Department of Applied Mechanics
S V NATIONAL INSTITUTE OF TECHNOLOGY, SURAT
ENGINEERING MECHANICS (TUTORIALS)

1 FORCES AND RESOLUTION OF FORCES

1. Differentiate between
   (a) Concurrent forces and Non Concurrent forces,
   (b) Coplanar forces and collinear forces.
2. Draw and Explain : (i) Free- body diagram
3. Write only, Conditions of equilibrium of particle.
4. State Lami's theorem. In which situation is it used?
5. State the law of Parallelogram of forces.
6. State the law of Polygon of forces

7. **Fill in the blanks**
   a) Magnitude, direction, sense and _____ are characteristics of a force.
   b) A_____ is a single force which can replace two or more forces and produce the same effect as the forces.
   c) The splitting of a force into two perpendicular directions without changing its effects is called_____.
   d) If coplanar and concurrent forces are in equilibrium, then the polygon drawn of these forces will be _____.
   e) The effect of a given force remains unaltered along line of action. This is according to law of_____.

8. **True or false:**
   a) If a coplanar concurrent force system forms a closing polygon, then resultant is zero.
   b) The state of a body is unaltered if force is replaced by unlike parallel forces of the same magnitude acting along the line of action of replaced force.
   c) Coplanar forces pass through a single point.
   d) Coplanar non-concurrent forces are collinear.

Numerical Problems:

1. If the force exerted on point A is 100N in the direction shown in Figure, determine the force components acting along(a) the x and y axes,(b)the x' and y' axes,(c) the x and y' axes and (d) determine the angle α, knowing that the component of force along the x axis is to be 80N while resolving along the x and y' axes. **(figure 1.1)**
2. Determine the magnitude and direction of the resultant of five forces. Specify its direction measured counter clockwise from the positive X axis.**(figure 1.2)**

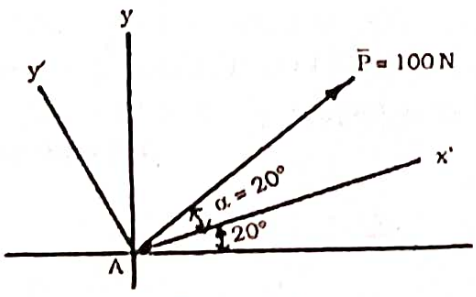


Figure 1.1

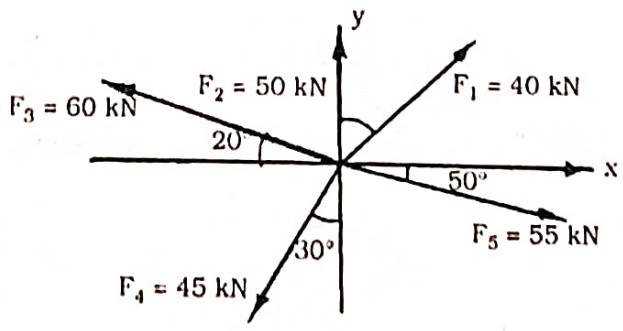


Figure 1.2

3. Two cables are tied together at C and are loaded as shown. Determine the tension (a) in cable AC, (b) in cable BC. **(figure 1.3)**

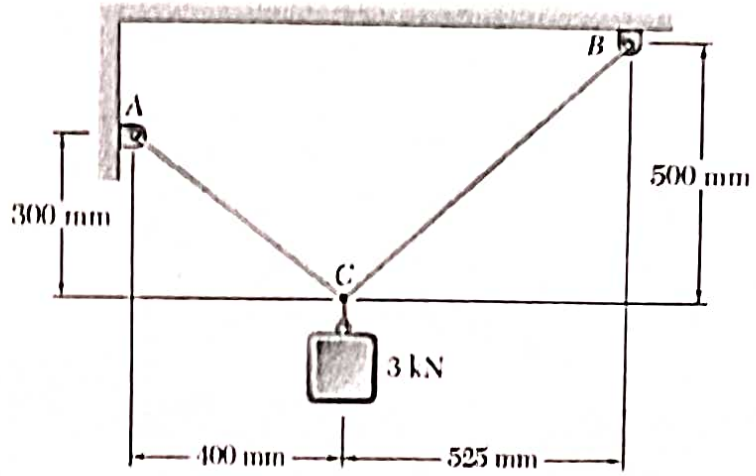


Figure 1.3

4. Two cables tied together at C are loaded as shown. Knowing that the maximum allowable tension in each cable is 900 N, Determine (a) the magnitude of the largest force P which may be applied at C, (b) the corresponding value of α. **(Figure 1.4)**

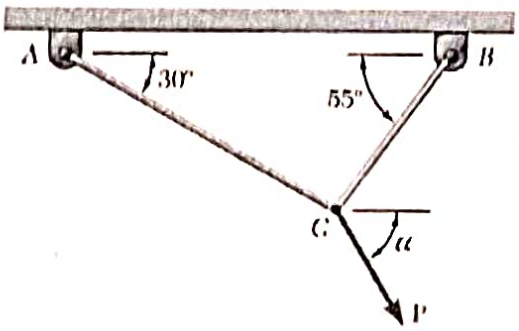


Figure 1.4

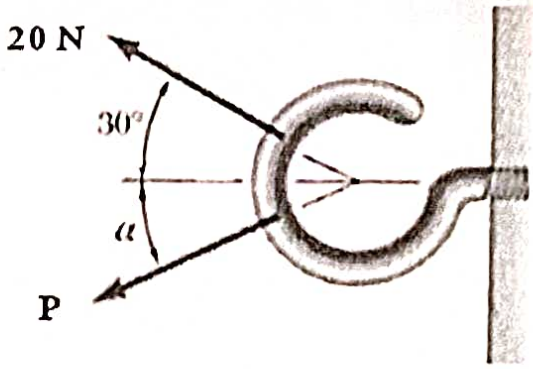
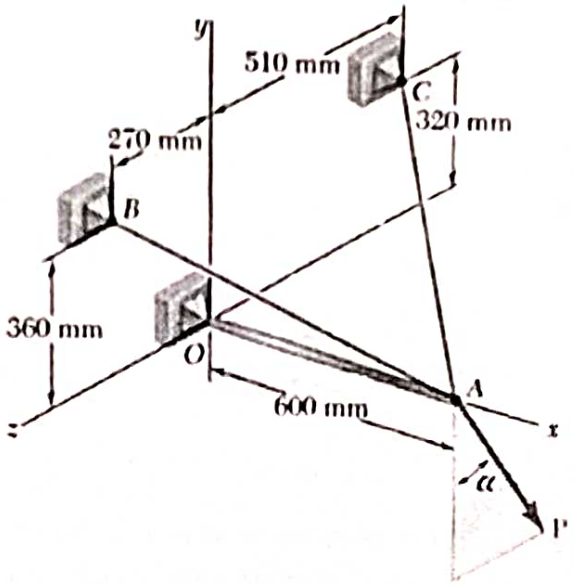


