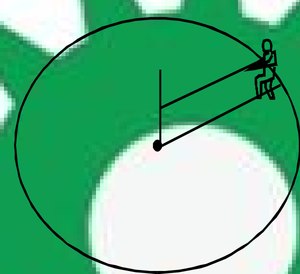
ROTATIONAL MECHANICS_PART-II_($\vec{L}$, rolling)

PART-A

LEVEL-I_(THEORY)

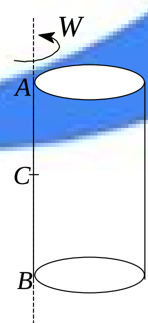
SINGLE ANSWER CORRECT

1. A man is sitting in a smooth groove on a horizontal circular table at the edge by holding a rope joined to the centre. The moment of inertia of table is I. Mass of man = M. Man now pulls the rope so that he comes to the centre. The angular velocity of the table :



(A) must increase (B) may increase (C) must decrease (D) may decrease

2. Consider a vertical cylinder of uniform mass distribution rotating about a vertical axis which is touching its curved surface as shown in the figure. Length of the cylinder $AB = l$, where A & B are fixed points on the axis of rotation touching the edges of the cylinder and C is the midpoint of line AB. Let $\vec{L}_A$ and $\vec{L}_C$ be the angular momentum of the cylinder about calculated about points A and C respectively. Then



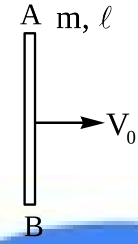
A) $\vec{L}_A = \vec{L}_C$

B) $|\vec{L}_A| = |\vec{L}_C|$ but are not parallel vectors

C) $|\vec{L}_A| < |\vec{L}_C|$

D) $|\vec{L}_A| > |\vec{L}_C|$

3. A thin uniform rod AB of mass m and length 'ℓ' is in translational motion with a speed V_0. The end A is suddenly stopped and is brought to rest in a small time interval dt. During this interval, angular momentum of the rod is conserved about



a) Point A b) centre of mass of the rod

c) point B d) point fixed to space and coinciding with end A.

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

(A) $\omega_0/3$ (B) $\omega_0/2$ (C) $\omega_0/4$ (D) $\omega_0/7$

5. Four solid objects, each with the same mass and radius, are spinning freely with the same angular momentum. Which object requires the most work to stop it?

(a) A solid sphere spinning about a diameter

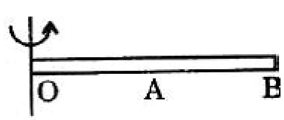
(b) A hollow sphere spinning about a diameter

(c) A solid disk spinning about an axis perpendicular to the plane of the disk and through the center

(d) A hoop spinning about an axis along a diameter

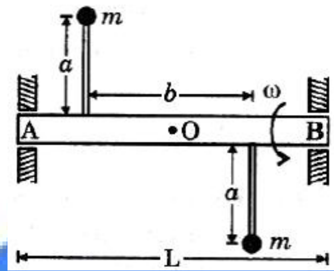
(e) The work required is the same for all four objects

6. A rod OB of length ℓ, hinged about its end O is rotating with an angular velocity ω. The rod breaks at its midpoint A and a result the part OA starts rotating with angular velocity 2ω. Then the angular velocity of AB about its centre of mass is :



A) ω B) 2ω C) 4ω D) None of these

7. A horizontal rod AB which is held by frictionless bearings at its ends, can rotate freely around its horizontal axis. Two equal masses held in position, as shown, by rigid rods of negligible mass are symmetrically located relative to the centre of rod. If the system is rotating with angular velocity ω in absence of gravity, then choose the correct alternative(s) :



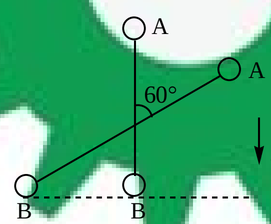
A) The angular momentum of system about point O is along axis of rotation

B) The reaction force at bearings on rod is upwards at A and downwards at B

C) The reaction force at bearings on rod is downwards at A and upwards at B

D) There would be no reaction force at bearings

8. A dumbbell has two small balls of mass 'm' each connected by a light rigid rod of length 'a'. The dumbbell is released from rest on a smooth table in vertical position. Which of the following statements is not true, when the dumbbell rod makes an angle 60^o with the vertical?



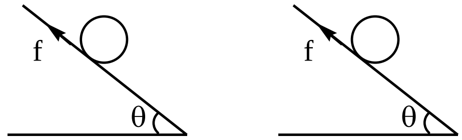
(a) Velocity of ball B is horizontal

(b) Velocity of centre of mass of the ball A+ball B system is vertical

(c) Power delivered by gravity to ball A+ball B+light rod system is rate of change of $\frac{1}{2}Mv_{cm}^2$ where M is mass of the system and v_{cm} is speed of centre of mass of the system

(d) Power delivered by contact forces between light rod and balls to ball A + ball B system is zero

9. In fig(a) a disc is rolling down the inclined plane with slipping and in fig(b) a sphere of same mass is rolling down the inclined plane with no slipping. If ‘f’ represents the frictional force developed, then f is.



(a) (b)

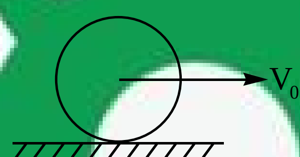
A) Proportional $\sin\theta$ in fig(a) and linearly dependent on $\cos\theta$

B) Proportional $\cos\theta$ in fig(a) and linearly dependent on $\sin\theta$

C) Proportional to $\cos\theta$ in both cases

D) Proportional to $\sin\theta$ in both cases

10. A sphere of mass m is projected on a rough ground with a velocity of v_0 without any spin. This is observed from ground and by an observer moving with constant velocity v_0. For both the frames, origin is on ground and direction of motion is positive x-axis. Choose the **incorrect** statement.



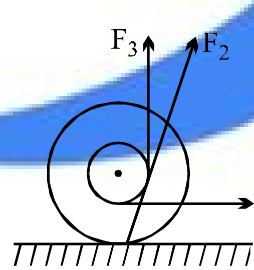
A) Change in angular momentum of the ball about origin in any time interval is same from both frames

B) Work done by friction on the ball in any time interval is same from both frames

C) total heat dissipated in any time interval is same from both frames

D) Change in momentum of ball in any time interval is same from both frames

11. A yo-yo is resting on a rough horizontal table. Forces F_1, F_2 and F_3 are applied separately as shown. The correct statement is



(A) when F_3 is applied the centre of mass will move to the right.

