# PHYSICS

# BOOKS - MODERN PUBLICATION

# Rotational Motion

## Example

**1.** show that the vectors $\vec{A} = \hat{i} - 5\hat{j}$ and $\vec{B} = 2\hat{i} - 10\hat{j}$ are parallel to each other

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**2.** The motor of an engineis rotating about its axis with an angular velocity of 120 RPM. it comes to rest in 10 seconds, after being switched off. assuming counts in deceleration calculate the number of revolutions made by it before coming to rest.

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**3.** In order to open a door, a boy applies a force of 50 N on its handle in a direction normal to the plane of the door. If the applied force acts at a

distance of 0.6 m from the hinges, find the torque of the force.

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**4.** In hydrogen atom, electron revolves in a circular orbit of radius $0.53 \times 10^{-10}$ with a velocity of $2.2 \times 10^{6} ms^{-1}$. If the mass of electron is $9 \times 10^{-31} kg$, find the angular momentum

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**5.** $\vec{A}$ and $\vec{B}$ are two vectors and $\theta$ is the angle between them. If $\left|\vec{A} \times \vec{B}\right| = \sqrt{3}\left(\vec{A} . \vec{B}\right)$, then find the value of $\theta$

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**6.** Show that $\left(\vec{A} + \vec{B}\right) \times \left(\vec{A} - \vec{B}\right) = 2\left(\vec{B} \times \vec{A}\right)$

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**7.** If $\vec{A} \times \vec{B} = \vec{0}$ and $\vec{A} . \vec{B} = \vec{0}$, does it implies that one of the vectors $\vec{A}$ or $\vec{B}$ must be null vector?

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**8.** The spin dryer of a washing machine revolving at 15 RPS slows down to 5 RPS while making 50 revolutions. find angular acceleration

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**9.** The spin dryer of a washing machine revolving at 15 RPS slows down to 5 RPS while making 50 revolutions. find angular acceleration

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**10.** The radius of earth's orbit is $1.5 \times 10^{11}$m and its period of revolution is $3.2 \times 10^{7}$s. Find the magnitude of the velocity

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**11.** The radius of earth's orbit is $1.5 \times 10^{11}$m and its period of revolution is $3.2 \times 10^{7}$s. Find the acceleration of the earth in its motion around sun.

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**12.** A force of 36 N is applied to a particle located at 0.15 m from the axis of rotation. what is the magnitude of the torque about this Axis if the angle between the direction of the applied force and the radius vector is $60^{\circ}$

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**13.** A force of 36 N is applied to a particle located at 0.15 m from the axis of rotation. what is the magnitude of the torque about this Axis if the angle between the direction of the applied force and the radius vector is is $90^\circ$

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**14.** A force of 36 N is applied to a particle located at 0.15 m from the axis of rotation. what is the magnitude of the torque about this Axis if the angle between the direction of the applied force and the radius vector is $120^\circ$

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**15.** In our bodies, torque produced due to the contraction of the muscles cause some bones move at the joints. For example in lifting a load with the hand, torque is applied by the bicep muscles on the elbow. If the axis of rotation through the elbow point and the muscle attached is 4 cm from the joint, find the magnitudes of the muscle torques in the two cases, if the muscle exerts a force of 600 N?

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**16.** A wheel of grind stone has applied at its axle 2 cm in radius a constant tangential force of 600 N. Find the torque acting on it

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**17.** A wheel of grind stone has applied at its axle 2 cm in radius a constant tangential force of 600 N. Find the angular momentum acquired after 8s.

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**18.** The earth revolves round the sun in an orbit of radius $1.5 \times 10^{11} m$ once in a year. Calculate the orbital angular monentum of the earth, if its mass is $6 \times 10^{24} kg$

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**19.** An electron of mass $9 \times 10^{-31} kg$ revolves in a circle of radius 0.53 Å around the nucleus of hydrogen with a velocity of $2.2 \times 10^{6} ms^{-1}$. Show that its angular momentum is equal to $\frac{h}{2}\pi$, where h is Plank's constant of value $6.6 \times 10^{-34} Js$.

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**20.** Show that the angular momentum of a satellite of mass $M_s$, revolving round the earth having mass $M_e$, in an orbit of radius r is equal to $\left[GM_eM_s^2r\right]^{\frac{1}{2}}$

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**21.** A particle of mass m = 2 kg is moving with a uniform speed $3\sqrt{2}ms^{-1}$ in the XOY plane along the line y = x + 6. Find the magnitude of the angular momentum of the particle about the origin.