Figure 1.5

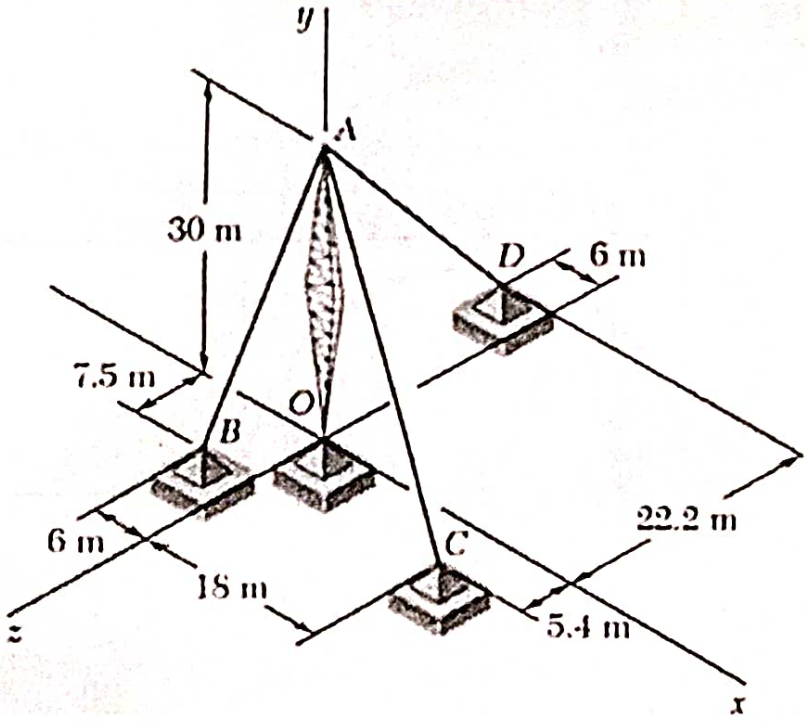
5. Two forces are applied as shown to a hook support. Using trigonometry and knowing that the magnitude of P is 14 N. determine (a) the required angle α if the resultant R of the two forces applied to the support is to be horizontal, *(b)* the corresponding magnitude of R. **(Figure 1.5)**

6. The boom *OA* carries a load P and is supported by two cables as shown. Knowing that the tension is 510 N in cable *AB* and 765 N in cable AC. determine the magnitude and direction of the resultant of the forces exerted at *A* by the two cables. **(Figure 1.6)**



(Figure 1.6)

7. A transmission tower is held by three guy wires attached to a pin at *A* and anchored by bolts at *B, C,* and *D.* knowing that the tower exerts on the pin at *A* an upward vertical force of 8 kN, determine the tension in each wire. **(Figure 1.7)**



(Figure 1.7)

2. Centroid and Moment of Inertia

Objective Questions:

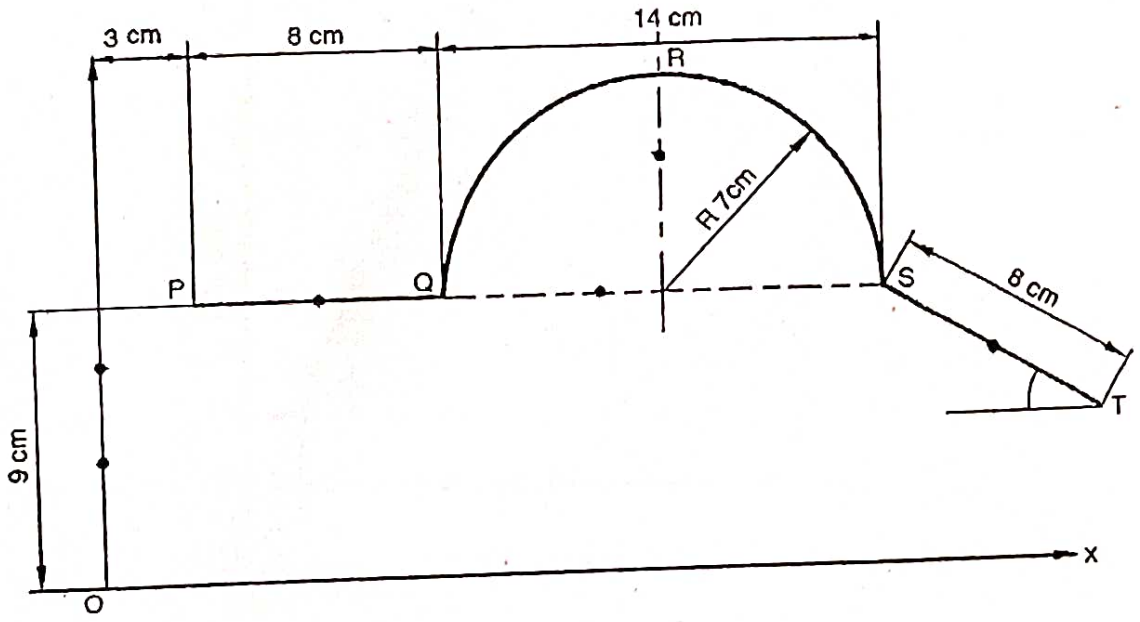
1) The coordinates of centroid of quarter circle arc situated in first quarter are _____ with respect to reference axis. $\left[\left(\frac{2r}{\pi},\frac{2r}{\pi}\right),\left(\frac{4r}{\pi},\frac{4r}{\pi}\right),\left(\frac{r}{2\pi},\frac{2r}{\pi}\right),\left(\frac{4r}{3\pi},\frac{4r}{3\pi}\right)\right]$
2) _____ moment of area is called moment of Inertia. (first, second)
3) The flywheel is used to store _____ energy. (kinematic, kinetic)
4) To find out the moment of inertia about any axis _____ theorem is used. (perpendicular, parallel)
5) The volume of hemisphere is _____. ($2\pi r^3$, $-\pi r^3$, $-\pi r^3$)
6) The centroid of semicircular area lies at distance of _____ from base along the vertical axis. (—, —)
7) The equation of radius of gyration is _____.
8) The volume of a body of revolution is equal to the generating _____ times distance travelled by the centroid of area. (length, area, volume)
9) For any plane area I_{zz} = _____

