# UNIT I - BASICS & STATICS OF PARTICLES

## PART - A (2 Marks Questions and Answers)

1. **Define Engineering Mechanics.**

Engineering mechanics is that branch of science which deals with the behavior of a body when the body is at rest or in motion. Engineering mechanics is the application of mechanics to solve problems involving common engineering elements. The engineering mechanics may be divided into statics and dynamics.

2. **Define Force.**

A force may be defined as an action in the form of push or pull exerted by one body on another body. Force tends to move a body in the direction of its action. The characteristics of force are magnitude, direction and point of application.

3. **State law of parallelogram of vectors.**

If two vectors are represented in magnitude and direction by two adjacent sides of a parallelogram, their resultant is represented in magnitude and direction by the diagonal of the parallelogram drawn from the common point.

4. **State the principle of transmissibility of force.**

According to principle of transmissibility of force, the force can be transmitted from one point to another on it is line of action without causing by any change in the motion of the object.

5. **Define space and time.**

It is defined as the geometric region occupied by a body whose position is described by linear and angular measurements with respect to coordinate system. Time is a measure of the succession of events.

6. **State triangle law of forces.**

If two forces are represented in magnitude and direction by two sides of a triangle taken in order, their resultant is represented in magnitude and direction by the third side of the triangle drawn from starting point of first force to end point of the second force.

7. **State Lami's theorem.**

If a particle acted upon by three forces remains in equilibrium then, each force acting on the particle bears the same proportionality with the since of the angle between the other two forces". Lami's theorem is also known as law of sines.

8. **What is a free body diagram?**

It is a sketch of the isolated body which shows the external forces on the body and the reactions exerted on it by the removed elements. In a free body diagram, all the supports (like walls, floors, hinges etc) are removed and replaced by the reactions which these supports exert on the body.

9. **State the principle of resolution.**

The algebraic sum of the resolved parts of a number of forces in a given direction is equal to the resolved part of their resultant in the same direction of their resultant and in the same direction.

**10. What is the difference between the resultant force and equilibrant force?**

When a number of forces acting on a particle are replaced by a single force which produces the same effect as that of all give it forces, then such a single force is called resultant force. The force which brings the set of forces in equilibrium is called an equilibrant.

**11. State the necessary and sufficient condition for static equilibrium of a particle in two dimensions.**

The necessary and sufficient conditions for static equilibrium of a particle in two dimensions are:

- The algebraic sum of horizontal components of all forces acting the particle must be zero.
- The algebraic sum of vertical components of all forces acting the particle must be zero.

**12. What are the characteristics of a force?**

The characteristics of a force are:

- Magnitude,
- Direction
- Line of action

**13. Define Particle.**

It can be defined as an object which has only mass and no size. Such a body cannot exist theoretically. When we deal with the problems involving distances considerably larger compared to the size of the body, the body may be treated as particle.

**14. Define the term" Vector quantity**

A quantity which is completely defined by magnitude and direction is known as a vector quantity. Some examples of vector quantities are velocity, acceleration, force and momentum.

**15. What is the significance of parallelogram law in statics of particles?**

The significances of parallelogram law in statics of particles are:

- Parallelogram law is used to find the resultant of two concurrent coplanar forces.
- It can be applied by both analytically and graphically.

**16. Define Equilibrium.**

It is a force is a vector quantity which means that it has both a magnitude (size) and a direction associated with it. If the size and direction of the forces acting on an object are exactly balanced, then there is no net force acting on the object and the object is said to be in equilibrium.

**17. State Newton's third law.**

Formally stated, Newton's third law is: For every action, there is an equal and opposite reaction. The statement means that in every interaction, there is a pair of forces acting on the two interacting objects. The size of the forces on the first object equals the size of the force on the second object.

**18. Define unit vector.**

Vectors of magnitude one is called unit vector. The unit vector of any given vector is obtained by dividing the given vector by the magnitude of vector.

**19. State Newton's Law of Gravitation.**

Newton's law of universal gravitation states that a particle attracts every other particle in the universe using a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

**20. What is a scalar quantity?**

A quantity which is characterized by a positive or negative number is called scalar quantity that is a scalar quantity is one which is completely defined by its magnitude alone. Some examples of scalar quantities are mass, length, time and area.

**21. State Newton's Second law.**

Newton's second law of motion can be formally stated as follows: The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.

**22. What is a vector quantity?**

A quantity which is completely defined by magnitude and direction is known as a Vector quantity. Some examples of vector quantities are velocity, acceleration, force and momentum.

**23. State Newton's First law.**

Newton's first law of motion - sometimes referred to as the law of inertia. An object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

**24. Define Concurrent forces.**

Concurrent forces are defined as forces that pass through a common point. In other words, a concurrent force system is a set of two or more forces whose lines of action intersect at a point at the same time.

**25. What is gravity?**

Gravity is a force pulling together all matter (which is anything you can physically touch). The more matter, the more gravity, so things that have a lot of matter such as planets and moons and stars pull more strongly.

Mass is how we measure the amount of matter in something. The more massive something is, the more of a gravitational pull it exerts. As we walk on the surface of the Earth, it pulls on us, and we pull back. But since the Earth is so much more massive than we are, the pull from us is not strong enough to move the Earth, while the pull from the Earth can make us fall flat on our faces.

**26. What is an Orbit?**

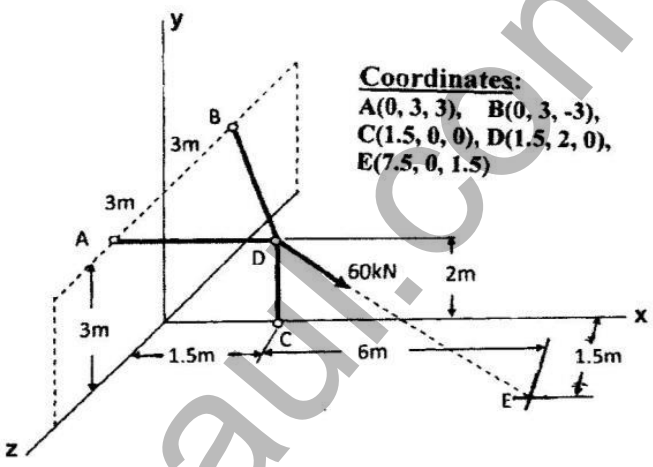
An orbit is a regular, repeating path that an object in space takes around another one. An object in an orbit is called a satellite. A satellite can be natural, like the moon, or human.

In our solar system, the Earth orbits the Sun, as do the other eight planets. They all travel on or near the orbital plane, an imaginary disk-shaped surface in space. All of the orbits are circular or elliptical in their shape. In addition to the planets' orbits, many planets have moons which are in orbit around them.

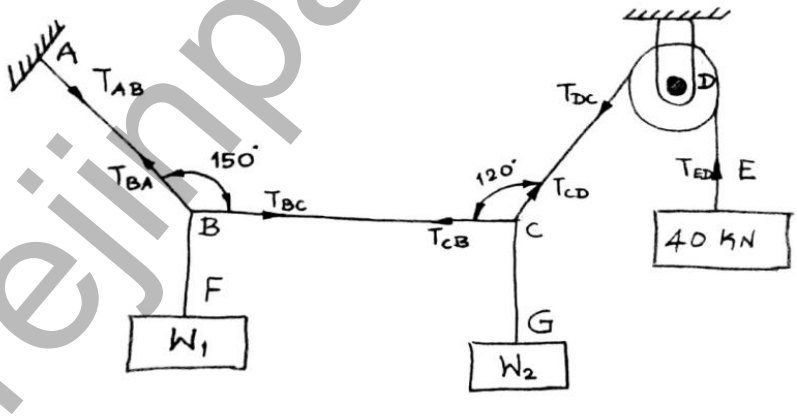
## PART - B (16 Marks Questions)

27. In the figure shown, three wires are joined at D.

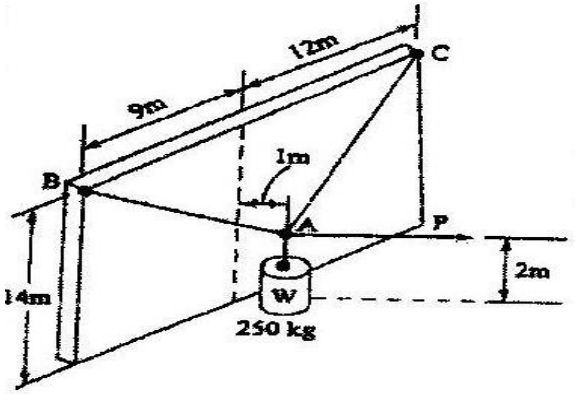
    Two ends A and B are on the wall and the other end C on the ground. The wire CD is vertical. A force of 60 KN is applied at 'D' and it passes through a point E on the ground as shown in figure. Find the forces in all the three wires. (AU JUN'10, JUN'12)



