PHYSICS

BOOKS - HC VERMA PHYSICS (ENGLISH)

ROTATIONAL MECHANICS

Example

1. The motor of an engine is rotating about its axis with an angular velocity of 100

rev/minute. It comes to rest in 15 s, after being switched off. Assuming constant angular deceleration, calculate the number of revolutions made by it before coming to rest.

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2. Starting from rest, a fan takes five seconds to attain the maximum speed of 400 rpm (revolutions per minute). Assuming constant acceleration find the time taken by the fan in attaining half the maximum speed.

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3. A bucket is being lowered down into a well through a rope passing over a fixed pulley of radius 10 cm. Assume that the rope does not slip on the pulley. Find the angular velocity and angular acceleration of the pulley at an instant when the bucket is going down at at speed of 20 cm/s and has an acceleration of $4.0\frac{m}{s^2}$.

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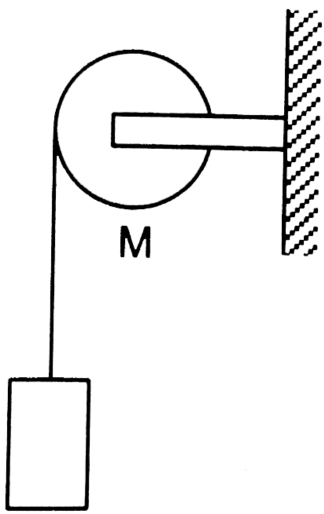
4. Consider a pulley fixed at its centre of mass by a clamp. A light rope is wound over it and the free end is tied to block. The tension in the rope is T. a. Write the forces acting on the pulley. How are they related? B. Locate the axis of rotation. c. Find the torque of the forces abut the axis of rotation.



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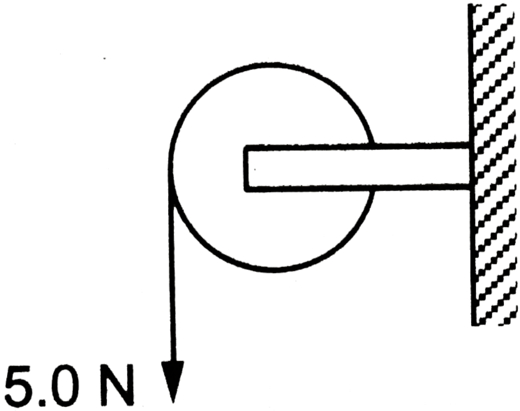
5. A wheel of radius 10 cm can rotate freely about its centre as shown in figure. A string is wrapped over its rim and is pulled by a force of 5.0 N. It is found that the torque produces an angular acceleration 2.0 $rads^{-2}$ in the wheel. Calculate the moment of inertia of the wheel.



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6. A wheel is rotating at an angular speed ω about its axis which is kept vertical. An identical wheel initially at rest is gently dropped into the same axle and the two wheels start rotating with a common angular speed. Find this common angular speed.

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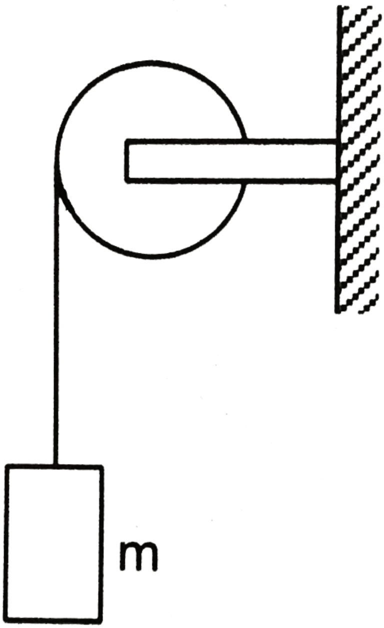
7. A wheel of moment of inertia I and radius r is free to rotate about its centre as shown in figure. A string is wrapped over its rim and a block of mass m is attached to the free end of the string. The system is released from rest. Find the speed of the block as it descends through a height h.



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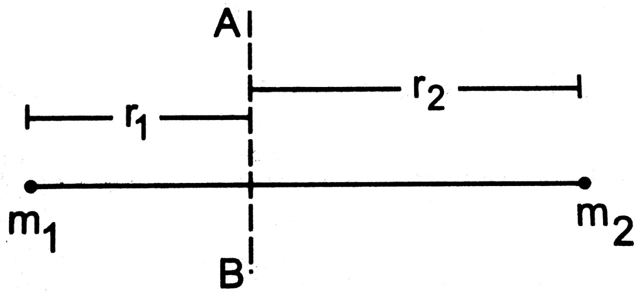
8. Consider a light rod with two heavy mass particles at its ends. Let AB be a line perpendicular to the rod as shown in figure. What is the moment of inertia of the system about AB?



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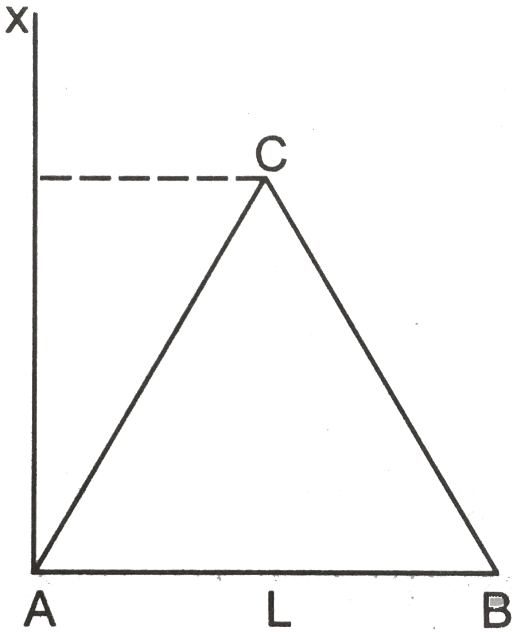
9. Three particles, each of mass m are situated at the vertices of an equilateral triangle ABC of side L as shown in the figure. Find the moment of inertia of the system about the line AX perpendicular to AB in the plane of ABC



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10. Find the moment of inertia of a uniform ring of mass M and radius R about a diameter.

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11. Find the moment of inertia of a solid cylinder of mass M and radius R about a line parallel to the axis of the cylinder and on the surface of the cylinder.

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12. A uniform sphere of mass 200 g rolls without slipping on a plane surface so that its centre moves at a speed of 2.00 cm/s. Find its kinetic energy.

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Worked Out Examples

1. A wheel rotates with a constant acceleration of $2.0 \frac{rad}{s^2}$. If the wheel starts from rest, how many revolutions will it make in the first 10 seconds?

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2. The wheel of a motor, accelerated uniformly from rest, rotates through 2.5 radian during the first second. Find the angle rotated during the next second.

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3. A wheel having moment of inertia 2 kg m^2 about its axis, rotates at 50 rpm about this axis. Find the torque that can stop the wheel in one minute.

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4. 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 it 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 seconds.

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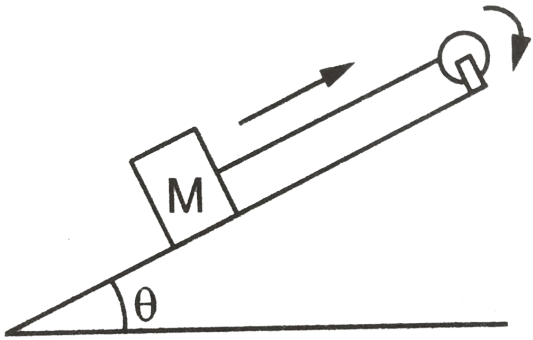
5. A wheel of radius r and moment of inertia I about its axis is fixed at top of an inclined plane of inclination θ as shown in figure. A string is wrapped round the wheel and its free end supports a block of mass M which can slide on the plane. Initially, the wheel is rotating at a speed ω in direction such that the block slides up the plane. How far will the block move before stopping?



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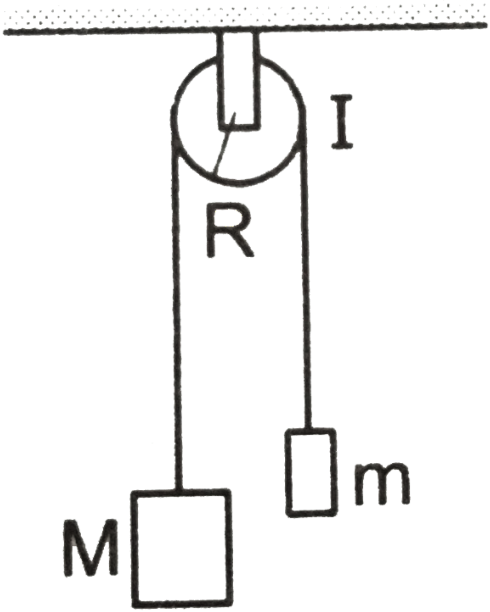
6. The pulley shown in figure has a moment of inertia I about it's axis and its radius is R. Find the magnitude of the acceleration of the two blocks. Assume that the string is light and does not slip on the pulley.



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7. Two small kids weighing 10 kg and 15 kg respectively are trying to balance a seesaw of

total length 5.0 with the fulcrum at the centre. If one of the kids is sitting at an end where should the other sit?

