



# PHYSICS

## BOOKS - JBD PUBLICATION

### MOTION OF SYSTEM OF PARTICLES AND RIGID BODY

#### Exercise

1. A constant torque acting on a uniform circular wheel changes its angular momentum

from  $L$  to  $4L$  in 4 seconds. The magnitude of torque is :

A.  $3\frac{L}{4}$

B.  $L$

C.  $4\frac{L}{3}$

D.  $\frac{L}{4}$ .

**Answer:**



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2. A uniform rod has mass  $M$  and length  $L$ . Its radius of gyration about an axis through its one end and perpendicular to its length is :

A.  $\frac{L}{\sqrt{3}}$

B.  $\frac{L}{\sqrt{6}}$

C.  $\frac{L}{\sqrt{9}}$

D.  $\frac{L}{\sqrt{12}}$ .

**Answer:**



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3. An inclined plane makes angle of  $30^\circ$  with horizontal. A solid sphere rolls down this inclined plane from rest without slipping. The acceleration of the sphere is :

A.  $\frac{1}{3}g$

B.  $\frac{2}{3}g$

C.  $\frac{5}{7}g$

D.  $\frac{5}{14}g$ .

**Answer:**



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4. A spherical ball rolls on a horizontal surface without slipping .then the fraction of its total energy associated with rotatio is :

A.  $\frac{2}{5}$

B.  $\frac{2}{7}$

C.  $\frac{3}{5}$

D.  $\frac{3}{7}$ .

**Answer:**



5. A person is standing on a rotating platform with his arms outstretched. Suddenly, he folds his hands near to his body. Which of the following is correct?

- A. Angular speed decreases
- B. Angular momentum decreases
- C. Torque decreases
- D. moment of inertia will decrease

**Answer:**



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**6.** A disc, a solid sphere, a hollow sphere and a ring of the same mass and radius are allowed to slide down on an inclined plane. Which one reaches the bottom first?

A. solid sphere

B. Ring

C. Hollow sphere

D. Disc.

**Answer:**



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7. The moment of inertia of a solid sphere of density  $\rho$  and radius  $R$  about its diameter is given by :

A.  $\frac{176}{105} \rho R^3$

B.  $\frac{176}{105} \rho R^4$



C.  $\frac{176}{105}\rho R^3$

D.  $\frac{176}{105}\rho R^2.$

**Answer:**



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**8. Define moment of inertia**

A.  $9ma^2$

B.  $40ma^2$

C.  $50ma^2$

D.  $60ma^2$ .

**Answer:**



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9. A hollow and a solid sphere of the same mass have equal moment of inertia about their diameters. The ratio of their radii is :

A.  $\sqrt{3} : \sqrt{5}$

B.  $3 : 5$

C.  $\sqrt{5} : \sqrt{3}$

D.  $5 : 3$ .

**Answer:**



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**10.** The moment of inertia of ring about an axis parallel to one of its diameter and angular to the ring is :

A.  $\frac{3}{2}MR^2$

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

C.  $MR^2$

D.  $\frac{5}{4}MR^2$ .

**Answer:**



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**11.** A body of momentum of inertia  $I$  has an angular momentum  $L$ . The rotational KE of the body is :

A.  $L^2 2I$

B.  $L^2 / I$

C.  $I / 2L^2$

D.  $i / L^2$ .

**Answer:**



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**12.** A body of mass  $m$  slides down on an inclined plane and reaches the bottom with speed  $v$ . If the same mass were in the form of a

ring which rolls down. The same inclined plane, then the velocity of the ring on reaching the bottom would be :

A.  $v$

B.  $v\sqrt{2}$

C.  $v/\sqrt{2}$

D.  $2v$ .

**Answer:**



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13. A flywheel at rest is to acquire an angular velocity of  $36\text{rads}^{-1}$  in 6 seconds. The total angle turned during this interval is :

A. 216 rad

B. 144 rad

C. 108 rad

D. 72 rad

**Answer:**



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14. A metre stick is held vertically with one end on the floor and then allowed to fall. The speed of the other end when it hits the floor (assuming that the lower end does not slip) is :