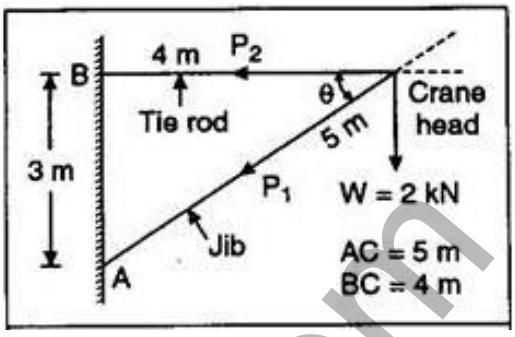

28. ABCDE is a light string whose end A is fixed. The weights W1 and W2 are attached to the string at B & C and the string passes round a small smooth wheel at D carrying a weight 40KN at the free end E. In the position of equilibrium, BC is horizontal and AB and CD make angles 150° and 120° with horizontal. Find (i) the tensions in AB, BC and DE of the given string (ii) magnitudes of W1 and W2. (AU DEC'12)



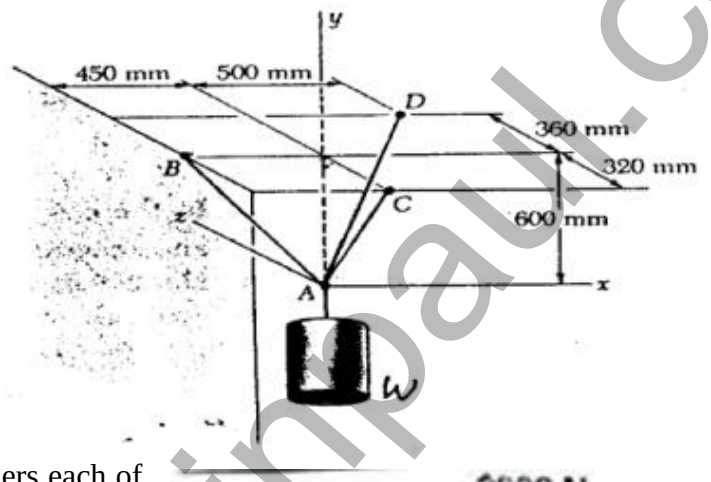

29. A horizontal force P normal to the wall holds the cylinder in the position shown in figure below. Determine the magnitude of P and the tension in each cable.



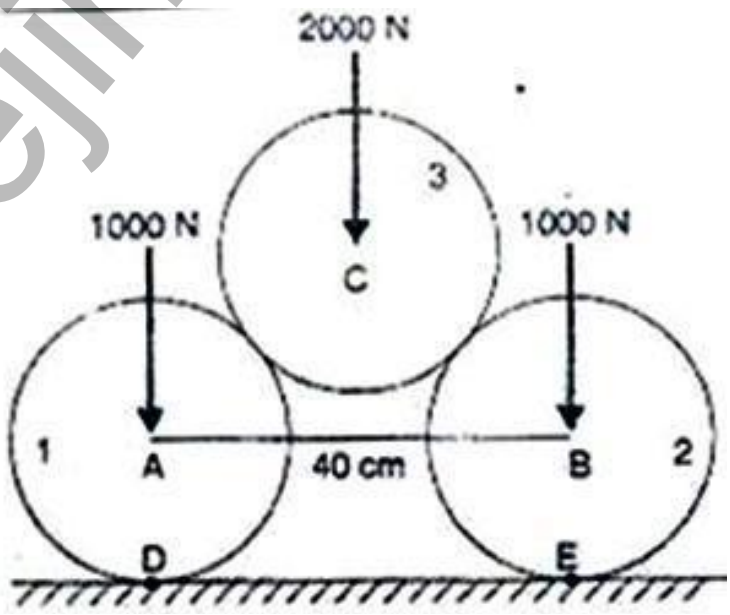
30. In a jib crane, the jib and the tie rod are 5 m and 4 m long respectively. the height of crane post in 3 m and the ties red remains horizontal. Determine the forces produced in jib and tie rod when a load of 2kN in suspended at the crane head.




31. A container is supported by three cables which are attached to a ceiling as shown. Determine the weight, W of the container, knowing that the tension in cable AD is 4.3kN.




32. Two smooth circular cylinders each of weight 1000 N and radius 15 cm are connected at their centers by a string AB of length 40 cm and rest upon a horizontal plane, supporting above them a third cylinder of weight 2000 N and radius 15 cm as shown in Figure. Predict the force S in the string AB and reactions on the floor at the points of contact D and E.



# UNIT II - EQUILIBRIUM OF RIGID BODIES

## PART - A (2 Marks Questions and Answers)

1. **State and prove Varignon's theorem. or State the principle of moments. (June 2001) (Dec2005) (Dec2006) (May 2004) (May 2009) (Dec2009) (May 2010) (Dec2010) (May 2011) (Dec2012) (Dec2013)**

   Varignon's theorem: When a number of forces act simultaneously on a particle, the algebraic sum of the moments of all the forces about any point is equal to the moment of the resultant force about the same point.

2. **State the necessary and sufficient conditions for equilibrium of rigid bodies in two dimensions. (Nov 1997) (Dec 2002) (May 2006) (Dec 2011)**

$$\sum H = 0 \quad \sum V = 0 \quad \sum M = 0$$

3. **The position vector and force are 2i - 3j + 4k and 120i - 260j + 320k respectively. Find the moment of the Force about the origin. And also find the scalar quantity of the moment.**

$\overrightarrow{Mo} = \overrightarrow{r} \times \overrightarrow{F}$

$= 2i - 3j + 4k \times 120i - 260j + 320k$

$$= \begin{vmatrix} i & j & k \\ 2 & -3 & 4 \\ 120 & -260 & 320 \end{vmatrix}$$

**$= 80i - 160j - 160k$**

Scalar quantity $= \sqrt{(M^2_X + M^2_Y + M^2_Z)}$

$= \sqrt{(80^2 + (-160)^2 + (-160)^2)} = 240$units

4. **In the above problem, find the angles made by the moment along x, y and z axes**

$$\phi_X = \cos^{-1}(Mx/M) = \cos^{-1}(80/240) = 70.52^0$$

$$\phi_Y = \cos^{-1}(My/M) = \cos^{-1}(-160/240) = 131.8^0$$

$$\phi_Z = \cos^{-1}(Mz/M) = \cos^{-1}(-160/240) = 131.8^0$$

5. **Define the term couple?**

i. A couple is that two forces are of equal magnitude opposite sensed parallel forces, which lie in the same plane.

6. **What are the characteristics of a couple?**

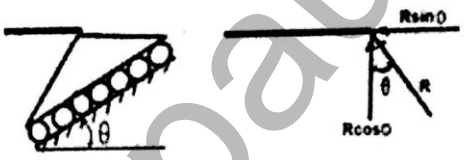
The characteristics of a couple are:

a) The algebraic sum of the forces is zero.
b) The algebraic sum of the moments of the forces about any point is the same and equal to the moment of the couple itself.

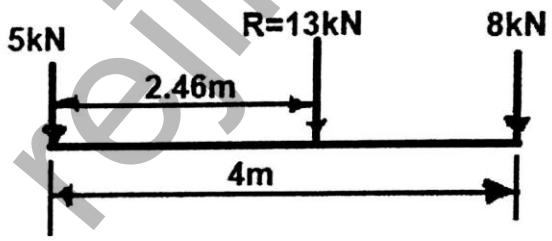
7. **Represent a (a) Horizontal roller support and (b) Inclined roller support showing its direction of the reactions. (Dec 2010)**

**Horizontal roller support:**


**Inclined roller support:**




8. **Find the magnitude and position of the resultant of two forces 5 kN and 8kN both acting vertically upwards and separated by 4m. (Dec 2010)**




Resultant R = 5 + 8 =**13 kN**

Applying Varignon's theorem,

Moment of the resultant = Moment of the resulatnt of individual forces

$$Rx = \sum Fx$$

$$13x = 5 \times 0 + 8 \times 4 = 32$$

$$x = \frac{32}{13} = \mathbf{2.46\ m}$$

Magnitude of resultant, **R = 13 kN Ans**

Position of the resultant= **2.46 m right side from the left support. Ans**

9. **Define moment of a force?**

The moment of a force about a point is defined as the turning effect of the force about that point.

Moment = Force X Perpendicular distance

10. **For what condition the moment of a force will be zero?**

A force produces zero moment about an axis or reference point which intersects the line of action of the force.

