{aB}{5}\right)$ (B) $\pi a^4\left(\frac{A}{4}+\frac{aB}{5}\right)$

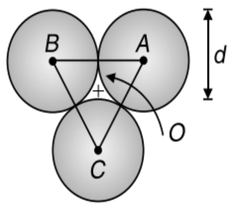
(C) $2\pi a^4\left(\frac{aA}{4}+\frac{B}{5}\right)$ (D) $2\pi a^4\left(\frac{A}{4}+\frac{B}{5}\right)$

15. **[Online January 2020]**
A uniform sphere of mass $500g$ rolls without slipping on a plane horizontal surface with its center moving at a speed of 5.00 cms^{-1}. Its kinetic energy is

(A) 8.75×10^{-4} J (B) 8.75×10^{-3} J
(C) 6.25×10^{-4} J (D) 1.13×10^{-3} J

16. **[Online January 2020]**
Three solid spheres each of mass m and diameter d are stuck together such that the lines connecting the centers from an equilateral triangle of side of length d. The ratio $\frac{I_0}{I_A}$ of moment of inertia I_0 of the system

about an axis passing the centroid and about center of any of the spheres I_A and perpendicular to the plane of the triangle is

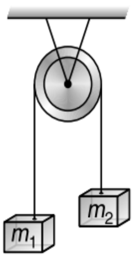


(A) $\frac{13}{23}$ (B) $\frac{15}{13}$

(C) $\frac{23}{13}$ (D) $\frac{13}{15}$

17. [Online January 2020]

A uniformly thick wheel with moment of inertia I and radius R is free to rotate about its center of mass (see figure). A massless string is wrapped over its rim and two blocks of masses m_1 and $m_2\ (m_1 > m_2)$ are attached to the ends of the string. The system is released from rest. The angular speed of the wheel m_1 descends by a distance h is



(A) $\left[\frac{m_1+m_2}{(m_1+m_2)R^2+I}\right]^{\frac{1}{2}} gh$

(B) $\left[\frac{2(m_1-m_2)gh}{(m_1+m_2)R^2+I}\right]^{\frac{1}{2}}$

(C) $\left[\frac{2(m_1+m_2)gh}{(m_1+m_2)R^2+I}\right]^{\frac{1}{2}}$

(D) $\left[\frac{(m_1-m_2)}{(m_1+m_2)R^2+I}\right]^{\frac{1}{2}} gh$

18. [Online April 2019]

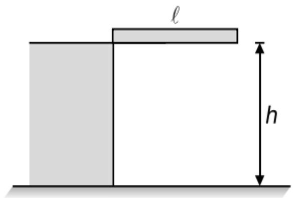
A thin circular plate of mass M and radius R has its density varying as $\rho(r) = \rho_0 r$ with ρ_0 as constant and r is the distance from its centre. The moment of inertia of the circular plate about an axis perpendicular to the plate and passing through its edge is $I = a(MR^2)$. The value of the coefficient a is

(A) $\frac{3}{2}$ (B) $\frac{1}{2}$

(C) $\frac{3}{5}$ (D) $\frac{8}{5}$

19. [Online April 2019]

A rectangular solid box of length $0.3\ \text{m}$ is held horizontally, with one of its sides on the edge of a platform of height $5\ \text{m}$. When released, it slips off the table in a very short time $\tau = 0.01\ \text{s}$, remaining essentially horizontal. The angle by which it would rotate when it hits the ground will be (in radians) close to

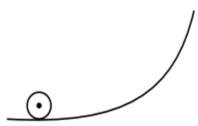


(A) 0.3 (B) 0.02

(C) 0.28 (D) 0.5

20. [Online April 2019]

A solid sphere and solid cylinder of identical radii approach an incline with the same linear velocity (see figure). Both roll without slipping all throughout. The two climb maximum heights h_{sph} and h_{cyl} on the incline. The ratio $\frac{h_{sph}}{h_{cyl}}$ is given by



(A) $\frac{4}{5}$ (B) $\frac{2}{\sqrt{5}}$

(C) 1 (D) $\frac{14}{15}$

21. [Online April 2019]

A stationary horizontal disc is free to rotate about its axis. When a torque is applied on it, its kinetic energy as a function of θ, where θ is the angle by which it has rotated, is given as $k\theta^2$. If its moment of inertia is I, then the angular acceleration of the disc is

(A) $\frac{2k}{I}\theta$ (B) $\frac{k}{I}\theta$

(C) $\frac{k}{2I}\theta$ (D) $\frac{k}{4I}\theta$

22. [Online April 2019]
The following bodies are made to roll up (without slipping) the same inclined plane from a horizontal plane
(1) a ring of radius R,
(2) a solid cylinder of radius $\frac{R}{2}$ and
(3) a solid sphere of radius $\frac{R}{4}$.
If, in each case, the speed of the centre of mass at the bottom of the incline is same, the ratio of the maximum heights they climb is
(A) $14:15:20$ (B) $10:15:7$
(C) $4:3:2$ (D) $2:3:4$

23. [Online April 2019]
A thin smooth rod of length L and mass M is rotating freely with angular speed ω_0 about an axis perpendicular to the rod and passing through its center. Two beads of mass m and negligible size are at the center of the rod initially. The beads are free to slide along the rod. The angular speed of the system, when the beads reach the opposite ends of the rod, will be
(A) $\frac{M\omega_0}{M+3m}$ (B) $\frac{M\omega_0}{M+m}$
(C) $\frac{M\omega_0}{M+6m}$ (D) $\frac{M\omega_0}{M+2m}$

24. [Online April 2019]
Moment of inertia of a body about a given axis is $1.5\ \text{kgm}^2$. Initially the body is at rest. In order to produce a rotational kinetic energy of $1200\ \text{J}$, the angular acceleration of $20\ \text{rads}^{-2}$ must be applied about the axis for a duration of
(A) 2.5 s (B) 2 s
(C) 5 s (D) 3 s

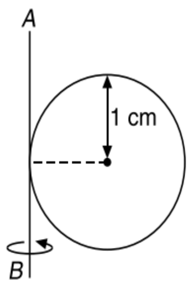
25. [Online April 2019]
Two coaxial discs, having moments of inertia I_1 and $\frac{I_1}{2}$ are rotating with respective angular velocities ω_1 and $\frac{\omega_1}{2}$ about their common axis. They are brought in contact with each other and thereafter they rotate with a common angular velocity. If E_f and E_i are the final and initial total energies, then $(E_f - E_i)$ is
(A) $-\frac{I_1\omega_1^2}{12}$ (B) $\frac{3}{8}I_1\omega_1^2$
(C) $\frac{I_1\omega_1^2}{6}$ (D) $-\frac{I_1\omega_1^2}{24}$

26. [Online April 2019]
A particle of mass m is moving along a trajectory given by $x = x_0 + a\cos\omega_1 t$ and $y = y_0 + b\sin\omega_2 t$.
The torque, acting on the particle about the origin, at $t = 0$ is
(A) $-m\left(x_0 b\omega_2^2 - y_0 a\omega_1^2\right)\hat{k}$ (B) $m(-x_0 b + y_0 a)\omega_1^2\hat{k}$
(C) $+my_0 a\omega_1^2\hat{k}$ (D) ZERO

27. [Online April 2019]
A thin disc of mass M and radius R has mass per unit area $\sigma(r) = kr^2$ where r is the distance from its centre. Its moment of inertia about an axis going through its centre of mass and perpendicular to its plane is
(A) $\frac{MR^2}{3}$ (B) $\frac{MR^2}{6}$
(C) $\frac{MR^2}{2}$ (D) $\frac{2MR^2}{3}$

28. [Online April 2019]
The time dependence of the position of a particle of mass $m = 2$ is given by $\vec{r}(t) = 2t\hat{i} - 3t^2\hat{j}$. Its angular momentum, with respect to the origin, at time $t = 2$ is
(A) $-34(\hat{k} - \hat{i})$ (B) $48(\hat{i} - \hat{j})$
(C) $36\hat{k}$ (D) $-48\hat{k}$

29. [Online April 2019]
A metal coin of mass 5 g and radius 1 cm is fixed to a thin stick AB of negligible mass as shown in Figure. The system is initially at rest. The constant torque, that will make the system rotate about AB at 25 rotations per second in 5 s, is closed to



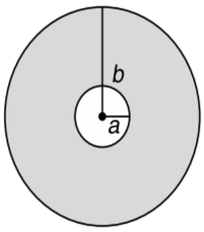
(A) 4.0×10^{-6} Nm (B) 7.9×10^{-6} Nm
(C) 2.0×10^{-5} Nm (D) 1.6×10^{-5} Nm

30. [Online April 2019]
A solid sphere of mass M and radius R is divided into two unequal parts. The first part has a mass of $\frac{7M}{8}$ and is converted into a uniform disc of radius $2R$. The second part is converted into a uniform solid sphere.

Let I_1 be the moment of inertia of the disc about its axis and I_2 be the moment of inertia of the new sphere about its axis. The ratio $\frac{I_1}{I_2}$ is given by

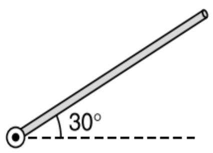
(A) 140 (B) 185
(C) 285 (D) 65

31. [Online April 2019]
A circular disc of radius b has a hole of radius a at its centre (see figure). If the mass per unit area of the disc varies as $\left(\frac{\sigma_0}{r}\right)$, then the radius of gyration of the disc about its axis passing through the centre is



(A) $\frac{a+b}{2}$ (B) $\sqrt{\frac{a^2+b^2+ab}{2}}$
(C) $\frac{a+b}{3}$ (D) $\sqrt{\frac{a^2+b^2+ab}{3}}$

32. [Online January 2019]
A rod of length 50 cm is pivoted at one end. It is raised such that it makes an angle of 30° from the horizontal as shown and released from rest. Its angular speed when it passes through the horizontal (in rads^{-1}) will be $\left(g = 10\ \text{ms}^{-2}\right)$



(A) $\frac{\sqrt{20}}{3}$ (B) $\sqrt{30}$
(C) $\sqrt{\frac{30}{2}}$ (D) $\frac{\sqrt{30}}{2}$

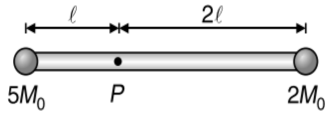
33. [Online January 2019]
To mop-clean a floor, a cleaning machine presses a circular mop of radius R vertically down with a total force F and rotates it with a constant angular speed about its axis. If the force F is distributed uniformly over the mop and if coefficient of friction between the mop and the floor is μ, the torque, applied by the machine on the mop is

(A) $\frac{\mu FR}{2}$ (B) $\frac{\mu FR}{3}$
(C) $\frac{\mu FR}{6}$ (D) $\frac{2}{3}\mu FR$

34. [Online January 2019]
A homogeneous solid cylindrical roller of radius R and mass M is pulled on a cricket pitch by a horizontal force. Assuming rolling without slipping, angular acceleration of the cylinder is

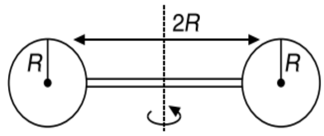
(A) $\frac{F}{2MR}$ (B) $\frac{2F}{3MR}$
(C) $\frac{F}{3MR}$ (D) $\frac{3F}{2MR}$

35. [Online January 2019]
A rigid massless rod of length $3l$ has two masses attached at each end as shown in Figure. The rod is pivoted at point P on the horizontal axis (see figure). When released from initial horizontal position, its instantaneous angular acceleration will be