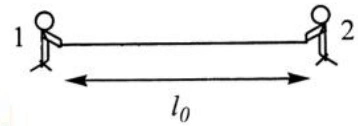
(B) when F_2 is applied the centre of mass will move to the left.

(C) when F_1 is applied the centre of mass will move to the right.

(D) when F_2 is applied the centre of mass will move to the right.

ONE OR MORE THAN ONE ANSWER CORRECT

12. Two astronauts each having mass 'm' are connected by a light rope of length l_0. They are orbiting around their centre of mass with angular speed $'\omega_0'$ in free space. Now astronaut – 1 starts collecting rope slowly-slowly such that finally length of string between them reduces to $\frac{l_0}{2}$. (treat astronaut as particle) Then



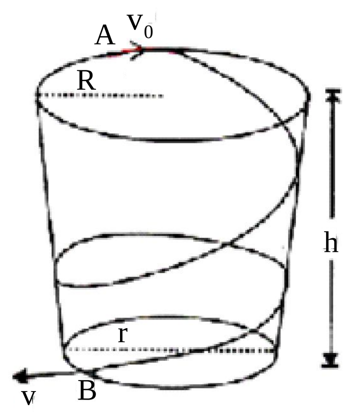
A) Final angular speed of system is $2\omega_0$

B) Final angular speed of system is $4\omega_0$

C) Work done by astronaut-1 in process is $\frac{3ml_0^2\omega_0^2}{4}$

D) Work done by astronaut-1 in processes is $\frac{3ml_0^2\omega_0^2}{8}$

13. A frustum has been mounted with its axis vertical. It has a height h and radii of its upper and lower cross sections are R and r respectively. A particle is projected with horizontal velocity v_0 along its upper brim. The particle spirals down the inner surface and leaves the lower face at point B. The inner wall of the frustum is smooth. Mark the correct options regarding motion on the surface of frustum



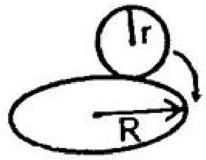
A) Mechanical energy is conserved

B) Kinetic energy is conserved

C) Angular momentum about axis of frustum is conserved

D) Work done by normal is zero

14. A ring of radius r is moving without slipping on a circular track of radius R. Angular speed of the ring about its axis is ω. Ignoring the fact that the ring axis is inclined.



A) the angular acceleration of the ring is $\frac{\omega^2 r}{R}$

B) the angular acceleration of the ring is $\frac{(R-r)}{R}\omega^2$

C) the angular velocity of centre of the ring about vertical axis passing through the centre of track is $\frac{r\omega}{R}$

D) the angular velocity of centre of the ring about vertical axis passing through the centre of track is $\frac{(R-r)}{R}\omega$

15. Consider four objects, all solid spheres. Sphere (A) has radius r and mass m, (B) has radius 2r and mass m, (C) has radius r and mass 2m, and (D) has radius r and mass 3m. All can be placed at the same point on the same inclined plane where they will roll without slipping to the bottom. The answer to the following questions might also be (E), all are the same.

(a) Which object has the largest rotational inertia?

(b) If released from rest, which object will experience the largest net torque?

(c) If released from rest, which object will experience the largest linear acceleration?

(d) If allowed to roll down the incline, which object will have the largest speed at the bottom of the incline?

(e) If allowed to roll down the incline, which object will reach the bottom of the incline in the shortest time?

16. Consider four objects: (A) a solid sphere; (B), a spherical shell; (C), a solid disk; and (D) a metal hoop. All have the same mass and radius; all can be placed at the same point on the same inclined plane where they will roll without slipping to the bottom. The answer to the following questions might also be (E), all are the same.

(a) Which object has the largest rotational inertia about its axis of symmetry?

(b) If released from rest, which object will experience the largest net torque?

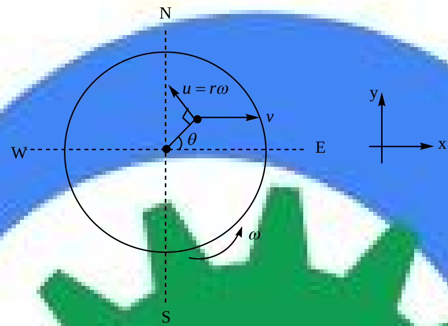
(c) If released from rest, which object will experience the largest linear

(d) If allowed to roll down the incline, which object will have the largest speed at the bottom of the incline

(e) If allowed to roll down the incline, which object will reach the bottom of the incline in the shortest time?

PASSAGE

A person walks at constant speed v eastward with respect to a turn table that rotates counter clockwise at constant angular velocity ω about a fixed vertical axis passing through its centre. At some point of time position of person with respect to ground is shown in diagram. The velocity of the person with respect to ground is sum of $v\hat{i}$ and $\bar{u}$ (where u = rω). So equation of motion of person can be written as $\frac{dx}{dt} = v - u\sin\theta$ and $\frac{dy}{dt} = u\cos\theta$. Answer following questions.



17. Trajectory of person with respect to ground is

A) Straight line B) Circular C) Parabola D) Elliptical

18. Trajectory of person in the frame of turn table is

A) Straight line B) Circular C) Parabolic D) Elliptical

PASSAGE

Two wires are attached to the ends of the axle of a bicycle wheel so that the wheel is suspended, free to rotate in a vertical plane. The wheel is spun about the axle at a high speed. One of the wires supporting the axle is cut; the wheel as viewed from this side of the axle is rotating in a clockwise direction.

19. Which way, as viewed from above, will the axis of the wheel process?

(a) Clockwise (b) Counterclockwise

(c) The wheel will not process, because it is not a spinning top.