11. **What is the difference between a moment and a couple? (Dec 2006) (May 2011) (Dec 2012)**

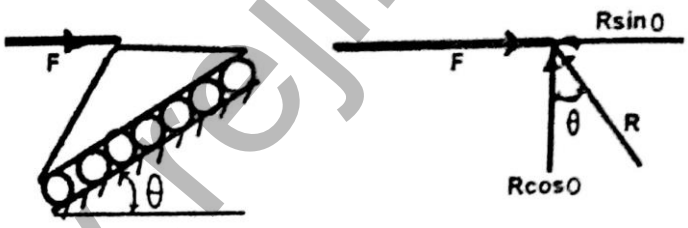
The couple is a pure turning effect which may be moved anywhere in its own plane, or into a parallel plane without change of its effect on the body, but the moment of a force must include a description of the reference axis about which the moment is taken.

12. **What is the difference between a fixed vector and a free vector?**

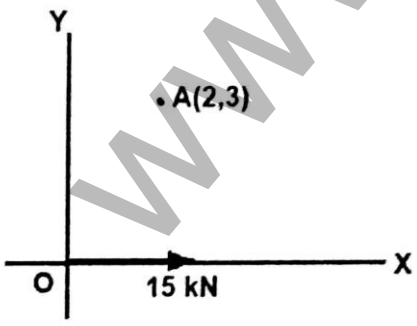
- A force which is applied at a particular location on a body is a fixed vector. Example: A moment.
- A force which can be moved anywhere in its own plane or in a parallel plane without change in its effect on the body is called free vector. Example: A couple.

13. **With the help of a simple illustration, define free body diagram. (Dec 2009)**

It is a sketch which shows all the forces and couple moments the surrounding exerts on a body.

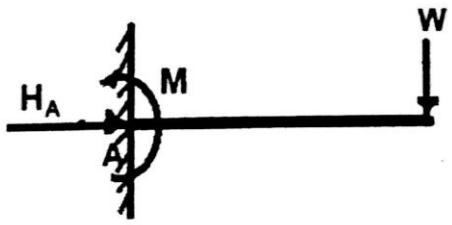



14. **Find the moment of the force of 15N acting along the positive direction of X-axis about the point A (2,3). (Dec 2005)**




Answer: $M_A$ = 15 X 3 = 45 kNm (Anticlockwise).

15. **Sketch the idealized, graphical and reaction of a cantilever support at a point. (May 2010)**




16. **State the requirements for equilibrium of a body acted upon by a parallel force system?**

1. The algebraic sum of the forces is zero.i.e., .ΣF=0.
2. The algebraic sum of the moments about any point is zero. i.e., .ΣM=0.

17. **What are the necessary and sufficient conditions for the equilibrium of a rigid body in three dimensions?**

$$\Sigma F_X = 0 \quad \Sigma M_X = 0$$
$$\Sigma F_Y = 0 \quad \Sigma M_Y = 0$$
$$\Sigma F_Z = 0 \quad \Sigma M_Z = 0$$

18. **What are the common types of supports used in two dimensions?**

1. Roller support
2. Hinged support
3. Fixed support

19. **What are the common types of supports used in three dimensions?**

1. Ball support
2. Ball and Socket support
3. Fixed (or Welded) support

20. **Define equilibrant?**

The force which brings the system of forces into equilibrium is called equilibrant. It is equal to the resultant force in magnitude collinear but opposite in nature.

21. **What are the common types of loads?**

1. Point load (or concentrated load)
2. Uniformly distributed load
3. Uniformly varying load

22. **What is statically determinate structure?**

A structure which can be completely analyzed by static conditions of equilibrium ($\Sigma H = 0$; $\Sigma V = 0$ and $\Sigma M = 0$) alone is statically determinate structure.

23. **What are the reactions at a fixed support of a plane beam that are possible?**

The reaction at fixed support of a plane beam consist of,

1) A reaction force in the plane which can be represented by its two components (Generally taken to be horizontal and vertical) &,

2) A reaction moment.

24. **State the necessary and sufficient conditions for equilibrium of rigid bodies in two dimensions?**

The necessary and sufficient conditions for equilibrium of rigid bodies in two dimensions are:

1) Algebraic sum of horizontal components of all forces acting on the body is must be zero,

2) Algebraic sum of vertical components all forces acting on the body is must be zero,

3) Algebraic sum of moments due to all forces and couple moments acting the body is in must be zero.

25. **When is moment of force maximum about a point ?**

Moment of force is maximum about a point when,

i) Its applied at maximum result from the point and,

ii) It is applied perpendicular to the line joining the point to the point of application of force.

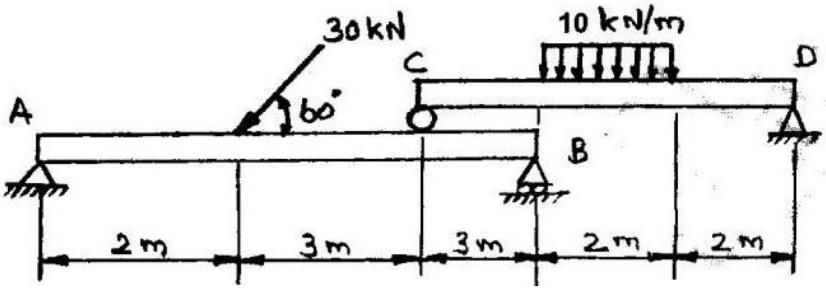
26. **When is moment of force zero about a line?**

Moment of force about a line is zero when,

i) Force is parallel to that line or,
ii) Line of action of force intersects that line.

## PART - B (16 Marks Questions)

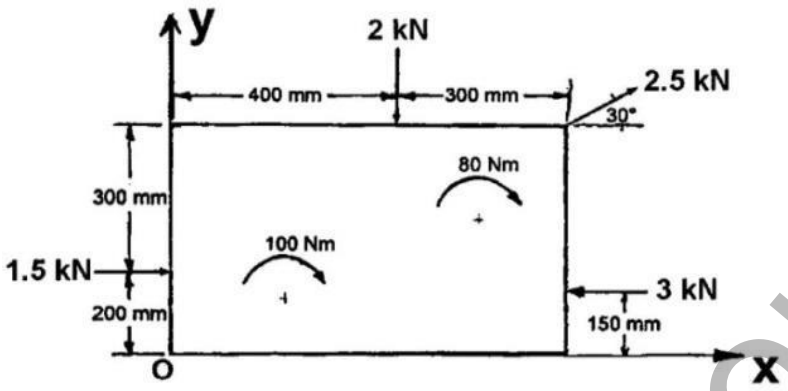
27. Two beams AB and CD are shown in figure. A and D are hinged supports. B and C are roller supports.




(i) Sketch the free body diagram of the beam AB and determine the reactions at the supports A & B.

(ii) Sketch the free body diagram of beam AB and determine the reactions at the supports C and D. (AU Dec'10, DEC'12)

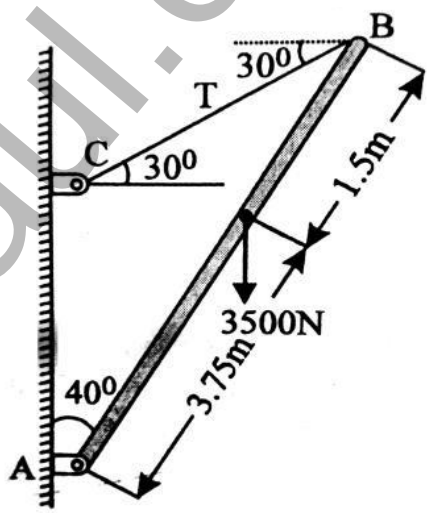
28. A force couple system acting on a rectangular plate is shown in figure below.




(i) Find the equivalent force couple system at the origin O.

(ii) Find the single resultant force and its location on x – axis. (AU Dec'11, JUN 10)

29. A load of 3500 N is acting on the boom, which is held by a cable BC as shown in figure below, the weight of the boom can be neglected. (AU Dec'11)

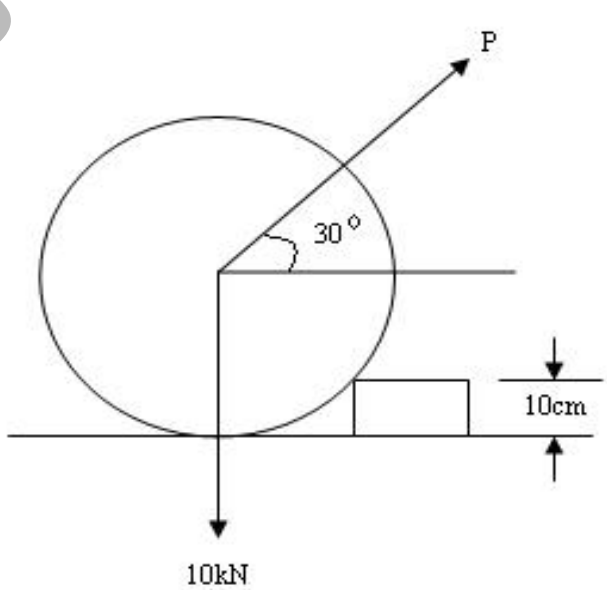



(i) Sketch the free body diagram of the boom.