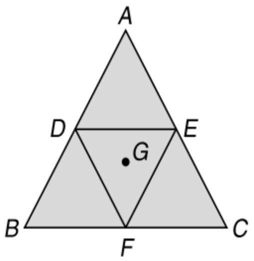
(A) $\frac{g}{2l}$ (B) $\frac{g}{3l}$
(C) $\frac{g}{13l}$ (D) $\frac{7g}{3l}$

36. [Online January 2019]
Two identical spherical balls of mass M and radius R each are stuck on two ends of a rod of length $2R$ and mass M (see figure). The moment of inertia of the system about the axis passing perpendicularly through the centre of the rod is



(A) $\frac{152}{15}MR^2$
(B) $\frac{17}{15}MR^2$
(C) $\frac{209}{15}MR^2$
(D) $\frac{137}{15}MR^2$

37. [Online January 2019]
An equilateral triangle ABC is cut from a thin solid sheet of wood (see figure). D, E and F are the mid-points of its sides as shown and G is the centre of the triangle. The moment of inertia of the triangle about an axis passing through G and perpendicular to the plane of the triangle is I_0. If the smaller triangle DEF is removed from ABC, the moment of inertia of the remaining figure about the same axis is I. Then

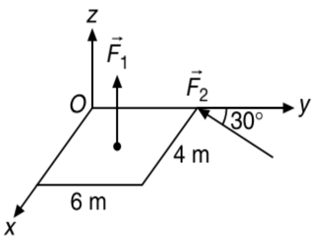


(A) $I = \frac{3}{4}I_0$ (B) $I = \frac{15}{16}I_0$

(C) $I = \frac{I_0}{4}$ (D) $I = \frac{9}{16}I_0$

38. [Online January 2019]

A slab is subjected to two forces $\vec{F}_1$ and $\vec{F}_2$ of same magnitude F as shown in Figure. Force $\vec{F}_2$ is in xy plane while force F_1 acts along z-axis at the point $(2\vec{i} + 3\vec{j})$. The moment of these forces about point O will be

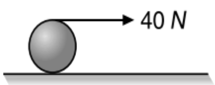


(A) $(3\hat{i} - 2\hat{j} + 3\hat{k})F$ (B) $(3\hat{i} + 2\hat{j} - 3\hat{k})F$

(C) $(3\hat{i} + 2\hat{j} + 3\hat{k})F$ (D) $(3\hat{i} - 2\hat{j} - 3\hat{k})F$

39. [Online January 2019]

A string is wound around a hollow cylinder of mass 5 kgand radius 0.5 m. If the string is now pulled with a horizontal force of 40 N and the cylinder is rolling without slipping on a horizontal surface (see figure), then the angular acceleration of the cylinder will be (Neglect the mass and thickness of the string)



(A) 16 rads^{-2} (B) 20 rads^{-1}

(C) 12 rads^{-2} (D) 10 rads^{-2}

40. [Online January 2019]

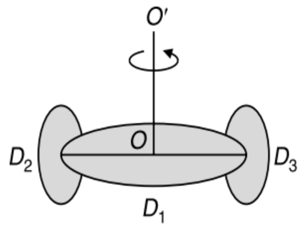
The magnitude of torque on a particle of mass 1 kg is 2.5 Nm about the origin. If the force acting on it is 1 N and the distance of the particle from the origin is 5 m, the angle between the force and the position vector is (in radians)

(A) $\frac{\pi}{8}$ (B) $\frac{\pi}{6}$

(C) $\frac{\pi}{3}$ (D) $\frac{\pi}{4}$

41. [Online January 2019]

A circular disc D_1 of mass M and radius R has two identical discs D_2 and D_3 of the same mass M and radius R attached rigidly at its opposite ends (see figure). The moment of inertia of the system about the axis OO', passing through the centre of D_1 as shown in Figure, will be



(A) $3MR^2$ (B) $\frac{4}{5}MR^2$

(C) MR^2 (D) $\frac{2}{3}MR^2$

42. [Online January 2019]

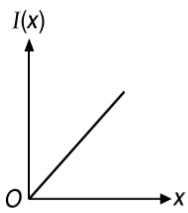
Let the moment of inertia of a hollow cylinder of length 30 cm (inner radius 10 cm and outer radius 20 cm), about its axis be I. The radius of a thin cylinder of the same mass such that its moment of inertia about its axis is also I, is

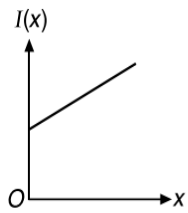
(A) 14 cm (B) 12 cm

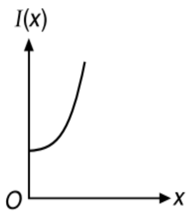
(C) 16 cm (D) 18 cm

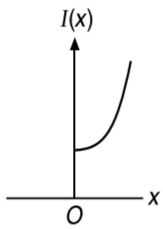
43. [Online January 2019]

The moment of inertia of a solid sphere, about an axis parallel to its diameter and at a distance of x from it, is $I(x)$. Which one of the graphs represents the variation of $I(x)$ with x correctly?

(A)


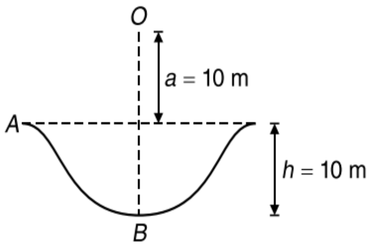
(B)


(C)


(D)


44. [Online January 2019]

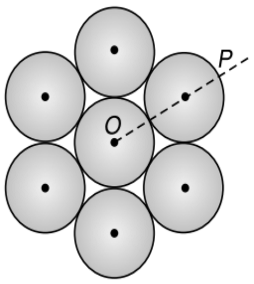
A particle of mass 20 g is released with an initial velocity 5 ms^{-1} along the curve from the point A, as shown in Figure. The point A is a height h from point B. The particle slides along the frictionless surface. When the particle reaches point B, its angular momentum about O will be (Take $g = 10$ ms^{-2})



(A) 2 kgm^2s^{-1} (B) 3 kgm^2s^{-1}

(C) 8 kgm^2s^{-1} (D) 6 kgm^2s^{-1}

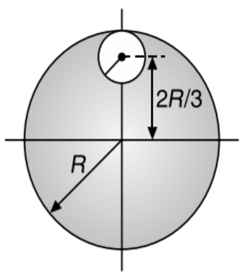
45. [2018]
Seven identical circular planar disks, each of mass M and radius R are welded symmetrically as shown. The moment of inertia of the arrangement about the axis normal to the plane and passing through the point P is



(A) $\frac{19}{2}MR^2$ (B) $\frac{55}{2}MR^2$

(C) $\frac{73}{2}MR^2$ (D) $\frac{181}{2}MR^2$

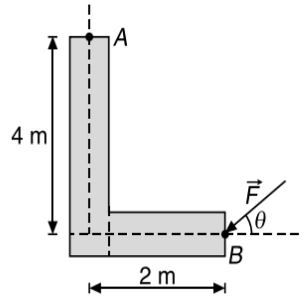
46. [2018]
From a uniform circular disc of radius R and mass $9M$, a small disc of radius $\frac{R}{3}$ is removed as shown in Figure. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through centre of disc is



(A) $4MR^2$ (B) $\frac{40}{9}MR^2$

(C) $10MR^2$ (D) $\frac{37}{9}MR^2$

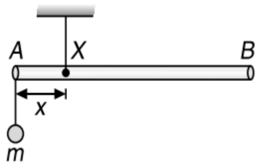
47. [Online 2018]
A force of 40 N acts on a point B at the end of an L-shaped object, as shown in Figure. The angle θ that will produce maximum moment of the force about point A is given by



(A) $\tan\theta = \frac{1}{2}$ (B) $\tan\theta = 4$

(C) $\tan\theta = 2$ (D) $\tan\theta = \frac{1}{4}$

48. [Online 2018]
A uniform rod AB is suspended from a point X, at a variable distance x from A, as shown. To make the rod horizontal, a mass m is suspended from its end A. A set of (m, x) values is recorded. The appropriate variables that give a straight line, when plotted are



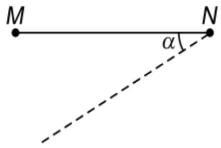
(A) $m, \frac{1}{x^2}$ (B) m, x^2

(C) m, x (D) $m, \frac{1}{x}$

49. [Online 2018]
A disc rotates about its axis of symmetry in a horizontal plane at a steady rate of 3.5 revolutions per second. A coin placed at a distance of 1.25 cm from the axis of rotation remains at rest on the disc. The coefficient of friction between the coin and the disc is $\left(g = 10\ ms^{-2}\right)$

(A) 0.7 (B) 0.5
(C) 0.3 (D) 0.6

50. [Online 2018]
A thin rod MN, free to rotate in the vertical plane about the fixed end N, is held horizontal. When the end M is released the speed of this end, when the rod makes an angle α with the horizontal, will be proportional to (see figure)

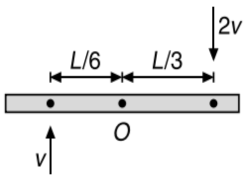


(A) $\cos\alpha$ (B) $\sin\alpha$

(C) $\sqrt{\cos\alpha}$ (D) $\sqrt{\sin\alpha}$

51. [Online 2018]

A thin uniform bar of length L and mass $8m$ lies on a smooth horizontal table. Two point masses m and $2m$ are moving in the same horizontal plane from opposite sides of the bar with speeds $2v$ and v respectively. The masses stick to the bar after collision at a distance $\frac{L}{3}$ and $\frac{L}{6}$ respectively from the centre of the bar. If the bar starts rotating about its center of mass as a result of collision, the angular speed of the bar will be

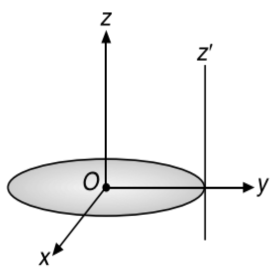


(A) $\frac{6v}{5L}$ (B) $\frac{v}{6L}$

(C) $\frac{v}{5L}$ (D) $\frac{3v}{5L}$

52. [Online 2018]

A thin circular disk is in the xy plane as shown in Figure. The ratio of its moment of inertia about z and z' axes will be



(A) 1:4 (B) 1:3

(C) 1:2 (D) 1:5

53. [2017]

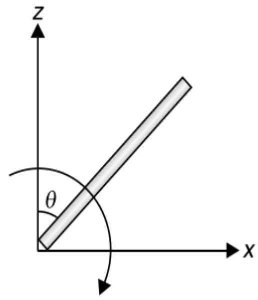
The moment of inertia of a uniform cylinder of length l and radius R about its perpendicular bisector is I. What is the ratio $\frac{l}{R}$ such that the moment of inertia is minimum?