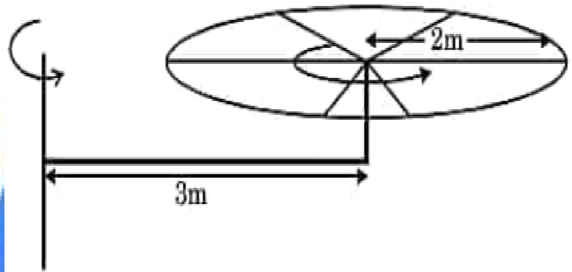
20. Before one of the two wires is cut, each wire has a tension of W/2 where W is the weight of the wheel. After cutting one of the wires, the magnitude of the tension in the wire that is still connected will be –

(a) W/2 (b) slightly more than W/2

(c) approximately (d) exactly W

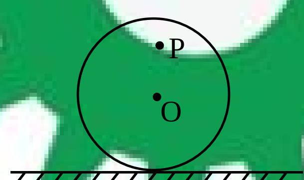
INTEGER TYPE

21. A bicycle wheel (ring) of mass 1 kg and radius 2m is attached at the end of a long rod of mass 1 kg and length 3m, with the axis of wheel perpendicular to the rod. The rod is rotating counter clockwise as seen from above, about its other end with an angular speed 0.5 rad/s. If wheel is also rotating about its axis with same angular speed in counter clock wise sense as seen from above. Find angular momentum of the system (in kg - m^2/s) about the axis passing through one end of rod. (Neglect mass of spokes and mass of rod connecting end of rod of length 3m and centre of ring)



MATCHING

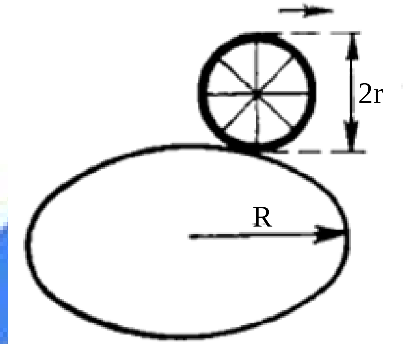
22. A uniform disc rolls without slipping on a rough horizontal surface with uniform angular velocity. Point O is the centre of disc and P is a point on disc as shown in figure. In each situation of column I a statement is given and the corresponding results are given in column II. Match the statement in column I with the results in column II



	Column I		Column II
A)	The velocity of point P on disc	P)	Changes in magnitude with time
B)	The acceleration of point P on disc	Q)	is always directed from that point (the point on disc given in column-I) towards centre of disc
C)	The tangential acceleration of point P on disc	R)	is always zero
D)	The acceleration of point on disc which is in contact with rough horizontal surface	S)	is non-zero and remains constant in magnitude
		T)	Changes in direction with time

SUBJECTIVE TYPE

23. A stunt rider on a unicycle is riding around the arena of a circus in a circle of radius R. The radius of the wheel of the unicycle is r and the angular velocity with which the wheel rotates is ω. What is the angular acceleration of the wheel? (Ignore the fact that the wheel axis is inclined.)

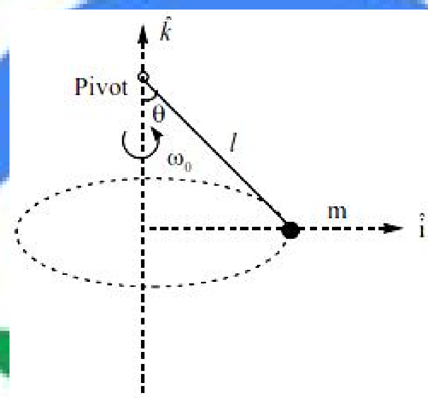


PART-B

LEVEL-II_(APPLICATION)

SINGLE ANSWER CORRECT

1. A conical pendulum is composed of a bob of mass m = 200gm and light string of length *l* = 50 cm. It swings with constant angular velocity $\omega_0 = \frac{10}{\sqrt{3}}$ rad/s as shown in figure. The angular momentum vector of bob with respect to pivot at the instant shown in figure. $\left(g = 10\,m/s^2\right)$



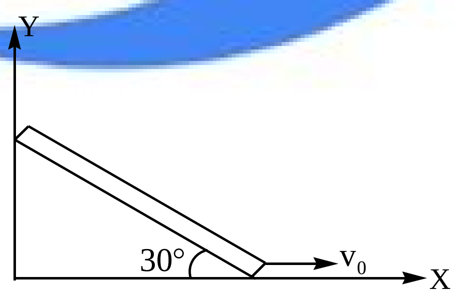
A) $\frac{8}{25\sqrt{3}}\hat{k}$ N−m−s

B) $\frac{2}{25\sqrt{3}}\left(3\hat{i}+4\hat{k}\right)$ N−m−s

C) $\frac{2}{25\sqrt{3}}\left(4\hat{i}+3\hat{k}\right)$ N−m−s

D) $\frac{4}{25\sqrt{3}}\left(3\hat{i}+4\hat{k}\right)$

2. A rod of mass m and length ℓ is sliding against a smooth vertical wall as shown. The floor is assumed to be frictionless. The speed of the bottom end of the rod at the instant shown is v_0. The magnitude of angular momentum of the rod about ICR (instantaneous axis of rotation) at the instant when angle $\theta = 30°$ is



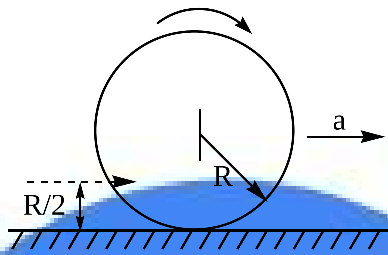
A) $\frac{2}{3}mv_0\ell$

B) $\frac{1}{6}mv_0\ell$

C) $\frac{1}{12}mv_0\ell$

D) None of these

3. Inside a uniformly accelerating thin-walled spherical shell of radius R, which is undergoing pure rolling on horizontal surface, there is small body slipping around. Angle of friction between body and inner surface of sphere is $23°$. Which of the following can be the acceleration 'a' of the center of sphere to ensure that the small body stays at R/2 distance from the surface ?