Questions:

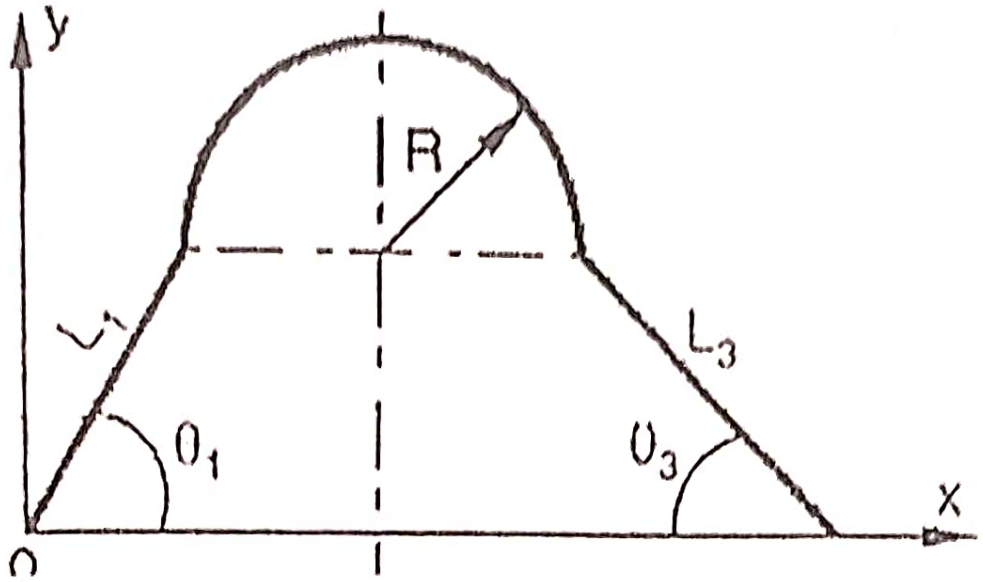
1) Determine centroid of quarter circular arc using first principle.
2) Explain with sketch Pappus and Guldinus theorem for area and volume.
3) Prove that $I_{zz} = I_{xx} + I_{yy}$.

Numerical Problems:

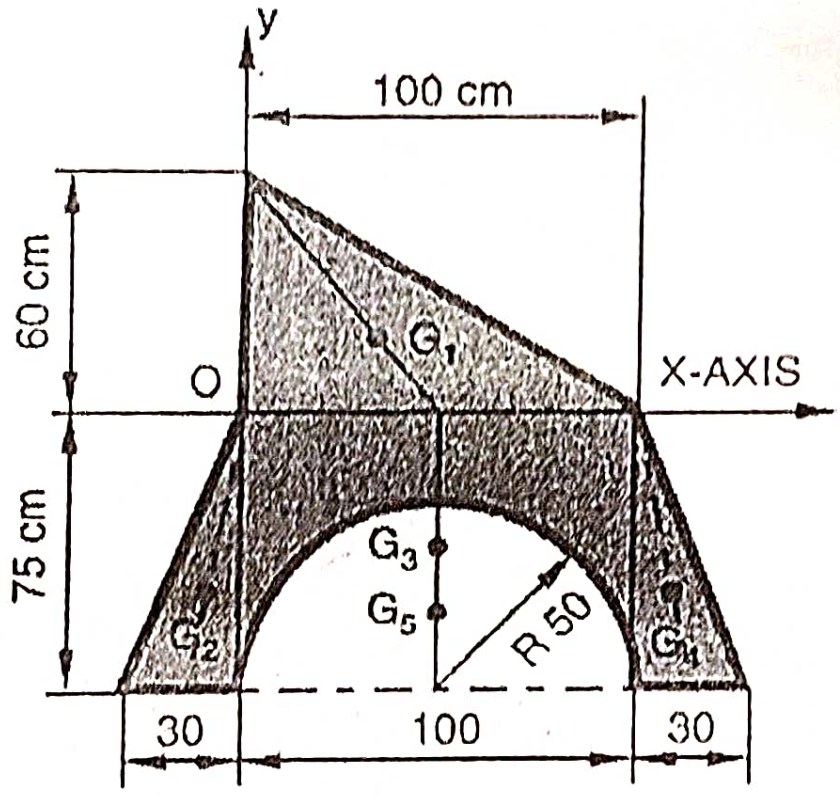
(1) Find the centroid of bent wire PQRST shown in figure below.



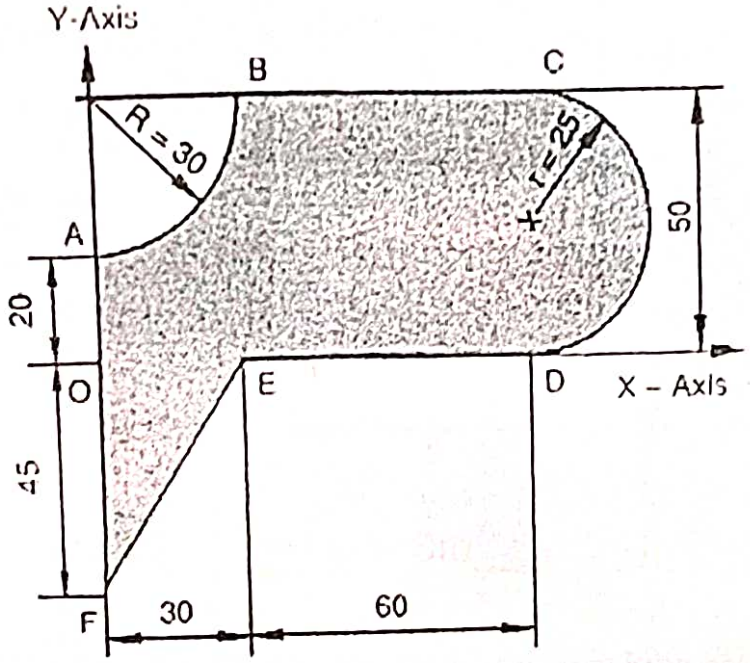
(2) A bent wire is as shown in the below figure. Locate the centroid of the wire. Take L_1=67 mm, θ_1=60°, R=44 mm and θ_3=60°.