A.  $\sqrt{3g}$

B.  $\sqrt{\frac{g}{3}}$

C.  $3g$

D.  $\frac{g}{3}$ .

**Answer:**





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15. If the earth suddenly contracts to half of its original size without any change in mass, the new duration of the day would be :

A. 12 h

B. 6 h

C. 3 h

D. 1.5 h

**Answer:**



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16. If  $A$  is the areal velocity of a planet of mass  $M$ , then its angular momentum is :

A.  $M$

B.  $2 MA$

C.  $MA$

D.  $MA^2$ .

**Answer:**



17. A tube of length  $L$  is filled completely with an incompressible liquid of mass  $M$  and closed at both the ends. The tube is then rotated in a horizontal circle about one of its end with uniform angular velocity  $\omega$ . The force exerted by the liquid at the other end is :

A.  $\frac{M\omega^2 L}{2}$

B.  $M\omega^2 L$

C.  $\frac{M^2\omega}{2}$

D.  $ML^2\omega$ .

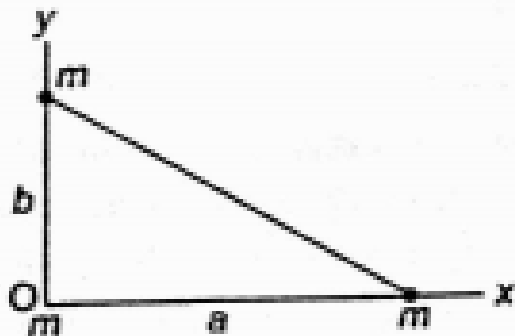
**Answer:**



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**18.** Three particles each of mass  $m$  are placed at the corners of a right angled triangle as shown in figure if  $OA=a$  and  $OB=b$ , the position

vector of the centre of mass is:



A.  $\frac{1}{3}(a\hat{I} + b\hat{J})$

B.  $\frac{1}{3}(a\hat{I} - b\hat{J})$

C.  $\frac{1}{2}(a\hat{I} - \hat{J})$

D.  $\frac{1}{2}(a\hat{i} + b\hat{j})$ .

**Answer:**



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19. Two discs of moments of inertia  $I_1$  and  $I_2$  about their respective axes (normal to the disc and passing through the centre), and rotating with angular speed  $\omega_1$  and  $\omega_2$  are brought into contact face to face with their axes of rotation coincident. Find the angular speed of the two-disc system.

A. 
$$\frac{l_1\omega_1 - l_2\omega_2}{l_1 - l_2}$$

B. 
$$\frac{l_1\omega_1 + l_2\omega_2}{l_1 + l_2}$$

C.  $\frac{l_1\omega_2 + l_2\omega_1}{l_1 + l_2}$

D.  $\frac{l_1\omega_2 - l_2\omega_1}{l_1 - l_2}$ .

**Answer:**



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**20.** A solid cylinder of mass 2kg and radius 20 cm is rotating about its axis with a frequency  $(10/\pi)Hz$ . The rotational kinetic energy of the cylinder is :

A. 4 J

B. 8 J

C. 16 J

D. 32 J.

**Answer:**



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**21.** A shell following a parabolic path explodes somewhere in its flight. The centre of mass of fragments will continue to move in:



- A. vertical direction
- B. any direction
- C. horizontal direction
- D. same parabolic path.

**Answer:**



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**22.** The angular velocity of a wheel increases from 100 rps to 300 rps in 10 sec. The number of revolutions made during this time is :

A. 1000

B. 1500

C. 2000

D. 4000

**Answer:**



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**23.** Two bodies of different masses of 2 kg and 4 kg are moving with velocities  $2ms^{-1}$  and  $10ms^{-1}$  towards each other due to mutual

gravitational attraction. What is velocity of their centre of mass?

A.  $-5ms^{-1}$

B.  $-6ms^{-1}$

C.  $-8ms^{-1}$

D. zero.

**Answer:**



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24. Which of the following statements about angular momentum is correct?

- A. Angular momentum remains conserved
- B. Angular momentum is the product of moment of inertia and angular velocity
- C. Moment of inertia is directly proportional to angular momentum for constant angular speed.
- D. All of the above.

**Answer:**



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**25.** How angular momentum related to areal velocity?