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8. A uniform ladder of mass 10 kg leans against a smooth vertical wall making an angle of 53^0 with it. The other end rests on a rough horizontal floor. Find the normal force and the frictional force that the floor exerts on the ladder

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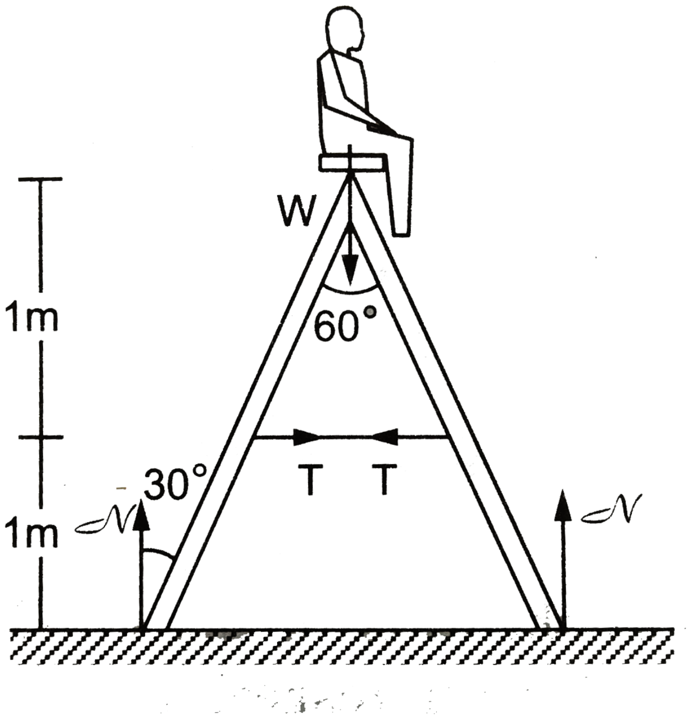
9. The ladder shown in figure has negligible mass and rests on a frictionless floor. The crossbar connects the two legs of the ladder at the middle. The angle between the two legs is 60^0. The fat person sitting on the ladder has a mas of 80 kg. Find the contact force exerted by the floor on each leg and the tension in the cross bar.



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10. Two small balls A and B each of mass m, are attached tightly to the ends of a light rod of length d. The structure rotates about the perpendicular bisector of the rod at an angular speed ω. Calculate the angular momentum of the individual balls and of the system about the axis of rotation.

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11. Two particles of mass m each are attached to a light rod of length d, one at its centre and the other at a free end, The rod is fixed at the other end and is rotated in a plane at an angular speed ω. Calculate the angular momentum of the particle at the end with respect to the particle at the centre

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12. A particle is projected at time t=0 from a point P wilth a speed v_0 at an angle of 45° to the horizontal. Find the magnitude and the direction of the angular momentum of the particle about the point P at time $t = \frac{v_0}{g}$

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13. 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.

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14. A wheel rotating at an angular speed of 20 rad/s is brought to rest by a constant torque in 4.0 seconds. If the moment of inertia of the wheel about the axis of rotation is 0.20 $kg - m^2$ find the work done by the torque in the first two seconds.

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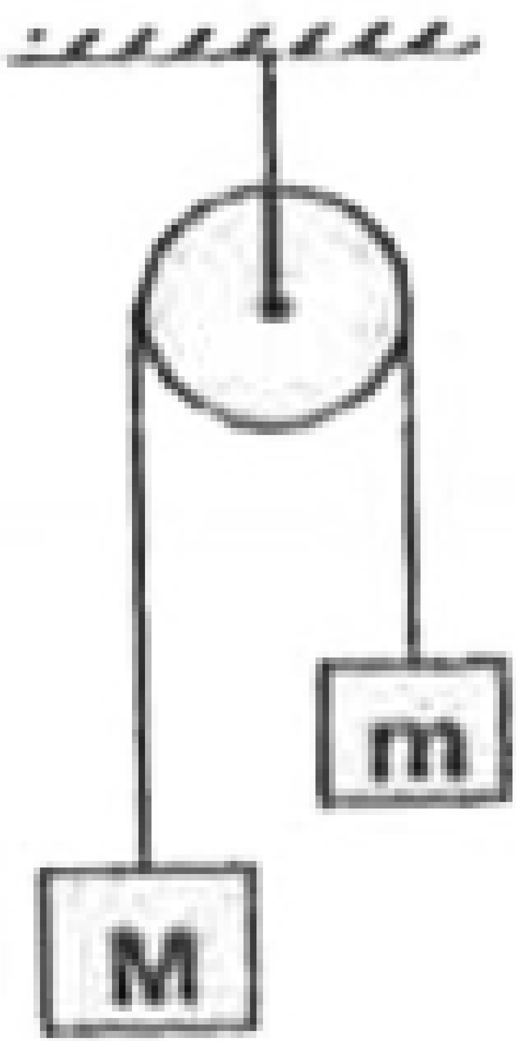
15. Two masses m and $M(m < M)$ are joined by a light string passing over a smooth and light pulley (as shown)



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16. Figure shows a mass m placed on a frictionless horizontal table and attached toa string passing through a mall hole in the surface. Initially, themas movesin a circle of radius r_0 with a speed v_0 and the ree end of the string is held by a person. The person pulls on the string slowly to decrease the radius of th circle of r. a. Find the tension in the string when the mass moves in the circle of radius r. b. Calculate the chasnge in the kinetic energy of the mass

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17. A uniform rod of mas m and length l is kept vertical with the lower end clamed. It is slightly pushed to let it fall down under gravity. Find its angular speed when the rod is passing through its lowest positon. Neglect any friction at the clamp. What will be the linear speed of the free end at this instant?

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18. Four particles each of mass 'm' are kept at the four corners of a square of edge 'a'. Find the moment of inertia of the system about a line perpendicular to the plane of the square and passing through the center of the square.

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19. Two identical spheres each of mass 1.20 kg and radius 10.0 cm are fixed at the ends of a light rod so that the separation between the centers is 50.0 cm. Find the moment of inertia of the system about an axis perpendicular to the rod passing through its middle point.

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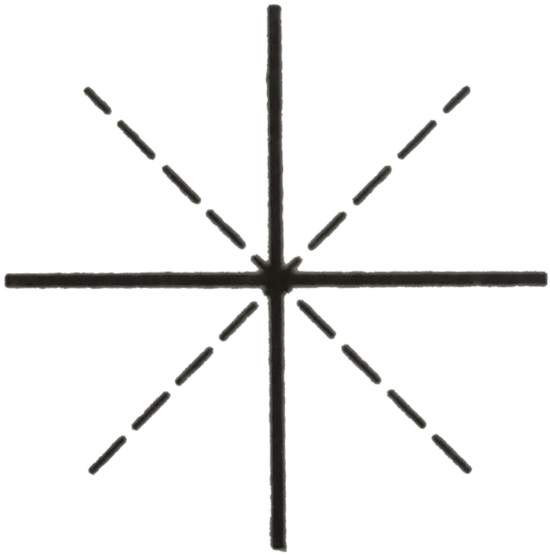
20. Two uniform identicla rods each of mass M and length l are joined to form a cross as shown in figure. Find the momet of inertia of the cross about a bisector as shown doted in the figure



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21. A uniform rod of mass M and length a lies on a smooth horizontal plane. A particle of mass m moving at a speed v perpendicular to the length of the rod strikes it at a distance $\frac{a}{4}$ from the centre and stops after the collision. Find a. the velocity of the cente of the rod and b. the angular velocity of the rod abut its centre just after the collision.

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22. A wheel of perimeter 220 cm rolls on a level road at a speed of 9 km/h. How many revolutions does the wheel make per second?

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23. A cylinder is released from rest from the top of an incline of inclination θ and length 'L'. If the cylinder rolls without slipping. What will be its speed when it reaches the bottom?

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24. A sphere of mass m rolls without slipping on an inclined plane of inclination θ. Find the linear acceleration of the sphere and the force of friction acting on it. What should be the minimum coefficient of static friction to support pure rolling?

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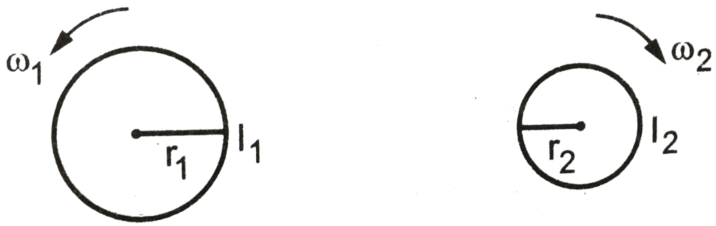
25. Figure shows two cylinders of radii r_1 and r_2 having moments of inertia I_1 and I_2 about their respective axes. Initially the cylinders rotate about their axes with angular speed ω_1 and ω_2 as shown in the figure. The cylinders are moved closer to touch each other keeping the axes parallel. The cylinders first slip over each other at the contact but the slipping finally ceases due to the friction between them. Find the angular speeds of the cylinders after the slipping ceases.



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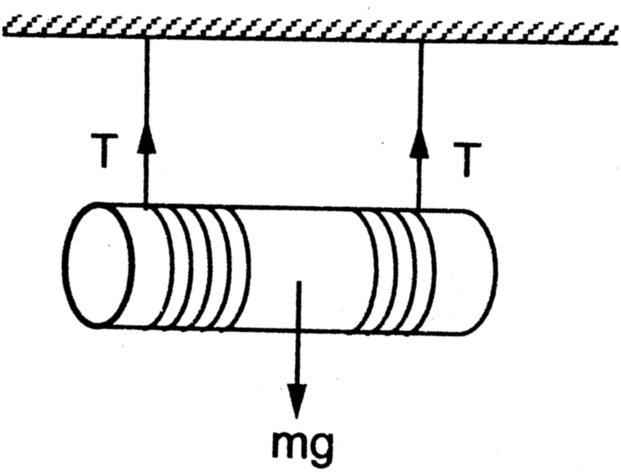
26. A cylinder of mass m is suspended through two strings wrapped around it as shwon in figure . Find a. the tension T in the string and b. the speed o the cylinder as it falls through a distance h.



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27. A force F acts tangentially at the highest point of a sphere of mass m kept on a rough horiozontal plane. If the sphere rolls withut slipping, find the accelerastioni of the centre of the sphere.