(A) $\sqrt{\frac{3}{2}}$ (B) $\frac{\sqrt{3}}{2}$

(C) 1 (D) $\frac{3}{\sqrt{2}}$

54. [2017]

A slender uniform rod of mass M and length l is pivoted at one end so that it can rotate in a vertical plane (shown in Figure). There is negligible friction at the pivot. The free end is held vertically above the pivot and then released. The angular acceleration of the rod when it makes an angle θ with the vertical is

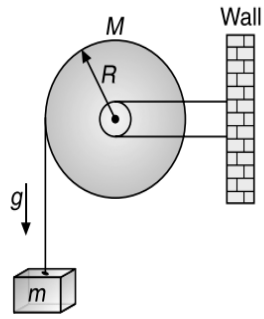


(A) $\frac{3g}{2l}\sin\theta$ (B) $\frac{2g}{3l}\sin\theta$

(C) $\frac{3g}{2l}\cos\theta$ (D) $\frac{2g}{3l}\cos\theta$

55. [Online 2017]

A uniform disc of radius R and mass M is free to rotate only about its axis. A string is wrapped over its rim and a body of mass m is tied to the free end of the string as shown in Figure. The body is released from rest. Then the acceleration of the body is



(A) $\frac{2mg}{2m+M}$ (B) $\frac{2Mg}{2m+M}$

(C) $\frac{2Mg}{2M+m}$ (D) $\frac{2mg}{2M+m}$

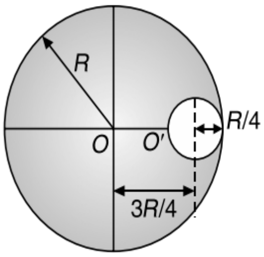
56. [Online 2017]

In a physical balance working on the principle of moments, when 5 mg weight is placed on the left pan, the beam becomes horizontal. Both the empty pans of the balance are of equal mass. Which of the following statements is correct?

(A) Left arm is shorter than the right arm
(B) Left arm is longer than the right arm
(C) Every object that is weighed using this balance appears lighter than its actual weight
(D) Both the arms are of same length

57. [Online 2017]

A circular hole of radius $\frac{R}{4}$ is made in a thin uniform disc having mass M and radius R, as shown in Figure. The moment of inertia of the remaining portion of the disc about an axis passing through the point O and perpendicular to the plane of the disc is

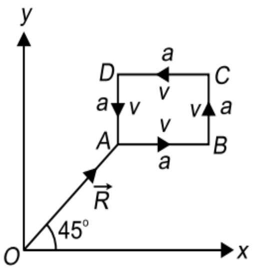


(A) $\frac{219MR^2}{256}$ (B) $\frac{197MR^2}{256}$

(C) $\frac{19MR^2}{512}$ (D) $\frac{237MR^2}{512}$

58. [2016]

A particle of mass m is moving along the side of a square of side a, with a uniform speed v in the x-y plane as shown in Figure.



Which of the following statements is false for the angular momentum $\vec{L}$ about the origin?

(A) $\vec{L} = \frac{mvR}{\sqrt{2}}\hat{k}$ when the particle is moving from D to A

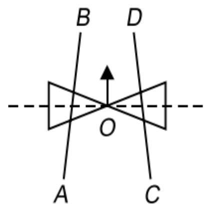
(B) $\vec{L} = -\frac{mvR}{\sqrt{2}}\hat{k}$ when the particle is moving from A to B

(C) $\vec{L} = mv\left(\frac{R}{\sqrt{2}} - a\right)\hat{k}$ when the particle is moving from C to D

(D) $\vec{L} = mv\left(\frac{R}{\sqrt{2}} + a\right)\hat{k}$ when the particle is moving from B to C

59. [2016]

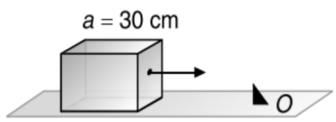
A roller is made by joining together two cones at their vertices O. It is kept on two rails AB and CD which are placed asymmetrically (see figure), with its axis perpendicular to CD and its centre O at the centre of line joining AB and CD (see figure). It is given a light push so that it starts rolling with its centre O moving parallel to CD in the direction shown. As it moves, the roller will tend to



(A) turn left and right alternately
(B) turn left
(C) turn right
(D) go straight

60. [Online 2016]

A cubical block of side 30 cm is moving with velocity 2 ms^{-1} on a smooth horizontal surface. The surface has a bump at a point O as shown in Figure. The angular velocity (in $rads^{-1}$) of the block immediately after it hits the bump, is



(A) 13.3 (B) 5.0
(C) 9.4 (D) 6.7

61. [Online 2016]

Concrete mixture is made by mixing cement, stone and sand in a rotating cylindrical drum. If the drum rotates too fast, the ingredients remain stuck to the wall of the drum and proper mixing of ingredients does not take place. The maximum rotational speed of the drum in revolutions per minute (rpm) to ensure proper mixing is close to (Take the radius of the drum to be 1.25 m and its axle to be horizontal)

(A) 27.0 (B) 0.4
(C) 1.3 (D) 8.0

62. [2015]

From a solid sphere of mass M and radius R a cube of maximum possible volume is cut. Moment of inertia of cube about an axis passing through its center and perpendicular to one of its faces is

(A) $\frac{MR^2}{32\sqrt{2}\pi}$ (B) $\frac{MR^2}{16\sqrt{2}\pi}$

(C) $\frac{4MR^2}{9\sqrt{3}\pi}$ (D) $\frac{4MR^2}{3\sqrt{3}\pi}$

63. [Online 2015]

A uniform solid cylindrical roller of mass m is being pulled on a horizontal surface with force F parallel to the surface and applied at its centre. If the acceleration of the cylinder is a and it is rolling without slipping then the value of F is

(A) ma (B) $2ma$

(C) $\frac{3}{2}ma$ (D) $\frac{5}{3}ma$

64. [Online 2015]

Consider a thin uniform square sheet made of a rigid material. If its side is a, mass m and moment of inertia I about one of its diagonals, then

(A) $I > \frac{ma^2}{12}$ (B) $\frac{ma^2}{24} < I < \frac{ma^2}{12}$

(C) $I = \frac{ma^2}{12}$ (D) $I = \frac{ma^2}{24}$

65. [Online 2015]

A particle of mass 2 kg is on a smooth horizontal table and moves in a circular path of radius 0.6 m. The height of the table from the ground is 0.8 m. If the angular speed of the particle is 12 rads^{-1}, the magnitude of its angular momentum about a point on the ground right under the centre of the circle is

(A) 8.64 kgm^2s^{-1}

(B) 11.52 kgm^2s^{-1}

(C) 14.4 kgm^2s^{-1}

(D) 20.16 kgm^2s^{-1}

66. [2014]

A bob of mass m attached to an inextensible string of length l is suspended from a vertical support. The bob rotates in a horizontal circle with an angular speed ω rads^{-1} about the vertical. About the point of suspension

(A) angular momentum is conserved.

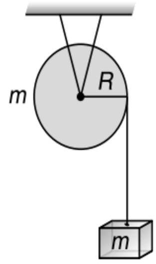
(B) angular momentum changes in magnitude but not in direction.

(C) angular momentum changes in direction but not in magnitude

(D) angular momentum changes both in direction and magnitude

67. [2014]

A mass m is supported by a massless string wound around a uniform hollow cylinder of mass m and radius R. If the string does not slip on the cylinder, with what acceleration will the mass fall on release?



(A) $\frac{2g}{3}$ (B) $\frac{g}{2}$

(C) $\frac{5g}{6}$ (D) g

68. [2013]

A hoop of radius r and mass m rotating with an angular velocity ω_0 is placed on a rough horizontal surface. The initial velocity of the centre of the hoop is zero. What will be the velocity of the centre of the hoop when it ceases to slip?

(A) $\frac{r\omega_0}{4}$ (B) $\frac{r\omega_0}{3}$

(C) $\frac{r\omega_0}{2}$ (D) $r\omega_0$

69. [2011]

A pulley of radius 2 m is rotated about its axis by a force $F = (20t - 5t^2)$ newton (where t is measured in seconds) applied tangentially. If the moment of inertia of the pulley about its axis of rotation is 10 kgm^2, the number of rotations made by the pulley before its direction of motion if reversed, is

(A) less than 3

(B) more than 3 but less than 6

(C) more than 6 but less than 9

(D) more than 9

70. [2011]

A mass m hangs with the help of a string wrapped around a pulley on a frictionless bearing. The pulley has mass m and radius R. Assuming pulley to be a perfect uniform circular disc, the acceleration of the mass m, if the string does not slip on the pulley, is

(A) $\frac{3}{2}g$ (B) g

(C) $\frac{2}{3}g$ (D) $\frac{g}{3}$

71. [2011]

A thin horizontal circular disc is rotating about a vertical axis passing through its centre. An insect is at rest at a point near the rim of the disc. The insect now moves along a diameter of the disc to reach its other end. During the journey of the insect, the angular speed of the disc

(A) remains unchanged
(B) continuously decreases
(C) continuously increases
(D) first increases and then decreases

72. **[2009]**
A thin uniform rod of length l and mass m is swinging freely about a horizontal axis passing through its end. Its maximum angular speed is ω. Its centre of mass rises to a maximum height of

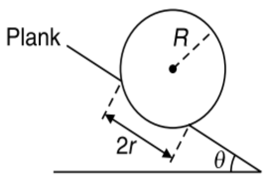
(A) $\frac{1}{3}\frac{l^2\omega^2}{g}$ (B) $\frac{1}{6}\frac{l\omega}{g}$
(C) $\frac{1}{2}\frac{l^2\omega^2}{g}$ (D) $\frac{1}{6}\frac{l^2\omega^2}{g}$

ARCHIVE: JEE ADVANCED

Single Correct Choice Type Problems

In this section each question has four choices (A), (B), (C) and (D), out of which ONLY ONE is correct.

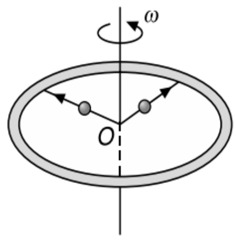
1. **[JEE (Advanced) 2020]**
A football of radius R is kept on a hole of radius $r(r < R)$ made on a plank kept horizontally. One end of the plank is now lifted so that it gets tilted making an angle θ from the horizontal as shown in Figure.



The maximum value of θ so that the football does not start rolling down the plank satisfies (figure is schematic and not drawn to scale)

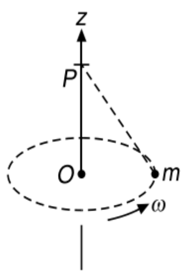
(A) $\sin\theta = \frac{r}{R}$ (B) $\tan\theta = \frac{r}{R}$
(C) $\sin\theta = \frac{r}{2R}$ (D) $\cos\theta = \frac{r}{2R}$

2. **[JEE (Advanced) 2015]**
A ring of mass M and radius R is rotating with angular speed ω about a fixed vertical axis passing through its centre O with two point masses each of mass $\frac{M}{8}$ at rest at O. These masses can move radially outwards along two massless rods fixed on the ring as shown in Figure. At some instant, the angular speed of the system is $\frac{8}{9}\omega$ and one of the masses is at a distance of $\frac{3}{5}R$ from O. At this instant, the distance of the other mass from O is



(A) $\frac{2}{3}R$ (B) $\frac{1}{3}R$
(C) $\frac{3}{5}R$ (D) $\frac{4}{5}R$

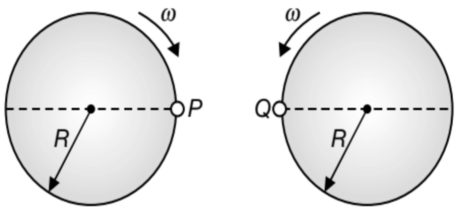
3. **[IIT-JEE 2012]**
A small mass m is attached to a massless string whose other end is fixed at P as shown in Figure. The mass is undergoing circular motion in the x-y plane with centre at O and constant angular speed ω. If the angular momentum of the system, calculated about O and P are denoted by $\vec{L}_O$ and $\vec{L}_P$ respectively, then

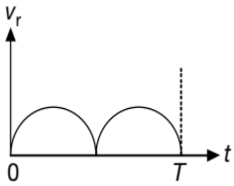


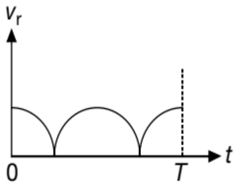
(A) $\vec{L}_O$ and $\vec{L}_P$ do not vary with time
(B) $\vec{L}_O$ varies with time while $\vec{L}_P$ remains constant
(C) $\vec{L}_O$ remains constant while $\vec{L}_P$ varies with time
(D) $\vec{L}_O$ and $\vec{L}_P$ both vary with time