(ii) Determine the tension in cable BC.

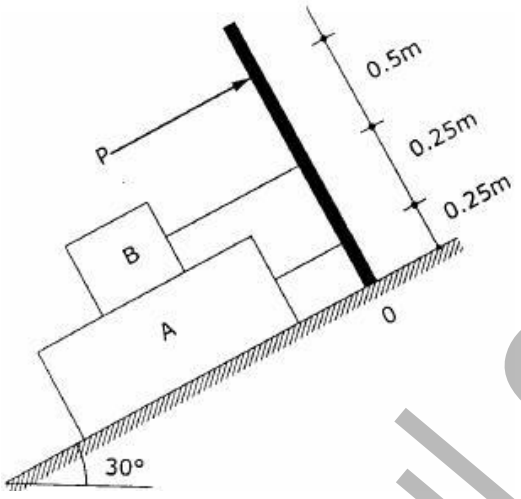
(iii) Find the magnitude and direction of the reaction at A.

30. A cylindrical roller has a weight of 10kN and it is being pulled by a force which is inclined at 30° with the horizontal as shown in fig. While moving it comes across an obstacle of 10cm height. Predict the force required to cross this obstacle when the diameter of the roller is 70cm.

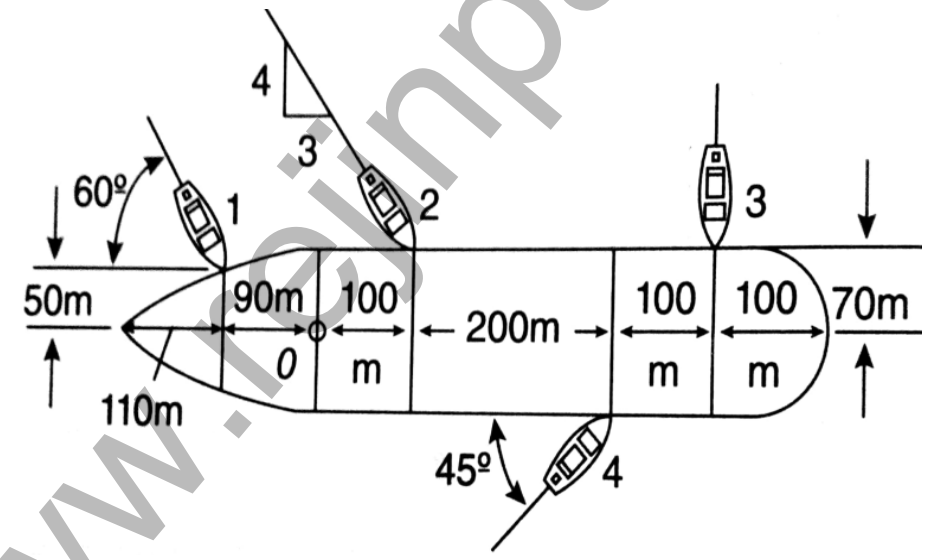



31. Blocks A and B of weight 200N and 100N respectively, rest on a 30 inclined plane and are attached to the post which is held perpendicular to the plane by force P, parallel to the plane, as

shown in fig. Assume that all surfaces are smooth and that the cords are parallel to the plane. Determine the value of P. Also find the Normal reaction of Blocks A and B.




32. Four tug boats are used to bring a large ship to its pier. Each tug boat exerts a 5000 N force in the direction as shown in Fig. Determine the equivalent force - couple system at point 'O' and the point on hull where a single more powerful tug boat should push to produce the same effect as the original four boats.



## UNIT – III PROPERTIES OF SURFACES AND SOLIDS

### PART - A (2 Marks Questions and Answers)

1. **What is meant by centre of gravity?**

Centre of gravity of a body is that point through at which whole weight of the body acts irrespective of the orientation of the body. It is represented by C.G (or) G. The point at which whole area of the body is assumed to have concentrated is called as centre of gravity.

2. **What is meant by centroid?**

The plane figures (like Triangle, Quadrilateral, Circle, etc.) have only area and no mass. The centre of area of such figure is known as centriod.

3. **What is centre of mass?**

Centre of mass is the point where the entire mass of a body may be assumed to be concentrated. The centre of mass (C.M) and centre of gravity (C.G) of a body are different only when the gravitational field is not uniform and parallel. For most practical purpose they assumed to be same.

4. **What is meant by reference axes?**

The centroid (G) is the point of intersection of the diagonals. But the location of centriod is always measured with reference to some reference axes. OX and OY axes with the point of origin O are used as reference axes for the centroid of the plane figure.

5. **What is meant by centroidal axis?**

The axes which are passing through the centroid of the figure is called as the centroidal axis. Here xx and yy are the horizontal and vertical axis passing through the centroid (G).

6. **What is parallel axes theorem for moment of inertia?**

The moment of inertia about axes in the plane is the sum of the moment of inertia about a parallel axis passing through centroid and the product of the area and square of the distance between the two parallel axes. $I_{AB}=I_{xx}+Ah^2$

Where

$I_{AB}$= Moment of inertia of the area about AB.

$I_{xx}$ =Moment of inertia of the area about centroidal xx axis.

A= Area of the section.

h = Distance between centroidal axis and the axis AB.

7. **What is perpendicular axes theorem for moment of inertia?**

Moment of inertia of an area about an axis perpendicular to its plane at any point is equal to the sum of moments of inertia about any two mutually perpendicular axes about the same point in plane of the area. It is also known as polar moment of inertia

Mathematically, $I_{zz}=I_{xx}+I_{yy}$

Where

$I_{xx}$ =Moment of inertia of the given lamina about xx axis.

$I_{yy}$= Moment of inertia of the given lamina about yy axis.

$I_{zz}$= Moment of inertia of the given lamina about zz axis.

**8. What is product of inertia?**

The product of inertia of an area is summation of product of inertia of its elements about two perpendicular reference axes (x and y axis). It is denotes by $I_{xy}$.

$I_{xy} = \int xy\, dA.$

**9. What is principal moment of inertia?**

The values of moment of inertia about two perpendicular axes depend on the orientation of the axis. At certain angle of orientation, the moment of inertia will be maximum along one axis and minimum along the other. These maximum and minimum moments of inertias are called as principal moment of inertia.

**10. What is mass moment of inertia?**

The moment of inertia of solid figure is generally refereed as "Mass Moment of Inertia". It is denoted by the symbol "I". Mass moment inertia is a measure of its inertial behavior, ie. Resistance to the rotational acceleration of the mass of the body.

$$I = m_1r_1^2 + m_2r_2^2 + \ldots\ldots + m_nr_n^2$$

Where,

$m_1, m_2 \ldots m_n$ = Mass of the particle

$r_1, r_2 \ldots r_n$ = Distance respectively about origin.

**11. Define Radius of Gyration**

Radius of Gyration of a body (or a given lamina) is defined as the distance from the axis of reference to where the whole mass (or area) of a body is assumed to be concentrated. It is denoted by " K ".

$K = \sqrt{I/A}$

Were,

I = Moment of inertia.

A = Area of the section.

**12. State Pappus theorem.**

It states that the area of surface of revolution is the product of length of the generating curve and the distance travelled by the centroid of the curve, while the surface is being generated.

**13. State Guldinus theorem.**

It states that the volume of a body of revolution is obtained from the product of generating area and the distance travelled by the centroid of the area, while the body is being generated.

**14. Write the formula for centre of gravity of composite solid figures.**

The centre of gravity of solid bodies is found out in the same way as that plane figures. The only difference between the plane figure and solid bodies is calculated.

If composite solid made of same material,

$$\dot{x} = \frac{V1X1+V2X2+\cdots\ldots+VnXn}{V1+V2+\cdots.+Vn}$$

$$\bar{y} = \frac{V1Y1+V2Y2+\cdots\ldots+VnYn}{V1+V2+\cdots.+Vn}$$

Where,

$V_1$, $V_2$….$V_n$ are the volume of the different components.

$X_1$, $X_2$….$X_n$ are the centrodial distance from OY axis.

$Y_1$, $Y_2$…$Y_n$ are the centrodial distance from OX axis.

**15. When will the product of inertia of an become zero?**

Product of inertia becomes zero when the area is symmetrical with respect to one or both the axes, then the product of inertia will be zero.

**16. Define first moment of an area about an axis.**

The plane are of well known geometrical shape like rectangle, square, triangle., etc are called simple plane figure and the plane areas, combination of two or more simple plane figures are called the composite plane figures. Centroid of composite plane figures is called first moment of area.

