ROTATIONAL MECHANICS PROBLEMS

Q.1. A mass m is moving with a constant velocity v_0 along a line y = -a and away from the origin. Find the magnitude of its angular momentum with respect to origin.

Q.2. A solid cylinder of mass M and radius R rolls down an inclined plane with height h without slipping. Find the speed of its centre of mass when it reaches its bottom.

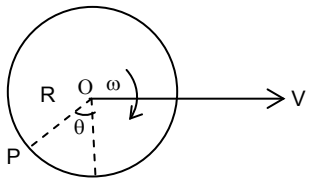
Q.3. If the radius of the earth were to contract to half its present value, find the new period. The angular velocity of earth about its own axis is $\frac{2\pi}{24}$ rad./hr.

Q.4. The centre of a wheel rolling on a plane surface moves with a speed v_0. Find the speed of a particle P on the rim of the wheel at the same level as the centre and another particle Q on the rim just below centre.

Q.5. A circular disc rolls down an inclined plane with a height 'h' from horizontal surface. Find
(a) Direction of friction force on disc
(b) What will be the fraction of the total energy associated with its translational energy?
(c) Is there any work done by friction force (yes/no) ?

Q.6. A circular disc rolls down an inclined plane with a height 'h' from horizontal surface. Find
(a) Direction of friction force on disc
(b) What will be the fraction of the total energy associated with its translational energy?
(c) Is there any work done by friction force (yes/no) ?
(c) In case of rolling, there is no slipping so work done by the friction force is zero.

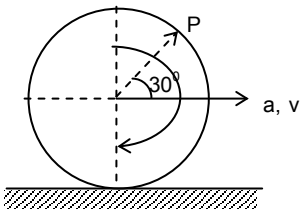
Q.7. Show that in case of pure rolling the speed of a point P on the circumference of the body shown at the instant in figure is 2V sin $\theta/2$ or $2R\omega$ sin $(\theta/2)$



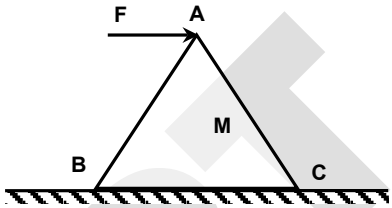
Q.8. A mass m is moving with a constant velocity v_0 along a line y = -a and away from the origin. Find the magnitude of its angular momentum with respect to origin.

Q.9. A solid cylinder of mass M and radius R rolls down an inclined plane with height h without slipping. Find the speed of its centre of mass when it reaches its bottom.

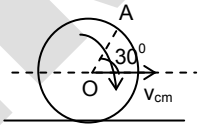
Q.10. A disc of radius R is rolling on a horizontal surface. If the acceleration of centre of mass of the disc is a and velocity is v. Find the acceleration of point P at the instant represented in the figure.



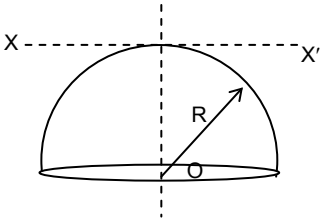
Q.11. A constant horizontal force (F) is applied at the vertex A of an equilateral triangular wedge ABC of mass M and side length AB=BC=CA= ℓ, placed on a rough horizontal surface as shown in the figure. Even after the application of force F the wedge remains stationary. Calculate the torque of normal reaction acting between the wedge and the floor about the vertex B.



Q.12. A disc of mass m is rolling on a rough surface. The velocity of centre of mass of disc is 10 m/s. Find the velocity of point A which makes an angle 30^0 from horizontal anticlockwise as shown in figure. (There is no slipping at point of contact.)



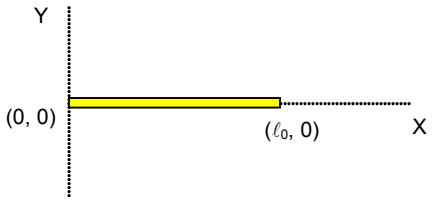
Q.13. Find the moment of inertia of a thin uniform hemispherical shell of mass M and radius R about axis XX′.



Q.14. A metre rod of mass 2kg is placed on a horizontal frictionless surface. A force of 10N is constantly applied (constantly) at a distance ¾ from one of its end. The rod is free to rotate about an axis passing though one of its end. Find the angular displacement of the centre of mass of the rod in first 1 sec.

Q.15. A 10 m long ladder rests against a vertical wall and makes an angle of 60^o with the horizontal floor. If it starts to slip, then find the position of its instantaneous axis of rotation.

Q.16. A rod of length ℓ_0 is lying on X axis between points (0, 0) and (ℓ_0, 0) as shown. The mass per unit length λ varies with x as $\lambda = \lambda_0 x$. Find the moment of inertia of the rod about Y-axis.

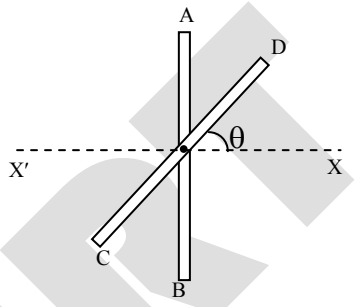


Q.17. A uniform rod AB of mass m and length ℓ is at rest on smooth horizontal surface. An impulse P is applied to the end B perpendicular to the length of the rod. The time taken by the rod to turn a angle θ is $\frac{\pi mL}{24P}$. Find θ.

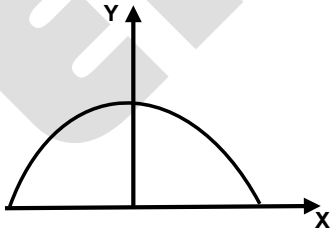
Q.18. (a) A wheel rotates about a stationary axis so that the rotation angle θ varies with time as $\theta = at^2$ where a = 0.2 rad/sec^2. Find the magnitude of net acceleration of the point A at a distance 0.65m from the axis at the time t = 2.5 sec.