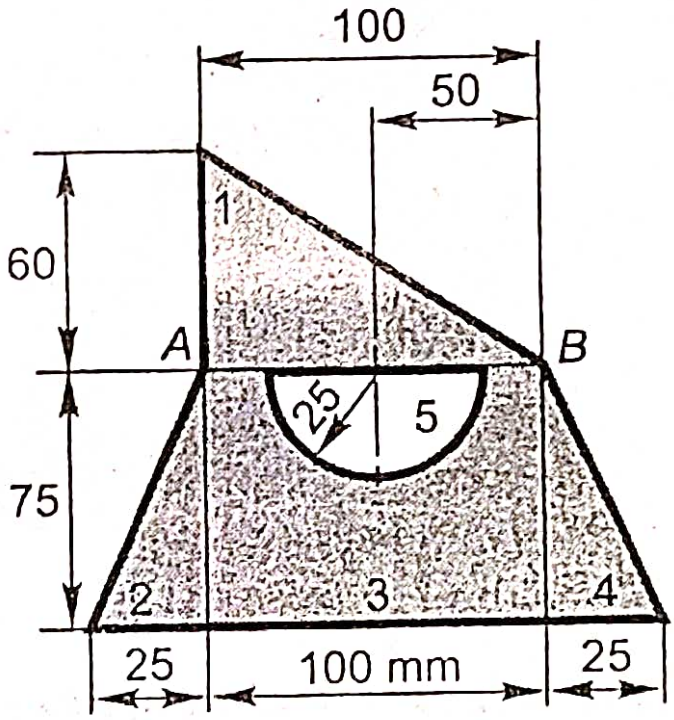
(3) Determine the centroid of the plane figure with respect to x and y axes as shown in figure below.



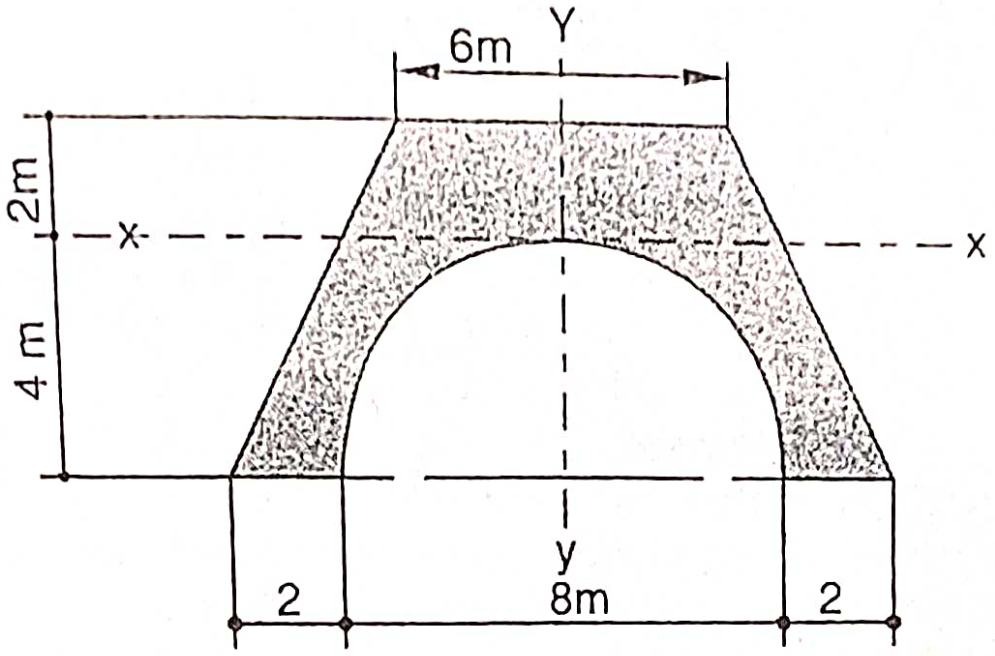
(4) Determine the centroid of the plane area shown in the figure below.
(All dimensions are in mm)



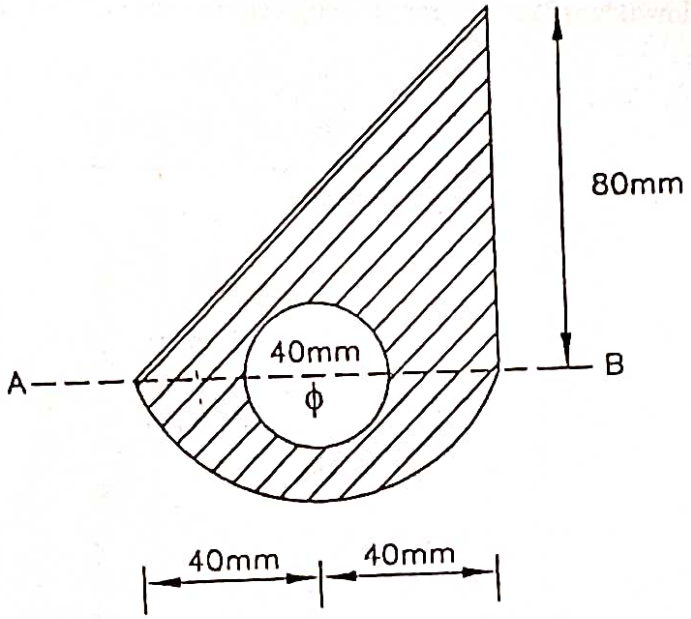
(5) Determine the moment of inertia of plane area about AB axis as shown in figure.
(All Dimensions are in mm)



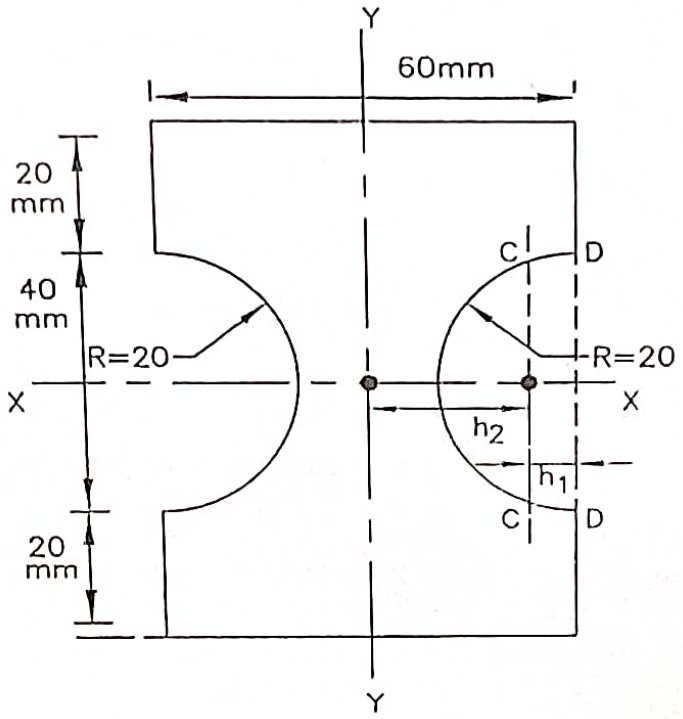
(6) Compute the moment of inertia of the shaded area about x-x and y-y axis as shown in the figure below.