A.  $L = 2m \times \text{areal velocity}$

B.  $L = 2p \times \text{areal velocity}$

C.  $\text{Areal velocity} = 2mL$

D.  $2m = L \times \text{areal velocity}$ .

**Answer:**



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**26.** The moment of inertia of a rod about an axis through its centre and perpendicular to its length is  $ML^2/12$  (where  $M$  is the mass and  $L$  is the length of the rod). The rod is bent in the middle so that the two halves make an angle  $60^\circ$ . The moment of inertia of the bent rod about the same axis would be :

A.  $\frac{1}{48}ML^2$

B.  $\frac{1}{12}ML^2$

C.  $\frac{1}{24}ML^2$

D.  $\frac{ML^2}{8\sqrt{3}}$ .

**Answer:**



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**27.** A solid cylinder has mass  $M$ , length  $L$  and radius  $R$ . The moment of inertia of this cylinder about a generator is :

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

B.  $ML^2 / 4$

C.  $\frac{1}{2}MR^2$

D.  $\frac{3}{2}MR^2$ .

**Answer:**



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**28.** Moment of inertia of two spheres of equal radii are equal. One of the spheres is solid and



has the mass 5 kg. What is the mass of the hollow sphere?

A.  $\frac{2}{3}kg$

B.  $3kg$

C.  $\frac{2}{5}kg$

D. 5 kg.

**Answer:**



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29. Two circular iron discs are of the same thickness. The diameter of A is twice that of B. The moment of inertia of A as compared to that of B is :

- A. twice as large
- B. four times as large
- C. 8 times as large
- D. 16 times as large.

**Answer:**



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**30.** The momentum of inertia of a cube will be minimum about an axis which:

- A. is an edge of the cube
- B. is a face diagonal
- C. joins midpoints of opposite faces
- D. is a body diagonal.

**Answer:**



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31. Two spheres each of mass  $M$  and radius  $R/2$  are connected with a massless rod of length  $2R$  as shown in fig. What will be the moment of inertia of the system about an axis passing through the centre of one of the spheres and perpendicular to the rod?

A.  $\frac{21}{5}MR^2$

B.  $\frac{2}{5}MR^2$

C.  $\frac{5}{2}MR^2$

D.  $\frac{5}{21}MR^2$ .

**Answer:**



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**32.** The moment of inertia of a ring is  $0.40 \text{ kgm}^2$ . If it is making 2100 rpm, What torque is required to stop it in 2 seconds?

A. 22 N m

B. 33 N m

C. 44 N m

D. 55 N m.

**Answer:**



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**33.** What remains constant when the earth revolves around the sun?

- A. Angular momentum
- B. Linear momentum
- C. Angular kinetic energy
- D. Linear kinetic energy.

**Answer:**



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**34.** A spherical ball rolls without slipping on a horizontal surface and its rotational kinetic energy is equal to the translational kinetic energy. The body is :

A. disc

B. sphere

C. cylinder

D. ring

**Answer:**



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**35.** There are two identical balls of same material ,one being solid and the other being hollow. How will you distinguish them without weighing?

A. By spinning them using equal torques



B. By determining their moment of inertia

C. By rolling them down an inclined plane

D. By any one of these methods.

**Answer:**



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**36.** A horizontal platform is rotating with uniform angular velocity about a vertical axis passing through its centre. At some instant of time, a viscous fluid of mass  $m$  is

dropped at its centre and is allowed to spread out and finally fall, The angular velocity during this period:

- A. decreases continuously
- B. decreases initially and then increases
- C. remains unaltered
- D. increases continuously.

**Answer:**



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37. Three thin metal rods, each of mass  $M$  and length  $L$ , are welded to form an equilateral triangle. The moment of inertia of the composite structure about an axis passing through the centre of mass of the structure and perpendicular to its plane is :

A.  $\frac{1}{2}ML^2$

B.  $\frac{1}{3}ML^2$

C.  $\frac{2}{3}ML^2$

D.  $\frac{1}{4}ML^2$ .

**Answer:**



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**38. Fill in the blanks**

If distribution of mass of a body changes, its .....  
will also change.



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**39. Fill in the blanks**

Moment of inertia of a body depends ..... on

its mass.



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**40.** Fill in the blanks

MOMent of inertia plays the same role in  
..... motion as mass plays in linear motion.