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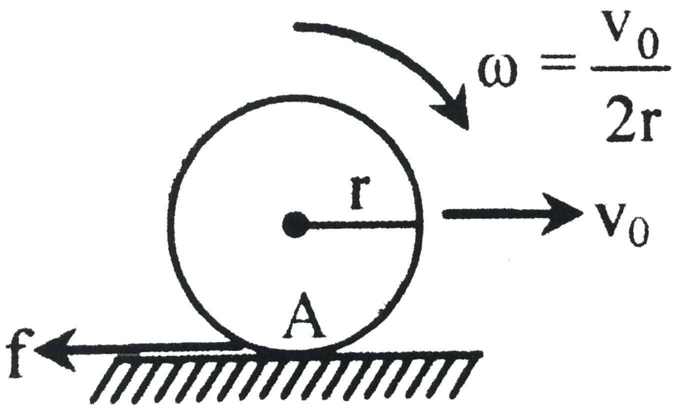
28. A sphere of mass M and radius r shown in figure slips on a rough horizontal plane. At some instant it has translational velocity V_0

and rotational velocity about the centre $\frac{v_0}{2r}$.

Find the translational velocity after the sphere starts pure rolling.



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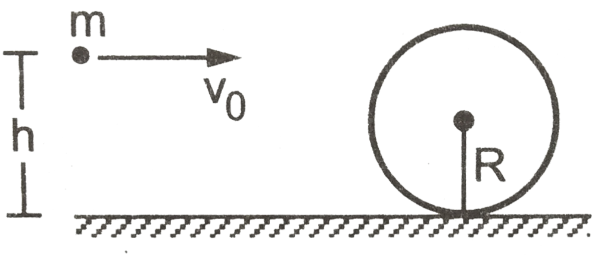
29. The sphere shown in figure lies on a rough plane when a particle of mass m travelling at a speed v_0 collides and sticks with it. If the line of motion of the particle is at a distance h above the plane, find a. the linear speed o the combined system just after the collision b. the angular speed of the system about the centre of the sphere just the collision c. the value of h for which the sphere starts pure rolling on the plane Assume that the mass M of the sphere is large compared to the mass of the particle so that the centre of mass of the combined system is not appreciably shifted from the centre of the sphere.



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Objective 1

1. Let $\overrightarrow{A}$ be a unit vector along the axis of rotation of a purely rotating body and $\overrightarrow{B}$ be a unit vector along the velocity of a particle P of

the body away from the axis. The value of $\overrightarrow{A} . \overrightarrow{B}$ is

A. 1

B. -1

C. 0

D. none of these

Answer: C

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2. A body is uniformly rotating bout an axis fixed in an inertial frame of reference. Let $\overrightarrow{A}$ be a unit vector along the axis of rotation and $\overrightarrow{B}$ be the unit vector along the resultant force on a particle P of the body away from the axis. The value of $\overrightarrow{A}\,.\,\overrightarrow{B}$ is

A. 1

B. -1

C. 0

D. none of these

Answer: C

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3. A particle moves with a constant velocity parallel to the X-axis. Its angular momentum with respect to the origin

A. is zero

B. remains constant

C. goes on increasing

D. goes on decreasing

Answer: B

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4. A body is in pure rotation. The linear speed 'v' of a particle, the distance 'r' of the particle from the axis and the angular velocity ω of the body are related as $\omega = \frac{v}{r}$. Thus

A. $\omega \propto \frac{1}{r}$

B. $\omega \propto r$

C. $\omega = 0$

D. ω is independent of r

Answer: D

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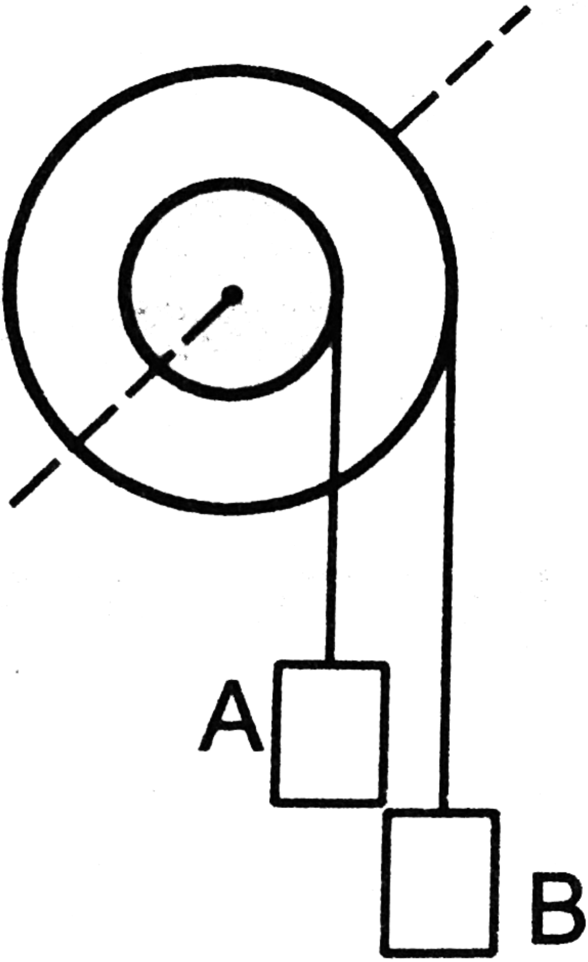
5. Figure shows a small wheel fixed coaxially on a bigger one of double the radius. The system rotates about the common axis. The strings supporting A and B do not slip on the wheels. If x and y be the distances travelled by A and B in the same time interval, then



A. $x = 2y$

B. $x = y$

C. $y = 2x$

D. none of these

Answer: C

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6. A body is rotating uniformly about a vertical axis fixed in an inertial frame. The resultant force on a particle of the body not on axis is

A. vertical

B. horizontal skew with the axis

C. horizontal and intersecting the axis

D. none of these

Answer: C

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7. A body is rotating anonuniformly abut a vertical axis fixed in an inertial frame. The resultant force on a particle of the body of thebody not on the axis is

A. vertical

B. horizontal and skew with the axis

C. horizontal and intersection

D. none of these

Answer: B

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8. Let $\overrightarrow{F}$ be the force acting on a particle having position vector $\overrightarrow{r}$ and $\overrightarrow{T}$ be the torque of this force about the origin. Then

A. $\overrightarrow{r}.\overrightarrow{\Gamma}=0$ and $\overrightarrow{F}.\overrightarrow{\Gamma}=0$

B. $\overrightarrow{r}.\overrightarrow{\Gamma}=0 but \overrightarrow{F}.\overrightarrow{\Gamma}\neq 0$

C. $\overrightarrow{r}.\overrightarrow{\Gamma}\neq 0 but \overrightarrow{F}.\overrightarrow{\Gamma}=0$

D. $\overrightarrow{r}.\overrightarrow{\Gamma}\neq 0$ and $\overrightarrow{F}.\overrightarrow{\Gamma}\neq 0$

Answer: A

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9. One end of a uniform rod of mas m and length l is clamped. The rod lies on a smooth horizontal surface and rotates on it about the clamped end at a uniform angular velocity ω. The force exerted by the clamp on the rod has a horizontal component

A. $m\omega^2 l$

B. $zero$

C. mg

D. $\frac{1}{2}m\omega^2 l$

Answer: D

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10. A uniform rod is kept vertically on a horizontally smooth surface at a point O. IF it is rotated slightly and released, it falls down on the horizontal surface. The lower end will remain

A. at O

B. at a distance less than $\frac{l}{2}$ from O

C. at a distance $\frac{l}{2}$ from O

D. at a distance larger than $\frac{l}{2}$ from O

Answer: C

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11. A circular disc A of radius r is made from an iron plate of thickness t and another circular disc B of radius 4r is made from an iron plate of thickness t/4. The relation between the moments of inertia I_A and I_B is

A. $I_A > I_B$

B. $I_A = I_B$

C. $I_A < I_B$

D. depends on the actual values of t and r

Answer: C

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12. Equal torques asct on the discs A and B of theh previous problem, initially both being at rest. At a later instant, theliear speeds of a point on therim of a A another potin on the rim of B are V_A and V_B respectively. We have

A. $V_A < V_B$

B. $V_A = V_B$

C. $V_A < V_B$

D. `the relation depends on the tactual magnitude of the torques

Answer: A

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13. A closed cylindrical tube containing some water (not filling the entire tube) lies in a horizontal plane. If the tube is rotated about a perpendicular bisector, the moment of inertia of water about the axis

A. increases

B. decreases

C. remains constant

D. increases if the rotation is clockwise and decreases if it is anticlockwise

Answer: A

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14. The moment of inertia of a uniform semicircular wire of mass 'M' and radius 'r' about a line perpendicular to the plane of the wire through the center is

A. Mr^2

B. $\frac{1}{2}Mr^2$

C. $\frac{1}{4}Mr^2$

D. $\frac{2}{5}Mr^2$

Answer: A

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15. Let I_1 and I_2 be the moments of inertia of two bodies of identical geometrical shape, the first made of aluminum and the second of iron.

A. $I_1 < I_2$

B. $I_1 = I_2$

C. $I_1 > I_2$

D. Relation between I_1 and I_2 depends on the actual shapes of the bodies

Answer: A

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16. A body having its centre of mass at the origin has three of its particles at $(a, 0, 0), (0, a, 0), (0, 0, a)$. The moments of inertia of the body about the X and Y axes are 0.20 kg $-m^2$ each. The moment of inertia about the Z-axis

A. is 0.20 $kg-m^2$

B. is 0.40 $kg-m^2$

C. is $0.20\sqrt{2}\,kg-m^2$

D. cannot be deduced with this information.

Answer: D

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17. A cubical block of mass M and edge a slides down a rougg inclined plane of inclination θ with a uniform velocity. The torque of the normal force on the block about its centre has magnitude.