**17. What do you mean by polar moment of inertia?**

The polar moment of inertia is defined as the moment of inertia of the lamina or plane about an axis perpendicular to the plane of the section. It is denoted by $I_p$ or J or $I_{zz}$

Mathematically, $I_P=I_{xx}+I_{yy}$

$I_{xx}$ =Moment of inertia of plane figure about its centroidal axes.

$I_{yy}$= Moment of inertia of plane figure about its centroidal axes.

**18. When will the centroid and centre of mass coincides?**

- The point at which whole area of the body is assumed to have concentrated is called as centre of gravity.
- Centre of mass is the point where the entire mass of a body may be assumed to be concentrated.
- The centroid and centre of mass coincide when the density of the material is uniform throughout the body.

**19. Express the centroidal coordinates of a quadrant of the circle.**

$$\dot{x} = \frac{4R}{3\pi}$$

$$\bar{y} = \frac{4R}{3\pi}$$

Where,

r = Radius of circle.

**20. How will you locate the principal axes of inertia?**

The axes at which the product of inertia is zero are called principal axes. The moment of inertia about the principal axes are called principal moment of inertia.

There will always be two principal axes at a given point in the area and they will be mutually perpendicular to each other. The maximum moment of inertia is called major principal moment of inertia and the minimum moment of inertia is called the minor principal moment of inertia.

**21. What are the various methods to find centre of gravity?**

The centre of gravity is found out by the following three methods

i) Geometrical consideration
ii) Graphical method
iii) Method of moments

**22. What is section modulus?**

The modulus of the section (or section modulus) of a of a figure obtained by dividing the moment of inertia of the figure about its centre of gravity by the distance of the extreme fibre from centroidal axis. It is generally denoted by Z and the suffixes (XX or YY) indicate the axis. ($Z_{XX}$ or $Z_{YY}$)

$$Z_{XX} = \frac{Ixx}{(\frac{d}{2})} \; ; \qquad Z_{YY} = \frac{Iyy}{(\frac{d}{2})}$$

**23. State the relationship between the second moment of area and mass moment of inertia for a thin uniform plate.**

The mass moment of inertia and second moment of area of a thin plate can be related as,

$(I_{xx})_{mass} = \rho t (I_{xx})_{area}$

Where,

$(I_{xx})_{mass}$ = Moment of Inertia of mass,

$(I_{xx})_{area}$ = Moment of Inertia of area,

$\rho$ = Mass density of the plate material,

t = Thickness of the plate.

**24. What are the theorems that deal with moment of inertia?**

- Parallel axis theorem
- Perpendicular axis theorem
- Routh's rule.

**25. What are major and minor principal axes**?

In a given area, there are two principal axes at a point. These two axes will be mutually perpendicular to each other. The moment of inertia about one of the axis will be maximum and other will be minimum. These axes are called major principal axis and minor principal axes respectively.

**26. Define principal axis and principal moment of inertia.**

The axis about which the product of inertia is zero is known as principal axis. The moment of inertia about the principal axis is called as principal moment of inertia.

**27. List out the steps involved in to find the moment inertia of composite section.**

- The given composite section should be divided into simple calculated section.
- Moment of Inertia of these simple sections about their respective C.G should calculate.
- M.I transferred about the required axis by parallel axis theorem.
- M.I for composite section obtained by summing the M.I of simple section about the required axis.

**28. Write the formula for finding the centroid of composite plane figure.**

$$\dot{x} = \frac{A1X1+A2X2+\cdots\ldots+AnXn}{A1+A2+\cdots+An}; \quad \bar{y} = \frac{A1Y1+A2Y2+\cdots\ldots+AnYn}{A1+A2+\cdots+An}$$

Where,

$A_1, A_2 \ldots A_n$ are the Area of the different components.

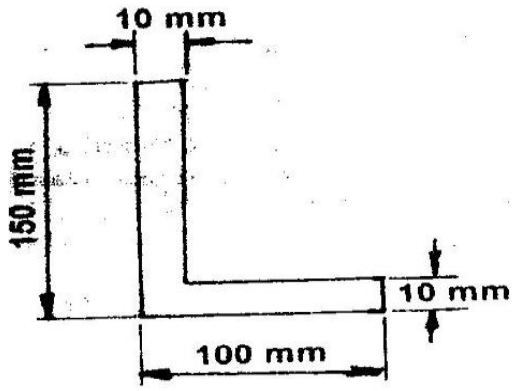
$X_1, X_2 \ldots X_n$ are the centroidal distance from OY axis.

$Y_1, Y_2 \ldots Y_n$ are the centroidal distance from OX axis.

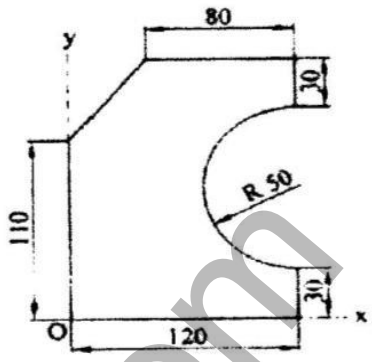
## PART - B (16 Marks Questions)

**29.** An area in the form of L section is shown in figure below (AU MAY'11, DEC'12)

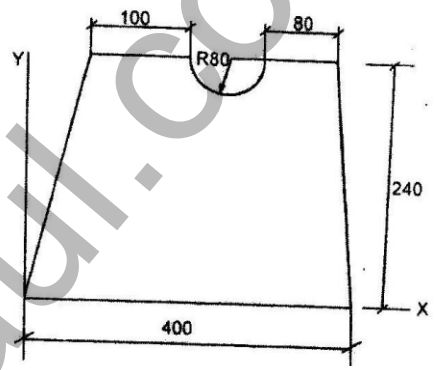
Find the moments of Inertia Ixx, Iyy, and Ixy about its centroidal axes. Also determine the principal moments of inertia.



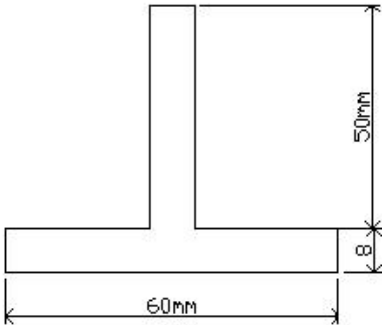
**30.** Locate the centroid of the area shown in figure below. The dimensions are in mm. (AU JUN'10, DEC 11)




**31.** Find the moment of inertia of a section shown in Fig below about the centroidal Axes.(Dimensions in mm) (AU JUN'09)

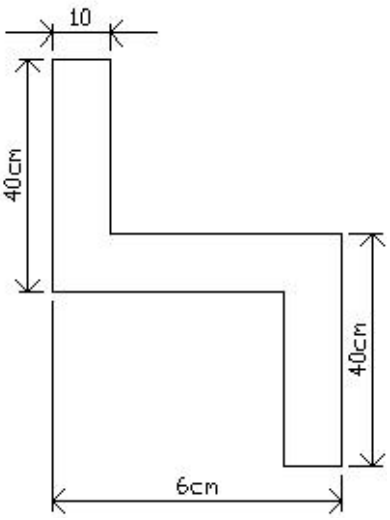



**32.** Determine the principal moments of inertia and find location of principal axes of surface shown in fig.




**33.** A Cylinder of height of 10 cm and radius of base 4 cm is placed under sphere of radius 4 cm such that they have a common vertical axis. If both of them are made of the same material, find the centre of gravity of the combined unit.

**34.** Design Moment of Inertia about the co-ordinate axes of plane area shown in fig. Also find Polar Moment of Inertia.



## UNIT IV - DYNAMICS OF PARTICLES

## PART - A (2 Marks Questions and Answers)

**1. State D' Alembert's principle. (AU May/June 2016,May/June 2013, Nov/ Dec 2010, May / June 2010, May /June 2007)**

D' Alembert's principle is an application of Newton's second law of motion. It states that the system of forces acting on a body in motion is dynamic equilibrium with the inertia force of the body.

**2. What happens if two perfectly elastic bodies are in impact? (AU May/June 2016)**

When two elastic bodies collide with each other, they tend to compress each other. Immediately after this, the bodies attempt to regain its original shape, due to elasticity. This process of regaining the original shape is called restitution.

**3. What is dynamic Equilibrium? (AU Jan 2016)**

According to Newton's Second law of motion,

$\Sigma F=ma$, $\Sigma F- ma=0$

This equation is also known as dynamic equilibrium equation. This principle is known as D' Alembert's principle. D' Alembert's principle is used to convert dynamics problem into a statics problem.

**4. What is impulsive force? (AU Jan 2016)**

When a large acts on a body for a short period of time, then the force is called an impulsive force.