(b) The position of a particle moving along a straight line varies with time according to law $x = t^2 - 4t + 4$. Draw approximate distance vs time and acceleration vs time graph.

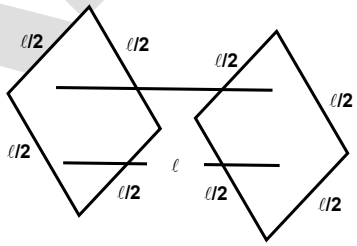
Q.19. Two identical thin rods AB and CD having mass 'M' and length 'L' as fixed as shown. Find the moment of inertia of the system about axis XX′.



Q.20. A semi circular ring of mass 1 kg and radius 0.5 m is held at rest in x-y plane. The ring is dislodged gently from the position of rest. Find the angular velocity with which it strikes the surface under no slip condition. [Assume the diameter is parallel to the horizontal surface.]

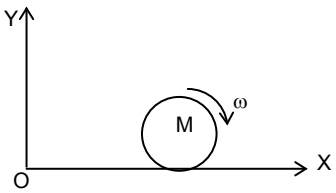


Q.21. Two lamina of equal length and breadth are to be rotated about an axis passing through centre of the lamina. Two lamina are attached with the light rod of length □, joining the centre of two lamina. If applied torque is 10 N-m, find the angular velocity of the lamina after 2 sec from the start.

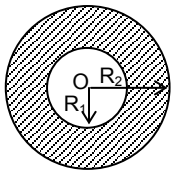


Q.22. A wheel rotates with an angular acceleration given by $\alpha = 4at^3 - 3bt^2$, where t is the time and a and b are constants. If the wheel has initial angular speed ω_0, write the equations for the (i) angular speed (ii) angular displacement.

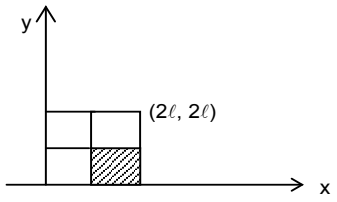
Q.23. A disc of mass M and radius R is rolling with angular speed ω on a horizontal plane as shown. Find magnitude of angular momentum about centre of mass.



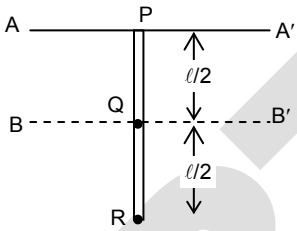
Q.24. A uniform disc of radius R_2 has a concentric round cut of radius R_1 as shown in the figure. The mass of the remaining (shaded) portion of the disc is M. Find the moment of inertia of such a disc relative to the axis passing through its centre and perpendicular to the plane of the disc.



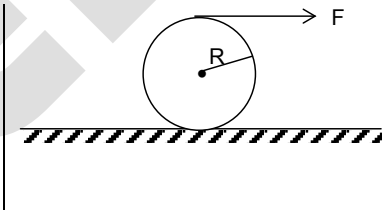
Q.25. A uniform square of side 2ℓ is divided into four square. If one of them is cut off (represented by shaded region in figure) then find the position of centre of mass of the remaining portion.



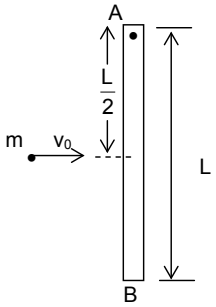
Q.26. A rod of length ℓ and mass M can rotate freely in a vertical plane about P. Two small fixed beads on the rod each has mass (m = M/2) are fixed at points Q and R as shown in figure. find moment of inertia about
(a) the axis AA′.
(b) the axis BB′ which is parallel to AA′



Q.27. A constant tangent force F acts at the top of a solid cylinder of mass m and radius R so that the cylinder rolls on a horizontal surface without slipping. Find the magnitude and the direction of the friction force exerted by the cylinder on the surface.

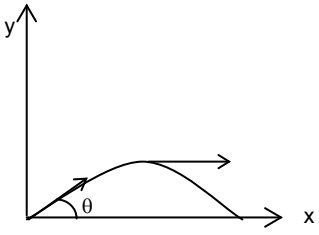


Q.28. A uniform rod AB which is free to swing in the vertical plane about a horizontal axis through A, is hanging freely. A particle of equal mass strikes the rod with a velocity v_0 and gets stuck to it. Find the angular velocity of the combination immediately after the collision.



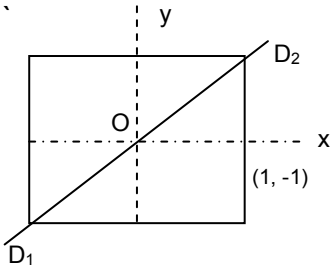
Q.29. A circular disc roll down an inclined plane, then what will be the fraction of the total energy associated with its rotational energy.

Q.30. A particle of mass m is projected with velocity v at an angle θ with the horizontal. Find its angular momentum about the pint of projection when it is at the highest point of its trajectory.



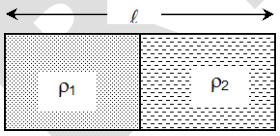
Q.31. One end of a massless spring of spring constant 100 N / m and natural length 0.5 m is fixed and the other end is connected to a particle of mass 0.5 kg lying on a frictionless horizontal table. The spring remains horizontal. If the mass is made to rotate at an angular velocity of 2 rad/s, find the elongation of the spring.

Q.32. Moment of inertia of a square plate about a diagonal is MK^2. where K is radius of gyration. Find the moment of inertia about the axis perpendicular to the plane of the plates and passing through the centre of the plate.

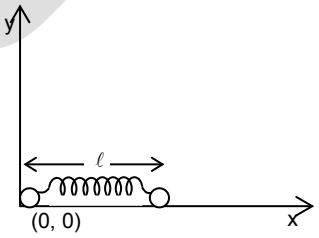


Q.33. A uniform circular disc of radius R and moment of inertia I is placed on a frictionless horizontal plane. Another identical disc having rough surface rotating with angular velocity ω is gently placed on the top of the first disc. Calculate the final angular velocity and the loss of kinetic energy.