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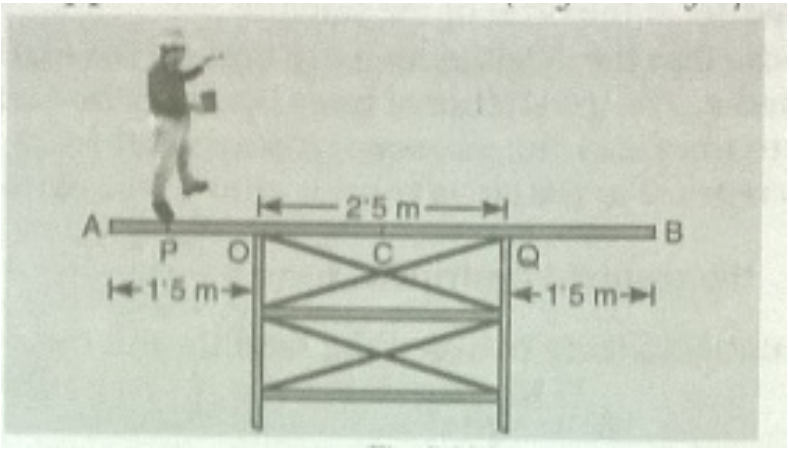
**22.** A painter weighing 60 kg paints the wall of a house, while standing on a scafford (a criss-cross stand made of steel bars and a long wooden board placed on it) as shown in Fig. If the mass of the board is 15 kg, how close to its end can the painter stand without risking the board to topple over?

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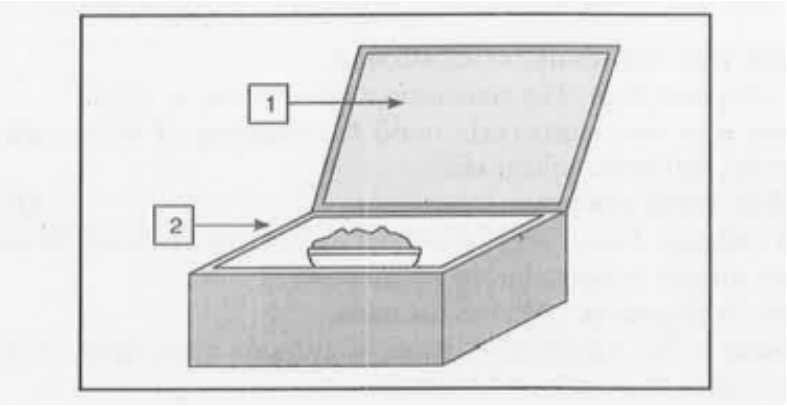
**23.** Label 1 and 2 in the given figure.

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**24.** An uniform steel bar of mass 5 kg and length 1.5 is supported at its two ends. a mass of 2 kg is suspended from a point 0.3 m from the left end of the bar determine the reactions at each end of the Steel bar

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**25.** Two boys weighing 40 kg and 50 kg are sitting on either side of a wooden plank at distances 4.5 m and 1.5 m respectively from the fulcrum coinciding with the centre of gravity of the plank. Where must a third boy weighing 35 kg sit to secure balance ?

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**26.** A uniform ladder of length 6 m and weight 20 kgf rests against a smooth wall making an angle of $60^\circ$ with the floor. A man weighing 50 kgf is

standing on the ladder 4 m from its bottom. Find the reactions of the wall and the floor.

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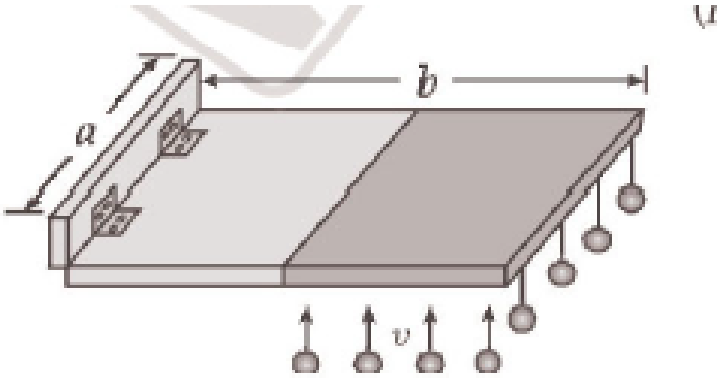
**27.** There is a rectangular plate of mass M kg of dimensions (axxb). The plate is held in horizontal position by striking n small balls each of mass m per unit area per unit time. These are striking in the shaded halt region of the plate. The balls are colliding elastically with velocity v. What is v? It is given n=100, M=3 kg, m=0.01 kg, a=1 m,b= 2 m and

`g=10 ms^-1.