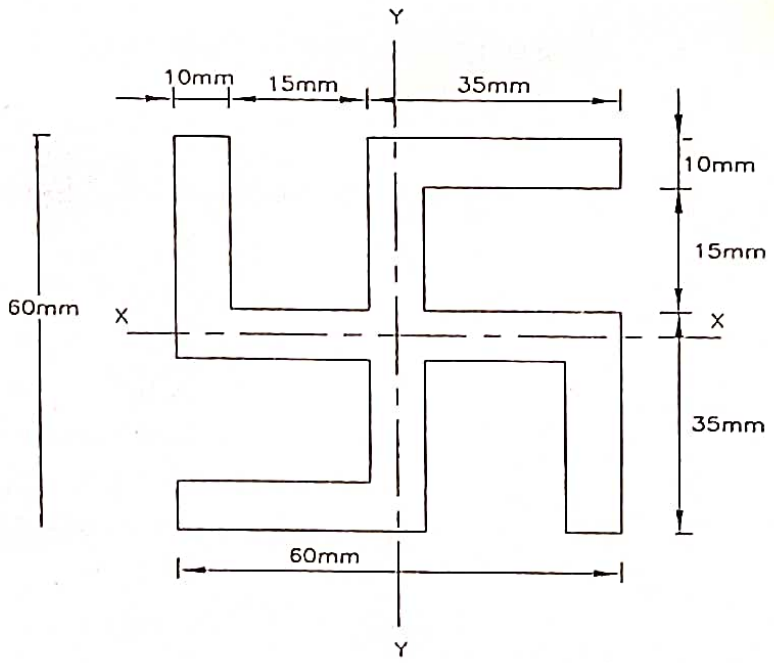
(7) Find the moment of inertia of the shaded area shown in the figure below about axis AB.



(8) Compute the moment of inertia of a section shown in the figure about x-x and y-y axis.



(10) Find moment of inertia of swastic section about centroidal axis as shown in figure.



3. Transformation of Forces and Moments

Objective Questions:

1.) The Lami's theorem is applicable only for: -

a.) Coplanar forces

b.) Concurrent forces

c.) Coplanar and concurrent forces

d.) Any type of forces

2.) If a body is in equilibrium. We may conclude that: -

a.) No force is acting on the body

b.) The resultant of all the forces acting on it is zero

c.) The moment of the forces about any point is zero

d.) Both (b) and (c)

3.) If the sum of all the forces acting on a body is zero, than the body may be in equilibrium provided the forces are: -

a.) Concurrent

b.) Parallel

c.) Like parallel

d.) Unlike parallel

4.) A body is said to be in equilibrium, if it has no linear motion: -

a.) True

b.) False

5.) Lami's theorem can not be applied in case of concurrent forces: -

a.) Agree

b.) Disagree

6.) A couple consists of: -

a.) Two like parallel forces of same magnitude

b.) Two like parallel forces of different magnitudes

c.) Two unlike parallel forces of same magnitude

d.) Two unlike parallel forces of different magnitudes

7.) If the arm of a couple is doubled, it's moment will: -

a.) Be halved

b.) Remain the same

c.) Be doubled

8.) A couple can be balanced by a force equal to its magnitude: -

a.) Agree

b.) Disagree

9.) One of the characteristics of a couple is that it can cause a body to move in the direction of the greater force: -

a.) True

b.) False

10.) In a couple, the lines of the forces are: -

a.) Parallel

b.) Inclined

c.) None of the two

Questions:

1.) Distinguish between external forces and internal forces.

2.) Explain Varignon's theorem.

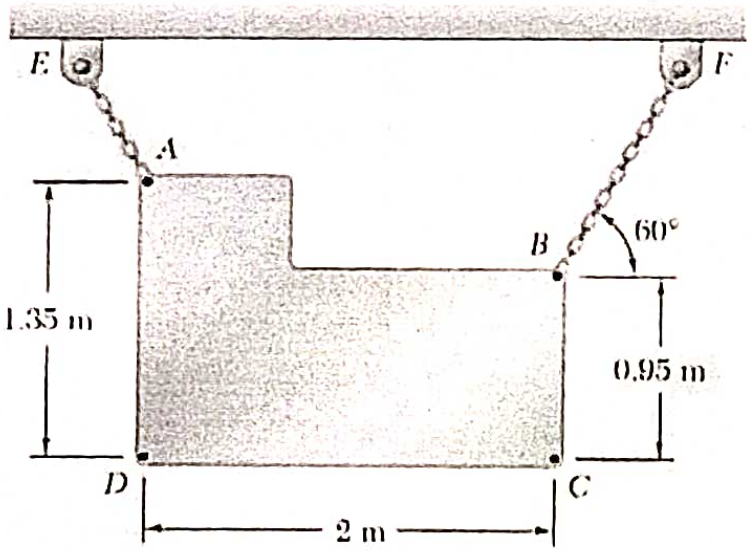
3.) Explain moment of couple.

4.) Explain equivalent couples.

5.) Explain how to resolve a given force at A in to a force at O and a couple?