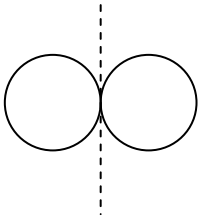
Q.34. Half of the rectangular plate shown in fig is made of a material of density ρ_1, and other half of density ρ_2. The length of the plate is ℓ. Locate the centre of mass of the plate.



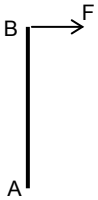
Q.35. Two particles of same mass m are connected by a light spring of natural length ℓ. This system is placed along x-axis as shown in figure. If at t = 0 particle at origin is given a velocity $v_0\,\hat{i}$ then find position of centre of mass at any time t.



Q.36. Two uniform discs of m and radius r are joined as shown in figure. Find moment of inertia of combined body about common tangent in the plane of discs.

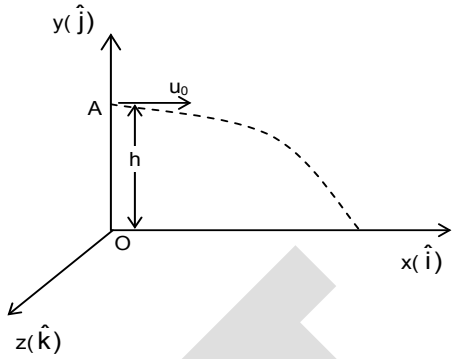


Q.37. A uniform bar AB of mass m and length ℓ is resting on a smooth horizontal surface. A force F is applied at end B perpendicular to AB. Find initial acceleration of end B w.r.t. ground.



Q.38. Calculate the radius of gyration of a thin rod of mass 1 kg and length 100 cm about an axis passing through its centre of gravity and perpendicular to its length.

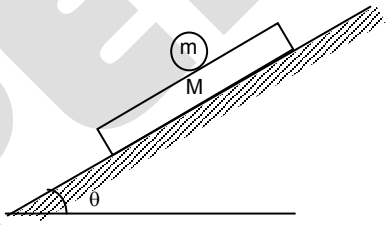
Q.39. A particle of mass m is projected horizontally from a point A with speed u_0. The point A is at a height h from the ground, and the particle is projected in the xy plane as shown in the figure. Find the angular momentum of the particle about the point O, when it reaches the ground.



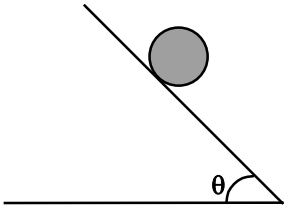
Q.40. There is a equilateral triangular solid plate of mass m and edge length a. Find the moment of inertia of the plate about an axis along the edge and in the plane of the edge.

Q.41. (a) A wheel rotates about a stationary axis so that the rotation angle θ varies with time as $\theta = at^2$ where a = 0.2 rad/sec^2. Find the magnitude of net acceleration of the point A at a distance 0.65m from the axis at the time t = 2.5 sec.

Q.42. On a smooth inclined plane, a plank of mass M is placed. A cylinder of mass m is placed over the plank. If plank and cylinder is released from rest. Find the acceleration of cylinder. Assume friction between cylinder and plank is sufficient to prevent slipping.



Q.43. Starting from rest, a sphere rolls down an incline. What is the value of the of static friction if there is to be no slipping.



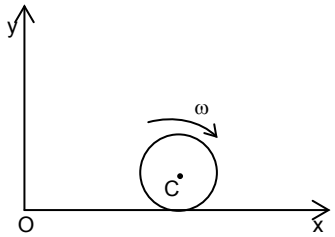
Q.44. A uniform disc of mass M and radius R is rotating with angular speed ω on a smooth horizontal plane as shown.

(a) Find the magnitude and sense of angular momentum about centre of mass .

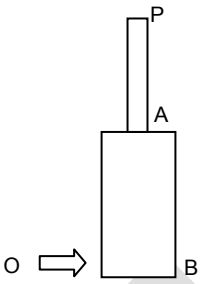
(b) Find the magnitude and sense of angular momentum about O.

(c) In case disc is rolling with angular speed ω on a horizontal plane as shown, find magnitude of angular momentum about

(i) C (ii) O

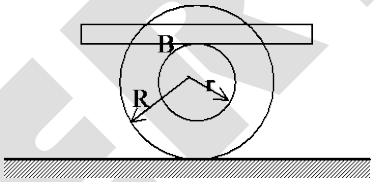


Q.45. Two uniform rods A and B of length 0.6 m each and of masses 0.01 kg and 0.02 kg respectively are rigidly joined end to end. The combination is pivoted at the lighter end P as shown in figure, such that it can freely rotate about point P in a vertical plane. A small object 'O' of mass 0.05 kg moving horizontally, hits the lower end of the combination and sticks to it. What should be the velocity and the object so that the system could just be raised to the horizontal position?

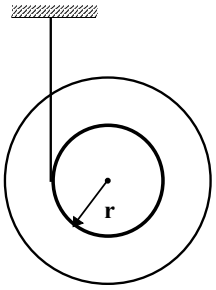


Q.46. A uniform circular disc of mass 200 g and radius 4.0 cm is rotated about one of its diameter at an angular speed of 10 rad/s. Find the kinetic energy of the disc and its angular momentum about the axis of rotation.

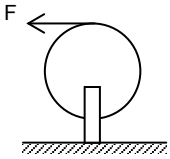
Q.47. A bobbin is pushed along on a rough stationary horizontal surface as shown in the figure. The board is kept horizontal and there is no slipping at any contact points. Find the distance moved by the board when distance moved by the axis of the bobbin is ℓ.