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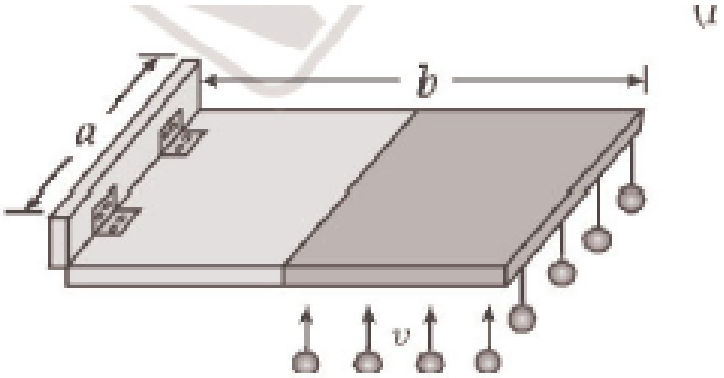
**28.** A U shaped tube contains a liquid of density $\rho$ and it is rotated about the line as shown in figure. Find the difference in the levels of the liquid

column.

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**29.** A particle of mass m is projected with velocity v making an angle of $45^\circ$ with the horizontal .The magnitude of the angular momentum of the projectile about the point of projection when the particle is at maximum height is :

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**30.** A rod of weight w is supported by two parallel knife edges A and B and is equilibrium in a horizontal position. The knives are at a distance d from each other. The centre of mass of the road is at a distance x from A. Find the normal reactions at the knife edges A and B.

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**31.** Define the cross product of two vectors

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**32.** Show that $\vec{A} \times \vec{A} = 0$

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**33.** What is the condition for two vectors to be parallel to each other?

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**34.** If $\vec{A} \times \vec{B} = 0$ what can be said about the vectors $\vec{A}$ and $\vec{B}$?

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**35.** The angle between vectors $\vec{A}$ and $\vec{B}$ is $60^\circ$. What is the ratio between $\vec{A} . \vec{B}$ and $\left|\vec{A} \times \vec{B}\right|$

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**36.** Do the internal forces affect the motion of a system under the effect of some external force?

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**37.** What do you mean by a rigid body?

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**38.** What is meant by torque in rotational motion?

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**39.** What is torque ? Give its S.I. unit.

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**40.** Define angular momentum. Give its SI unit.

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**41.** Which physical quantities are represented by the Rate of change of angular momentum.

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**42.** Which physical quantities are expressed by the following? Moment of lineaer momentum.

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**43.** If the torque acting on a particle about the origin is zero, what can we say about the angular momentum of the particle about the origin?

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**44.** Can a torque be balanced by a single force? Explain

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**45.** Explain law of conservation of angular momentum.

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## Exercise

**1.** What are the properties of cross product?

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**2.** What is the condition for two vectors to be parallel to each other?

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**3.** Find the condition for two vectors to be perpendicular to each other

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**4.** Show that the angle between $\vec{A} = \hat{i} - 5\hat{j}$ and $\vec{B} = 2\hat{i} - 10\hat{j}$ is zero

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**5.** If $\vec{A} \times \vec{B} = \vec{C} \times \vec{B}$ show that $\vec{C}$ need not be equal to $\vec{A}$

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**6.** If $\vec{A} \times \vec{B} = \vec{C} \times \vec{B}$. When will $\vec{C}$ be equal to $\vec{A}$ ?

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**7.** Explain, why it is difficult to open a door by pushing or pulling it near the hinge.

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**8.** While turning the page of a book, we usually apply force perpendicular to the plane of the page off the page at the farthest end. explain

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**9.** Torque and work are both defined as force times distance. How do they differ?

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**10.** A particle moves in a circular path with decreasing speed. what happen to its angular momentum?

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**11.** A ladder is more apt to slip when you are high up on its than when you are just begin to climb. Why?

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**12.** A planet revolves around the sun under the effect of gravitational force exerted by the sun. Why is the torque on the planet due to the gravitational force zero ?

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**13.** A projectile acquires angular momentum about its point of projection during its flight. Is its angular momentum constant over the entire orbit?

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**14.** What do you mean by mechanical equilibrium of a rigid body?

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**15.** State the condition for the rigid body to be in mechanical equilibrium.