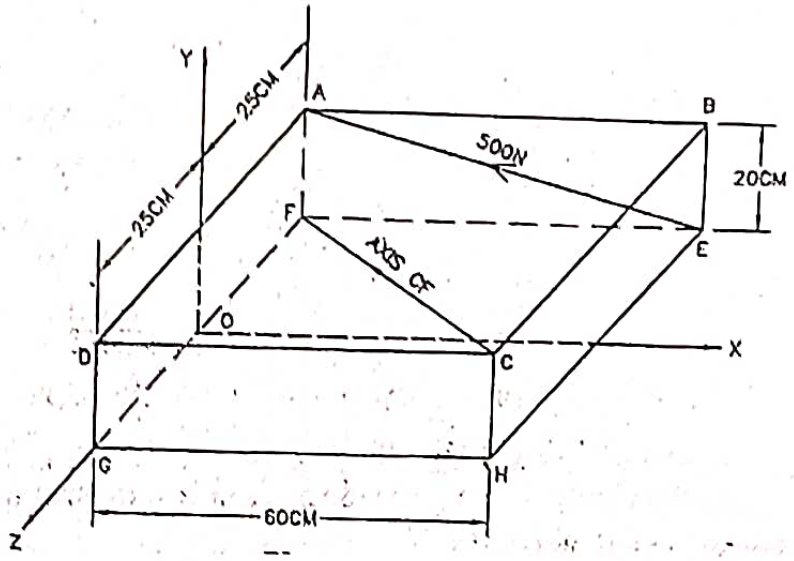
Numerical Problems:

Q 1. A sign is suspended from two chains AE and BE. Knowing that the tension in BF is 200 N. determine (a) the moment about A of the force exerted by the chain at B. (b) the smallest force applied at C which creates the same moment about A.

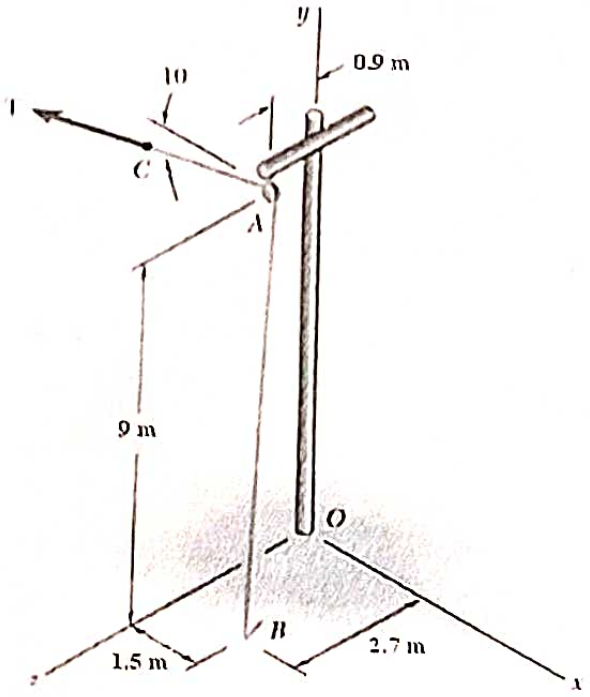


Q. 2 A Parallelepiped as shown in Figure is acted upon by a force 500 N at E. Determine the moment of this force about

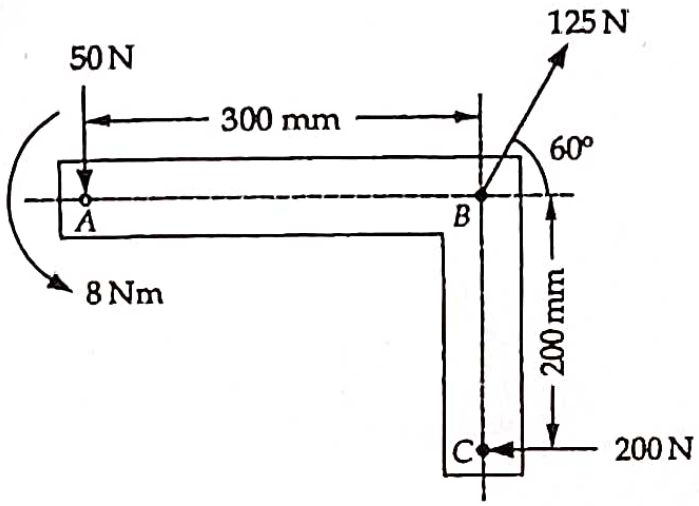
(i) Point H (ii) Axis CF



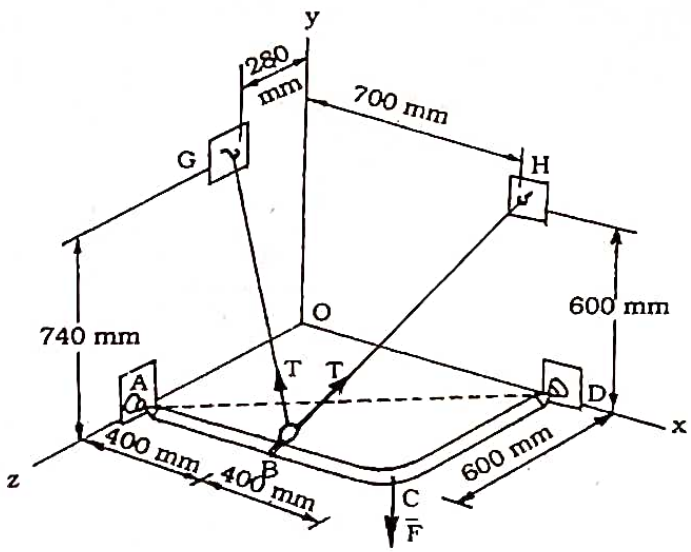
Q. 3. Before a telephone cable is strung, rope BAC is tied to a stake at B and is passed over a pulley at A. Knowing that portion AC of the rope lies in a plane parallel to the xy plane and that the magnitude of the tension T in the rope is 275 N, determine the moment about O of the resultant force exerted on the pulley by the rope.



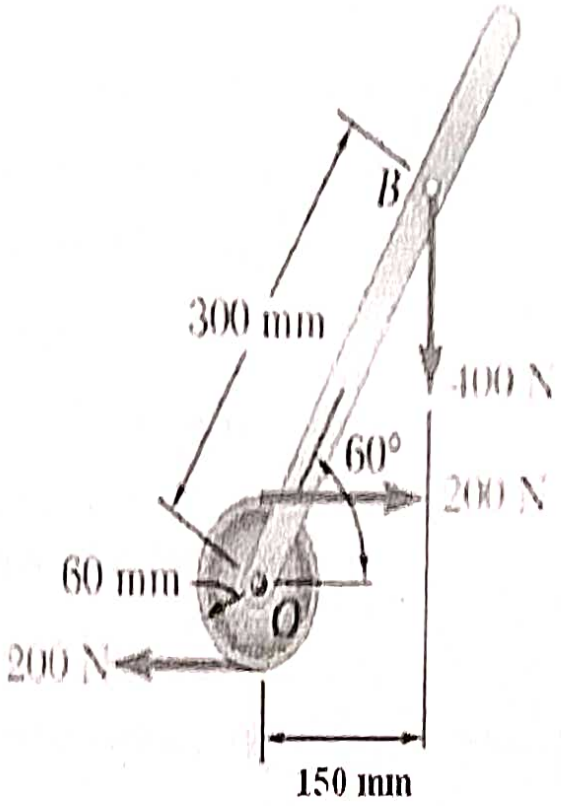
Q. 4 An angle bracket has been subjected to three forces and a couple as shown in figure. Determine the resultant of this system of forces. Proceed to locate the points where the line of action of the resultant intersects line AB and the line BC.