Q.48. A YO – YO of mass M and moment of inertia I about its c.m. is having a shaft of radius r around which a string is wound. The YO - YO starts from rest and unwinds itself. Show that the tension in the string during descent is given by $\left(\frac{MgI}{Mr^2 + I}\right)$



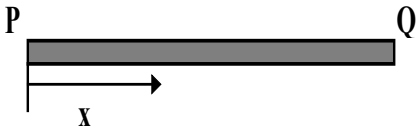
Q.49. A string is wrapped around the rim of a wheel of moment of inertia 0.20 kg-m^2 and radius 20 cm. The wheel is free to rotate about its axis. Initially, the wheel is at rest. The string is now pulled by a force of 20 N. Find the angular velocity of the wheel after 5.0 sec.



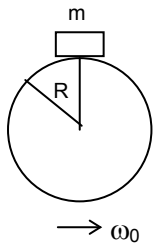
Q.50. Linear mass density of a rod PQ of length *l* and mass m is varying with the distance x (from P) , as $\lambda = \frac{m}{2l}(1 + ax)$

(i) Determine the value of a

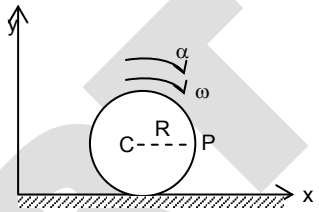
(ii) also determine the distance of c.m. from the end P.



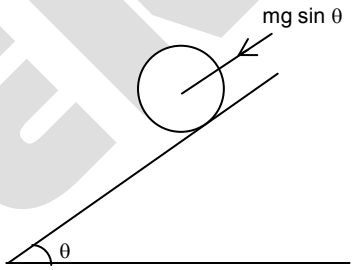
Q.51. On the top of a smooth sphere of radius R a small body is placed when the sphere is imparted a constant acceleration ω_0 in the horizontal direction, the body begin sliding down. Find at the moment of break off the velocity of the body relative to the sphere.



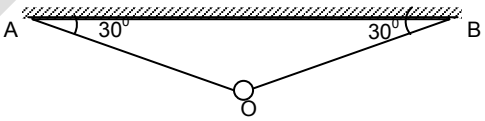
Q.52. A disc of radius R is undergoing pure rolling with constant angular acceleration α. at some instant its angular velocity is ω. At that particular instant find out acceleration of point P with respect to ground as shown in the figure.



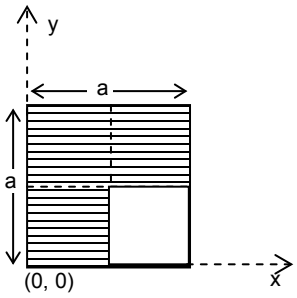
Q.53. A constant force F = mg sin θ is applied at the centre of a uniform disc. Force is always parallel and down the plane as shown in figure. Find out minimum coefficient of friction between inclined plane and disc so that pure rolling is possible.



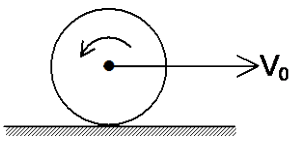
Q.54. A particle of mass m is suspended with two similar light, inextensible strings OB and OA as shown in the figure. If string OB is cut then calculate the ratio of tension in string OA before cutting OB and after cutting OB.



Q.55. A uniform plate of side a is placed as shown in the figure. Now $(1/4)^{th}$ portion is removed (right – bottom portion). Find out position of centre of mass of the system.

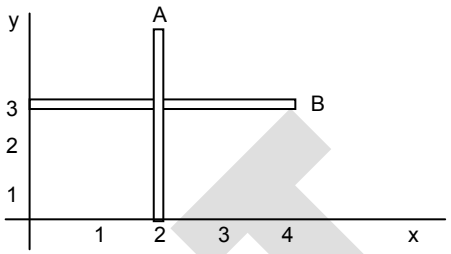


Q.56. A solid disc of mass m and radius r is given a velocity V_0 and an angular velocity of $\frac{2V_0}{r}$ as shown. It is then placed on a rough horizontal surface, whose coefficient of friction is μ . Find the time after which the sphere will start rolling without sliding.



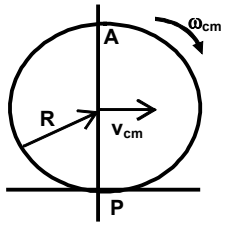
Q.57. A force F acts tangentially at the highest point of a sphere of mass m kept on a rough horizontal plane. If the sphere rolls without slipping, find the acceleration of the centre of the sphere.

Q.58. Two uniform rods A, B of equal length 4 m and masses 18 kg and 9 kg are placed along x = 2 m & y = 3 m as shown in the figure. Find coordinates of CM of system and moment of inertia of the system about axis passing through CM and along z axis.



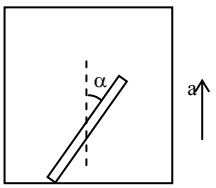
Q.59. A uniform solid sphere of mass m and R starts rolling without slipping down an inclined plane of length L and inclination 30° to the horizontal. Find
(a) the frictional force and its direction.
(b) work done by the frictional force.
(c) linear speed and linear acceleration of the sphere as a function of time.

Q.60. A disc of mass M and radius r is rolling without slipping with constant of motion as $v_{cm} = v_0$, $\omega_{cm} = \omega_0$ on a rough horizontal surface. At t = 0 a particle of mass m(m<<<M) gets detached from the point A of the disc. Assume that at t= 0, the lower most point 'P' is at origin. Find the co-ordinate of the particle and centre of mass of the disc when particle strike the ground. Assume that the particle does not strike the disc during its flight.