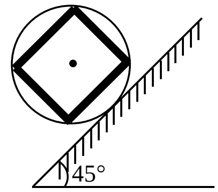


A) $\frac{g}{\sqrt{3}}$ B) $\frac{3g}{4}$ C) $g \tan 23°$ D) $\frac{g\sqrt{3}}{2}$

4. A rotten egg of owl (in the form of sphere) consists of a thin shell (of mass m and radius R) enclosing a viscous fluid of uniform density and mass 21m. When this egg rolls on the horizontal surface without slipping with centre of mass velocity v_0, the angular velocity of fluid increases uniformly in the radial direction from centre to surface i.e. from zero to $\omega_0 \left(\omega_0 = V_0 / R\right)$. Neglect the effect of deformation of fluid. The rotational kinetic energy of fluid is

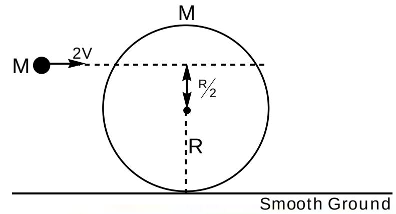
A) $\frac{1}{2}mV_0^2$ B) mV_0^2 C) $3mV_0^2$ D) $\frac{27}{2}mV_0^2$

5. Four identical rods, each of mass m are welded at their ends to form a square, and the corners are then welded to a light metal hoop of radius r. If the rigid assembly of rods and hoop is allowed to roll down the inclined rough surface. The minimum value of coefficient friction (static), which prevent shipping is



A) 0.4 B) 0.6 C) 0.3 D) 0.1

6. A small ball of mass M strikes a stationary disc of same mass with velocity 2V horizontally as shown. All the surfaces are smooth. The velocity of centre of disc after the collision is V.



Which of the following is **incorrect**?

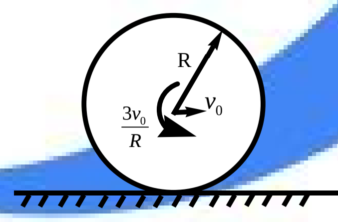
1) Impulse exerted by ground on disc is $\frac{MV}{\sqrt{3}}$

2) Angular velocity of disc is zero after collision

3) Coefficient of restitution for the collision is $e = \frac{1}{6}$

4) If the disc is replaced by a solid sphere keeping the other values remain same, the velocity of small ball just after collision is $\frac{V}{\sqrt{3}}$

7. Figure shows a uniform sphere on rough fixed horizontal surface. Initially sphere is moving with speed V_0 in forward direction and initial back spin is $\frac{3V_0}{R}$. Long time after when it begins pure rolling



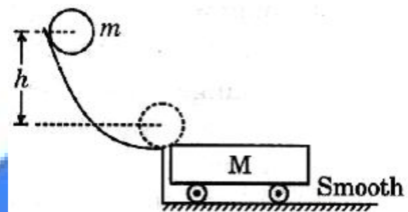
A) Centre of mass of sphere will be moving backward

B) Centre of mass will be moving forward

C) The total work done by friction on sphere is the heat released in the process

D) Work done by friction on body is not equal to the heat released in the process

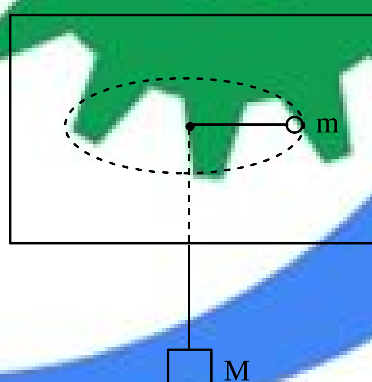
8. A uniform disc of mass m = 12 kg slides down along smooth, frictionless hill, which ends in a horizontal plane without break. The disc is released from rest at a height of h = 1.25 m (it has no initial speed and it does not rotate), and lands on the top of a cart of mass M = 6 kg, which can move on a frictionless surface. The coefficient of kinetic friction between the cart and the disc is $\mu = 0.4$. Find minimum length of the cart (in m) so that the disc begins to roll without slipping before losing contact with the cart.



A) $\frac{7}{8}$ B) $\frac{7}{4}$ C) 5.25 D) none of these

ONE OR MORE THAN ONE ANSWER CORRECT

9. A small disc of mass m is attached to the end of a light inextensible cord, which passes through a hole in a frictionless horizontal tabletop. At the other end of the cord, a weight of mass M is attached. Initially disc is moving on a circle of radius R with angular velocity ω. If the hanging weight is pulled slightly down by $x_0 (<< R)$ and then released,



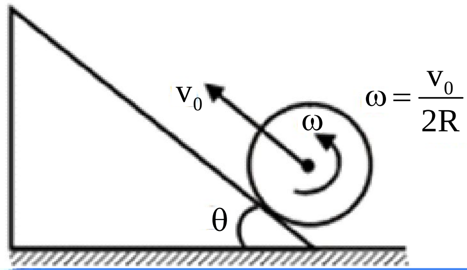
A) The net force on m at an instant when M moves up by $\frac{x_0}{2}$ after the release is $Mg + \frac{3x_0 mM\omega^2}{2(M+m)}$

B) The net force on M at an instant when M moves up by $\frac{x_0}{2}$ after the release is $Mg + \frac{3x_0 mM\omega^2}{2(M+m)}$

C) The net force on M at an instant when M moves up by $\frac{x_0}{2}$ after the release is $\frac{3x_0 mM\omega^2}{2(M+m)}$

D) Acceleration of m at an instant when M moves up by $\frac{x_0}{2}$ after the release is $\frac{3x_0 m\omega^2}{2(M+m)}$

10. A solid uniform cylinder of radius 'R' rolls up the plane on a sufficiently rough inclined plane of sufficient length. The initial conditions of motion are as shown in figure, then choose the correct statement(s) :



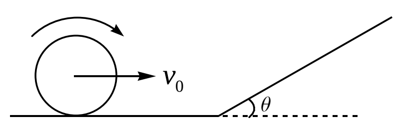
A) The initial direction of friction will be up the plane

B) The initial direction of friction will be down the plane

C) The direction of friction will get reversed when rolling without slipping is achieved