**Examples:** 1. Cricket ball hit by a bat

2. Foot ball kicked by the player, etc

**5. Distinguish between perfectly plastic impact and perfectly elastic impact. (AU April/May 2015)**

| Perfectly Plastic Impact | Perfectly Elastic Impact |
|---|---|
| **The relative velocities of the colliding object after impact are less than those before impact.** | **The relative velocities of the two objects after impact (separation velocities) are the same as their relative velocities before impact (approach velocities).** |

| | |
|---|---|
| **Some of the total energy of motion is lost.**<br><br>**Example: some may be transformed to heat associated with the deformation and restitution process.** | **The total energy of motion is not changed.** |

**6. Write the work energy equation of particles. (AU Nov/Dec 2014, Nov/Dec 2013)**

$Fs = \frac{mv^2}{2} - \frac{mu^2}{2}$ (Or) Work done = Change in Kinetic energy

This equation is known as work energy equation in which

Fs = Work done by the force acting on the body

$\frac{mv^2}{2}$ = Final Kinetic energy

$\frac{mu^2}{2}$ = Initial Kinetic energy

**7. State Newton's Second law of motion. (AU Nov/Dec 2014, Nov/Dec 2006)**

Newton's law states that, "The rate of change of momentum of a body is directly proportional to the external force applied on the body and takes place in the direction of the applied force."

F α ma (or) F= K.ma

Where,'K' is a constant of proportionality.

**8. State principle of work and energy. (AU May/June 2014, April/May 2009, May/ June 2008, Nov 2002)**

Principle of work and energy states that "When a particle moves from position $s_1$to $s_2$ under the action of a force F, the change in kinetic energy of the particle is equal to the work of the force F."

**9. Define the coefficient of restitution. (AU May/June 2014, Nov/Dec 2011,April/May 2009, May/June 2007)**

The coefficient of restitution between two bodies in a collision is defined as the ratio of the relative velocity of their separation after collision to the relative velocity of their approach before collision. It is denoted by 'e'.

Coefficient of restitution, $e = \frac{\text{Relative velocity of separation}}{\text{Relative velocity of approach}}$

**10. State impulse momentum principle. (AU Nov/Dec 2013, Nov/Dec 2010)**

Impulse momentum principle is

Impulse = Change in momentum

= Final momentum - Initial momentum

In other words, the impulse of the force acting on a particle is equal to the change in linear momentum of the particle.

**11.Define the term "Kinematics". (AU Nov/Dec 2012, May/June 2005)**

Kinematics is the study of motion of a moving body without considering the forces which cause the motion. Here, the study is made of the relationship between displacement, velocity, acceleration and time of a given motion without considering the forces which cause the motion.

**12. Distinguish between rectilinear and curvilinear motion. (AU Nov/Dec 2010, April/May 2008)**

When a particle moves along a straight line, then it is called rectilinear motion or translation.
Examples: A car moving on a straight road
A body projected vertically upward
A body falling vertically downward
When a particle moves in a curved path, then it is called curvilinear motion.
Example: A car moving in a curved path in a hill

**13. Define Law of conservation of energy. (AU Nov/Dec 2009)**

The Law of conservation of energy states that " Energy can neither be created nor destroyed though it can be transformed from one form to another". In other words, Total energy (sum of potential energy and kinetic energy) possessed by a body remains constant provided no energy is added or taken from it.

**14. Distinguish between curvilinear motion and projectile motion.(AU April May 2009)**

When a particle moves along a curved path then it is known as curvilinear motion. It is classified as plane curvilinear (two dimensional) and space curvilinear (Three dimensional) motion.

Projectile is the freely projected particle which moves under the combined effect of vertical and horizontal motion.

**15. State the principle of conservation of linear momentum. (AU April/May 2008, Nov 2001)**

The principle of conservation of linear momentum states that "if there is no external force acting on the system then the total linear momentum of the system remains constant." This means that the total momentum of the system before impact is equal to the total momentum of the system after impact.

**16.Distinguish between direct central impact and oblique central impact. (AU May/June 2008)**

**Direct central impact:** If the mass centers of colliding bodies are on the line of impact and velocities of the bodies are directed along the line of impact, it is called direct central impact.

**Oblique central impact:** If the mass centers of colliding bodies are on the line of impact and velocities of one or both the bodies are not along the line of impact, it is called oblique central impact.

**17. A car runs with an initial velocity of 30 m/s and uniform acceleration of 3 m/s$^2$. Find its velocity after 5 seconds. (AU May/June 2013)**

Given: u=30 m/s; $a = 3\ m/s^2$; $t = 5\ s$

using the equation, $v = u + at$

$= 30 + 3(5)$

$= 45\ m/s$

**18. A particle moves from rest along a straight line defined by the relationship**

**$x = t^3 - 6t^2 - 15t$, where x is the distance travelled and t is the time in second. Find the velocity and acceleration at the end of 10 seconds. (AU Nov/Dec 2009)**

Given: $x = t^3 - 6t^2 - 15t$

$v = \frac{dx}{dt} = 3t^2 - 12t - 15$

$a = \frac{dv}{dt} = 6t - 12$

Velocity at t = 10 s; $v = 3(10^2) - 12(10) - 15$

$= 165\ m/s$

Acceleration at t = 10 s; $a = 6(10) - 12$

$= 48\ m/s^2$

**19. Define uniformly accelerated motion. (AU April/May 2009)**

Uniform or constant acceleration is a type of motion in which the velocity of an object changes by an equal amount in every equal time period. A frequently cited example of uniform acceleration is that of an object in free fall in a uniform gravitational field.

**20. What is uniform motion? (AU Nov/Dec 2002)**

Uniform motion is the kind of motion in which a body covers equal distances in equal intervals of time. It does not matter how small the time intervals are, as long as the distances covered are equal.
If a body is involved in rectilinear motion and the motion is uniform, then the acceleration of the body must be zero.

**21. A small ball is dropped from a height of 19.62 m. At what velocity the ball will strike the ground? (AU Nov/Dec 2015)**

Given: u = 0; h = 19.62 m
using the equation $v^2 = u^2 + 2gh$

$$v = \sqrt{2gh}$$
$$v = \sqrt{2 * 9.81 * 19.62}$$
$$= 19.62 \text{ m/s}$$

**22. A particle is projected into space at an angle of 30˚ to the horizontal at a velocity of 40 m/s. Find the maximum height reached by the projectile. (AU April/May 2015)**

Given: Velocity of projection, u = 40 m/s
Angle of projection, α = 30˚
Maximum height reached by the projectile, $h_{max}$

$$h_{max} = \frac{u^2 \sin^2 \alpha}{2g}$$
$$= \frac{40^2 \sin^2 30}{2 * 9.81} = 20.39 \text{ m}$$

**23. A stone is dropped from the top of the tower. It strikes the ground after four seconds. Find the height of the tower. (AU May/June 2014)**

Given: Initial velocity, u = 0; Time, t = 4 s
Using the equation, $h = ut + (1/2)\, gt^2$

$$h = 0 + (1/2)\,(9.81)\,(4^2)$$
$$= 78.48 \text{ m}$$

**24. How will you calculate the linear restoring force of an elastic material? (AU Jan 2003)**

The magnitude of the linear restoring force developed by the elastic material is directly proportional to the displacement of the material from the unreformed position.

F = kx, where F= restoring force; k = stiffness of the material; x = displacement

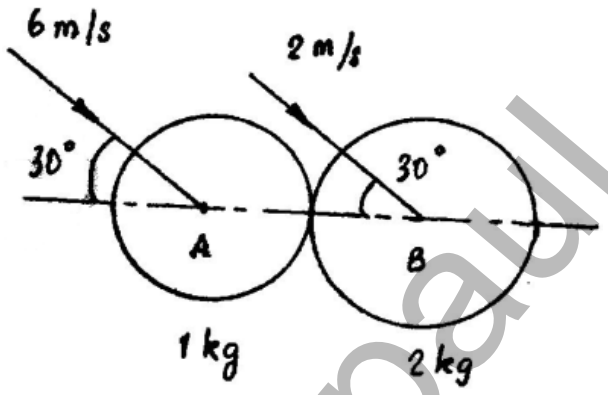
**25. A block having mass of 50 kg has a velocity of 15 m/s horizontally on a smooth frictionless surface. Determine the value of the horizontal force to be applied to the block for bringing the block to rest in 5 seconds. (AU April/May 2003)**

Given: mass, m = 50 kg; initial velocity, u = 15 m/s; time, t = 5 s; final velocity, v = 0
Applying impulse momentum equation,
F x t = m (v – u)

F x 5 = 50 (0 - 15)
F = -150 N
Negative sign indicates that the Force acts in opposite direction and will bring the mass to rest position.