A. zero

B. Mga

C. $Mga\sin\theta$

D. $\frac{1}{2}Mga\sin\theta$

Answer: D

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18. A thin circular ring of mass M and radius r is rotating about its axis with an angular speed ω. Two particles having mass m each are now attached at diametrically opposite points. The angular speed of the ring will become

A. $\frac{\omega M}{M+m}$

B. $\frac{\omega M}{M+2m}$

C. $\dfrac{\omega(M-2m)}{M+2m}$

D. $\dfrac{\omega(M+2m)}{M}$

Answer: B

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19. A man is sitting on a rotating stool with his arms outstretched. If suddenly he folds his arms the angular velocity of the man would

A. increases

B. decreases

C. remains unchanged

D. doubles

Answer: C

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20. The center of a wheel rolling on a plane surface moves with a speed v_0. A particle on the rim of the wheel at the same level as the center will be moving at speed

A. $zero$

B. v_0

C. $\sqrt{2}v_0$

D. $2v_0$

Answer: C

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21. A wheel of radius 20 cm is pushed ot move it on a rough horizontal surface. It is found to move through a distance of 60 cm on the road during the time it completes one revolutionabout the centre. Assume that the linear and the angular accelerations are uniform. The frictional force acting on the wheel by the surface is

A. along the velocity of the wheel

B. opposite to the velocity o the wheel

C. perpendicular to the velocity of the wheel

D. zero

Answer: A

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22. The angular velocity of the engine (and hence of the wheel) on a scooter is proportional to the petrol input per second. The scooter is moving on a frictionless road with uniform velocity. If the petrol input is increased by 10% the linear velocity of the scooter is increased by

A. 0.5

B. 10

C. 0.2

D. 0

Answer: D

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23. A solid sphere, a hollow sphere and a disc, all having the same mass and radius, are placed at the top of an incline and released.

The friction coefficients between the objects and the incline are same and not sufficient to allow pure rolling. The least time will be taken in reaching the bottom by

A. the solid sphere

B. the hollow sphere

C. the disc

D. all will take same time

Answer: D

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24. A solid sphere, a ring and a disc all having same mass and radius are placed at the top of an incline and released. The friction coefficient between the objects and the incline are same but not sufficient to allow pure rolling. Least time will be taken in reaching the bottom by

A. the solid sphere

B. the hollow sphere

C. the disc

D. all will take same time

Answer: D

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25. In the previous question the smallest kinetic energy at the bottom of the incline will be achieved by

A. the solid sphere

B. the hollow sphere

C. the disc

D. all will achieve same kinetic energy

Answer: B

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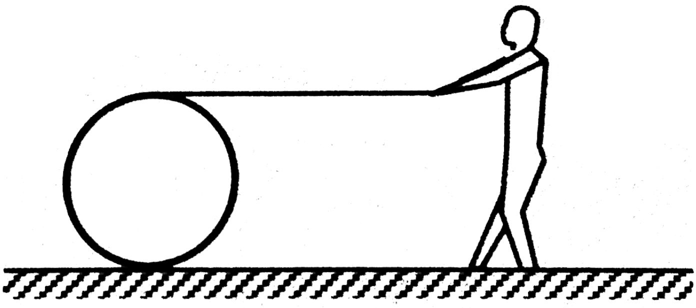
26. A string of negligible thicknes is wrapped several times around a cylinder kept on a rough horizontal surface. A man standing at a distance l from the cylinder holds one end of the sitting an pulls the cylinder towards him figure. There is no slipping anywhere. The length of the string passed through the hand of the man whicle the cylinder reaches his hands is



A. l

B. 2l

C. 3l

D. 4l

Answer: B

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Objective 2

1. The axis of rotation of a purely rotating body

A. must pass through the centre of mass

B. may pass through the centre of mass

C. must pass through a particle of the body

D. may pass through a particle of the body

Answer: B::D

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2. Consider the following two equations

A. $L = I\omega$

B. $\frac{dL}{dt} = \Gamma$

In non-inertial frames...

A. both A and B are true

B. A is true but B is false

C. B is true but A is false

D. both and B are false

Answer: B

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3. A particle moves on a straight line with a uniform velocity. It's angular momentum

A. is always zero

B. is zero about a point on the straight line

C. is not zero about a point away from the straight line

D. about any given point remains constant

Answer: B::C::D

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4. If there is no external force acting on a nonrigid body, which of the followhng quantities must remain constant?

A. angular momentum

B. linear momentum

C. kinetic energy

D. moment of inertia

Answer: A::B

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5. Let I_A and I_B be moments of inertia of a body about two axes A and B respectively. The axis A passes through the centre of mass of the body but B does not. Then

A. $I_A < I_B$

B. $If I_A < I_B$ the axes pareparallel

C. $If the axes are paral \leq l I_A < I_B$

D. $If the axes are \neg paral \leq l I_A \geq I_B$

Answer: C

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6. A sphere is rotating about a diameter

A. the particles on the surface of the sphere do not have any linear acceleration

B. the particles on the diameter mentioned above do not have any linear acceleration

C. different particle son the surfce have different angular speeds.

D. All particles on the surface have same linear speed

Answer: B

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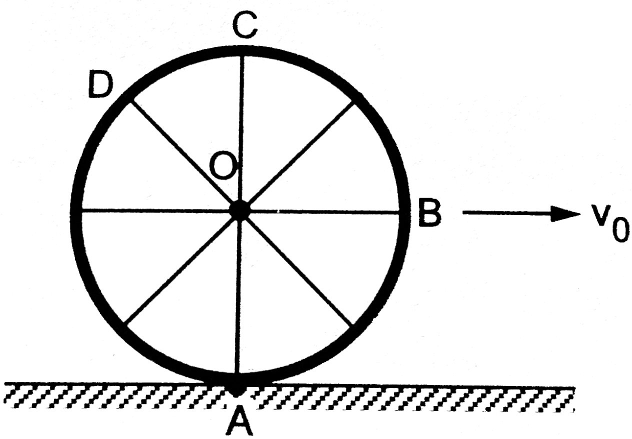
7. Consider a wheel of a bicycle rolling on a level road at a linear speed v_0 figure.



A. the speed of the particle A is zero

B. the speed of B,C and D are all equal to v_0

C. The speed of C is $2v_0$

D. the speed of B is greater than the speed of O.

Answer: A::C::D

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8. Two uniform solid spheres having unequal radii are released from rest from the same height on a rough incline. If the spheres roll without slipping

A. the heavier sphere reaches the bottom first

B. the bigger sphere reaches the bottom first

C. the two spheres reach the bottom together

D. the information given is not sufficient to tell whidch sphere will reach the bottom first.

Answer: C

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9. A hollow sphere and a solid sphere having same mass and same radii are rolled down a rough inclined plane.

A. the hollow sphere reaches the bottom first

B. the solid sphere reaches the bottom with greater speed.

C. the soid sphere reaches the bottom with greater kinetic energy

D. the two spheres will reach the bottom wilth same linear momentum

Answer: B

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10. A sphere cannot roll on

A. a smooth horizontal surface

B. a smooth inclined surface

C. a rough horizontal surface

D. a rough inclined surface

Answer: B

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11. In rear wheel drive cars the engine rotastes the rear whel and the front wheels rotates only becomes the car moves. Ilf such a car accelerates on horizontal road the friction

A. on the rear wheels ils i the forward direction

B. on the front whels is in the backward direction

C. on the rear wheels has larger magnitude thant the friction on the front wheels

D. on the car is in the backward direction

Answer: A::B::C

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12. A sphere can roll on a surface inclined at an angle θ if the friction coefficient is more than $\frac{2}{7}g\sin\theta$. Suppose the friction coefficient is $\frac{1}{7}g\sin\theta$, and a sphere is released from rest on the incline,

A. it will stay at rest

B. it wil make pure translation motion

C. it will translate and rotate about the centre

D. the angular momentum of the sphere about its centre will remain constant

Answer: C

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13. A sphere is rolled on a rough horizontal surface. It gradually slows down and stops. The force of friction tries to

A. decrease the linear velocity

B. increase the angular velocity

C. increase the linear momentum

D. decrese the angular velocity

Answer: A::B

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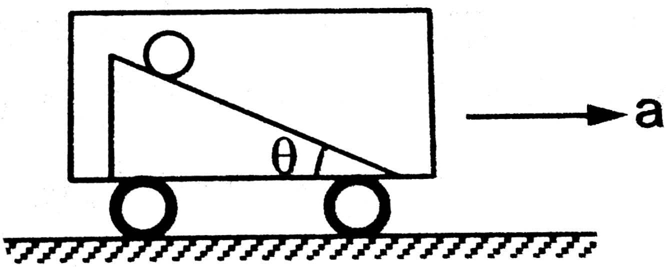
14. Figure shows smooth inclined plane fixed in a car accelerating on a horizontal road. The angle of incline θ is related to the acceleration a of the car as $a = g \tan \theta$. If the sphere is set in pure rolling on the incline



A. it will continue pure rolling

B. it will slip down the plane

C. its linear velocity will increase

D. it linear velocity will slowlyidecrease.

Answer: A

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Exercises

1. A wheel is making revolutions about its axis with uniform angular acceleration. Starting from rest, till it reaches 100 rev/sec in 4 seconds. Find the angular acceleration. Find the angle rotated during these four seconds.

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2. A wheel rotating wilth unifrom angular acceleration covers 50 revolutions in the first five seconds after the start. Find the angular acceleration and the angular velocity at the end of five seconds.

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3. A wheel starting from rest is uniformly accelerate at 4 $ra\frac{d}{s^2}$ for 10 seconds. It is allowed to rotate uniformly for the next 10 seconds and is finally brought to rest in the next 10 seconds. Find the total angle rotated by the wheel.

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4. A body rotates about a fixed axis with an angular acceleration of one radian/second/second. Through what angle does it rotate during the time in which its angular velocity increases from 5 rad/s to 15 rad/s.

Watch Video Solution

5. Find the angular velocity of a body rotating with an acceleration of $2re\frac{v}{s^2}$ as it completes the 5th revolution after the start

Watch Video Solution

6. A disc of radius 10 cm is rotating about its axis at an angular speed of 20 rad/s. Find the linear speed of

a. a point on the rim,

b. the middle point of the radius.

Watch Video Solution

7. A disc rotates about its axis with a constant angular acceleration of $4ra\frac{d}{s^2}$. Find the radial and tangential acceleration of a particle at a distance of 1 cm from the axis at the end of the first second after the disc starts rotating.