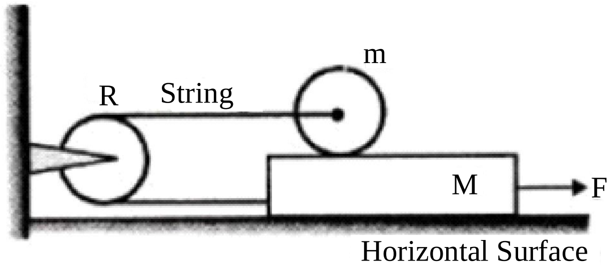
D) The direction of friction will remain the same when rolling without slipping is achieved

11. In a model experiment, a rigid surface consists of a rough horizontal plane and an inclined plane connecting to it. A thin hoop of radius r is rolling towards the slope without slipping at a velocity v_0, perpendicular to the base of the slope. The slope connects to the horizontal plane with a smooth curve of radius R > r, which is considered part of the slope, such that the hoop will move up the slope without collision. In three different models of the experiment, everything is kept same except the friction coefficient of slope which is $\mu_1 = 0$, $\mu_2 = \tan\theta$, $\mu_3 = 2\tan\theta$ respectively. In each case the height to which hoop rises on the incline before stopping momentarily is $\Delta h_1, \Delta h_2, \Delta h_3$ respectively. Then



a) $\Delta h_1 < \Delta h_2 < \Delta h_3$ b) $\Delta h_1 > \Delta h_2 > \Delta h_3$ c) $2\Delta h_1 = \Delta h_2$ d) $\Delta h_2 = \Delta h_3$

12. A solid cylinder of mass 'm' and radius R is placed on a plank of mass 'M' which in turn is placed on smooth horizontal surface. Given that sufficient friction is present between cylinder and the plank surface to prevent sliding of cylinder. The pulley is ideal and fixed. If plank is pulled with force F as shown in figure then which of the following options is/are correct:



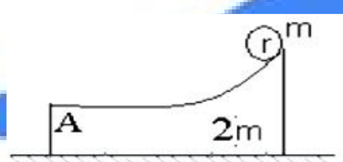
A) The acceleration of the cylinder is $\frac{F}{M+3m}$

B) The tension in the string is $\frac{2mF}{M+3m}$

C) The magnitude of friction between cylinder and plank is $\frac{mF}{M+3m}$

D) The hinge reaction at the pulley support is $\frac{2mF}{M+3m}$

13. A sphere of mass m and radius 'r' is released from rest from the top of a wedge of mass '2m' initially at rest on a smooth horizontal surface as shown. There is sufficient friction between the sphere and the wedge so that the sphere rolls on the wedge without slipping. The sphere leaves the wedge horizontally at A after descending through a vertical displacement h. Let V_1, V_2 and ω be the magnitudes of the velocity of the centre of sphere, velocity of wedge and the angular velocity of the sphere at the instant the sphere leaves the wedge. Choose the correct statements.



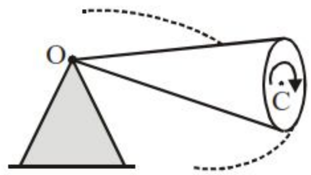
A) $V_1 + V_2 = r\omega$

B) Total mechanical energy of sphere and wedge system is conserved during the process

C) The ratio of total kinetic energy of the sphere and to the wedge at the instant the sphere leaves the wedges is 19 : 5

D) $V_1 = \sqrt{\frac{5gh}{6}}$

14. A round cone with half-angle $\alpha = 30°$ and the radius of the base R = 10cm rolls uniformly without slipping over horizontal plane. The apex is hinged at the point O (see figure) which is at the same level as the point C, the centre of the base. The velocity of the point C is $v = 10\ ms^{-1}$



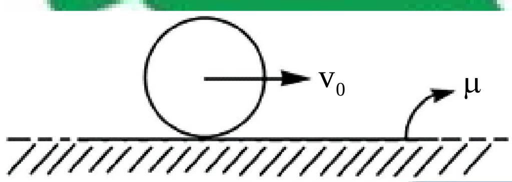
A) The angular velocity vector of cone about O is $\frac{100}{\sqrt{3}}$ rad/s

B) The angular velocity vector of cone about O is $\frac{200}{\sqrt{3}}$ rad/s

C) The angle made by this angular velocity vector with vertical is $30°$

D) The angle made by this angular velocity vector with vertical is $60°$

15. A sphere is thrown along a rough surface as shown. Mass of the sphere is M and radius is R. If t is total time taken to start pure rolling after thrown, then :



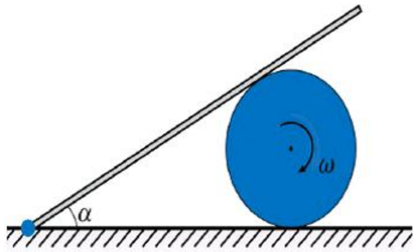
A) Speed of the sphere when it start pure rolling is $\frac{5v_0}{7}$

B) Work done by friction is greater in first half i.e. 0 to $\frac{t}{2}$ compare to later half i.e., $\frac{t}{2}$ to t

C) Work done by friction zero after time t

D) The net work done on the sphere is $\frac{1}{4}Mv_0^2$

16. A cylinder is moving along a horizontal surface without slipping with an angular velocity $\omega = 1.0$ rad/s. If the rod is leaning on the cylinder with one end hinged. Then which of the following statements is/are correct for the moment when angle $\alpha = 60°$?



A) Angular velocity of the rod is $\frac{1}{2}$ rad/s

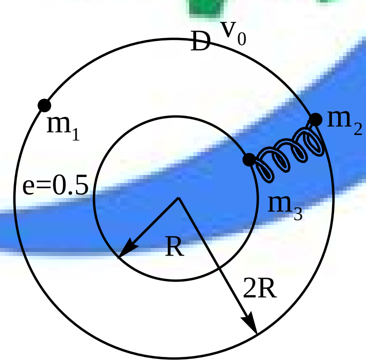
B) Angular velocity of the rod is $\frac{\sqrt{3}}{2}$ rad/s

C) Angular acceleration of the rod $\frac{\sqrt{3}}{4}$ rad/s^2

D) Angular acceleration of the rod $\frac{\sqrt{3}}{2}$ rad/s^2

PASSAGE

Three particles each of mass m can slide on fixed frictionless plane as shown in figure. Particle m_1 moves with velocity V_0 and hits particle m_2, the coefficient of restitution being $e = \frac{1}{2}$. Assuming that m_2 and m_3 are at rest initially and lie along a radial line before impact and the spring is initially unstretched. Consider only one collision between m_1 and m_2