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**16.** Why does the speed of a planet vary in its orbit around the sun ?

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**17.** 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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**18.** Explain vector product of two vectors. Mention its any two properties.

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**19.** Given that $\vec{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k}$ and $\vec{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k}$. Find $\vec{A} \times \vec{B}$

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**20.** Derive an expression for the area of a triangle in terms of the cross-product of two vectors

representing the two sides of the triangle.

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**21.** Starting from Newton's second law of motion, derive the equation of motion of a particle (capable of rotation about an axis) on which a torque r is acting. Assume that the motion of the particle is in a plane.

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**22.** Define the term torque. Show that torque is given by the product of the force and its lever arm.

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

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**24.** Deduce the relation between torque and moment of inertia.

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

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**26.** Derive expression for the torque acting on a system of n-particles

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**27.** Obtain the expression for angular momentum of a particle moving in XY-plane from the expression for the torque $\tau = xF_y - yF_x$ acting on it. How does it lead to define angular momentum of a particle as the product of its linear momentum and perpendicular distance from the axis of rotation

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**28.** Derrive expression for the angular momentum of a system in cartesian coordinates

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**29.** Derive an expression for rotational kinetic energy and hence define moment of inertia.

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**30.** Prove that the time rate of change of the angular momentum of a particle is equal to the torque acting on it.

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**31.** Derive a relation between angular momentum and torque.

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**32.** Define angular momentum. What are its units ? Establish the relation between angular momentum and torque.

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**33.** Define torque and the angular momentum. Show that $\vec{\tau} = \frac{d\vec{L}}{dt}$

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**34.** Obtain the relation between the torque and the angular momentum.

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**35.** Derive the relation between the torque and the angular momentum. Hence obtain and state the

law of conservation of angular momentum.

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**36.** State and prove the principle of momentum.

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**37.** State and explain the law of conservation of angular momentum.

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**38.** State law of conservation of angular momentum. Illustrate it with the help of two examples.

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**39.** State the law of conservation of angular momentum.

Watch Video Solution

**40.** Why angular speed of rotation of earth around the sun the increases, when it comes near the sun ?

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**41.** Define angular momentum. Prove that angular momentum of a particle is equal to twice the product of its mass and areal velocity.

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**42.** Deduce Kepler's second law of planetary motion from the law of conservation of angular momentum.

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**43.** Explain the vector product of two vectors

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**44.** Show by example that the vector product does not obey commutative law

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**45.** Explain vector product of two vectors. Mention its any two properties.

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**46.** Show by example that the cross product of vectors obeys distributive law

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**47.** Show that the cross product of two vectors $\vec{A}$ and $\vec{B}$ varies from 0 to AB.

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**48.** Define torque and the angular momentum. Show that $\vec{\tau} = \frac{d\vec{L}}{dt}$

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

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**50.** Explain work done by a variable force.

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**51.** Show that the torque at a point is equal to the product of the magnitude of force and the moment arm ( lever arm)of the force

Watch Video Solution

**52.** Show that the torque at a point is equal to the product of the magnitude of force and the moment arm ( lever arm)of the force

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**53.** Derrive expression for the angular momentum of a system in cartesian coordinates

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**54.** Derrive expression for angular momentum of a system in polar co-ordinate. Hence prove that angular momentum= linear momentum xx perpendicular distance from axis of rotation

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**55.** Define angular momentum. Give its SI unit.

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**56.** Show that the angular momentum is equal to twice the product of mass and real velocity.

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**57.** Show that the area of the parallelogram with diagonals $\vec{a}$ and $\vec{b}$, is $\frac{1}{2}\left|\vec{a} \times \vec{b}\right|$.

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**58.** Prove that

$$\left|\vec{A} . \vec{B}\right|^2 + \left|\vec{A} \times \vec{B}\right|^2 = A^2 B^2$$

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**59.** Show that $\left(\vec{A}+\vec{B}\right)\times\left(\vec{A}-\vec{B}\right)=2\left(\vec{B}\times\vec{A}\right)$

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**60.** Given that $\vec{A}\times\vec{B}-\vec{B}\times\vec{C}=\vec{0}$. If $\vec{A}$, $\vec{B}$ and $\vec{C}$ are not null vectors. Find the value of $\vec{C}\times\vec{A}$

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**61.** show that the vectors $\vec{A} = 2\hat{i} - 3\hat{j} - \hat{k}$ and $\vec{B} = -6\hat{i} + 9\hat{j} + 3\hat{k}$ are parallel