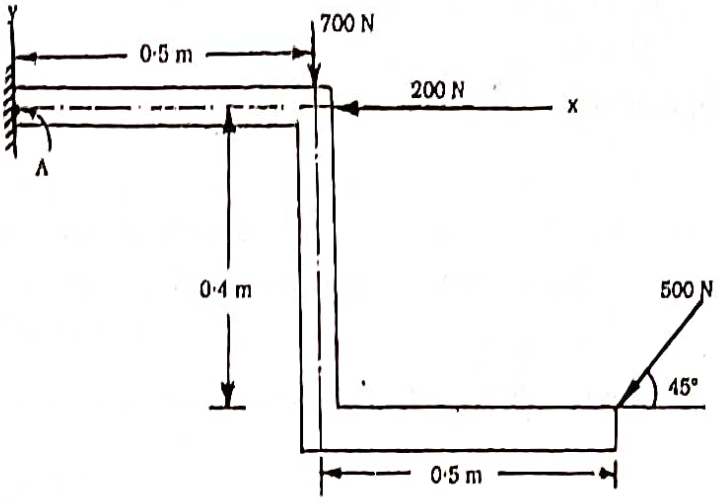
Q 5. A frame ACD is hinged at A and D and supported by a cable which passes through a ring at B and is attached to hooks at G and H. knowing that the tension in the cable is 1125 N, determine the moment about the diagonal AD of the force exerted on the frame by portion BH of the cable.



Q.6 Replace the couple and force shown by an equivalent single force applied to the lever. Determine the distance from the shaft to the point of application of this equivalent force.



Q. 7 Replace the force acting on the rod by an equivalent single resultant force and couple system acting at point A.



4. TRUSSES

Objective Questions:

(1) What is the nature of forces assumed to be present in the member of truss.

(a) Shear force (b) Bending moment (c) Axial force (d) Torsion

(2) What is the equation to calculate the degree of static indeterminacy of a truss?

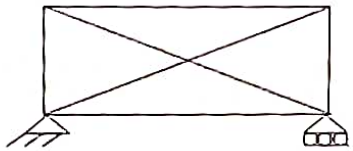
(a) 2j-3=m (b) 2m-3=m (c) 3m-2=j (d)2m-3=j

(3) What is the assumption made for the pure truss to calculate the force in the members?

(a) The members are pin connected
(b) The loads are directly acting on the pin joint.
(c) Only(a) is True
(d) Both (a) and (b) are true

(4)What is the degree of static indeterminacy of a truss shown in fig below?

(a) Statically determinate
(c) One degree statically indeterminate
(c) Two degree statically indeterminate
(d) Four degree statically indeterminate



(5) Which of the condition are used for equilibrium in case of truss?

(a) Summation of moments are zero
(b) Summation of vertical forces are zero
(c) Summation of horizontal forces are zero
(d) All of above

(6)The force in member DE of the truss shown in figure below is

(a) 100KN
(b) 0
(c) 355KN
(d) 25KN

(7)The force in member AE for a truss as shown in fig. is.

(a) 10
(b) 5KN
(c) 20KN
(d) 10KN

(8)State how will you make determinate the follow truss?

(a)By removing member AB
(b)By removing member AD
(c)By removing member BC
(d)Either of(b)and (c)

(9) Tension in the member is indirect by the symbol.

(a) 

(b) 

(c) Either of (a) and (b)

(d) None of above

(10) For the truss for bridge, Which Method would you like to use for convenience.

(a)Method of joint
(b)Method of section
(c)Graphical method
(d)None of above

Questions:

(1) Define and explain the term: Perfect frame, imperfect frame, deficient frame and a redundant frame.

(2) What is truss; define & differentiate between perfect truss and imperfect truss

(3) What are the assumptions made in finding out the force in truss?

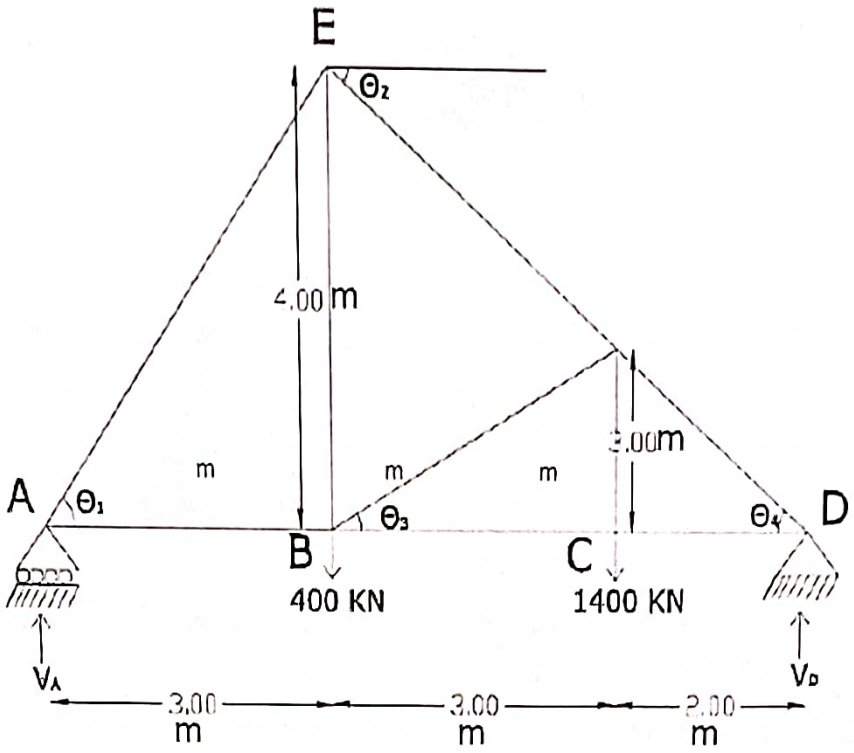
(4) What are the different methods for analysing the truss of perfect? Which one is used where and why?