## PART - B (16 Marks Questions)

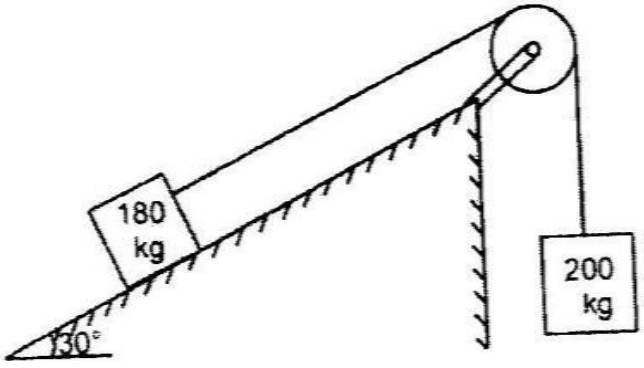
26. A ball of mass I kg moving with a velocity of 6 m/s strikes another ball of mass 2kg moving with a velocity of 2m/s at the instant of impact the velocities of the two balls are parallel and inclined at 30°to the line joining their centers as shown in figure below.



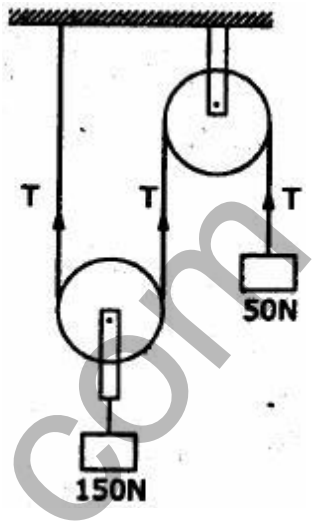

If the coefficient of restitution is 0.5, find the velocity and the direction the two balls after impact. Also calculate the loss in kinetic energy due to impact and the percentage of loss. (AU, Dec'10, Jun'12)

27. Two trains A and B leave the same station on parallel lines. A starts with a uniform acceleration of 0.15m/s2 and attains the speed of 24 km/hour after which its speed remains constant. B leaves 40 seconds later with uniform acceleration of 0.30 m/s2 to attain a maximum of 48 km/hour, its speed also becomes constant thereafter. When will B overtake A. (AU,Dec'11,JUN 12)

28. A block and pulley system is shown in fig below. The coefficient of kinetic friction between the block and the plane is 0.25. The pulley is frictionless. Find the acceleration of the blocks and the tension in the string when the system is just released. Also find the time required for 200kg block to come down by 2m. (AU, Jun'09,DEC 11)

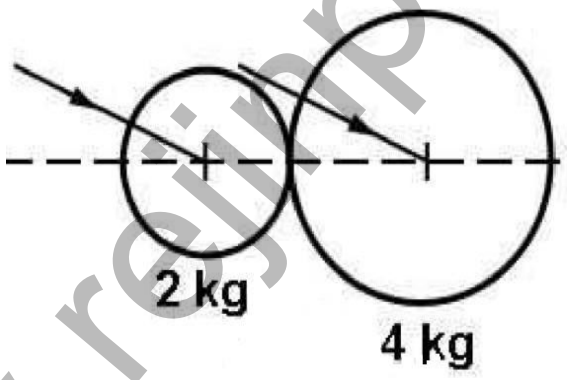


29. Two blocks of weight 150N and 50N are connected by a string, passing over a frictionless pulley as shown in fig. Predict the velocity of 150N block after 4 seconds. Also calculate the tension in the string.




30. Two bodies one of mass 30kg, moves with a velocity of 9m/s centrally. Solve the velocity of each body after impact, if the coefficient of restitution is 0.8

31. A ball of mass 2 kg, moving with a velocity of 3 m/s, impinges on a ball of mass 4 kg moving with a velocity of 1 m/s. The velocities of the two balls are parallel and inclined at 30◦ to the line of joining their centers at the instant of impact. If the coefficient of restitution is 0.5, Explain




(i). Direction, in which the 4 kg ball will move after impact; (8)

(ii). Velocity of the 4 kg ball after impact; (2)

(iii). Direction, in which the 2 kg ball will move after impact; (4)

(iv). Velocity of the 2 kg ball after impact. (2)

## UNIT V - FRICTION & ELEMENTS OF RIGID BODY DYNAMICS

### PART - A (2 Marks Questions and Answers)

1. **Define Friction**

   In practice, no object is perfectly smooth. When two surfaces are in contact with each other, and one surface tends to move with respect to the other, a tangential force will be developed at the contact surface, in the opposite direction of motion. This tangential force is called Frictional force or Friction.

2. **What are the types of Friction?**

   In general, two types of friction can occur between surfaces, namely

   - Dry Friction
     - Static friction
     - Dynamic friction
   - Sliding friction
   - Rolling friction
   - Fluid Friction

3. **Write about dry friction and its types.**

   Dry friction refers to the friction which develops between two dry surfaces, slide or tends to slide relative to another. Dry friction is classified into two types. They are,

   - Static friction
   - Dynamic friction

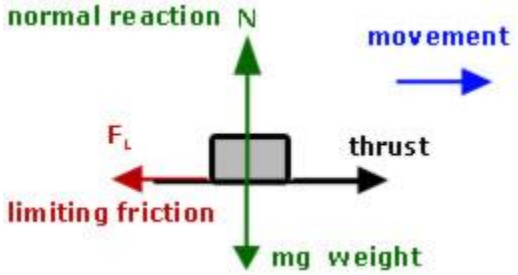
4. **Tell us about the Sliding friction and Rolling friction.**

   Both the sliding friction and sliding friction comes under the category of the Dynamic friction.

   - Sliding friction - It is the friction, experienced by a body during rest
   - Rolling friction - It is the friction, experienced by a body during motion

5. **Define limiting friction.**

   The limiting friction is the maximum frictional force that can arise before an object begins to slide. Typically, it is equal to the product of the static coefficient of friction and the perpendicular force between the surfaces. It is denoted by the $F_L$ or $F_m$.




6. **Define Co-efficient of friction**

A coefficient of friction is a value that shows the relationship between the force of friction between two objects and the normal reaction between the objects. It is a value that is sometimes used in physics to find an object's normal force or frictional force when other methods aren't available.

$$\mu = \frac{\text{Limiting Friction}}{\text{Normal Reaction}} = \frac{F_m}{N_R}$$

7. **Define Angle of friction.**

The angle of a plane to the horizontal when a body placed on the plane will just start to slide. The tangent of the angle of friction is the coefficient of static friction. In other words, the angle between the resultant and the normal reaction is called angle of friction.

$$\tan \emptyset = \frac{\text{Limiting Friction}}{\text{Normal Reaction}} = \frac{F_m}{N_R}$$

8. **Write the relationship between the Co-efficient of friction and Angle of friction.**

The relationship between the Co-efficient of friction and Angle of friction is,

Limiting friction = Co-efficient of friction x Normal Reaction

$$F_m = \mu \times N_R$$

- The coefficient of friction in static state is called as coefficient of static friction($\mu_s$).
- The coefficient of friction in dynamic state is called as coefficient of dynamic friction($\mu_k$).

9. **Name any three laws of static friction.**

The three laws of static friction are,

- The frictional friction always acts in the opposite direction to that the body tends to move.
- The frictional force does not depend on the shape and area of contact of the bodies.
- The friction depends on the degree of roughness of the area of contact between the bodies.

10. **Name any three laws of Dynamic friction.**

The three laws of dynamic friction are,

- The friction always acts in the opposite direction to that the body moves.
- The magnitude of dynamic friction bears a constant ratio to the normal reaction between the two surfaces.
- Co-efficient of kinetic friction is less that the co-efficient of static friction.

11. **Define Impending motion.**

When the maximum frictional force (limiting force) is attained and if the applied force exceeds the limiting friction, then the body starts sliding or rolling. This state is called impending motion. In other words, the state of motion of a body which is just about to move or slide is called impending motion.

12. **Define Angle of repose.**

The angle of the inclined, at which the body tends to slide down is known as angle of repose. It is denoted by $\alpha_m$ .

Angle of repose = Angle of Static

$$\alpha_m = \emptyset$$

13. **Name some of the engineering applications of simple contact friction.**

Some of the engineering applications of simple contact friction are,

- Ladder friction
- Wedge friction
- Screw friction
- Belt friction

14. **Define Rolling resistance.**

When one body is made to roll freely over an another body, a resistance is developed in the opposite direction, known as rolling resistance. This resistance helps to roll the body without any slipping or turning of the body. It is developed due to the deformation made by the rolling body over another body.

15. **What is co-efficient of rolling resistance?**

The horizontal distance of point of resistance measured from centre of wheel is known as co-efficient of rolling resistance. It is represented by "b".

$$\mathbf{b = \frac{Pr}{W}}$$

16. **Name the types of Plane rigid body motion.**

In general there are three types of plane rigid body motion. They are,

- Translation
- Rotation about a fixed axis
- General Plane Motion.

17. **Write about Translation in rigid body motion.**

A rigid body is said to be in translation, if the linear displacement of every point in the rigid body is the same, ie., the orientation of any line drawn on the body remains unchanged, but its position is changed.