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8. A block hangs from a string wrapped on a disc of radius 20 cm free to rotate about its axis which is fixed in a horizontal position. If the angular speed of the disc is 10 rad/s at some instant, with what speed is the block going down at that instant?

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9. Three particles, each of mass 200 g are kept at the corners of an equilateral triangle of side 10 cm. Find the moment of inertia of the system about an axis

a. joining two of the particles

b. passing through one of the particle perpendicular to the plane of the particles.

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10. Particles of masses 1g, 2g, 3g ....100g are kept at the marks 1cm, 2cm, 3cm ....., 100 cm respectively on a metre scale. Find the moment of inertia of the system of particles about a perpendicular bisector of the metre scale.

Watch Video Solution

11. Find the moment of inertia of a pair of spheres, each having a mass m and radius r kept in contact about the tangent passing through the point of contact.

Watch Video Solution

12. The moment of inertia of a uniform rod of mass 0.50 kg and length 1 m is 0.10 kg m^2 about a line perpendicular to the rod. Find the distance of this line from the middle point of the rod.

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13. Find the radius of gyration of a circular ring of radius r about a line perpendicular to the plane of the ring and passing through one of this particles.

Watch Video Solution

14. The radius of gyration of a uniform disc about a line perpendicular to the disc equals to its radius. Find the distance of the line from the centre.

Watch Video Solution

15. Find the moment of inertia of a uniform square plate of mass M and edge a about one of its diagonals.

Watch Video Solution

16. The surface density (mass/area) of a circular disc of radius a depends on the distance from the centre as $\rho(r) = A + Br$. Find its moment of inertia about the line perpendicular to the plane of the disc through its centre.

Watch Video Solution

17. A particle of mass m is projected with speed u at an angle θ with the horizontal. Find the torque of the weight of the particle about the point of projection when the particle is at the highest point.

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18. A simple pendulum of length l is pulled aside to make an angle θ with the vertical. Find the magnitude of the torque of the weight w of the bob about the point of suspension. When is the torque zero?

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19. When a force of 6.0 N is exerted at 30° to a wrench at a distance of 8 cm from the nut, it is just able to losen the nut. What force F would be sufficient to loosen it if it acts perpendicularly to the wrench at 16 cm from the nut?

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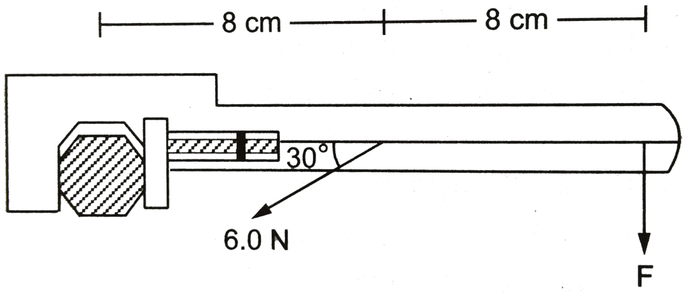

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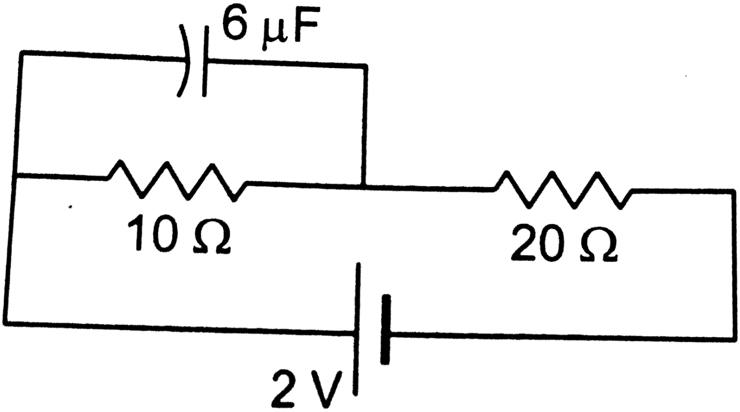
20. Find the charge on the capacitor shown in figure



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21. A cubical block of mass M and edge a slides down a rougg inclined plane of inclination θ with a uniform velocity. The torque of the normal force on the block about its centre has magnitude.

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22. A rod of mass m and length L , lying horizontally is free to rotate about a vertical axis through its centre. A horizontal force of constant magnitude F acts on the rod at a distance of L/4 from the centre. The force is always perpendicular to the rod. Find the angle rotated by the rod during the time t after the motion starts.

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23. A square plate of mass 120g and edge 5.00 cm rotates about one of the edges. If it has a uniform angular acceleration of $0.2ra\frac{d}{s^2}$, what torque acts on the plate?

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24. Calculate the torque on the square plate of the previous problem if it rorates about a diagonal with the same angular acceleration.

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25. A flywheel of moment of inertia 5.0 kg m^2 is rotated at a speed of 60 rad/s. Because of the friction at the axle, it comes to rest in 5.0 minutes. Find a. The average torque of the friction. B. the total work done by the friction and c. the angular momentum of the wheel 1 minute before it stops rotating.

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26. Because of the friction between the water in oceans with the earth's surface the rotational kinetic energy of the earth is continuously decreasing. If earth's angular speed decreases by 0.0016 rad/day in 100 years, find the average torque of the friction on the earth. Radius of the earth is 6400 km and its mass is $6.0 \times 10^{24} kg$.

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27. A flywheel rotating at a speed of 600 rpm about its axis is brought to rest by applying a constant torque for 10 seconds. Find the angular deceleration and angular velocity 5 second after the application of the torque.

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28. A wheel of mass 10 kg and radius 0.2 m is rotating at an angular speed of 100 rpm, when the motion is turned off. Neglecting the friction at the axis. Calculate the force that must be applied tangentially to the wheel to bring it to rest in 10 rev. Assumed wheel to be a disc.

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29. A cylinder rotating at an angular speed of 50 rev/s is brought in contact with an identical stationary cylinder. Because of the kinetic friction, torques act on the two cylinders, accelerating the stationary one and decelerating the moving one. If the common magnitude of the acceleration and deceleration be one revolution per second square, how long will it take before the two cylinders have equal angular speed?

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30. A body rotating at 20 rad/s is acted upon by a constant torque providing it a deceleration of $2\frac{rad}{s^2}$. At what time will the body have kinetic energy same as the initial value if the torque continues to act?

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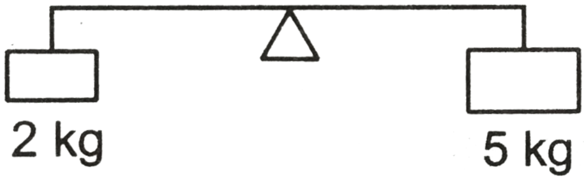
31. A light rod of length 1 m is pivoted at its centre and two masses of 5 kg and 2 kg are hung from the ends as shown in the figure. Find the initial angular acceleration of the rod assuming that it was horizontal in the beginning.



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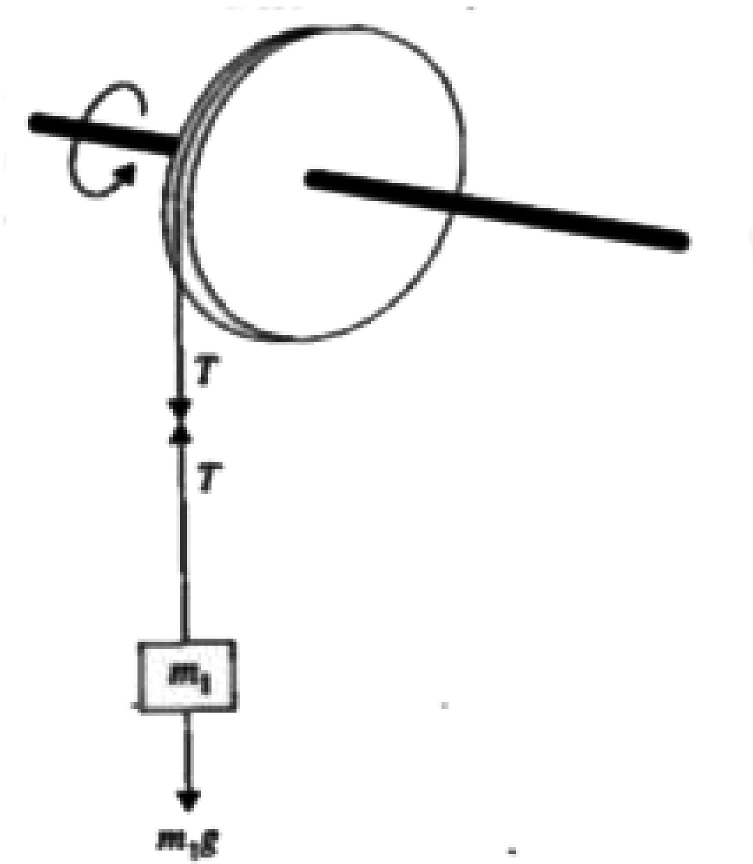
32. A wheel of mass 1.4 kg and radius 0.4 m is mounted on a frictionless, horizontal axle as shown in Fig. 7.2.50. Alight string wrapped around the rim supports a mass of 2 kg. What is the angular acceleration of the wheel and the tangential acceleration of a point on the rim ? Also find the tension in the string.



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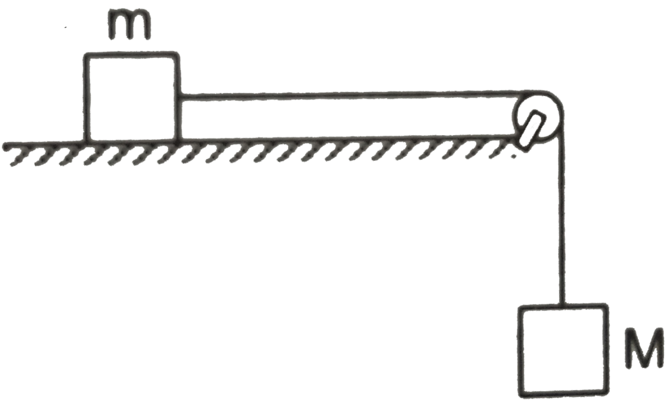
33. Figure shows two blocks of masses m and M connected by a string passing over a pulley. The horizontal table over which the mass m slides is smooth. The pulley has a radius r and moment of inertia I about its axis and it can freely rotate about this axis. Find the acceleration of the mass M assuming that the string does not slip on the pulley.