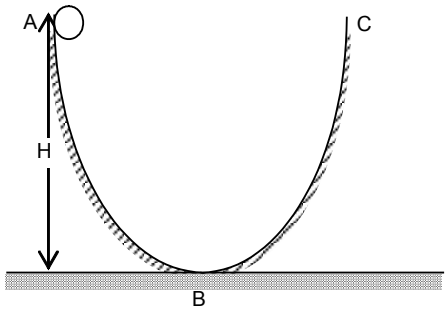
Q.61. A uniform rod of length ℓ is initially held with one end touching the smooth horizontal base of a lift, making an angle α with the vertical. The lift is moving upward with acceleration 'a', show that when the rod is released, its angular speed when it makes angle β with the vertical is given by

$$\omega = \sqrt{\frac{12(g+a)}{\ell}\frac{(\cos\alpha - \cos\beta)}{(1+3\sin^2\beta)}}$$



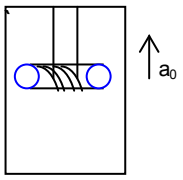
[6]

Q.62. A sphere of mass m and radius r is released from rest at point A on a track in vertical plane. From A to B track is rough enough to support rolling and form B onwards it is smooth. Find the maximum height attained by sphere from ground on its journey B onwards.

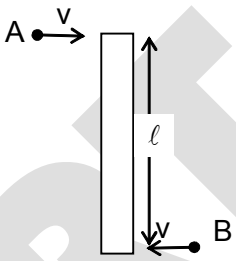


Q.63. Thin threads are tightly wound on the ends of a uniform solid cylinder of mass m. The free ends of the threads are attached to the ceiling of a lift. The lift starts moving up with

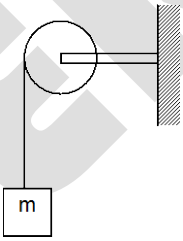
an acceleration a_0. Find the acceleration of the cylinder relative to the lift and the force F exerted by the cylinder on the ceiling.



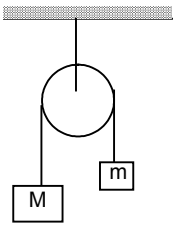
Q.64. Two particles A & B, each of mass m and moving with velocity v, hit the ends of a rigid bar of mass M and length ℓ simultaneously and stick to the bar. The bar is kept on a smooth horizontal plane (as shown). Find the linear and angular speed of the system (bar + particle) after the collision.



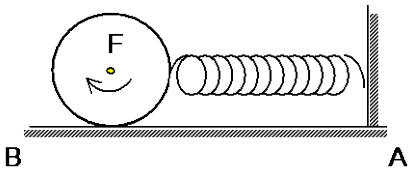
Q.65. A wheel of moment of inertia I and radius r is free to rotate about its center as shown in figure. A string is wrapped over its rim and a block of mass m is attached to the free end of the string and the system is released from rest. Find the speed of the block as it decends through a height h.



Q.66. The pulley shown in figure has a moment of inertia I about its axis and radius R. Find the magnitude of the acceleration of the two blocks. Assume that the string is light and does not slip on the pulley.



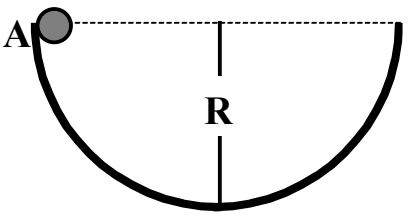
Q.67. A sphere of mass m and radius R rolls without sliding on a horizontal surface. It collides with a light spring of stiffness K with a kinetic energy E. If the surface (AB) under the spring is smooth, find the maximum compression of the spring.



Q.68. A rod AB of mass M and length L is lying on a horizonal frictionless surface. A particle of mass m travelling along the surface hits the end 'A' of the rod with a velocity v_0 in a direction perpendicular to AB. The collision is completely elastic. The particle comes to rest just after the collision.
(a) Find the ratio m/M.

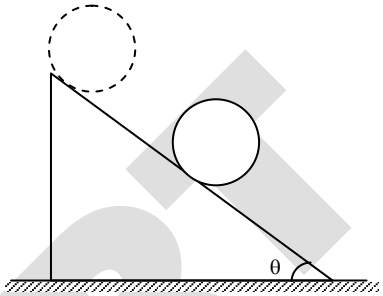
(b) A point P on the rod is at rest immediately after the collision. Find the distance AP.

Q.69. A small sphere of radius r is released from point *'A'* inside the fixed large hemispherical bowl of radius R as shown in figure. If the friction between the sphere and the bowl is sufficient enough to prevent any slipping then find
(a) what fractions of the total energy are translational and rotational , when the small sphere reaches the bottom of

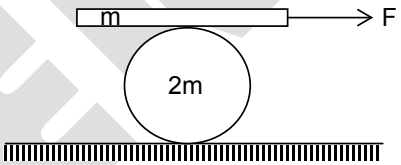


the hemisphere.
(b) and also the normal force exerted by the small sphere on the hemisphere when it is at the bottom of the hemisphere.

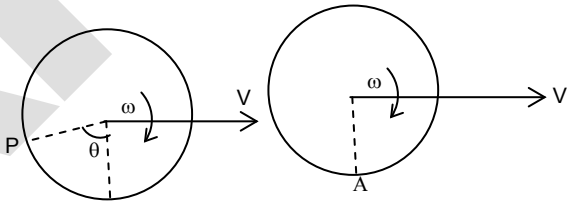
Q.70. Starting from rest, a uniform solid sphere of radius R rolls down on an incline plane. Find
(a) minimum value of the coefficient of static friction.
(b) angular acceleration about centre of mass and acceleration of centre of mass when it reaches on the bottom.



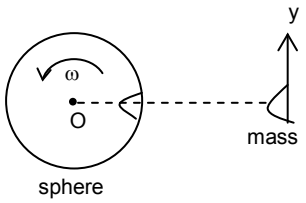
Q.71. A man pushes a cylinder of mass 2m with the help of a plank of mass m as shown in figure. There is no slipping at any contact. The horizontal component of the force applied by the man is F. Find the acceleration of plank and the acceleration of cylinder. The magnitude of force is 2mg.
Frictional forces are shown in diagram



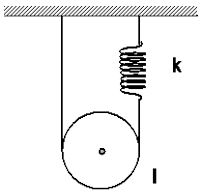
Q.72. (a) Show that in case of pure rolling the speed of a point P on the circumference of the body at the instant shown in figure is 2V sin θ/2 or 2Rω sin (θ/2)
(b) Using above find the distance travelled by the point A in one revolution of a disc of radius R rolls on a rough horizontal surface.