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**41.** Fill in the blanks

Moment of inertia is measured in .....



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## 42. Fill in the blanks

Centre of mass of a body may or may not lie  
..... the material of body.



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## 43. Fill in the blanks:

Centre of mass can lie \_ the body.



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## Example

1. A body is rotating, it is necessary being acted upon by an external torque?



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2. What is the position vector of centre of mass of two particles of equal masses?



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3. A heavenly body revolves around a massive star in a highly elliptical orbit..Is its angular momentum constant over the entire orbit?



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4. Where does centre of mass of a triangular lamina lie?



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5. Is the angular momentum a scalar quantity  
?State its unit.



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6. What is the direction of angular momentum  
of a body?



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7. Is centre of mass a reality?



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8. Which points on a cylinder rolling over a surface move rectilinearly?



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9. A shell fired from a gun explodes into pieces in air. How is the centre of mass of the shell affected?



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**10.** A ballet-dancer stretches her hands out for slowing down. What principle is involved in this ?



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**11.** Under what conditions angular momentum of a moving body is zero?



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**12.** Three identical spheres each of radius  $R$  are placed touching each other on a horizontal table. Where is the centre of mass of the system located?



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**13.** Center of mass of a body always lies at a point, where there is no mass?



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**14.** Does the angular momentum of an electron remain conserved when the electron rotates around a nucleus?



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**15.** What is an isolated system?



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**16.** Define centre of mass.



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**17.** What is rotational analogue of mass?



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**18.** Is radius of gyration of a body a constant quantity?



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**19.** About which axis is moment of inertia of cube minimum?



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**20.** Find the expression for moment of inertia of a thin uniform rod about an axis passing through its one end and perpendicular to its length.



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21. Which law is used by a ballet dancer to change her speed or rotation?



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22. Find the moment of inertia of a sphere about a tangent to the sphere, given the moment of inertia of the sphere about any of its diameters to be  $\frac{2MR^2}{5}$ , where  $M$  is the mass of the sphere and  $R$  is the radius of the sphere.



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**23.** What is the ratio of rotational K.E. to the translational K.E. of a rolling body?



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**24.** What is the ratio of translational K.E. to the total K.E. of a rolling body?



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**25.** A solid sphere and a hollow sphere are allowed to roll down an inclined plane. Which body reaches the bottom earlier?



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**26.** What is the condition for rolling of a solid cylinder without slipping on an inclined plane?



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**27.** What is torque due to gravity about an axis passing through C.M.?



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**28.** Where does centre of mass of a triangular lamina lie?



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**29.** Can the mass of a body be taken to the concentrated at its CM for calculating its rotational inertia?



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**30.** Three identical spheres each of radius  $R$  are placed touching each other on a horizontal table. Where is the centre of mass of the system located?



**Watch Video Solution**

**31.** What is the direction of angular momentum of a body?



**Watch Video Solution**

**32.** Which physical quantities are expressed by the following? Moment of linear momentum.



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**33.** Which physical quantities are expressed by the following? Rate of change of angular momentum.



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**34.** What is rotational analogue of mass?



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**35.** What is ratio of S.I to C.G.S. units of torque?



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**36.** Name a physical constant whose dimensions are the same as that of angular momentum.



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**37.** Which component of force produces no torque?



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**38.** Where does the centre of mass of a triangular lamina lie?



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**39.** Find the torque of a force  $(7\hat{i} + 3\hat{j} - 5\hat{k})$  about the origin. The force acts on a particle whose position vector is  $(\hat{i} - \hat{j} + \hat{k})$ .



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**40.** Illustrate with examples, the concept of centre of mass.



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**41.** Define centre of mass.



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**42.** A wrench with large arm is preferred. Why?



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**43.** What is geometrical meaning of angular momentum in two dimensions?



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**44.** What is law of conservation of momentum ?



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**45.** The speed of rotation of a person with some weights in his hands and standing on a rotating platform increases as he draws his arms close to his chest. Why? Explain.