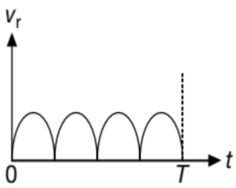
4. **[IIT-JEE 2012]**
Two solid cylinders P and Q of same mass and same radius start rolling down a fixed inclined plane from the same height at the same time. Cylinder P has most of its mass concentrated near its surface, while Q has most of its mass concentrated near the axis. Which statement(s) is(are) correct?
(A) Both cylinders P and Q reach the ground at the same time
(B) Cylinder P has larger linear acceleration than cylinder Q
(C) Both cylinders reach the ground with same translational kinetic energy
(D) Cylinder Q reaches the ground with larger angular speed

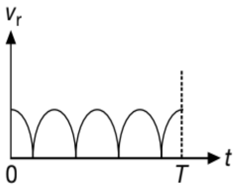
5. **[IIT-JEE 2012]**
Two identical discs of same radius R are rotating about their axes in opposite directions with the same constant angular speed ω. The disc are in the same horizontal plane. At time $t = 0$, the points P and Q are facing each other as shown in Figure. The magnitude of the relative speed between the two points P and Q is v_r which, as a function of time is best represented by



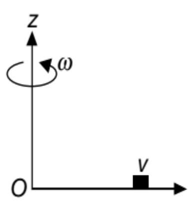
(A)


(B)


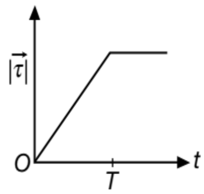
(C)


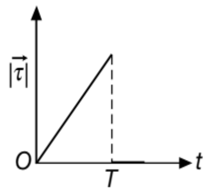
(D)


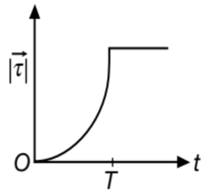
6. **[IIT-JEE 2012]**
A thin uniform rod, pivoted at O, is rotating in the horizontal plane with constant angular speed ω, as shown in Figure.

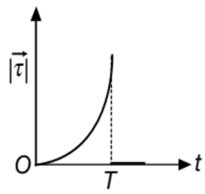


At time $t = 0$, a small insect starts from O and moves with constant speed v with respect to the rod towards the other end. It reaches the end of the rod at $t = T$ and stops. The angular speed of the system remains ω throughout. The magnitude of the torque $(|\vec{\tau}|)$ on the system about O, as a function of time is best represented by which plot?

(A)


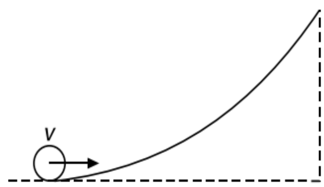
(B)


(C)


(D)


7. **[IIT-JEE 2009]**
A block of base $10 \text{ cm} \times 10 \text{ cm}$ and height 15 cm is kept on an inclined plane. The coefficient of friction between them is $\sqrt{3}$. The inclination θ of this inclined plane from the horizontal plane is gradually increased from $0°$. Then,
(A) at $\theta = 30°$, the block will start sliding down the plane
(B) the block will remain at rest on the plane up to certain θ and then it will topple
(C) at $\theta = 60°$, the block will start sliding down the plane and continue to do so at higher angles
(D) at $\theta = 60°$, the block will start sliding down the plane and on further increasing θ, it will topple at certain θ

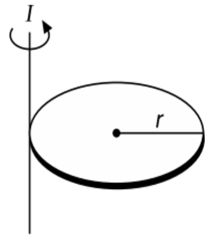
8. **[IIT-JEE 2007]**
A small object of uniform density rolls up a curved surface with an initial velocity v. It reaches up to a maximum height of $\frac{3v^2}{4g}$ with respect to the initial position. The object is



(A) ring (B) solid sphere
(C) hollow sphere (D) disc

9. **[IIT-JEE 2006]**
A solid sphere of radius R has moment of inertia I about its geometrical axis. It is melted into a disc of radius r and thickness t. If it's moment of inertia about

the tangential axis (which is perpendicular to plane of the disc), is also equal to I, then the value of r is equal to

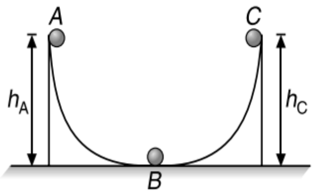


(A) $\frac{2}{\sqrt{15}}R$ (B) $\frac{2}{\sqrt{5}}R$

(C) $\frac{3}{\sqrt{15}}R$ (D) $\frac{\sqrt{3}}{\sqrt{15}}R$

10. [IIT-JEE 2006]

A ball moves over a fixed track as shown in Figure. From A to B the ball rolls without slipping. If surface BC is frictionless and K_A, K_B and K_C are kinetic energies of the ball at A, B and C respectively, then

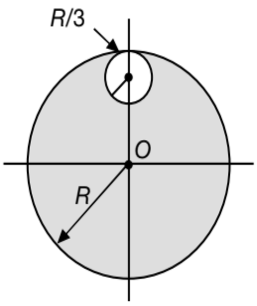


(A) $h_A > h_C; K_B > K_C$ (B) $h_A > h_C; K_C > K_A$

(C) $h_A = h_C; K_B = K_C$ (D) $h_A < h_C; K_B > K_C$

11. [IIT-JEE 2005]

A small disc of radius $\frac{R}{3}$ is removed from a circular disc of radius R and mass $9M$. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through O is



(A) $4MR^2$ (B) $\frac{40}{9}MR^2$

(C) $10MR^2$ (D) $\frac{37}{9}MR^2$

12. [IIT-JEE 2005]

A particle moves in a circular path with decreasing speed. Choose the correct statement

(A) Angular momentum remains constant

(B) Acceleration $(\vec{a})$ is towards the centre

(C) Particle moves in a spiral path with decreasing radius

(D) The direction of angular momentum remains constant

13. [IIT-JEE 2004]

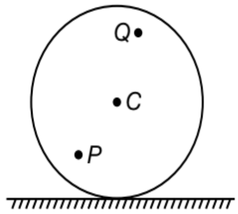
A child is standing with folded hands at the centre of a platform rotating about its central axis. The kinetic energy of the system is K. The child now stretches his arms so that the moment of inertia of the system doubles. The kinetic energy of the system now is

(A) $2K$ (B) $\frac{K}{2}$

(C) $\frac{K}{4}$ (D) $4K$

14. [IIT-JEE 2004]

A disc is rolling (without slipping) on a horizontal surface. C is its centre and Q and P are two points equidistant from C. Let v_P, v_Q and v_C be the magnitude of velocities of points P, Q and C respectively, then



(A) $v_Q > v_C > v_P$

(B) $v_Q < v_C < v_P$

(C) $v_Q = v_P$, $v_C = \frac{1}{2}v_P$

(D) $v_Q < v_C > v_P$

15. [IIT-JEE 2003]

A particle undergoes uniform circular motion. About which point on the plane of the circle, will the angular momentum of the particle remain conserved?

(A) Centre of circle

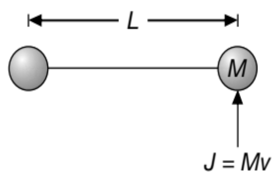
(B) On the circumference of the circle

(C) Inside the circle

(D) Outside the circle

16. [IIT-JEE 2003]

Consider a body, shown in Figure, consisting of two identical balls, each of mass M connected by a light rigid rod. If an impulse $J = Mv$ is imparted to the body at one of its end, then its angular velocity is

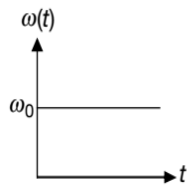


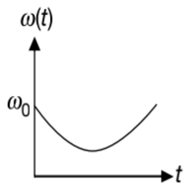
(A) $\frac{v}{L}$ (B) $\frac{2v}{L}$

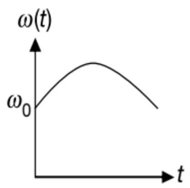
(C) $\frac{v}{3L}$ (D) $\frac{v}{4L}$

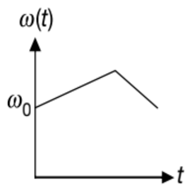
17. [IIT-JEE 2002]

A circular platform is free to rotate in a horizontal plane about a vertical axis passing through its centre. A tortoise is sitting at the edge of the platform. Now the platform is given an angular velocity ω_0. When the tortoise moves along a chord of the platform with a constant velocity (with respect to the platform). The angular velocity of the platform $\omega(t)$ will vary with time t as

(A)


(B)


(C)


(D)


18. [IIT-JEE 2002]

A cylinder rolls up an inclined plane, reaches some height and then rolls down (without slipping throughout these motions). The directions of the frictional force acting on the cylinder are

(A) up the incline while ascending and down the incline while descending

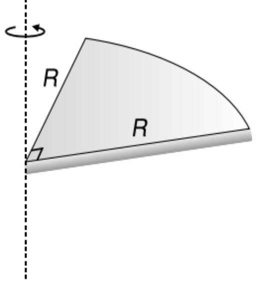
(B) up the incline while ascending as well as descending

(C) down the incline while ascending and up the incline while descending

(D) down the incline while ascending as well as descending

19. [IIT-JEE 2001]

One quarter sector is cut from a uniform disc of radius R. This sector has mass M. It is made to rotate about a line perpendicular to its plane and passing through the center of the original disc. Its moment of inertia about the axis of rotation is

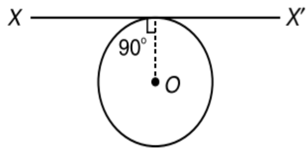


(A) $\frac{MR^2}{2}$ (B) $\frac{MR^2}{4}$

(C) $\frac{MR^2}{8}$ (D) $\sqrt{2}MR^2$

20. [IIT-JEE 2000]

A thin wire of length L and uniform linear mass density ρ is bent into a circular loop with centre at O as shown. The moment of inertia of the loop about the axis XX' is

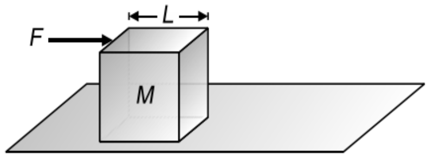


(A) $\frac{\rho L^3}{8\pi^2}$ (B) $\frac{\rho L^3}{16\pi^2}$

(C) $\frac{5\rho L^3}{16\pi^2}$ (D) $\frac{3\rho L^3}{8\pi^2}$

21. [IIT-JEE 2000]

A cubical block of side L rests on a rough horizontal surface with coefficient of friction μ. A horizontal force F is applied on the block as shown. If the coefficient of friction is sufficiently high so that the block does not slide before toppling, the minimum force required to topple the block is

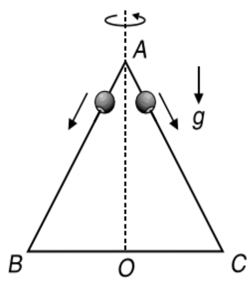


(A) infinitesimal (B) $\frac{mg}{4}$

(C) $\frac{mg}{2}$ (D) $mg(1-\mu)$

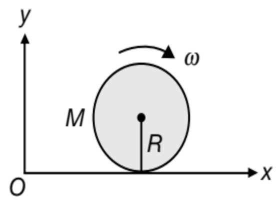
22. [IIT-JEE 2000]

An equilateral triangle ABC formed from a uniform wire has two small identical beads initially located at A. The triangle is set rotating about the vertical axis AO. Then the beads are released from rest simultaneously and allowed to slide down, one along AB and the other along AC as shown. Neglecting frictional effects, the quantities that are conserved as beads slide down are



(A) angular velocity and total energy (kinetic and potential).
(B) total angular momentum and total energy.
(C) angular velocity and moment of inertia about the axis of rotation.
(D) total angular momentum and moment of inertia about the axis of rotation.