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**62.** show that the vectors $\vec{A} = \hat{i} - 5\hat{j}$ and $\vec{B} = 2\hat{i} - 10\hat{j}$ are parallel

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**63.** show that the vectors $\vec{A} = 6\hat{i} + 9\hat{j} - 12\hat{k}$ and $\vec{B} = 2\hat{i} + 3\hat{j} - 4\hat{k}$ are parallel

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**64.** If $\vec{A} = 4\hat{i} - 5\hat{j} + 6\hat{k}$ and $\vec{B} = 3\hat{i} + 6\hat{j} - 7\hat{k}$, find $\vec{A} + \vec{B}$

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**65.** A vector $\vec{A}$ has magnitude 6 units and is directed along positive x axis. another vector $\vec{B}$ has magnitude four units and lies in xy plane making an angle of $30^\circ$ with positive x axis and then angle of $60^\circ$ with positive y axis. find the product $\vec{A} \times \vec{B}$

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**66.** find the unit vector perpendicular to each of the vectors $\vec{A} = 3\hat{i} + \hat{j} + 2\hat{k}$ and $\vec{B} = 2\hat{i} - 2\hat{j} + 4\hat{k}$ and the angle between them.

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**67.** A flywheel rotating at 420 RPM slows down at a constant rate of $2rads^{-2}$. what time is required to stop the flywheel?

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**68.** A constant torque is acting on a wheel. if starting from rest the wheel makes n rotations in t seconds. show that the angular acceleration is given by $\alpha = \frac{4\pi n}{t^2} rads^{-1}$

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**69.** On the application of a constant torque, a wheel is turned from rest through 400 radians in 10s. Find angular acceleration

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**70.** On the application of a constant torque, a wheel is turned from rest through 400 radians in 10s. Find angular acceleration

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

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**72.** A grinding stone of radius 2m revolving at 120 rpm accelerates to 660 r.p.m.in 9 seconds. Find the angular acceleration.

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**73.** A grinding stone of radius 2m revolving at 120 rpm accelerates to 660 r.p.m.in 9 seconds. Find the angular acceleration.

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**74.** The earth revolves round the sun in an orbit of radius $1.5 \times 10^{11} m$ once in a year. Calculate the orbital angular monentum of the earth, if its mass is $6 \times 10^{24} kg$

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**75.** the moon is is 3.824x10^5km from the centre of earth and requires 27.3 days for a revolution. what is the centripetal acceleration?

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**76.** the moon is is 3.824x10^5km from the centre of earth and requires 27.3 days for a revolution. what is the centripetal acceleration?

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**77.** a wheel of radius 1 m starts from rest and moves with an acceleration of $3rads^{-1}$. Find angular displacement of the wheel after 4 seconds

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**78.** a wheel of radius 1 m starts from rest and moves with an acceleration of $3rads^{-1}$. Find angular displacement of the wheel after 4 seconds. What is the centripetal acceleration at a point on its rim at that instant.

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**79.** A disc of radius 0.5 m is rotating about an axis passing through its centre and perpendicular to its plane. A tangential force of 2000 N is applied to bring the dics to rest 2 s . Calculate its angular momentum.

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**80.** A torque of 20 N-m is applied on a wheel initially at rest. Calculate the angular momentum of the wheel after 3 sec

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**81.** Calculate angular momentum to Neptune about the sun. Given,the distance of neptune from sun is $5 \times 10^{12} m$ mass of neptune = $10^{27} Kg$ and period of revolution around the sun = $5 \times 10^{9} s$

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**82.** a uniform metre rod weighing 50 grams is supported at its ends and two masses of 20 g and 30 g are suspended at 20 and 90 cm marks respectively. Find the reaction of the supports

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**83.** An iron rod of weight 50 kgf and a weight of 10 kgf is attached at one end . it balances itself at a point 6 m from the same end . find the length of the iron road

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**84.** a uniform metre rod weighing 50 grams is supported at its ends and two masses of 20 g and 30 g are suspended at 20 and 90 cm marks respectively. Find the reaction of the supports

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**85.** A uniform ladder of length 6 m and weight 20 kgf rests against a smooth wall making an angle of $60^\circ$ with the floor. A man weighing 50 kgf is

standing on the ladder 4 m from its bottom. Find the reactions of the wall and the floor.

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**86.** A ladder rest at an angle $\theta$ to the horizontal with the ends resting on a smooth floor and against a smooth vertical wall, the lower end being attached by string to the junction of the wall and the floor. Find the tension in the string in terms of weight of the ladder

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