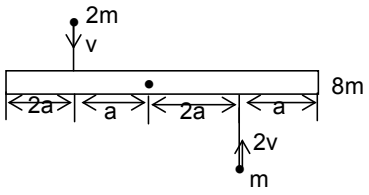
Q.73. A uniform solid sphere of mass 5 kg and diameter 2m is rotating about a fixed horizontal axis passing through its centre of mass 'O' at an angular velocity of 1 rad/sec. At a certain instant a certain mass 0.05 kg just separates out from the edge of the sphere and rises vertically upward from the point from which, its breaks off, find
(a) To what height above the point does it rise before it brings to fall.
(b) Angular momentum of the remaining part of the sphere.



Q.74. The pulley shown in figure has moment of inertia I about its axis and mass m. Find the time period of vertical oscillation of its cetre of mass. The spring has spring constant k and the string does not slip over the pulley.

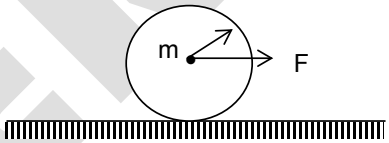


Q.75. A uniform bar of length 6a and mass 8m lies on a smooth horizontal table. Two point masses m and 2m moving in the same horizontal plane with speed v and 2v respectively, strike the bar as shown in figure and stick to the bar after collision. Calculate
(a) the velocity of the centre of mass.
(b) angular velocity about centre of mass.
(c) total kinetic energy just after collision.



Q.76. A ball is thrown in such a way that it slides with a linear speed v_0 initially without rolling.(a) Prove that it will roll without sliding when its linear speed falls to 5/7 v_0. The transition from pure sliding to pure rolling is gradual so that both sliding and rolling take place during this interval. (b) Find the distance travelled by the ball during the period of transition from sliding to rolling.(c) Also number of revolutions by the ball made during the period of transition.

Q.77. A force F is applied from its centre along horizontal direction
(i) Find direction and magnitude of frictional force acting on the cylinder. (No slipping)
(ii) Find maximum acceleration of cylinder without causing slip. Coefficient of friction between cylinder and surface is μ.

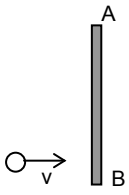


Q.78. (a) An electric motor shaft starts from rest and on the application of a torque, it gains an angular acceleration given by $\alpha = 4t - t^2$ during the first three seconds. For t > 3sec, $\alpha = 0$. Find its angular velocity after 5 seconds.
(b) Find the acceleration of a solid cylinder of radius R and mass M, rolling without slipping down an inclined plane of angle θ.

Q.79. (a) A cubical block of mass m and edge a slides down a rough inclined plane of inclination θ with a uniform speed. Find the torque of the normal force acting on the block about its centre.
(b) A spherical shell of mass m and radius R is released on an inclined plane of inclination θ. What should be the minimum coefficient of friction between the shell and the plane, to prevent slipping

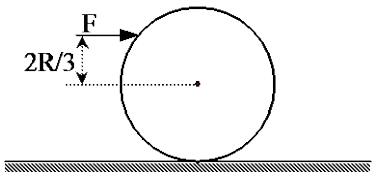
Q.80. A tall chimney cracks near its base and falls over. Express
(i) the radial and (ii) the tangential acceleration of the top of chimney as a function of the angle θ made by the chimney with the vertical.

Q.81. A uniform rod AB of mass 2m and length ℓ is resting on a smooth horizontal table. A particle of mass m strikes the end B perpendicularly with velocity v_0 and moves with velocity $v_0/2$ in same direction just after collision calculate coefficient of restitution between particle and rod.

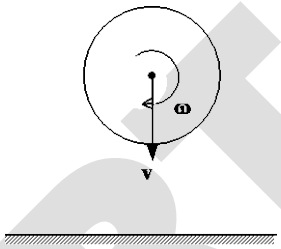


Q.82. A cylinder of mass 6 Kg lies on a rough horizontal surface. The coefficient of friction between the cylinder and the surface is $\mu = 0.2$. A constant force F

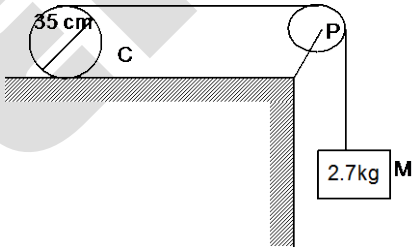
acts horizontally on the cylinder. The line of action of the force F is at a height $\frac{2R}{3}$ above the centre of the cylinder. Find the maximum value of F if the cylinder rolls without slipping



Q.83. A rotating ball hits a rough horizontal plane with a vertical velocity v and angular velocity ω. Given that the co-efficient of friction is μ and the vertical velocity of the ball after the collision is v/2, find the angular velocity after collision.

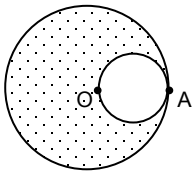


Q.84. A chord passes over a frictionless pulley P as shown in the fig. carrying a mass M of 2.7 kg at one end and wrapped around a solid cylinder C of mass 8.1 kg which is free to roll on a smooth horizontal plane. What is the acceleration of 2.7 kg mass if the cylinder rolls without slipping ?

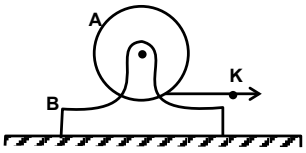


Q.85. In a double star, two stars (One of mass 'm' and the other '2m') distance 'd' apart rotate about their common centre of mass with same angular velocity ω. Find the ratio of their individual angular momenta and their individual kinetic energies.

Q.86. Inside the uniform isolated solid sphere of mass M and radius R a spherical cavity of radius R/2 is formed as shown in figure. A small particle of mass 'm' is now released from point A at the periphery of cavity; find the time taken by the particle to reach point O at the opposite end of cavity.