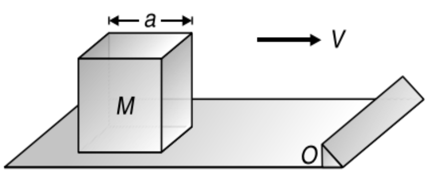
23. [IIT-JEE 1999]
A disc of mass M and radius R is rolling with angular speed ω on a horizontal plane as shown in Figure. The magnitude of angular momentum of the disc about the origin O is



(A) $\left(\frac{1}{2}\right)MR^2\omega$ (B) $MR^2\omega$
(C) $\left(\frac{3}{2}\right)MR^2\omega$ (D) $2MR^2\omega$

24. [IIT-JEE 1999]
A smooth sphere A is moving on a frictionless horizontal plane with angular speed ω and centre of mass velocity v. It collides elastically and head on with an identical sphere B at rest. Neglect friction everywhere. After the collision, their angular speeds are ω_A and ω_B. Then
(A) $\omega_A < \omega_B$ (B) $\omega_A = \omega_B$
(C) $\omega_A = \omega$ (D) $\omega = \omega_B$

25. [IIT-JEE 1999]
A cubical block of side a is moving with velocity v on a horizontal smooth plane as shown in Figure. It hits a ridge at point O. If the moment of inertia of the block about an axis passing through centre of gravity is $\frac{1}{6}ma^2$, then the angular speed of the block after it hits O is



(A) $\frac{3v}{4a}$ (B) $\frac{3v}{2a}$
(C) $\sqrt{\frac{3}{2}}\frac{v}{a}$ (D) ZERO

26. [IIT-JEE 1998]
Let I be the moment of inertia of a uniform square plate about an axis AB that passes through its centre and is parallel to two of its sides. CD is a line in the plane of the plate that passes through the centre of the plate and makes an angle θ with AB. The moment of inertia of the plate about the axis CD is then equal to
(A) I (B) $I\sin^2\theta$
(C) $I\cos^2\theta$ (D) $I\cos^2\left(\frac{\theta}{2}\right)$

27. [IIT-JEE 1997]
A mass M is moving with a constant velocity parallel to the x-axis. Its angular momentum with respect to the origin
(A) is zero
(B) remains constant
(C) increases
(D) decreases

28. [IIT-JEE 1995]
Two point masses of 0.3 kg and 0.7 kg are fixed at the ends of a rod of length 1.4 m and of negligible mass. The rod is set rotating about an axis perpendicular to its length with a uniform angular speed. The point on the rod through which the axis should pass in order that the work required for rotation of the rod is minimum, is located at a distance of
(A) 0.42 m from mass of 0.3 kg
(B) 0.70 m from mass of 0.7 kg
(C) 0.98 m from mass of 0.3 kg
(D) 0.98 m from mass of 0.7 kg

29. [IIT-JEE 1992]
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) $\frac{M\omega^2L}{2}$ (B) $M\omega^2L$
(C) $\frac{M\omega^2L}{4}$ (D) $\frac{M\omega^2L^2}{2}$

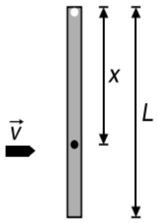
30. [IIT-JEE 1983]
A thin circular ring of mass M is rotating about its axis with a constant angular velocity ω. The two objects, each of mass m, are attached gently to the opposite ends of a diameter of the ring. The ring now rotates with an angular velocity
(A) $\frac{\omega M}{M+m}$ (B) $\frac{\omega(M-2m)}{M+2m}$
(C) $\frac{\omega M}{M+2m}$ (D) $\frac{\omega(M+2m)}{M}$

Multiple Correct Choice Type Problems

In this section each question has four choices (A), (B), (C) and (D), out of which ONE OR MORE is/are correct.

1. [JEE (Advanced) 2020]

A rod of mass m and length L, pivoted at one of its ends, is hanging vertically. A bullet of the same mass moving at speed v strikes the rod horizontally at a distance x from its pivoted end and gets embedded in it. The combined system now rotates with angular speed ω about the pivot. The maximum angular speed ω_M is achieved for $x = x_M$. Then



(A) $\omega = \dfrac{3vx}{L^2 + 3x^2}$ (B) $\omega = \dfrac{12vx}{L^2 + 12x^2}$

(C) $x_M = \dfrac{L}{\sqrt{3}}$ (D) $\omega_M = \dfrac{v}{2L}\sqrt{3}$

2. [JEE (Advanced) 2019]

A thin and uniform rod of mass M and length L is held vertical on a floor with large friction. The rod is released from rest so that it falls by rotating about its contact-point with the floor without slipping. Which of the following statement(s) is/are correct, when the rod makes an angle $60°$ with vertical? (g is the acceleration due to gravity)

(A) The angular acceleration of the rod will be $\dfrac{2g}{L}$

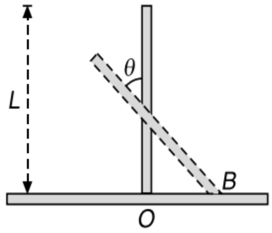
(B) The radial acceleration of the rod's centre of mass will be $\dfrac{3g}{4}$

(C) The angular speed of the rod will be $\sqrt{\dfrac{3g}{2L}}$

(D) The normal reaction force from the floor on the rod will be $\dfrac{Mg}{16}$

3. [JEE (Advanced) 2017]

A rigid uniform bar AB of length L is slipping from its vertical position on a frictionless floor (as shown in Figure). At some instant of time, the angle made by the bar with the vertical is θ. Which of the following statements about its motion is/are correct?



(A) Instantaneous torque about the point in contact with the floor is proportional to $\sin\theta$

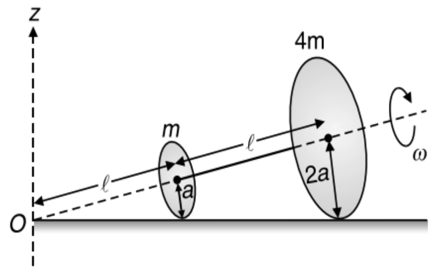
(B) The trajectory of the point A is parabola

(C) The mid-point of the bar will fall vertically downward

(D) When the bar makes an angle θ with the vertical, the displacement of its mid-point from the initial position is proportional to $(1 - \cos\theta)$

4. [JEE (Advanced) 2016]

Two thin circular discs of mass m and $4m$, having radii of a and $2a$, respectively, are rigidly fixed by a massless, rigid rod of length $l = \sqrt{24}a$ through their centers. This assembly is laid on a firm and flat surface and set rolling without slipping on the surface so that the angular speed about the axis of the rod is ω. The angular momentum of the entire assembly about the point O is $\vec{L}$ (see the figure). Which of the following statement(s) is(are) true?



(A) The center of mass of the assembly rotates about the z-axis with an angular speed of $\dfrac{\omega}{5}$

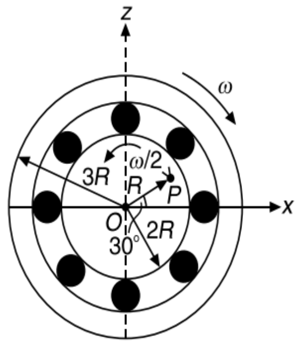
(B) The magnitude of angular momentum of center of mass of the assembly about the point O is $81ma^2\omega$.

(C) The magnitude of angular momentum of the assembly about its center of mass is $17\ ma^2\dfrac{\omega}{2}$

(D) The magnitude of the z-component of $\vec{L}$ is $55ma^2\omega$.

5. [JEE (Advanced) 2012]

The figure shows a system consisting of (i) a ring of outer radius $3R$ rolling clockwise without slipping on a horizontal surface with angular speed ω and (ii) an inner disc of radius $2R$ rotating anti-clockwise with angular speed $\frac{\omega}{2}$. The ring and disc are separated by frictionless ball bearings. The system is in the x-z plane. The point P on the inner disc is at a distance R from the origin, where OP makes an angle of 30° with the horizontal. Then with respect to the horizontal surface,



(A) the point O has a linear velocity $3R\omega\hat{i}$

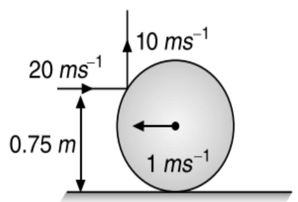
(B) the point P has a linear velocity $\frac{11}{4}R\omega\hat{i}+\frac{\sqrt{3}}{4}R\omega\hat{k}$

(C) the point P has a linear velocity $\frac{13}{4}R\omega\hat{i}-\frac{\sqrt{3}}{4}R\omega\hat{k}$

(D) the point P has a linear velocity $\left(3-\frac{\sqrt{3}}{4}\right)R\omega\hat{i}+\frac{1}{4}R\omega\hat{k}$

6. [IIT-JEE 2011]

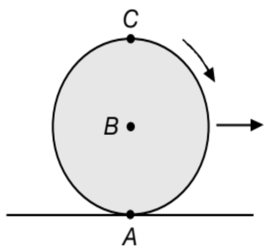
A thin ring of mass 2 kg and radius 0.5 m is rolling without slipping on a horizontal plane with velocity $1\ \text{ms}^{-1}$. A small ball of mass 0.1 kg, moving with velocity $20\ \text{ms}^{-1}$ in the opposite direction, hits the ring at a height of 0.75 m and goes vertically up with velocity $10\ \text{ms}^{-1}$. Immediately after the collision,



(A) the ring has pure rotation about its stationary CM
(B) the ring comes to a complete stop
(C) friction between the ring and the ground is to the left
(D) there is no friction between the ring and the ground

7. [IIT-JEE 2009]

A sphere is rolling without slipping on a fixed horizontal plane surface. In the figure, A is the point of contact, B is the centre of the sphere and C is its top-most point. Then,

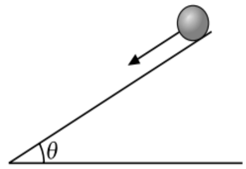


(A) $\vec{V}_C-\vec{V}_A=2(\vec{V}_B-\vec{V}_C)$ (B) $\vec{V}_C-\vec{V}_B=\vec{V}_B-\vec{V}_A$

(C) $|\vec{V}_C-\vec{V}_A|=2|\vec{V}_B-\vec{V}_C|$ (D) $|\vec{V}_C-\vec{V}_A|=4|\vec{V}_B|$

8. [IIT-JEE 2006]

A solid sphere is in pure rolling motion on an inclined surface having inclination θ



(A) frictional force acting on sphere is $f=\mu mg\cos\theta$
(B) f is dissipative force
(C) friction will increase its angular velocity and decrease its linear velocity
(D) If θ decreases, friction will decrease

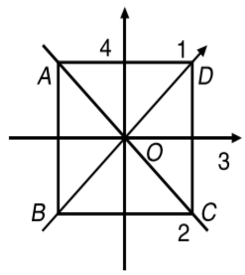
9. [IIT-JEE 1998]

The torque $\vec{\tau}$ on a body about a given point is found to be $\vec{A}\times\vec{L}$ where $\vec{A}$ is a constant vector and $\vec{L}$ is angular momentum of the body about that point. From this it follows that

(A) $\frac{d\vec{L}}{dt}$ is perpendicular to $\vec{L}$ at all instants of time.
(B) the component of $\vec{L}$ in the direction of $\vec{A}$ does not change with time.
(C) the magnitude of $\vec{L}$ does not change with time.
(D) $\vec{L}$ does not change with time.