17. The maximum velocity of m_3 is

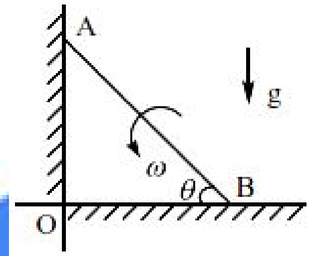
A) $\frac{3}{5}V_0$ B) $\frac{3}{10}V_0$ C) $\frac{V_0}{2}$ D) $\frac{V_0}{5}$

18. The maximum stretch of the spring is

A) $\frac{3}{4}V_0\sqrt{\frac{m}{5k}}$ B) $\frac{V_0}{4}\sqrt{\frac{m}{k}}$ C) $\frac{V_0}{4}\sqrt{\frac{m}{3k}}$ D) $\frac{3V_0}{4}\sqrt{\frac{m}{3k}}$

PASSAGE

A uniform rod of mass m and length l slides without friction along a vertical wall and horizontal floor as shown. Gravity and the contact forces from wall and floor are the only forces acting on the rod. At the instant shown, direction of angular velocity of rod ω is given as in diagram. A, B are end points of the rod and A', B' are points on the wall and floor in contact with A and B at this instant. C is centre of mass of the rod.



19. Which of the following is not applicable? (τ is the torque due to real forces)

A) $\tau = I\alpha$ equation about an axis perpendicular to the diagram and attached to A

B) $\tau = I\alpha$ equation about an axis perpendicular to the diagram and attached to C

C) $I\alpha = \left|\frac{d\vec{L}}{dt}\right|$ about an axis perpendicular to the diagram and attached to B

D) $\tau = \left|\frac{d\vec{L}}{dt}\right|$ about an axis perpendicular to the diagram and attached to B'

20. The magnitude of angular momentum of the rod about O and C at the instant shown is L_0 and L_C respectively. Then

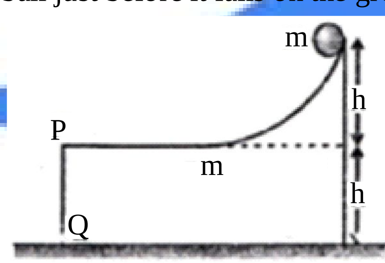
A) $L_0 = L_C$ B) $L_0 > L_C$ C) $L_0 < L_C$

D) relationship cannot be determined

PASSAGE

A small ball (uniform solid sphere) of mass m is released from the top of a wedge of the same mass m. the wedge is free to move on a smooth horizontal surface. The ball rolls without sliding on the wedge. The required height of the wedge are as mentioned in the figure.

21. The total kinetic energy of the ball just before it falls on the ground



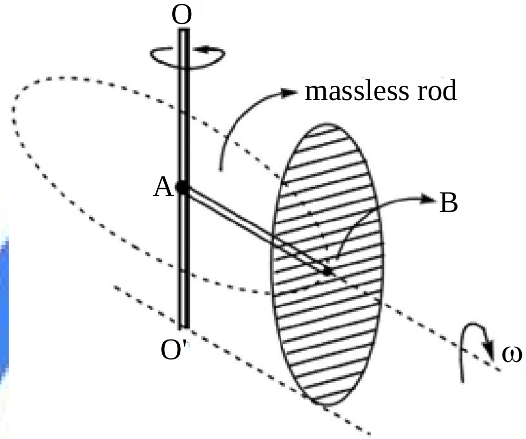
A) 2 mgh B) mgh C) $\frac{31}{18}$ mgh D) $\frac{mgh}{2}$

22. The horizontal separation between the ball and the edge 'PQ of wedge just before the ball falls on the ground is

A) $\frac{3\sqrt{10}}{2}h$ B) $\frac{2\sqrt{10}}{3}h$ C) 2h D) $\frac{\sqrt{10}}{3}h$

PASSAGE

Consider a uniform disc of radius R, connected with a massless rod AB of length R, whole system is connected to a vertical axis OO' as given in figure. Disc is rolling without slipping on rough horizontal surface about horizontal axis passing through its centre along the rod and whole system is also rotating about vertical axis OO' as given in figure.



Friction is absent at joints A and B

23. If mass of disc is M and angular velocity of disc about the axis passing through it's centre and along rod is ω, then what is the magnitude of total angular momentum of disc about point A is

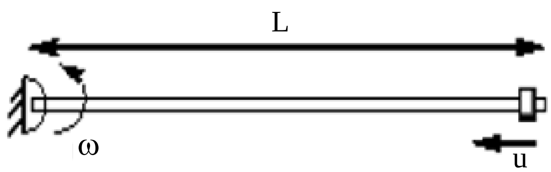
A) $\frac{MR^2\omega}{2}$ B) $\frac{5}{4}MR^2\omega$ C) $\frac{\sqrt{29}\,MR^2\omega}{4}$ D) $\frac{7}{4}MR^2\omega$

24. About point A torque required to maintain the described motion is

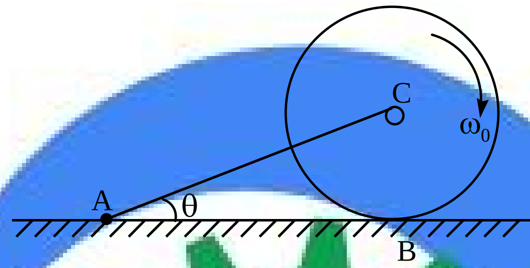
A) $\frac{MR^2\omega^2}{2}$ B) $\frac{5}{4}MR^2\omega^2$ C) $\sqrt{29}\frac{MR^2\omega^2}{4}$ D) $\frac{7}{4}MR^2\omega^2$

INTEGER TYPE

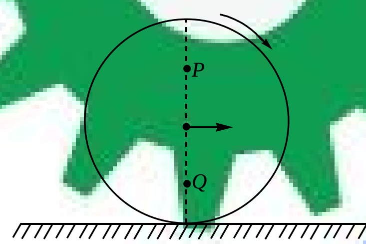
25. A small bead of mass M is launched from one end of a horizontal rod at a speed u along the rod, having same mass M, as shown in figure. The rod is free to rotate in a vertical plane about another end. Simultaneously the rod is given an angular velocity ω as shown in the figure. If the initial angular acceleration of the rod is $\frac{A}{BL}\left(\frac{3g}{2}-2u\omega\right)$, then A + B is ?