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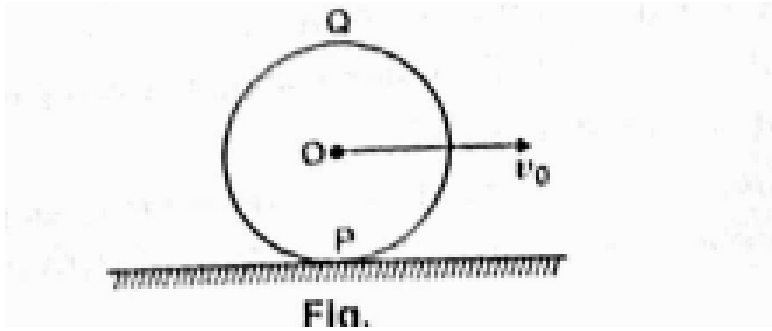
**46.** What is the ratio of translational K.E. to the total K.E. of a rolling body?



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**47.** A sphere is rolling without slipping on a horizontal surface and velocity of its CM.w.r.t,the ground is  $v$ ,What is linear velocity of :

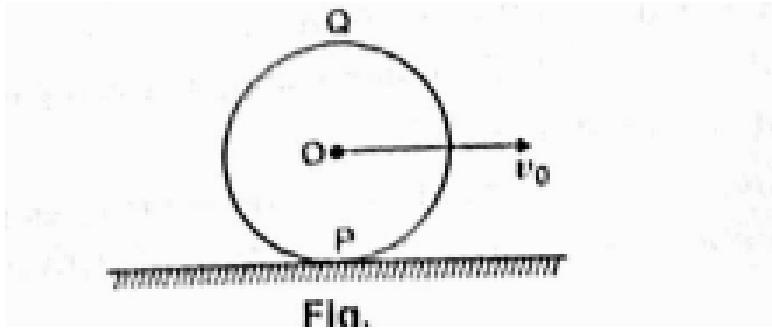
the point Q highest point as shown in the fig.



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**48.** A sphere is rolling without slipping on a horizontal surface and velocity of its CM.w.r.t,the ground is  $v$ ,What is linear velocity of:

the point Q highest point as shown in the fig.



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**49.** A wheel stays in the upright position while rolling, whereas it falls from its upright position when stationary. Why?



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50. Why are two propellers used in a helicopter?



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51. Consider a two - particle system with the particles having masses  $M_1$  and  $M_2$  .If the first particle is pushed towards the centre of mass through a distance  $a$ ,by what distance would the second particle be moved,so as t keep the centre of mass at the same position?



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**52.** 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.

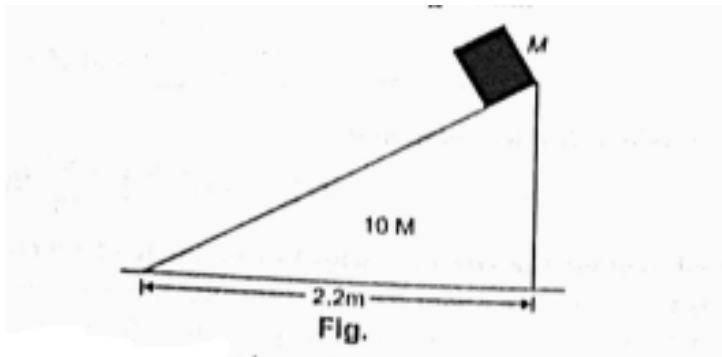


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**53.** A block of mass  $M$  is placed in the top of a bigger block of mass  $10 M$  as shown in fig. All



the surfaces are frictionless. The system is released from rest. Find the distance moved by the bigger block at the instant the smaller block reaches the ground.



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54. A wheel of radius  $10\text{ cm}$  can rotate freely about its centre as shown in fig. A string is

wrapped over its rim and is pulled by a force of 5.0N .It is found that the torque produces an angular acceleration  $2.0 \text{ rad//s}$  in the wheel.calculate the moment of inertia of the wheel.



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



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**56.** A wheel having moment of inertia  $2 \text{ kg m}^2$  about its axis, rotates at  $50 \text{ rpm}$ . About this axis, find the torque that can stop the wheel in one minute.



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**57.** A string is wrapped around the rim of a wheel of moment of inertia  $0.20 \text{ kgm}^2$  and radius  $20 \text{ cm}$ . 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 seconds.



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**58.** A shell fired from a gun explodes into pieces in air .How is the centre of mass of the shell affected?