18. **What are the types of Translation in rigid body motion.**

There are two types of translation in rigid body motion. They are

- Rectilinear translation - the paths of motion are straight lines.
- Curvilinear translation - the paths of motion are congruent curves.

19. **Explain rotation about a fixed axis.**

A rigid body is said to be in rotation, if all the particles of the body move along circles centered on a fixed axis, called axis of rotation. The planes of the circular paths are perpendicular to the axis of rotation. The common centre of the circular paths may be located either within the body or outside of it.

20. **Narrate about the general plane motion.**

A rigid body is said to be in general plane motion, if it undergoes a combination of translation and rotation. It is neither a pure translation nor a pure rotation. All the particles on the body translate some distance and also rotate through a certain angle. So, the general plane motion is a rotation with translation motion.

21. **Define angular displacement.**

Angular displacement is defined as, "the total angle, through which a body has rotated. It is denoted by " $\boldsymbol{\theta}$". It is expressed in terms of radians. It varies with time.

$$\boldsymbol{\theta = f(t)}$$

It is taken positive for anticlockwise rotation and negative for clockwise rotation.

22. **Write about Angular Velocity.**

It is the rate of change of angular displacement of the body. It is expressed in rad/s or rpm. It is usually denoted by "$\boldsymbol{\omega}$". In otherwords, if a rotating body describes equal angles in equal intervals of time, it is known as uniform angular velocity or otherwise known as variable angular velocity.

$$\boldsymbol{\omega = \frac{d\theta}{dt} = \frac{2\pi N}{60}}$$

23. **Define angular acceleration.**

It is defined as the rate of change of angular velocity. It is expressed in read/$s^2$ and it is usually denoted by "$\boldsymbol{\alpha}$".

$$\boldsymbol{\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}}$$

24. **Define instantaneous center of rotation.**

The combined motion of translation and rotation of a body may be treated as a motion of pure rotation for the sake of simplicity about a centre point known as instantaneous centre. It is denoted by the symbol IC and it can be either within or outside of the body. It is also called as instant centre of rotation.

25. **What are the hints to locate the instantaneous centre.**

The steps to be followed in locating instantaneous centre of rotation are detailed below:

- Identify the line of action for velocity of any two points on the rigid body.

- For each velocity line, draw perpendiculars through the respective points.
- The point of intersection of perpendicular line are drawn in the instantaneous centre "IC"

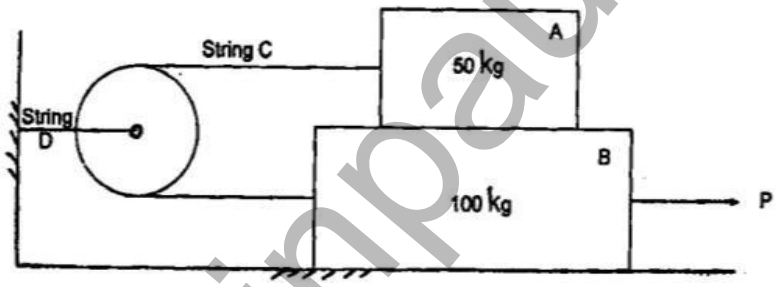
26. **When a screw is said to be self locking?**

If the friction angle is larger than the lead angle of screw, the load will be remain in place even after the removal of effort. This condition is said to be self locking. Most screws are designed to be self-locking, and in the absence of torque on the shaft will stay at whatever position they are left.

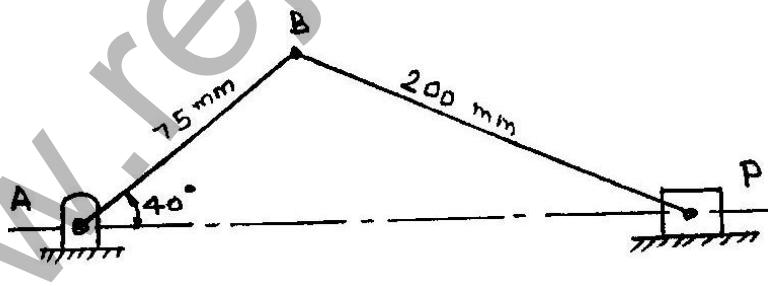
This self-locking property is one reason for the very large use of the screw in threaded fasteners such as wood screws, sheet metal screws, studs and bolts.

## PART - B (16 Marks Questions)

27. Two blocks A and B of mass 50 kg and 100 kg respectively are connected by a string C which passes through a frictionless pulley connected with the fixed wall by another string D as shown in figure. Find the force P required to pull the block B. Also find the tension in the string D. Take coefficient of friction at all contact surfaces as 0.3. (AU, Dec'10, Dec'11)



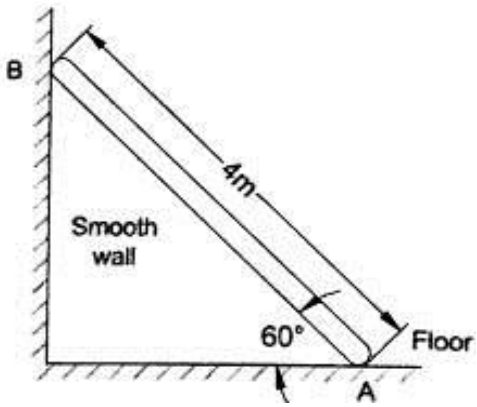

28. In the engine system shown in figure, the crank AB has a constant clock wise angular speed of 3000 r.p.m.



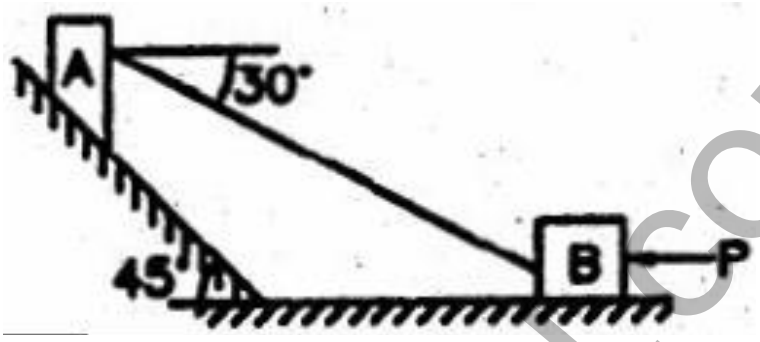

For the crank position indicated, find (i) the angular velocity of the connecting rod BP. (ii) Velocity of piston P. (AU, Dec'11, Jun'10)

29. A ladder of weight 1000N and length 4m rests as shown in figure below.

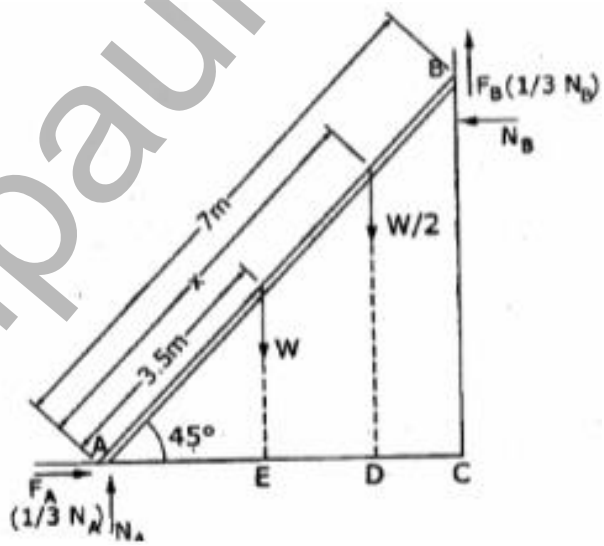
If a 750 N weight is applied at a distance of 3m from the top of ladder, it is at the point of Sliding. Determine the coefficient of friction between ladder and the floor.(AU, Jun'10, Apr'11,Dec'12)



30. Block A weighing 1000 N rests on a rough inclined plane whose inclination to the horizontal is 45°. It is connected to another block B, weighing 3000 N rests on a rough horizontal plane by a weightless rigid bar inclined at an angle of 30° to the horizontal as shown in fig. Find the horizontal force required to be applied to the block B just to move the block A in upward direction. Assume angle of friction as 15° at all surfaces where there is sliding.




31. A 7m long ladder rests against a vertical wall, with which it makes an angle of 45° and on a floor. If a man whose weight is one half that of the ladder climbs it, at what distance along the ladder will he be, when the ladder is about to slip? Take coefficient of friction between the ladder and the wall is 1/3 and that between the ladder and the floor is ½.




32. Block (2) rests on block (1) and is attached by a horizontal rope AB to the wall as shown in fig. What force P is necessary to cause motion of block (1) to impend? The co-efficient of friction between the blocks is ¼ and between the floor and block (1) is 1/3. Mass of blocks (1) and (2) are 14kg and 9 kg respectively.