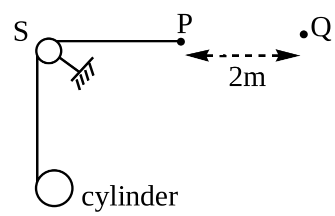
26. A disc of radius r and mass m hinged to a light rod AC has initial angular velocity ω_0 as shown. End A of rod is fixed and disc is free to rotate about C in vertical plane. Coefficient of friction between the disc and surface B is μ. If disc is suddenly allowed to rest its full weight on the horizontal rough plane, the time after which it comes to rest is $t = \frac{r\omega_0}{2ag}(1 - b\tan\theta)$. Then $\frac{a}{b} =$ ___________



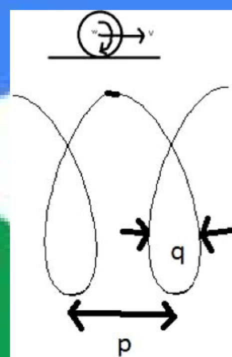
27. A disc is purely rolling on smooth horizontal surface. The distance between the centre of curvatures of two points P & Q which are midway between centre and circumference on a vertical diameter is k times the radius. Find 'k'



28. A light string is wrapped on a cylinder of mass 1 kg. The string passes over a fixed smooth pulley S. The cylinder is released from rest while a constant force 100 N is applied at the end P of the string. When P has moved to Q, the Centre of mass of the cylinder is found to ascend by 4 m. The kinetic energy of the cylinder at this instant is 160x Joule. Then Find x. (Take g = 10 m/s^2)

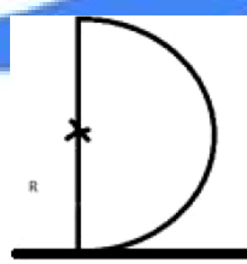


29. A ring of radius R is moving on a smooth horizontal surface such that the velocity of centre of mass is v and its angular velocity about its centre of mass is ω such that $R\omega = 2v$ and the path of any material point on the ring is shown in the figure. Here P is the minimum distance between two consecutive points on the ground where it is touching the ground and q is the minimum horizontal distance between two consecutive points where the net velocity is vertical. (refer figure)

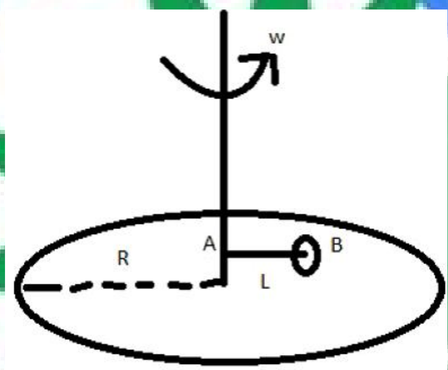


If $\frac{1}{R}\left(q+\frac{P}{3}\right) = x$. Find x^2

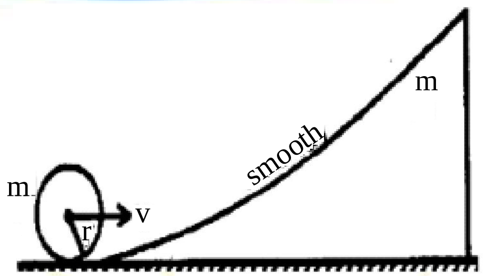
30. A solid hemisphere of mass m and radius R is kept vertical on a smooth horizontal surface as shown in the figure and released. The maximum magnitude of the normal reaction from the ground is N_{max} and $N_{max} = \frac{x}{y}mg$, find $\frac{x-y}{10}$



31. A uniform disc of mass M and radius R is rotating freely about its stationary smooth central vertical axis with angular speed ω_0. Another disc of mass m and radius r is free to rotate about a horizontal rod AB. Length of the rod AB is L (<R). And its end A is rigidly attached to the vertical axis of the first disc. The disc of mass m, initially at rest, is placed gently on the disc of mass M as shown in the figure. Find the time in seconds after which the slipping between the two discs will cease. Assume that normal reaction between the two disc is equal to mg, coefficient of friction between the two discs is μ given M = 1 kg, m = 1 kg, L = 0.5 m, $\mu = 0.1$, $\omega_0 = 5 \text{ rad/sec}$

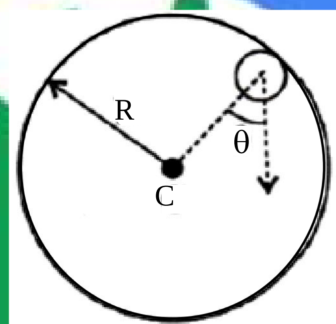


32. A thin disc of mass m and radius r is rolling purely on the smooth horizontal surface with velocity $v = \sqrt{80} \text{ m/s}$. Find the maximum height reached by the given disc (in m) on the movable wedge (initially at rest) of same mass m kept on the smooth surface as shown. (Disc and wedge have a smooth surface)

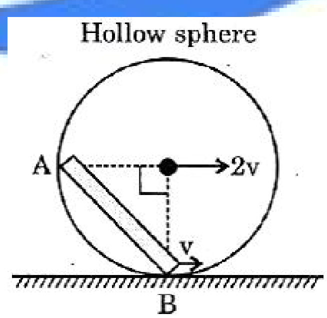


33. A rotten egg of owl (in the form of sphere) consists of a thin shell (of mass m and radius R) enclosing a viscous fluid of uniform density and mass 21m. When this egg rolls on the horizontal surface without slipping with centre of mass velocity V_0, the angular velocity of fluid increases uniformly in the radial direction from centre to surface i.e. from zero to $\omega_0 \left(\omega_0 = V_0 / R\right)$. Neglect the effect of deformation of fluid. The rotational kinetic energy of fluid is AmV_0^2, the value of A is ?