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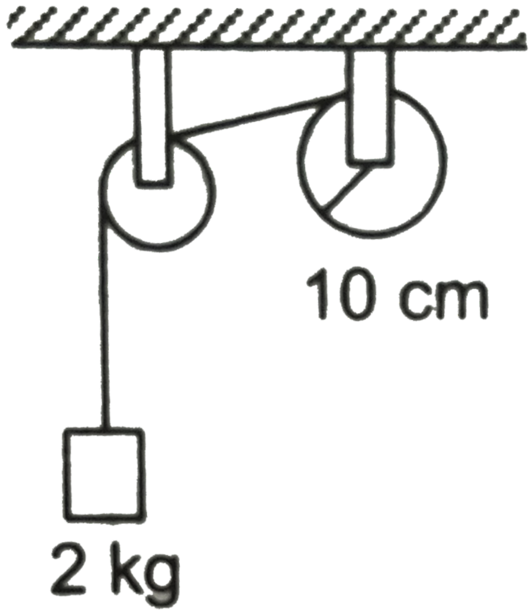
34. A string is wrapped on a wheel of moment of inertia 0.20 kg-m^2 and radius 10 cm and goes through a light pulley to support a block of mass 2.0 kg as shown in figure. Find the acceleration of the block.



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35. Suppose the smaller pulley of the previous problem has its radius 5.0 cm and moment of inertia 0.10 kg-m^2. Find the tension in the part of the string joiningk the pulleys.

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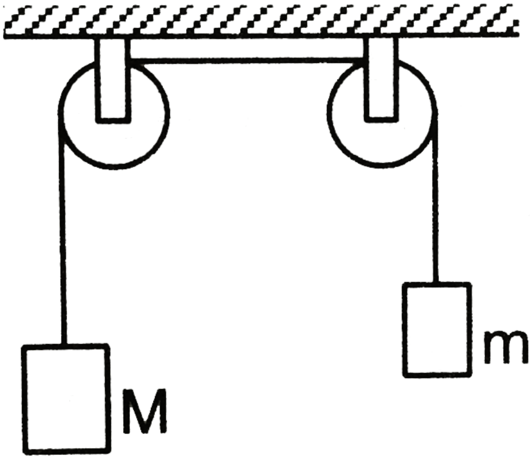
36. The pulleys in figure are identical, each having a radius R and moment of inertia I. Find the acceleration of the block M.



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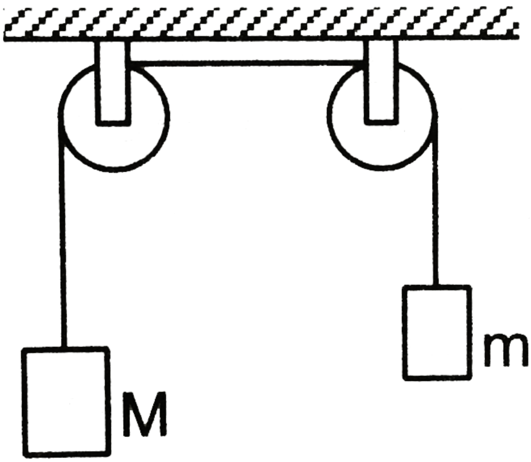
37. The pulleys in figure are identical, each having a radius R and moment of inertia I. Find the acceleration of the block M.



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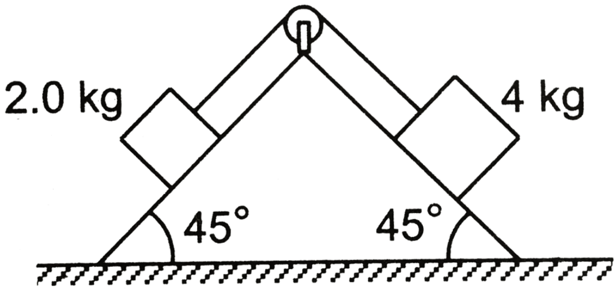
38. The pulley shown in figure has a radius 10 cm and moment of inertia 0.5 kg-m^2 about its axis. Assuming the inclined planes to be frictionless, calculate the acceleration of the 4.0 kg block.



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39. Solve the previous problem if the firction coefficient between the 2.0 kg block and the plane below it is 0.5 and the plane below the 4.0 kg block is frictionless.

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40. A uniform metre stick of mass 200 g is suspended from the ceiling through two vertical strings of equal lengths fixed at the ends. A small object of mass 20 g is placed on the stick at a distance of 70 cm from the left end. Find the tensions in the two strings.

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41. A uniform ladder of length 10.0 m and mass 16.0 kg is resting against a vertical smooth wall making an angle of 37° with it. An electrian weighing 60.0 kg climbs up the ladder. If the stays on the ladder at a point 8.00 m from the lower end, what will be normal force and the force of friction on the ladder by the ground? What should be the minimum coefficient of friction for the electrician to work safely?

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42. Suppose the friction coefficient between the ground and the ladder of the previous problem is 0.540. Find the maximum weight of a mechanic who could go up and do the work from the same position of the ladder.

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43. A 6.5 m long ladder rests against as vertical wall reaching a height of 6.0 m. A 60 kg man stands hlf way up the ladder. A. Find the torque of the force exerted by the man on the ladder bout the upper end of the ladder. b.Assuming the weight of the ladder of be negligible as compared to the man and assuming the wall to be smooth find the force exerted by the ground on the ladder.

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44. the door of an almirah is 6 ft high, 1.5 ft wide and weights 8 kg. The door is supported by two hinges situated at a distance of 1 ft from the ends. If the magnitude of the forces exerted by the hinges on the door are equal find this magnitude.

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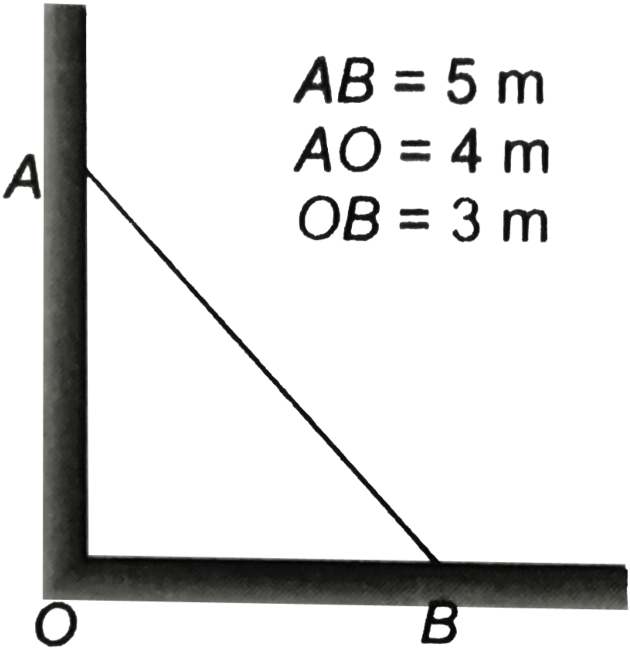
45. A ladder of length $5m$ is placed against a smooth wall as shown in figure. The coefficient or friction is μ between ladder and ground. What is the minimum value of μ , If the ladder is not to slip?



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46. A uniform rod of mass 300 g and length 50 cm rotates at a uniform angular speed of 2 rad/s about an axis perpendicular to the rod through an end. Calculate a. the angular momentum of the rod about the axis of rotation b. the speed of the centre of the rod and c. its kinetic energy.

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47. A uniform square plate of mass 2.0 kg and edge 10 cm rotates about one of its diagonals under the action of a constant torque of 0.10 Nm. Calculate the angular momentum and the kinetic energy of the plate at the end of the fifth second after the start.

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48. Calculate the ratio of the angular momentum of the earth about its axis due to its spinning motion to that about the sun due to its orbital motion. Radius of the earth =6400 km and radius of the orbit of the earth about the sun $= 1.5 \times 10^8 km$.

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49. Two particles of masses m_1 and m_2 are joined by a light rigid rod of length r. The system rotates at an angular speed ω about an axis through the centre of mass of the system and perpendicular to the rod. Show that the angular momentum of the system is $L = \mu r^2 \omega$ where μ is the reduced mass of the system defined as $\mu = \frac{m_1 m_2}{m_1 + m_2}$

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50. A dumb bell consists of two identicasl small balls offmss 1/2 kg each connected to the ends of a 50 cm long light rod. The dumb bell is rotating about a fixed axis through the centre of the rod and perpendicular to it t an angular speed of 10 rad/s. An impulsive force of average magnitude 5.0 N acts on one of the masses in the direction of its velocity for 0.10s. Find the new angular velocity of the system.

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51. A wheel of moment of inertia $0.500 kg - m^2$ and radius 20.0 cm is rotating about its axis at an angular speed of 20.0 rad/s. It picks up a stationary particle of mass 200 g at its edge. Find the new angular speed of the wheel.

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52. A diver having a moment of inertia of $6.0 kg - m^2$ about an axis through its centre of mass rotates at an angular speed of 2 rad/s about this axis. If he folds his hands and feet to decrease the moment of inertia to 5.0 kg-m^2` what will be the new angular speed?

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53. A boy is seated in a revolving chair revolving at an angular speed of 120 revolutions per minute. Two heavy balls form part of the revolving system and the boy can pull the balls closer to himself or may push them apart. If by pulling the balls closer, the boy decreases the moment of inertia of the system from $6kg - m^2 \to 2kg - m^2$ what will be the new angular speed?