10. [IIT-JEE 1992]

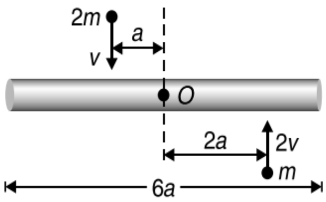
The moment of inertia of a thin square plate $ABCD$ of uniform thickness about an axis passing through the centre O and perpendicular to the plate is



(A) I_1+I_2 (B) I_3+I_4

(C) I_1+I_3 (D) $I_1+I_2+I_3+I_4$

11. [IIT-JEE 1991]
A uniform bar of length $6a$ and mass $8m$ lies on a smooth horizontal table. Two point masses m and $2m$ moving in the same horizontal plane with speeds $2v$ and v, respectively, strike the bar as shown in Figure and stick to it after collision. Denoting angular velocity (about the centre of mass), total energy and the centre of mass velocity by ω, E and V_c respectively, we have after collision



(A) $V_c = 0$ (B) $\omega = \frac{3v}{5a}$

(C) $\omega = \frac{v}{5a}$ (D) $E = \frac{3mv^2}{5}$

12. [IIT-JEE 1990]
A particle of mass m is projected with velocity v making an angle of 45° with the horizontal. The magnitude of angular momentum of the projectile about point of projection when the particle is at maximum height h is

(A) ZERO (B) $\frac{mv^3}{4\sqrt{2}g}$

(C) $\frac{mv^3}{\sqrt{2}g}$ (D) $m\sqrt{2gh^3}$

Reasoning Based Questions

This section contains Reasoning type questions, each having four choices (A), (B), (C) and (D) out of which ONLY ONE is correct. Each question contains STATEMENT 1 and STATEMENT 2. You have to mark your answer as

Bubble (A) If both statements are TRUE and STATEMENT 2 is the correct explanation of STATEMENT 1.
Bubble (B) If both statements are TRUE but STATEMENT 2 is not the correct explanation of STATEMENT 1.
Bubble (C) If STATEMENT 1 is TRUE and STATEMENT 2 is FALSE.
Bubble (D) If STATEMENT 1 is FALSE but STATEMENT 2 is TRUE.

1. [IIT-JEE 2008]
Statement-1: Two cylinders, one hollow (metal) and the other solid (wood) with the same mass and identical dimensions are simultaneously allowed to roll without slipping down an inclined plane from the same height. The hollow cylinder will reach the bottom of the inclined plane first.
Statement-2: By the principle of conservation of energy, the total kinetic energies of both the cylinders are identical when they reach the bottom of the incline.

Linked Comprehension Type Questions

This section contains Linked Comprehension Type Questions or Paragraph based Questions. Each set consists of a Paragraph followed by questions. Each question has four choices (A), (B), (C) and (D), out of which only one is correct. (For the sake of competitiveness there may be a few questions that may have more than one correct options)

Comprehension I

One twirls a circular ring (of mass M and radius R) near the tip of one's finger as shown in Figure 1. In the process the finger never loses contact with the inner rim of the ring. The finger traces out the surface of a cone, shown by the dotted line. The radius of the path traced out by the point where the ring and the finger is in contact is r. The finger rotates with an angular velocity ω_0. The rotating rings rolls without slipping on the outside of a smaller circle described by the point where the ring and the finger is in contact (Figure 2). The coefficient of friction between the ring and the finger is μ and the acceleration due to gravity is g.

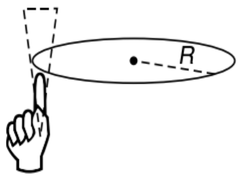


Figure 1

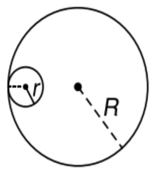


Figure 2

1. [JEE (Advanced) 2017]
The total kinetic energy of the ring is

(A) $M\omega_0^2(R-r)^2$ (B) $\frac{1}{2}M\omega_0^2(R-r)^2$

(C) $M\omega_0^2R^2$ (D) $\frac{3}{2}M\omega_0^2(R-r^2)$

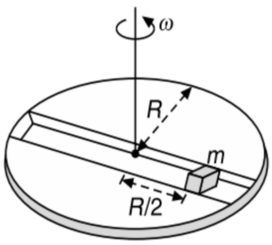
2. [JEE (Advanced) 2017]
The minimum value of ω_0 below which the ring will drop down is

(A) $\sqrt{\frac{g}{2\mu(R-r)}}$ (B) $\sqrt{\frac{3g}{2\mu(R-r)}}$

(C) $\sqrt{\frac{g}{\mu(R-r)}}$ (D) $\sqrt{\frac{2g}{\mu(R-r)}}$

Comprehension 2

A frame of the reference that is accelerated with respect to an inertial frame of reference is called a non-inertial frame of reference. A coordinate system fixed on a circular disc rotating about a fixed axis with a constant angular velocity ω is an example of a non-inertial frame of reference. The relationship between the force $\vec{F}_{\text{rot}}$ experienced by a particle of mass m moving on the rotating disc and the force $\vec{F}_{\text{in}}$ experienced by the particle in an inertial frame of reference is, $\vec{F}_{\text{rot}} = \vec{F}_{\text{in}} + 2m(\vec{v}_{\text{rot}} \times \vec{\omega}) + m(\vec{\omega} \times \vec{r}) \times \vec{\omega}$, where, $\vec{v}_{\text{rot}}$ is the velocity of the particle in the rotating frame of reference and $\vec{r}$ is the position vector of the particle with respect to the centre of the disc



Now, consider a smooth slot along a diameter of a disc of radius R rotating counter-clockwise with a constant angular speed ω about its vertical axis through its centre. We assign a coordinate system with the origin at the centre of the disc, the X-axis along the slot, the Y-axis perpendicular to the slot and the z-axis along the rotation axis $(\omega = \omega\hat{k})$. A small block of mass m is gently placed in the slot at $\vec{r} = \left(\frac{R}{2}\right)\hat{i}$ at $t = 0$ and is constrained to move only along the slot.

3. [JEE (Advanced) 2016]

The distance r of the block at time t is

(A) $\frac{R}{2}\cos 2\omega t$ (B) $\frac{R}{2}\cos \omega t$

(C) $\frac{R}{4}(e^{\omega t} + e^{-\omega t})$ (D) $\frac{R}{4}(e^{2\omega t} + e^{-2\omega t})$

4. [JEE (Advanced) 2016]

The net reaction of the disc on the block is

(A) $m\omega^2 R \sin \omega t \hat{j} - mg\hat{k}$

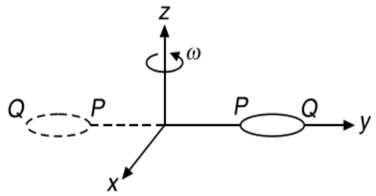
(B) $\frac{1}{2}m\omega^2 R(e^{\omega t} - e^{-\omega t})\hat{j} + mg\hat{k}$

(C) $\frac{1}{2}m\omega^2 R(e^{2\omega t} - e^{-2\omega t})\hat{j} + mg\hat{k}$

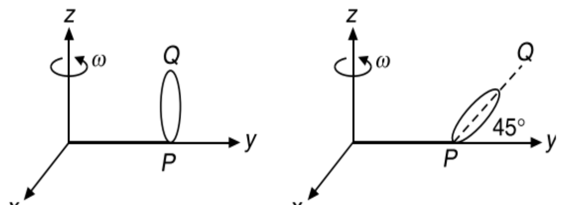
(D) $-m\omega^2 R \cos \omega t \hat{j} - mg\hat{k}$

Comprehension 3

The general motion of a rigid body can be considered to be a combination of (i) a motion of its centre of mass about an axis and (ii) its motion about an instantaneous axis passing through the centre of mass. These axes need not be stationary. Consider, for example, a thin uniform disc welded (rigidly fixed) horizontally at its rim to a massless stick, as shown in Figure.



When the disc-stick system is rotated about the origin on a horizontal frictionless plane with angular speed ω, the motion at any instant can be taken as a combination of (i) a rotation of the centre of mass of the disc about the z-axis and (ii) a rotation of the disc through an instantaneous vertical axis passing through its centre of mass (as is seen from the changed orientation of points P and Q). Both these motions have the same angular speed ω in this case. Now, consider two similar systems as shown in Figure : Case (a) the disc with its face vertical and parallel to x-z plane; Case (b) the disc with its face making an angle of 45° with x-y plane and its horizontal diameter parallel to x-axis. In both the cases, the disc is welded at point P and the systems are rotated with constant angular speed ω about the z-axis.



Case (a) Case (b)

5. [IIT-JEE 2012]

Which of the following statements regarding the angular speed about the instantaneous axis (passing through the centre of mass) is correct?

(A) It is $\sqrt{2}\omega$ for both the cases

(B) It is ω for case (a) and $\frac{\omega}{\sqrt{2}}$ for case (b)

(C) It is ω for case (a) and $\sqrt{2}\omega$ for case (b)

(D) It is ω for both the cases

6. **[IIT-JEE 2012]**
Which of the following statements about the instantaneous axis (passing through the centre of mass) is correct?
(A) It is vertical for both the cases (a) and (b)
(B) It is vertical for case (a) and is at 45° to the x-z plane and lies in the plane of the disc for case (b)
(C) It is horizontal for case (a) and is at 45° to the x-z plane and is normal to the plane of the disc for case (b)
(D) It is vertical for case (a) and is at 45° to the x-z plane and is normal to the plane of the disc for case (b)

Comprehension 4

Two discs A and B are mounted coaxially on a vertical axle. The discs have moments of inertia I and $2I$ respectively about the common axis. Disc A is imparted an initial angular velocity 2ω using the entire potential energy of a spring compressed by a distance x_1. Disc B is imparted an angular velocity ω by a spring having the same spring constant and compressed by a distance x_2. Both the discs rotate in the clockwise direction.

7. **[IIT-JEE 2007]**
The ratio $\frac{x_1}{x_2}$ is
(A) 2 (B) $\frac{1}{2}$
(C) $\sqrt{2}$ (D) $\frac{1}{\sqrt{2}}$

8. **[IIT-JEE 2007]**
When disc B is brought in contact with disc A, they acquire a common angular velocity in time t. The average frictional torque on one disc by the other during this period is
(A) $\frac{2I\omega}{3t}$ (B) $\frac{9I\omega}{2t}$
(C) $\frac{9I\omega}{4t}$ (D) $\frac{3I\omega}{2t}$

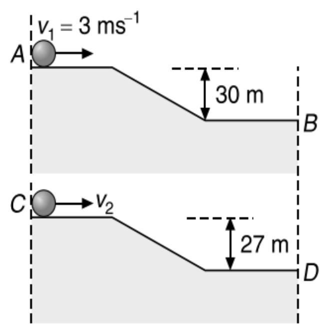
9. **[IIT-JEE 2007]**
The loss of kinetic energy during the above process is
(A) $\frac{I\omega^2}{2}$ (B) $\frac{I\omega^2}{3}$
(C) $\frac{I\omega^2}{4}$ (D) $\frac{I\omega^2}{6}$

Integer/Numerical Answer Type Questions

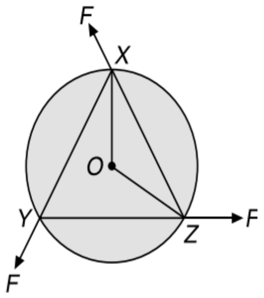
In this section, the answer to each question is a numerical value obtained after series of calculations based on the data provided in the question(s).