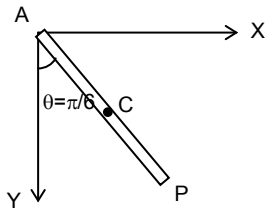


Q.87. A uniform solid cylinder A of mass m_1 can freely rotate about a horizontal axis fixed to a mount of mass m_2. A constant horizontal force F is applied to the end K of a light thread tightly wound on the cylinder. The friction between the mount and the supporting horizontal plane is assumed to be absent. Find the acceleration of the point K.



Q.88. A cart with mass M has four wheels (idealized as uniform discs), each of radius r and mass m. Find the acceleration of the cart when a horizontal force F is applied on it. There is no slipping between the wheels and the horizontal road.

Q.89. A uniform rod of length 1 m and mass 4 kg can rotate freely in a vertical plane about its end A. The rod is initially held in a horizontal position and then released. At the time the rod makes an angle 30^0 with the vertical, calculate



(a) its angular acceleration

(b) its angular velocity

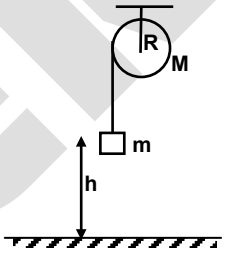
(c) its total acceleration vector of tip P (in terms of ω, ℓ, α, θ).

Q.90. A rod AB of mass M and length L is lying on a horizontal frictionless surface. A particle of mass m travelling along the surface hits the end 'A' of the rod with a velocity v_0 in a direction perpendicular to AB. The collision is completely elastic. The particle comes to rest just after the collision.

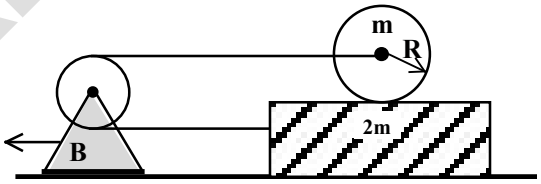
(a) Find the ratio m/M.

(b) A point P on the rod is at rest immediately after the collision. Find the distance AP.

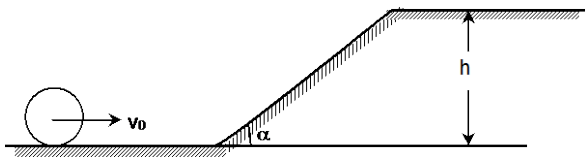
Q.91. A massless rope is wrapped several times on a disc of mass M and radius R. The other end is tied to a mass m which at the beginning is at a height h above the ground as shown in figure, when released, find the time taken by the mass to touch the ground. Also find velocity of mass m when it touches the ground.



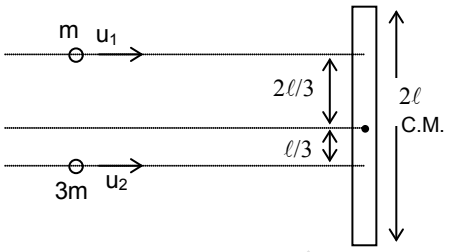
Q.92. A solid cylinder of mass m and radius R rest on a plank of mass 2M lying on an smooth horizontal surface. String connecting cylinder to the plank is passing over a massless pulley mounted on a movable light block B and the friction between the cylinder and the plank is sufficient to prevent slipping. If the block B is pulled with a constant force F, find the acceleration of the cylinder and that of the plank.



Q.93. A cylinder of mass M and radius R is given a linear velocity v_o on a rough horizontal plane with coefficient of friction μ. The horizontal surface turns into a rough incline with inclination α with horizontal which again turns into a horizontal at a height h form initial surface as shown. Find the maximum value of v_o so that the cylinder rolls from inclined plane to top horizontal plane without being separated from the surface. Assume that the friction to be sufficient for pure rolling at each surface and cylinder starts pure rolling before climbing the incline without experiencing any shock at bottom of incline.



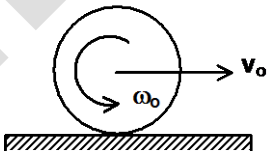
Q.94. A uniform rod of mass 4m, length 2ℓ (=2meter) is kept on a smooth horizontal surface. Two balls of masses m and 3m moving with velocities u_1 = 20 m/s, u_2 = 10 m/s respectively, hit simultaneously on the rod. The direction of their velocities are perpendicular to length of the rod and immediately after collision both balls come to rest. Find



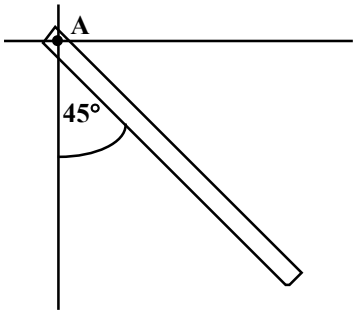
(a) velocity of the centre of mass of the rod, immediately after collision.
(b) angular velocity of the rod about its centre of mass, immediately after collision.

Q.95. A rod AB of mass M and length L is lying on a horizontal frictionless surface. A particle of mass m traveling along the surface hits the end 'A' of the rod with a velocity v_0 in a direction perpendicular to AB. The collision is completely elastic. The particle comes to rest just after the collision.
(i) Find the ratio m/M.
(ii) A point P on the rod is at rest immediately after the collision. Find the distance AP.
(iii) Find the linear speed of the point P at a time $\pi L/(3v_0)$ after the collision.

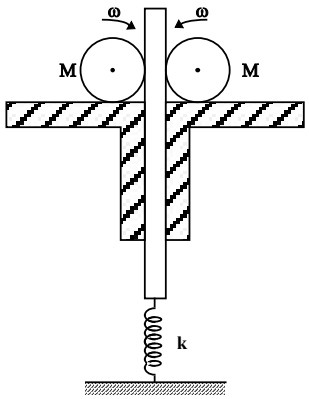
Q.96. A disc of radius R is spun to an angular speed ω_o about its axis and then imparted a horizontal velocity of magnitude $\frac{\omega_0 R}{4}$ (at t = 0) with its plane remaining vertical. The coefficient of friction between the disc and the plane is μ. The sense of rotation and direction of its linear speed are shown in the figure. Will the disc return to its initial point? If yes, how long will it take to return?