34. A ring of mass m = 2 kg and radius r = 4 m rolls without sliding on a fixed vertical cylinder of radius R = 20 m. For the position shown in the figure, find the magnitude of frictional force in newton if $\theta = 30°$.

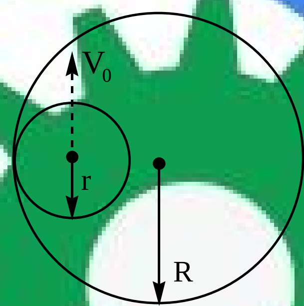


35. A uniform rod AB of mass M and length $\sqrt{2}\,R$ is moving in a vertical plane inside a hollow sphere of radius R. The sphere is rolling on a fixed horizontal surface without slipping with velocity of its centre 2v. When the end B is at the lowest position, its speed is found to be v as shown in the figure. If the kinetic energy of the rod at this instant is $\frac{4}{K}Mv^2$. Find K.



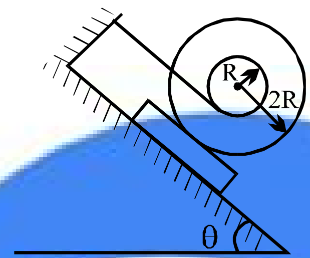
MATCHING

36. A uniform disc of radius r and mass m is at rest inside a cylindrical room of radius R with its flat surface lying on the floor of room and its periphery just touching the wall of the room. Figure shows the top view of the room and disc. There is no friction between floor and disc. The friction coefficient between wall and disc is μ. The disc is given an impulse, which imparts a velocity V_0 to its centre of mass, tangential to wall of room and initial angular velocity is zero. Given that $V_0 = 20\,m/s$, m = 2kg, $\mu = 0.5$, R = 5m and r = 1m and $g = 10\,m/s^2$. Some values are given in column II in SI units match these value to the corresponding quantities of column I



	Column I		Column II
A)	The time at which disc starts pure rolling is	P)	$\frac{40}{3}$
B)	The speed of centre of mass of disc when it starts pure rolling is	Q)	$\frac{4}{20}$
C)	The angular velocity of disc about its centre after it starts pure rolling is	R)	$\frac{800}{9}$
D)	Normal force acting on the disc when it starts pure rolling is	S)	$\frac{820}{9}$
		T)	10/3

37. In the arrangement shown here friction between the spool of mass m, moment of inertia I and the plank of mass M is sufficient to prevent sliding and incline makes angle θ with horizontal. There is no slipping of rope. Assume that the system starts from rest rolling.



	Column-I		Column-II
A)	When m > M and there is no friction between the plank's and the inclined surface	P)	Plank will ascend
B)	When M > m and there is no friction between the plank's and the inclined surface	Q)	Plank will descend
C)	When m = M and there is no friction between the plank's and the inclined surface	R)	Plank will remain stationary
D)	When m = M and friction coefficient between the plank's and the inclined surface is tan θ	S)	Spool may rotate clockwise
		T)	Spool may rotate anticlockwise

PART-A_LEVEL-I_(THEORY)_KEY

1	2	3	4	5	6	7	8	9	10
B	B	D	D	A	B	C	C	B	B
11	12	13	14	15	16	17	18	19	20
C	BD	ACD	AC	B,D,E,E,E	D,D,A,A,A	B	B	A	C
21	22			23					
8	A–PT,B–QST,C–PT,D–QS			-					

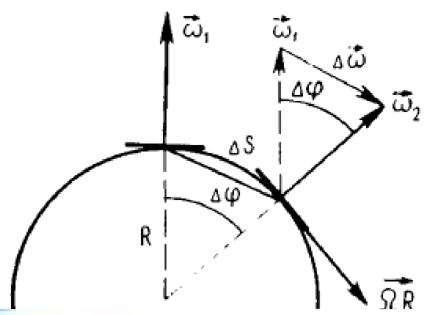
23.

1.19. In the course of time Δt the angular velocity vector will vary from $\boldsymbol{\omega}_1$ to $\boldsymbol{\omega}_2$ without changing its length. The direction of the vector will change by an angle of $\Delta\varphi$. This angle is equal, on the one hand, to $|\Delta\boldsymbol{\omega}|/\omega$ and, on the other, to $\Delta S/R$, where ΔS stands for the displacement of the center of the wheel.* This displacement is equal to $\Omega R \Delta t$, where Ω is the angular velocity of the center of the wheel. Thus,

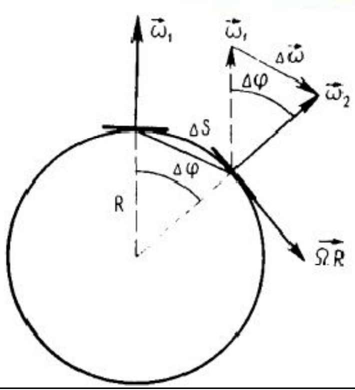
$$|\Delta\boldsymbol{\omega}|/\omega = \Omega R \Delta t / R \quad \text{and} \quad \varepsilon = \lim_{\Delta t \to 0} \frac{\Delta\omega}{\Delta t} = \omega\Omega.$$

When the wheel is rotating, the point at which it touches the arena will shift in the course of Δt by a distance of $r\omega\Delta t$ on the wheel and by $R\Omega\Delta t$ on the arena. Hence, ω and Ω are linked by the following formula: $\omega r = \Omega R$, whence

$$\varepsilon = \omega^2 \frac{r}{R}.$$



* It is assumed that $\Delta\varphi \ll 1$ rad.



PART-B_LEVEL-II_(APPLICATION)_KEY

1	2	3	4	5	6	7	8	9	10
B	A	B	C	A	4	C	A	AC	BC
11	12	13	14	15	16	17	18	19	20
CD	ABC	ABCD	BD	ABC	AC	B	A	A	B
21	22	23	24	25	26	27	28	29	30
A	B	C	A	7	1	4	1	3	9
31	32	33	34	35	36	37			
1	2	3	5	3	A-Q, B-P, C-P, D-S	(A) P,S (B) Q,T (C) R, (D) R			

"Please kindly report any error (with proper explanation) if found in key to physicssirjee@gmail.com with a subject line : Error in key in Rotation part-2 "