1. **[JEE (Advanced) 2020]**
Put a uniform meter scale horizontally on your extended index fingers with the left one at 0.00 cm and the right one at 90.00 cm. When you attempt to move both the fingers slowly towards the centre, initially only the left finger slips with respect to the scale and the right finger dos not. After some distance, the left finger stops and the right one starts slipping. Then the right finger stops at a distance x_R from the centre (50.00 cm) of the scale and the left one starts slipping again. This happens because of the difference in the frictional forces on the two fingers. If the coefficients of static and dynamic friction between the fingers and the scale are 0.40 and 0.32, respectively, the value of x_R (in cm) is ……

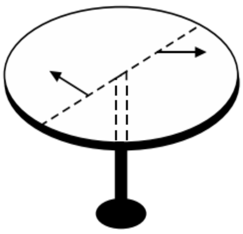
2. **[JEE (Advanced) 2015]**
Two identical uniform discs roll without slipping on two different surfaces AB and CD (see figure) starting at A and C with linear speeds v_1 and v_2, respectively and always remain in contact with the surfaces. If they reach B and D with the same linear speed and $v_1 = 3\ \text{ms}^{-1}$, then v_2 in ms^{-1} is $\left(g = 10\ \text{ms}^{-2}\right)$



3. **[IIT-JEE 2014]**
A uniform circular disc of mass 1.5 kg and radius 0.5 m is initially at rest on a horizontal frictionless surface. Three forces of equal magnitude $F = 0.5$ N are applied simultaneously along the three sides of an equilateral triangle XYZ with its vertices on the perimeter of the disc (see figure). One second after applying the forces, the angular speed of the disc in rad s^{-1} is

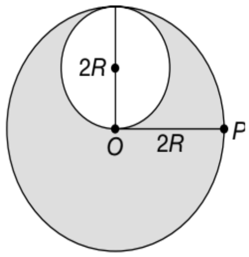


4. **[JEE (Advanced) 2014]**
A horizontal circular platform of radius 0.5 m and mass 0.45 kg is free to rotate about its axis. Two massless spring toy-guns, each carrying a steel ball of mass 0.05 kg are attached to the platform at a distance 0.25 m from the centre on its either sides along its diameter (see figure). Each gun simultaneously fires the balls horizontally and perpendicular to the diameter in opposite directions. After leaving the platform, the balls have horizontal speed of $9\ ms^{-1}$ with respect to the ground. The rotational speed of the platform in $rads^{-1}$ after the balls leave the platform is

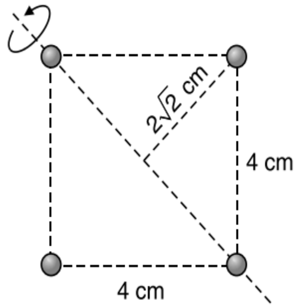


5. **[JEE (Advanced) 2013]**
A uniform circular disc of mass 50 kg and radius 0.4 m is rotating with an angular velocity of $10\ rads^{-1}$ about its own axis, which is vertical. Two uniform circular rings, each of mass 6.25 kg and radius 0.2 m, are gently placed symmetrically on the disc in such a manner that they are touching each other along the axis of the disc and are horizontal. Assume that the friction is large enough such that the rings are at rest relative to the disc and the system rotates about the original axis. The new angular velocity (in $rads^{-1}$) of the system is

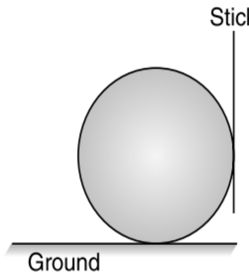
6. **[IIT-JEE 2012]**
A lamina is made by removing a small disc of diameter $2R$ from a bigger disc of uniform mass density and radius $2R$, as shown in Figure. The moment of inertia of this lamina about axes passing through O and P is I_O and I_P, respectively. Both these axes are perpendicular to the plane of the lamina. Find the ratio $\frac{I_P}{I_O}$ to the nearest integer.



7. **[IIT-JEE 2011]**
Four solid spheres each of diameter $\sqrt{5}$ cm and mass 0.5 kg are placed with their centers at the corners of a square of side 4 cm. The moment of inertia of the system about the diagonal of the square is $N \times 10^{-4}\ kgm^2$, find N.



8. **[JEE (Advanced) 2011]**
A boy is pushing a ring of mass 2 kg and radius 0.5 m with a stick as shown in Figure.



The stick applies a force of 2 N on the ring and rolls it without slipping with an acceleration of $0.3\ ms^{-2}$. The coefficient of friction between the ground and the ring is large enough that rolling always occurs and the coefficient of friction between the stick and the ring is $\left(\frac{P}{10}\right)$. The value of P is

ANSWER KEYS–TEST YOUR CONCEPTS AND PRACTICE EXERCISES

Test Your Concepts-I (Based on Moment of Inertia and Applications)

1. $23\ \text{kgm}^2, 45\ \text{kgm}^2, 27\ \text{kgm}^2, 0$
2. $34.6\ \text{kgm}^2, 23\ \text{kgm}^2$
3. $\dfrac{ml^2}{3}$
4. (a) $2ML^2$, (b) $\dfrac{1}{3}ML^2$
5. $\dfrac{\pi^2}{6}$
6. $m(a^2 - b^2)$
7. (a) $8md^2$, (b) $4m\ell^2$
8. $\sigma\pi R^3(2h+R)$
9. $14mR^2$
10. $\dfrac{2}{5}M\left(\dfrac{a^5-b^5}{a^3-b^3}\right)$
11. $\dfrac{1}{2}M\left(\dfrac{R^4-a^4-2a^2b^2}{R^2-a^2}\right)$
12. $MR^2\left(\dfrac{1}{2}-\dfrac{16}{9\pi^2}\right)$
13. $\dfrac{a^2}{4}(m_1+m_2)$
14. $\dfrac{R}{\sqrt{2}}$
15. $\dfrac{2MR^2}{3}$
16. $\dfrac{11}{12}mL^2$
17. $\dfrac{m\ell^2}{2}, \dfrac{\ell}{\sqrt{6}}$

Test Your Concepts-II (Based on Rotational Kinematics, Combined Effect of Rotation and Translation Motion)

1. (a) $4\ \text{rads}^{-1}, 28\ \text{rads}^{-1}$ (b) $12\ \text{rads}^{-2}$ (c) $6\ \text{rads}^{-2}, 18\ \text{rads}^{-2}$
2. $\vec{a}_1 = (a+R\omega^2)\hat{i} + (R\alpha)\hat{j},\ \vec{a}_2 = (a+R\alpha)\hat{i} - (R\omega^2)\hat{j},$
   $\vec{a}_3 = (a-R\omega^2)\hat{i} - (R\alpha)\hat{j},\ \vec{a}_4 = (a-R\alpha)\hat{i} + (R\omega^2)\hat{j}$
3. $(1.2\hat{i} - 4.4\hat{j})\ \text{ms}^{-2}$
4. (a) $4\pi\ \text{rads}^{-1}$, (b) 8π rad, (c) 4
5. $\dfrac{\omega l}{2}\cos\theta$
6. (a) $20.2\ \text{ms}^{-2}$, (b) 0.3 rev
7. $4\ \text{cms}^{-1}$, $1.6\ \text{cms}^{-2}$, towards centre C
8. $\dfrac{r}{R+r}$
9. $v_0t - R\sin(\omega_0 t),\ R - R\cos(\omega_0 t)$
10. v
11. $2\hat{i} + 3\hat{i} - 4\hat{j} = (5\hat{i} - 4\hat{j})\ \text{ms}^{-1}$

Test Your Concepts-III (Based on Instantaneous Axis of Rotation, Pure Rolling and Conservation of Energy)

1. $2.7R,\ 2.5R$
2. $\dfrac{5}{7}h$
3. $\dfrac{17}{8}mv^2$
4. $\sqrt{\dfrac{10g(R+r)}{17r^2}}$
5. $\sqrt{\dfrac{8}{3}gR}$
6. $\sqrt{\dfrac{3g}{2\ell}}$
7. $\sqrt{\dfrac{4mg}{(2m+M)R}}$
8. $\dfrac{3v}{l}, \dfrac{v}{2}, \dfrac{1}{2}mv^2$
9. $2.5a$
10. 0.6 m
11. $R\omega_0\sqrt{\dfrac{3m}{2k}}$
12. $0.745\ \text{ms}^{-1}$

Test Your Concepts-IV (Based on Torque and Applications)

1. $9\sqrt{2}dm$
2. $\sqrt{\dfrac{6F\sin\phi}{m\ell}}$
3. $2.73\ \text{ms}^{-1},\ 27.3\ \text{rads}^{-1},\ 233.5\ \text{N},\ 238.2\ \text{N},\ 1.47\ \text{s}$

4. $\frac{mg}{4}(1-3\cos\theta)^2, \frac{3}{2}mg\sin\theta\left(\frac{3}{2}\cos\theta-1\right)$, Yes

5. $\frac{2(m_2-m_1)g}{(2m_1+2m_2+m)R}, \frac{m_1(m+4m_2)}{m_2(m+4m_1)}$

6. (a) $Mg\tan\theta$, (b) 0

7. $4\sqrt{\frac{2g}{a}}$

8. $\frac{2m_2 g\sin\theta}{2m_2+m_1}, \frac{m_1 m_2 g\sin\theta}{2m_2+m_1}, mgh, mgh, \sqrt{\frac{2gh}{1+\frac{m_1}{2m_2}}}$

9. $\frac{3g\sin\theta}{8-3\cos\theta}$

10. (a) $\frac{3g}{2}$, (b) $\frac{3g}{4}$, (c) $\frac{mg}{4}$

11. $\frac{2g}{3}, \frac{Mg}{3}$

12. $\frac{32g}{a}$

13. (a) 8.16 rads^{-1}, (b) 8 rads^{-1}

14. $\frac{2g}{5R}, \frac{4g}{5}, \frac{mg}{5}$

15. $\sqrt{\frac{6g\sqrt{3}}{11r}}, \frac{3g}{11r}$

16. $\frac{\ell}{2\sqrt{3}}, \frac{g\sqrt{3}}{\ell}$

Test Your Concepts-V (Based on Uniform and Accelerated Pure Rolling)

1. $\frac{F}{M}-\mu_k g, \frac{2}{R}\left(\frac{F}{M}-\mu_k g\right)$

2. $\frac{g\sin\theta}{1+\frac{I}{mr^2}}$

3. $\frac{4}{11}g, \frac{4gt}{11}$

4. $\frac{F}{2M}, \frac{F}{2}$

5. $0.79Mg$

6. (a) $5.3 \text{ ms}^{-1}, 5.1 \text{ ms}^{-1}, 4.43 \text{ ms}^{-1}$
   (b) 4.2 N, 4.9 N, 7.4 N
   (c) 1.5 s, 1.6 s, 1.8 s

7. $\frac{3\mu MgR}{R+2b}$

8. $\frac{4F\cos\theta}{3M+8m}, \frac{3MF\cos\theta}{3M+8m}$ and $\frac{MF\cos\theta}{3M+8m}$

9. 1.4 ms^{-2}

10. $\frac{F}{3m+M}$

11. $\frac{2}{7}mg\sin\theta, \frac{mg}{7}(17\cos\theta-10)+\frac{mv_0^2}{(R-r)}$

Test Your Concepts-VI (Based on Angular Momentum and its Conservation)