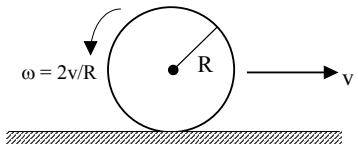
Q.97. A rod of length 1m and mass 4 kg , can rotate freely in a vertical plane around its end A. The rod is initially held in a horizontal position and then released. At the time the rod makes an angle 45°with the vertical, calculate
(a) its angular acceleration ,
(b) its angular velocity, and
(c) the magnitude of the force exerted by the rod at the pivot.



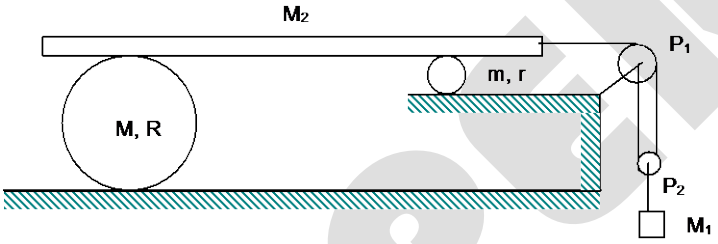
Q.98. In the given figure the rough horizontal surface has a frictionless vertical groove. A massless bar can move freely into the vertical groove. It is attached to a spring of force constant k. Now two solid spheres each of mass M are rotated to high angular velocity ω and placed in the corners as shown. The co-efficient of kinetic friction between the spheres and the bar, and between the spheres and the horizontal surface is μ. Find the compression of the spring.



Q.99. A solid sphere is set spinning about its centre and is given a translational velocity v when placed on the horizontal surface as shown in fig. Find the linear speed of the sphere.
(i) when it stops rotating and
(ii) when slipping finally ceases and pure rolling starts.

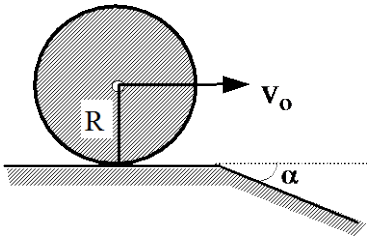


Q.100. A plank of mass M_2 = 1 kg is kept on two rollers of masses M = 5 kg and m = 2.5 kg respectively and radius R = 20 cm and r = 10 cm respectively. One end of the plank is attached with a string which passes through two light pulleys P_1 and P_2. A block M_1 = 1 kg is suspended through the pulley P_2 as shown in figure. If the system is released from rest, then find the
(a) acceleration of the block M_1
(b) magnitude and direction of force of friction acting on bigger roller
(c) acceleration of smaller roller

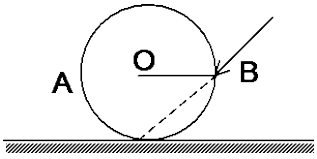


Q.101. A ball of radius r is released from the top of a rough hemispherical surface of radius of curvature R so that the ball rolls without sliding. Find the tangential speed of the ball at the time of losing contact with the hemi-spherical surface.

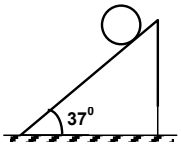
Q.102. A uniform solid cylinder of radius R = 15 cm rolls over a horizontal plane passing into an inclined plane forming an angle $\alpha = 30^o$ with the horizontal. Find the maximum value of the velocity v_o which still permits the cylinder to roll onto the inclined plane section without a jump. The sliding is assumed to be absent.



Q.103. AB is a horizontal diameter of a ball of mass m =0.4 kg and radius R = 0.10 m. At time t = 0 a sharp impulse is applied at B at an angle 45^0 with horizontal as shown in figure so that the ball immediately starts to move with velocity v_0 = 10 ms^{-1}. Calculate
(i) the impulse, if μ = 0.1
(ii) velocity of ball when it stops sliding.
(iii) time t at that instant
(iv) horizontal distance travelled by ball till that instant
(v) energy lost due to friction.

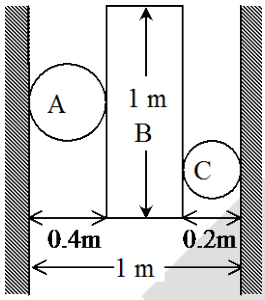


Q.104. A solid metallic sphere of mass m and radius R is free to roll (without sliding) over inclined surface of wooden wedge of mass m. Wedge lies on a smooth horizontal floor. When the system is released from rest.

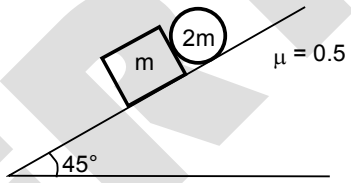


Find frictional force between sphere and wedge.

Q.105. Three cylinders A, B and C are held between two walls at a separation of 1m (see in figure). The length of cylinder B is 1m and mass 2.5 kg while the masses and diameters of A and C are 2 kg, 0.4m and 1 kg and 0.2 m respectively. The system is in a vertical plane and is released from rest. The cylinders A and C roll without slipping along the vertical wall and cylinder B. Find the acceleration of the cylinder B.



Q.106. A block of mass m and a cylinder of mass 2m are released on a rough inclined plane of inclination 45°. Coefficient of friction for all the surfaces of contact is 0.5. Find the accelerations of the block and the cylinder.



Q.107. A particle of mass m moving with a velocity $(3\hat{i}+2\hat{j})$m/s collides with a stationary body of mass M and finally moves with a velocity $(-2\hat{i}+\hat{j})$ m/s. If $\frac{m}{M}=\frac{1}{13}$ find

(a) the velocity of the mass M
(b) the impulse received by each
(c) the coefficient of restitution.