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**59.** A system consists of two particles of masses  $M$  and  $m$  ( $M > m$ ) separated by a distance. What will be the position of CM?



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**60.** The cap of the pen can be easily opened with the help of two fingers than with one finger. Explain why.



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**61.** Derive expression for torque in cartesian co-ordinate system.



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**62.** A spinning top stands erect but a top which is not spinning falls. Why ?



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**63.** A disc spinning about its axis is placed lightly without an translational push on a perfectly frictionless table. Will the centre of mass of the disc advance?

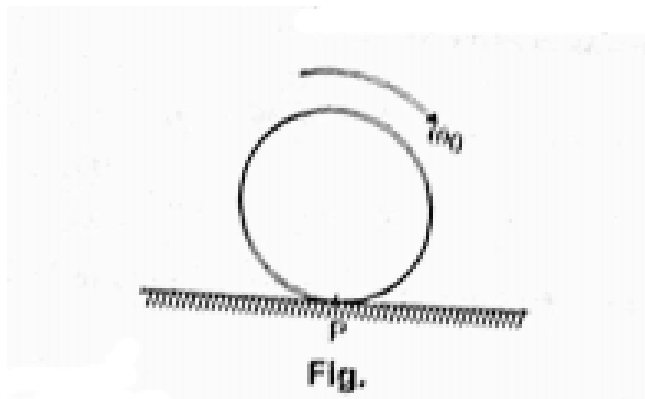


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**64.** A disc spinning clockwise about its axis with angular velocity  $\omega_0$  is set on a rough horizontal plane[Fig.].

What is the direction of frictional force at

point P and sense of frictional torque ,before pure rolling starts?

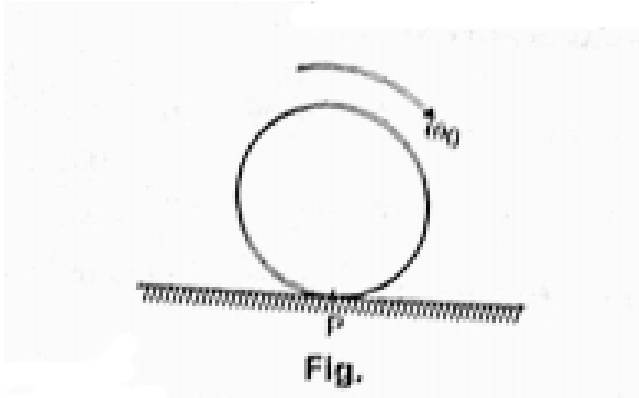


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**65.** A disc spinning clockwise about its axis with angular velocity  $\omega_0$  is set on a rough horizontal plane[Fig.].



What is the force of friction after rolling without slipping starts?



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**66.** A ring and disc have the same mass and radius. What is the ratio of their moment of inertia about their axis of symmetry?



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**67.** A constant torque acting on a uniform circular wheel changes its angular momentum from  $L$  to  $4L$  in 4 seconds. The magnitude of torque is :



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**68.** What is the total kinetic energy of a solid sphere rolling on a surface and having

translational velocity  $v$ ?



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**69.** Derive an expression for acceleration of a body moving down an inclined plane.



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**70.** Moment of a solid cylinder about its axis of symmetry is equal to moment of inertia about an axis passing through its centre and

perpendicular to its length. Show that

$$L/r = \sqrt{3}.$$



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71. The moment of inertia of two bodies are  $I_a$  and  $I_b$  with  $I_a > I_b$  and their angular moments are equal. Which one of them has greater kinetic energy?



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**72.** Derive Kepler's second law of planetary motion, using the law of conservation of angular momentum.



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**73.** Find the moment of inertia of a sphere about a tangent to the sphere, given the moment of inertia of the sphere about any of its diameters to be  $\frac{2MR^2}{5}$ , where  $M$  is the

mass of the sphere and  $R$  is the radius of the sphere.