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54. A boy is sitting on a horizontal platform in the shape of a disc at a distance of 5m from its centre. The boy begins to slip when the speed of wheel exceeds 10 rpm. The coefficient of friction between the boy and platform is: $(g = 10ms^{-2})$

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55. A wheel of moment of inertia $0.10kg - m^2$ is rotating about a shaft at an angular speed of $160\frac{rev}{\min}$. A second wheel is set into rotation at 300 rev/minute and is coupled to the same shaft so that both the wheels finally rotate with as common angular speed of 200 rev/minute. Find the moment of inertia of the second wheel.

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56. A kid of mass M stands at the edge of a platform of radius R which can be freely rotated about its axis. The moment of inertia of the platform is I . The system is at rest when a friend throws as ball of mass m and the kid catches it. If the velocity of the ball is v horizontally along the tangent to the edge of the platform when it was caught by the kid find the angular speed of the platform after the event.

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57. Suppose the platform of the previous problem is brought to rest with the ball in tehhad of the kid standin on the rim. The kid throuws the ball horizontaly to his friend in a direction tangentiasl to the rim with a speed v as seen by his friend. Find the angular velocity wilth which the platform will start rotating.

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58. Suppose the platform with the kid in the previous problemis rotting in anticlockwise directioin at an angular speed ω. The kid starts walking along the rim with a speed v relative to the platform also in the anticlockwise direction. Find the new angular speed of the platform.

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59. A uniform rod of mass m and length l is struck at an end by a force F perpendicular to the rod for a short time interval t. Calculate a. the speed of the centre of mass ,b. the angular speed of the rod about centre of mass, c. the kinetic energy of the rod and d. the angular moment of the rod about the centre of mass after the force has stopped to act. Assume that t is so small that the rod does not apreciably change its direction while the force acts.

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60. A uniform rod of length L lies on a smooth horizontal table. A particle moving on the table strikes the rod perpendicularly at an end and stops. Find the distance travelled by the centre of the rod by the time it turns through a right angle. Show that if the mass of the rod is four times that of the particle, the collision is elastic

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61. Suppose the particle of the previous problem has a mass m and a speed v before the collision and it sticks to the rod after the collision. The rod has a mass M. a. Find the velocity of the particle with respect to C of the system consituting the rod plus the particle. b. Find the velociyt of the particle with respect to C before the collision. c. Find the velocity of the rod with respect to C before the colision. e. find the moment of inertia of the system about the vertical axis through the centre of mass C after the collision. f. Find the velociyt of the centre of mass C and the angular velocity of the system about the centre of mass after the collision.

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62. Two small bals A and B, each of mass m, are joined rigidlyl by a light horizontal rol of lengh L. The rod is clasmped at the centre in such a way that it c an rotate freely about a verticl axis through its centre. The systemis rotated with an angualr speed ω about the axis. A particle P of masss m kept at rest sticks to the ball A as the ball collides with it. Find the new angular speed of the rod.

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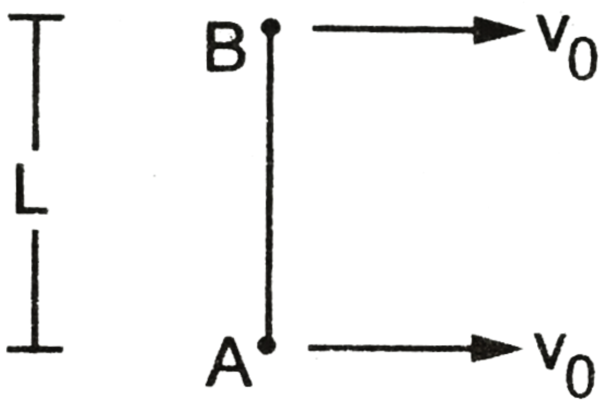
63. Two small balls A and B each of mass m, are joined rigidly to the ends of a light rod of length L figure. The system translates on a frictionless horizontal surface with a velocity v_0 in a direction perpendicular to the rod. A particle P of mass kept at rest on the surface sticks to the ball A as the ball collides with it .

Find

a. the linear speeds of the balls A and B after the collision, b. the velocity of the centre of mass C of the system A+B+P and c. the angular speed of the system about C after the collision.



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64. Suppose the rod with the balls A and B of theprevious problem is clamped at the centre in such a way that it ca rotate freely about a horizontal axis through the clamp. The system is kept at rest in the horizontal position. A particle P of the same mass m is dropped from a heigh h hon the ball B. The particle collides with B and sticks to it. a. Find the angular momentum and the angular speed of the system just after the collision. b. What should be the minimum value of h so that the system makes a full rotation after the collision.

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65. Two masses M and m are connect by a light string gong over a pulley of radis r. The pulley is free to rotate about its axis which is kept horizontal. The moment of inertia of the pulley about the axis is I. The system is releaed from rest. Find the angular momentum fo teh system when teh mass Mhas descended through a height h. The string does not slip over the pulley.

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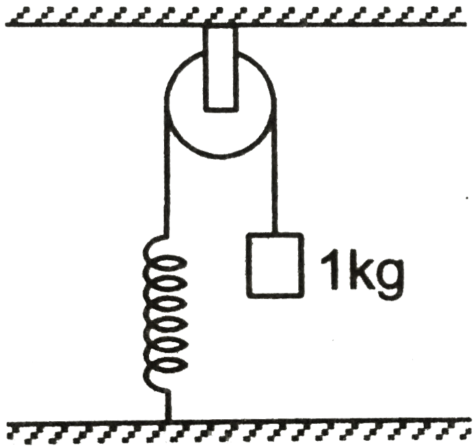
66. The pulley shown in figure has a radius of 20 cm and moment of inertial 0.2 kg-m^2. The string going over it is attached at one end to a vertical sprign of spring constant 50 N/m fixed from below and supports a 1 kg mas at other end. The system is released from rest with the spring at its natural length. Find the speed of the block when it has desceds through 10 cm.

Take $g = 10\frac{m}{s^2}$.



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67. A metre stick is is held verticaly with one end on a rough horizontal floor. It is gently alowed to fal on the floor. Assuming that the end ast the floor does not slip find the angular speed of the rod when it hits the floor.

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68. A metre stick weighing 240 g is pivoted at its upper end in such a way that it can freely rotate in a vertical plane through this end figure. A particle of mass 100 g is attached to the upper end of the stick through a light sting of length 1 m. Initially the rod is kept veritcal and the string horizontal when the system is released from rest. The particle colides with the lower end of the stick and sticks there. Find the maximum angle through which the stick will rise.

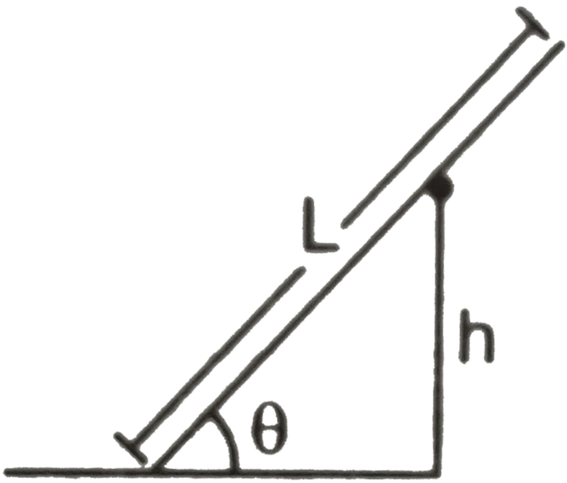

Figure 10-E9

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69. A uniform rod is placed vertically on a smooth surface and then released . Then,

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70. A cylinder rolls on a horizontal plane surface. If the speed of the centre is 25 m/s, what is the speed of the highest point?

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71. A sphere of mass m rolls on a plane surface. Find its kinetic energy at an instant when its centre moves with speed v.

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72. A string is wrapped over the edge a uniform disc and the free end is fixed with the ceiling. The disc moves down, unwinding the string. Find the downward acceleration of the disc.

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73. A small spherical ball is released from a point at a height h on a rough track shown in figure. Assuming that it does not slip anywhere, find its linear speed when it rolls on the horizontal part of the track.

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74. A small disc is set rolign wioth a speed v on the horizontal part of the track of the previous problem from right to left. To what height will it climb up the curved part?

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75. A sphere starts rolling down can incline of inclination theta. Find the speed of its centre when it has covered a distance l.

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76. A hollow sphere is released from the top of an inlcined plane of inclination θ. A. What should be the minimum coefficientof friction between the shphere and the plane to prevent sliding? B. Find the kinetic energy of the ball as it moves down a length l on the incline if the friction coefficient is half the value calculated in part a.

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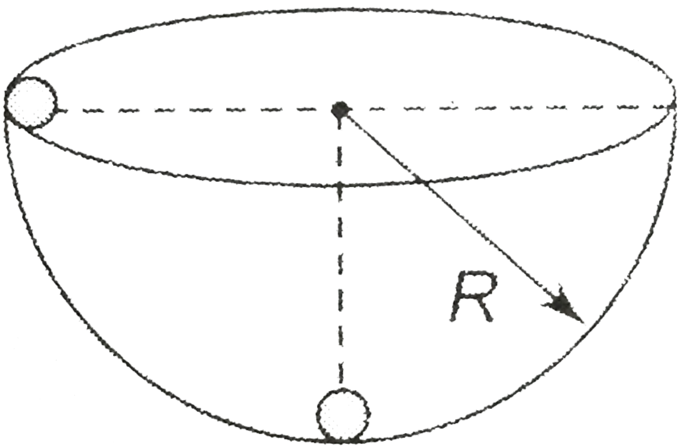
77. Consider the situation as shown in the figure. A solid sphere of mass m is released from rest from the rim of a hemispherical cup so that it rolls along the surface. Find the normal contact force between the solid sphere and the cup at the bottom most point.



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78. Figure shows a rough track a portion of which is in the form of a cylinder of radius R. With what minimum linear speed should as sphere of radius r be set rolling on the horizontal part so that it completely goes round the circle on the cylindrical part.