1. $\sqrt{2g\ell\sec\theta}$

2. (a) $\frac{2v}{9L}$, (b) $\frac{1}{9}$

3. $\frac{I\omega_0}{I+mR^2}$

4. $\frac{\omega}{2}$

5. $2\sqrt{\frac{g}{r}}, 2m\sqrt{gr}$

6. (a) $\left(1+\frac{2m}{M}\right)\omega_0$, (b) $\frac{1}{2}m\omega_0^2R^2\left(1+\frac{2m}{M}\right)$

7. $\sqrt{2gr\sec\theta_0}$

8. $\frac{4m\ell\omega}{3}$

9. $\frac{\omega_0 R}{6}, \frac{\omega_0}{6}$

10. $\left(\frac{2m_1}{m_2+2m_1}\right)\theta$

11. $\frac{v_1}{R\left(1+\frac{I}{MR^2}\right)}$

12. $\frac{9mv_0^2}{2\ell}$

13. Linear momentum, angular momentum and kinetic energy, $\frac{M\ell^2}{12d^2+\ell^2}$

14. $\frac{3J}{7ma}, J>2m\sqrt{\frac{7ga}{3}}$

15. $\frac{\omega_0 r}{\sqrt{1+\frac{mr^2}{I}}}$

Test Your Concepts-VII
(Based on Rolling with Slipping)

1. $\dfrac{2\omega_0^2 r^2}{81\mu g}$
2. $\dfrac{2v_0}{R}$
3. $\dfrac{\omega_0 R}{3\mu g}, -\dfrac{1}{6}m\omega_0^2 R^2$
4. $\dfrac{12v_0^2}{49\mu_k g}$
5. $\dfrac{\omega_0 R}{g} + 6\sqrt{\dfrac{R}{g}}$
6. $\dfrac{5v_0}{2R}, \dfrac{v_0}{\mu g}, \dfrac{v_0^2}{2\mu g}$
7. $\dfrac{12v_0^2}{49\mu_k g}$
8. $\dfrac{3F}{3M+m}, \dfrac{F}{3M+m}, \dfrac{F}{R(3M+m)}$
9. $\dfrac{2}{7}\left(\dfrac{v_0 + R\omega_0}{\mu g}\right), \dfrac{1}{7}(5v_0 + 2R\omega_0)$
10. $\dfrac{r^2\omega_0^2(\mu\cos\alpha - \sin\alpha)}{2g(3\mu\cos\alpha - \sin\alpha)^2}, \dfrac{r^2\omega_0^2(\mu\cos\alpha - \sin\alpha)}{4g\sin\alpha(3\mu\cos\alpha - \sin\alpha)}$

Single Correct Choice Type Questions

1. C	**2.** A	**3.** C	**4.** C	**5.** B	**6.** B	**7.** B	**8.** B	**9.** B	**10.** D
11. D	**12.** B	**13.** C	**14.** B	**15.** D	**16.** A	**17.** C	**18.** D	**19.** C	**20.** C
21. D	**22.** C	**23.** A	**24.** B	**25.** B	**26.** D	**27.** C	**28.** B	**29.** C	**30.** B
31. C	**32.** A	**33.** B	**34.** D	**35.** C	**36.** D	**37.** B	**38.** B	**39.** D	**40.** D
41. B	**42.** D	**43.** A	**44.** D	**45.** B	**46.** B	**47.** D	**48.** D	**49.** B	**50.** C
51. A	**52.** C	**53.** D	**54.** C	**55.** A	**56.** D	**57.** A	**58.** A	**59.** D	**60.** A
61. B	**62.** A	**63.** A	**64.** A	**65.** C	**66.** D	**67.** C	**68.** A	**69.** B	**70.** D
71. A	**72.** B	**73.** C	**74.** D	**75.** D	**76.** D	**77.** C	**78.** A	**79.** C	**80.** B
81. C	**82.** C	**83.** B	**84.** B	**85.** D	**86.** C	**87.** A	**88.** D	**89.** C	**90.** A
91. B	**92.** B	**93.** D	**94.** B	**95.** B	**96.** B	**97.** C	**98.** B	**99.** C	**100.** D
101. B	**102.** B	**103.** D	**104.** C	**105.** B	**106.** A	**107.** D	**108.** D	**109.** A	**110.** C
111. C	**112.** C	**113.** A	**114.** C	**115.** B	**116.** C	**117.** B	**118.** B	**119.** D	**120.** B
121. B	**122.** C	**123.** D	**124.** C	**125.** D	**126.** A	**127.** D	**128.** B	**129.** B	**130.** B
131. B	**132.** A	**133.** B	**134.** D	**135.** B	**136.** D	**137.** A	**138.** B	**139.** B	**140.** A
141. C	**142.** B	**143.** C	**144.** A	**145.** D	**146.** D	**147.** C	**148.** A	**149.** C	**150.** B
151. C	**152.** B	**153.** D	**154.** D	**155.** B	**156.** D	**157.** A	**158.** B	**159.** B	**160.** B
161. B	**162.** D	**163.** B	**164.** B	**165.** B	**166.** C	**167.** B	**168.** B	**169.** C	**170.** D
171. B									

Multiple Correct Choice Type Questions

1. A, B	**2.** A, B, C	**3.** B	**4.** A, B, D	**5.** A, C, D
6. B, D	**7.** B, C	**8.** A, B, C	**9.** A, C	**10.** B, D
11. C, D	**12.** A, C	**13.** A, C	**14.** A, C	**15.** A, B, C, D
16. C, D	**17.** A, B, C, D	**18.** C, D	**19.** B, C	**20.** B, D
21. A, C, D	**22.** B, D	**23.** B, C, D	**24.** B, D	**25.** A, D
26. A, B, C, D	**27.** A, B	**28.** A, D	**29.** A, B, C	**30.** A, C
31. A, C	**32.** B, D	**33.** A, B, C, D	**34.** A, D	**35.** A, B, D

36. A, C	**37.** A, D	**38.** A, B	**39.** B, D	**40.** A, C
41. A, B, D	**42.** A, B, D	**43.** B, D	**44.** A, B, C	

Reasoning Based Questions

1. A	**2.** B	**3.** D	**4.** B	**5.** D	**6.** C	**7.** A	**8.** A	**9.** B	**10.** D
11. A	**12.** A	**13.** B	**14.** A	**15.** A					

Linked Comprehension Type Questions

1. C	**2.** B	**3.** D	**4.** B	**5.** C	**6.** C	**7.** B	**8.** B	**9.** A	**10.** D
11. D	**12.** C	**13.** B	**14.** C	**15.** D	**16.** B	**17.** D	**18.** C	**19.** C	**20.** C
21. D	**22.** C	**23.** B	**24.** D	**25.** B	**26.** C	**27.** C	**28.** A	**29.** D	**30.** B
31. A	**32.** C	**33.** B	**34.** B	**35.** A	**36.** C	**37.** D	**38.** C	**39.** B	**40.** D
41. B	**42.** A	**43.** D	**44.** A	**45.** D	**46.** C	**47.** A	**48.** B	**49.** A	**50.** C
51. B	**52.** C	**53.** C	**54.** D	**55.** D	**56.** B	**57.** B	**58.** A	**59.** C	**60.** B
61. A	**62.** C	**63.** C	**64.** A	**65.** C	**66.** A	**67.** A	**68.** B	**69.** A	**70.** C
71. A	**72.** B	**73.** A	**74.** C	**75.** B	**76.** A	**77.** C	**78.** B	**79.** B	**80.** A
81. D	**82.** C	**83.** B	**84.** C	**85.** D	**86.** C	**87.** B	**88.** C	**89.** A	**90.** B

Matrix Match/Column Match Type Questions

1. A → (r)	B → (p)	C → (p)	D → (s)
2. A → (q, r)	B → (p)	C → (s)	D → (q)
3. A → (r, s)	B → (p, q)	C → (s)	D → (p, q, r, s)
4. A → (s)	B → (q)	C → (p)	D → (r)
5. A → (q)	B → (p)	C → (s)	D → (r)
6. A → (r)	B → (q)	C → (t)	D → (p)
7. A → (s)	B → (r)	C → (q)	D → (p)
8. A → (p, s)	B → (p, r)	C → (q, r)	D → (p, r)
9. A → (q)	B → (s)	C → (q)	D → (r)
10. A → (p, q, r)	B → (p, q, r)	C → (p, q, r)	D → (s)
11. A → (r)	B → (p)	C → (p)	D → (q)
12. A → (p)	B → (s)	C → (p)	D → (r)
13. A → (q)	B → (r)	C → (p)	D → (r)
14. A → (t)	B → (s)	C → (p)	D → (p)
15. A → (q)	B → (s)	C → (q)	D → (p)
16. A → (p, r, s)	B → (q, r, s)	C → (q, r, s)	D → (p, r, s)
17. A → (q)	B → (s)	C → (p)	D → (s)
18. A → (p, r)	B → (p, r)	C → (q, s)	D → (p, s)
19. A → (s)	B → (p)	C → (p)	D → (q, r)
20. A → (q)	B → (r)	C → (p)	D → (s)
21. A → (q)	B → (s)	C → (s)	D → (p)

Integer/Numerical Answer Type Questions

1. 5	2. 3	3. 75	4. 40	5. 9
6. 20, 8	7. 15	8. 2.25	9. 5	10. 1
11. 20	12. (a) 36, (b) 6	13. (a) 4, (b) 5, (c) 50	14. 9	15. (a) 1, (b) 5, (c) 1
16. 1.5	17. 100, 3, 30, 1	18. (a) 4, 40 (b) 500, 180 (c) 1	19. 20	20. 40
21. 3	22. 11	23. 4	24. 4, 8	25. 2
26. 25	27. (a) 4, (b) 90	28. 8, 8, 4	29. (a) 1.37, (b) 131, (c) 206	30. 20
31. 251.43	32. 0.7	33. 195	34. (a) 14.3, (b) 40, 181 (c) 141	35. 6

ARCHIVE: JEE MAIN

1. D	2. D	3. D	4. B	5. B	6. B	7. B	8. C	9. A	10. B
11. D	12. C	13. B	14. A	15. A	16. A	17. B	18. D	19. D	20. D
21. A	22. Bonus	23. C	24. B	25. D	26. C	27. B	28. D	29. C	30. A
31. D	32. B	33. D	34. B	35. C	36. D	37. B	38. A	39. A	40. B
41. A	42. C	43. C	44. D	45. D	46. A	47. A	48. D	49. D	50. D
51. A	52. B	53. A	54. A	55. A	56. A	57. D	58. A, C	59. B	60. B
61. A	62. C	63. C	64. C	65. C	66. C	67. B	68. C	69. B	70. C
71. D	72. D								

ARCHIVE: JEE ADVANCED

Single Correct Choice Type Problems

1. A	2. D	3. C	4. D	5. A	6. B	7. B	8. D	9. A	10. D
11. A	12. D	13. B	14. A	15. A	16. A	17. C	18. B	19. A	20. D
21. C	22. B	23. C	24. B	25. A	26. A	27. B	28. C	29. A	30. C

Multiple Correct Choice Type Problems

1. A, C, B	2. B, C, D	3. A, C, D	4. A, C	5. A, B
6. A, C	7. B, C	8. C, D	9. A, B, C	10. A, B, C
11. A, C, D	12. B, D			

Reasoning Based Questions

1. D

Linked Comprehension Type Questions

1. A	2. C	3. C	4. B	5. D	6. A	7. C	8. A	9. B

Integer/Numerical Answer Type Questions

1. 25, 6	2. 7	3. 2	4. 4	5. 8	6. 3	7. 9	8. 4