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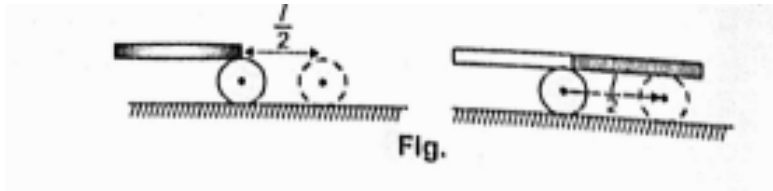
**74.** If the earth suddenly contracts to half of its original size without any change in mass, the new duration of the day would be :



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75. A cylindrical drum is pushed by a wooden plank as shown in the fig. The cylinder rolls forward on the ground by a distance  $\frac{l}{2}$  equal to half of the length of the plank. There is no slipping at any point of contact.

Where is the board then?



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**76.** Explain how a cat is able to land gently on its feet after a fall taking the advantage of the law of conservation of angular momentum?



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**77.** Read each statement below carefully, and state, with reasons, if it is true or false :-  
During rolling, the force of friction acts in the same direction as the direction of motion of the CM of the body.







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**78.** Read each statement below carefully, and state, with reasons, if it is true or false :- The instantaneous speed of the point of contact during rolling is zero.



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**79.** Read each statement below carefully, and state, with reasons, if it is true or false :- The

instantaneous acceleration of the point of contact during rolling is zero.



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**80.** Read each statement below carefully, and state, with reasons, if it is true or false :- A wheel moving down a perfectly frictionless inclined plane will undergo slipping (not rolling) motion.



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**81.** A rope of negligible mass is wound round a hollow cylinder of mass 3 kg and radius 40 cm. What is the angular acceleration of the cylinder if the rope is pulled with a force of 30 N ? What is the linear acceleration of the rope ? Assume that there is no slipping.



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**82.** The oxygen molecule has a mass of  $5.30 \times 10^{-26} \text{ kg}$  and a moment of inertia of  $1.94 \times 10^{-46} \text{ kgm}^2$  about an axis through its

centre perpendicular to the lines joining the two atoms. Suppose the mean speed of such a molecule in a gas is  $500\text{ m/s}$  and that its kinetic energy of rotation is two thirds of its kinetic energy of translation. Find the average angular velocity of the molecule.



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**83.** State the principle of conservation of angular momentum.



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**84.** A flywheel of mass 30 kg has a radius of 0.2 m .What force should be applied tangentially to the rim of the flywheel so that it acquires an angular acceleration of  $23\text{rad} / \text{s}^2$ ?



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**85.** What is physical significance of moment of inertia?



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**86.** How is moment of inertia of a body different from its mass?



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**87.** If the angular momentum is conserved in a system whose MI is decreased, will its rotational KE be also conserved? Explain.



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**88.** Calculate the radius of gyration of a rod of mass 100 g and length 100 m about an axis passing through its centre of gravity and perpendicular to its length.



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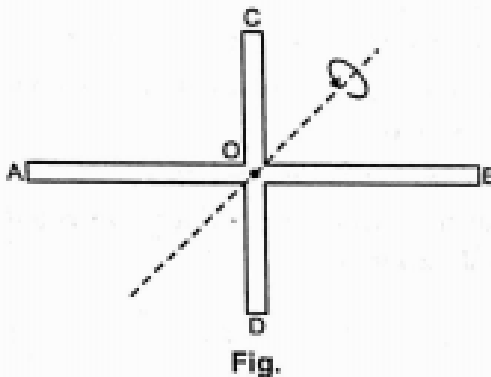
**89.** A thin circular ring of diameter 15 cm has a mass of 100g. Find its moment of inertia about an axis passing through its centre and perpendicular to its plane.





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90. Two uniform identical rods AB and CD each of mass  $M$  and length  $L$  are joined to form a cross as a shown in fig. find the moment of inertia of the cross about a bisector as shown dotted in the figure.



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**91.** Discuss general motion of a rigid body.



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**92.** What do you understand by couple?



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**93.** Given that linear momentum of a system of particles is zero.





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**94.** Define angular momentum and find its relation with moment of inertia.



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**95.** What is the moment of inertia of a disc about their diameters?



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**96.** Prove that:

$$L = I\omega$$



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**97.** Prove that:

$$\tau = I\alpha$$



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**98.** Prove that

$$\vec{r} = d \frac{d\vec{L}}{dt}$$



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**99.** Show that the area of the triangle contained between the vectors  $a$  and  $b$  is one half of the magnitude of  $a \times b$ .



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**100.** Prove the theorem of parallel axes.



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