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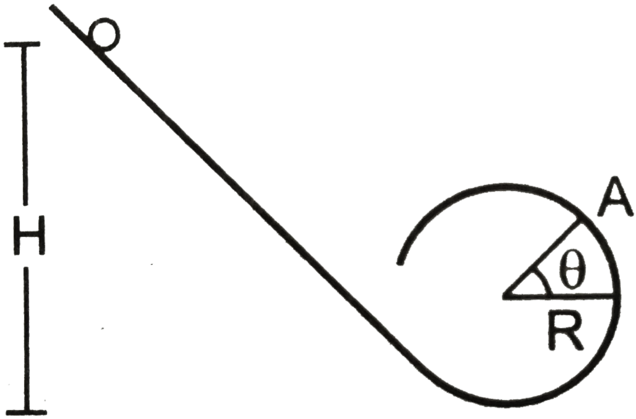
79. Figure shows a smasll sphereical bal of mass m rolling down the loop track. Thebasll is released on the linear portion at a verticla height H from the lowest point. The circular part show has a radius R.

a. find the kinetic energy of the ball when it is at a point where the radius makes an angle θ with the horizontal.

Find the radial and the tangential accelerations of the cente when the ball is at A. c. find the bnormal force and the frictionasl force acting on the ball if H=60 cm, R=10cm

$\theta = 0$ and m=70 fg.



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80. A thin spherical shell of radius R lying on a rough horizontal surface is hit sharply and horizontally by a cue. Where should it be hit so that the shell does not slip on the surface?

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81. A uniform sphere of radius R is palced on a rough horizontal surface and given a linear velocity v_0 and an angular velocity ω_0 as shown . If the angular velocity and the linear velocity both become zero simultaneously, then

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82. A uniform wheel of radius R is set lying on a rough horizontal surface is hit by as cue is such a way that the line of action passes thruogh the centre of the shell. As a result the shelll starts movign with a linear speed v without any initial angular velocity. Find the linear speed of the shell after it starts pure rolling on the surface.

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83. A holow sphere of radius R lies on a smoth horizontal surface. It is pulle dby a horizontl force acting tasngentially from the highest point. Find the distance travelled by the sphere durint eh time it makes oen full rotation.

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84. A solid sphere of mass 0.50 kg is kept on a horizontal surface. The coefficient of static friction between the surfaces in contact is 2/7. What maximum force can be applied at the highest point in the horizontal direction so that the sphere does not slip on the surface?

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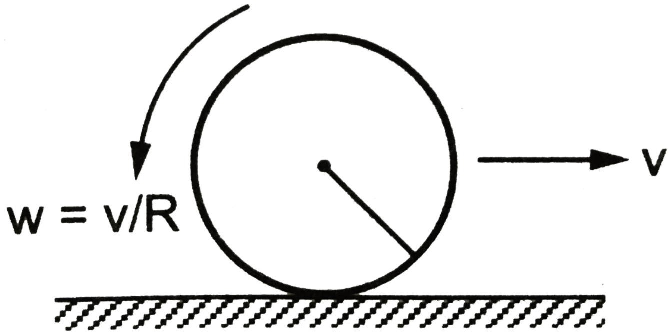
85. A solid sphere is set into motion on a rough horizontal surfce with a linar speed v in the forward direction and an angular speed v/R in the anticlockwise direction as shown infigure . Find the linear speed of the sphere a.

where it stops rotating and b. when slipping finally ceases sand pure rolling starts.



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86. A solid sphere rolling on a rough horizontl surface with a lilner speed v collides elastically with a fixed, smooth, vertical wall. Find the speed of the sphere after it has started pure rolling in the backward direction.

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Questions For Short Answer

1. Can an object be in pure translation as well as in pure rotation?

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2. A simple pendulum is a pont mass suspended by a light thread from a fixed point. The particle is displaced towards one side and then released. It makes small ocillations. Is the motion of such a simple pendulum a pure rotation? If yes, wher is the axis of rotation?

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3. In a rotating body $a = \alpha r$ and $v = \omega r$. Thus $\frac{a}{\alpha} = \frac{v}{\omega}$. Can you use the theorems of ratio and proportion studied in algebra so as to write

$$\frac{a+\alpha}{a-\alpha}=\frac{v+\omega}{v-\omega}$$

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4. A ball is whirled in a circle by attaching it to a fixed point with a string. Is there an angular rotation of the ball about its centre? If yes, is this angular velocity equal to the angular velocity of the ball about the fixed point?

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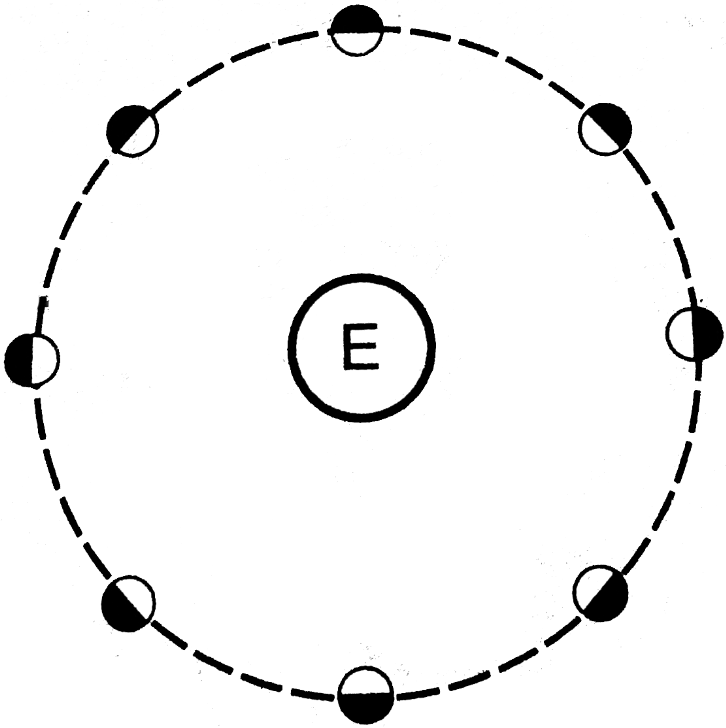
5. The moon rotates about the earth in such a way that only one hemisphere of the mon faces the earth figure. Can we ever see the other face of the moon from the earth? Can a person on the moon ever see all the faces of the earth?



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6. The torque of the weight of any body about any vertical axis is zero. Is it always correct?

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7. The torque of a force $\vec{F}$ about a point is defined as $\vec{\Gamma} = \vec{r} \times \vec{F}$. Suppose $\vec{r}, \vec{F}$ and $\vec{\Gamma}$ are all nonzero. Is $\vec{r} \times \vec{\Gamma} \mid \mid \vec{F}$ always true? Is it ever true?

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8. A heavy particle of mass m falls freely near the earth's surface.Whati si the torque acting on this particle about a point 50 cm east to the lie of motiin? Does this a point 50 cm east to the line of motion? Does this toruque produce any angular accelertio in the particle?

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9. If several forces act on a particle, the total torque on the particle mauy be obtained by first finding the resultant force and then taking torque of this resultant. Prove this. Is this result valid for the forces actin on difeent partivles of a body in such a way that their lines of acting intersect at a common point?

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10. If the sum of all the forces acting on a body is zero, is it necessarily in equilibrium ? If the sum of all the forces on a particle is zero, is it necessarily in equilibrium?

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11. If the angular momentum of a body is found to be zero about a point is it necessary that it will also be zero about a different point?

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12. If the resultant torque of all the forces acting on a body is zero about a point is it necessary that it will be zero about any other point?

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13. A body is in translational equilibrium under the sctin of coplanar forces. If the torque of these force is zero about a point is it necessary that it will also be zero abut any other point?

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14. A rectangular brick is kept on a table with a part of its length projecting out. It remains at rest if thelength projected is slightly less than half the total length but it falls down if the length projected is slightly more than half the total length. Give reason.

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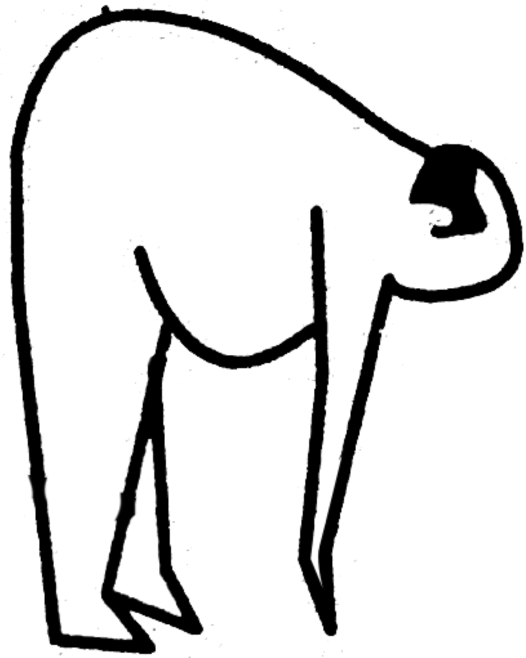
15. When a fat person tries to touch hit toes, keepig the legs straight he generally falls.

Explain with reference to figure.



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16. A ladder is kept at rest with is upper end against a wall and the lower end on the ground. The ladder is more like to slip when a mass stands on it at the top than at the bottom. Why ?

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17. The density of a rod AB continuously increases from A to B. Is it easier to set it in rotatio by clamping ilt at A and applying a perpendicular force at B or by clamping it at B and applying the force at A?

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18. When tall buildings are constructed on earth, the duration of day night slightly increases. Is it true?

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19. If the ice at the poles melts and flows towasrdsd the equato, how will it afect the durtion of day night?

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20. A hollow sphere, a solid sphere, a disc and a ring all having same mass nd radius are rolled on an inclined plane. If no slipping takes place, which one will take the smallest time to cover a given length?

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21. A sphere rolls on a horizontal surface. Is there any point of the sphere which has a vertical velocity?

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