(5) What do you understand by Maxwell's Diagram?

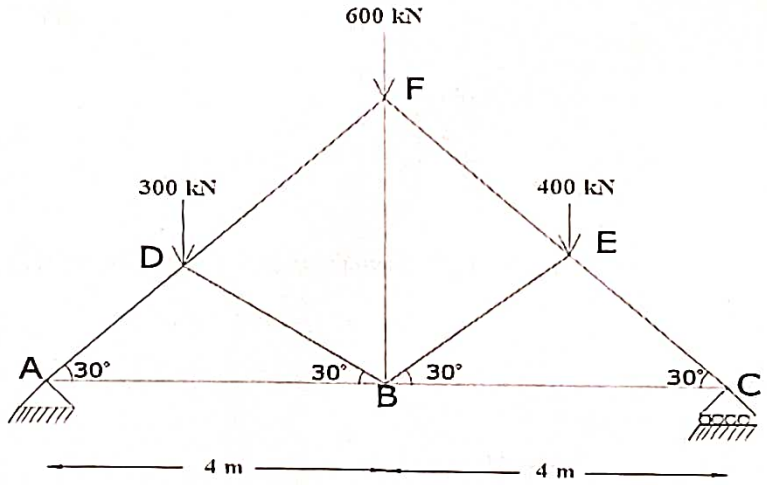
(6) What do you mean by null number? Explain with the examples.

Numerical Problems:

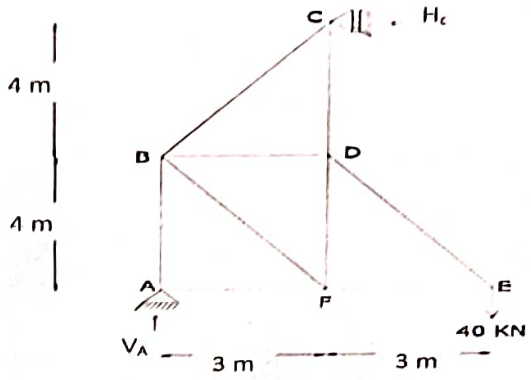
Pb 1: Find forces in all members of the truss shown in figure below.



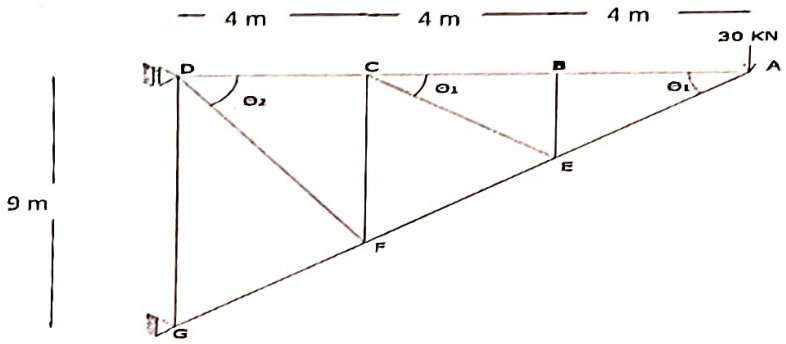
Pb 2: Find forces in all members of the truss shown in figure below.



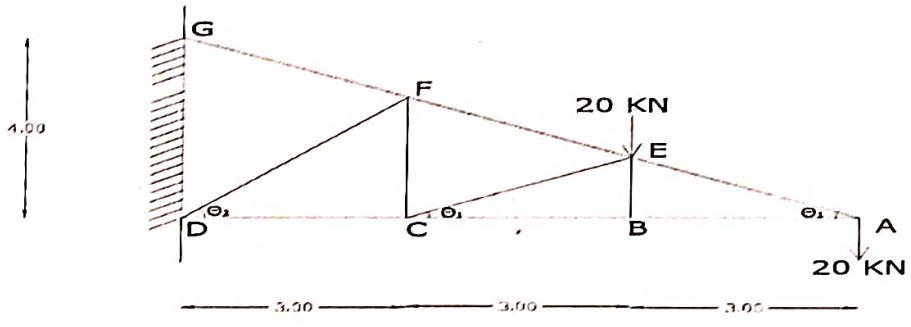
Pb 3: Find forces in all members of the truss shown in figure below.



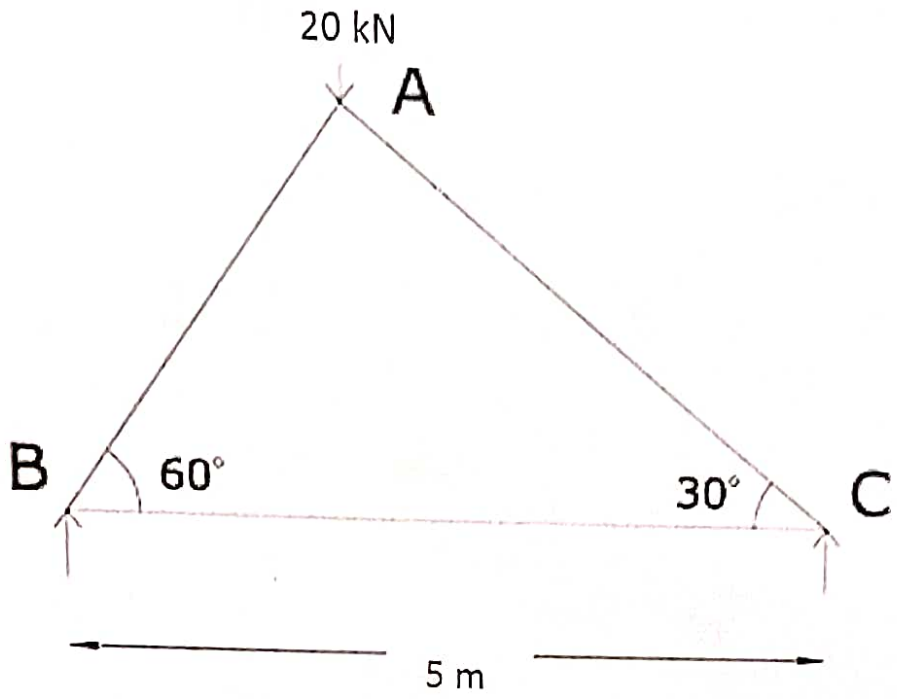
Pb 4: Find forces in all members of the truss shown in figure below.



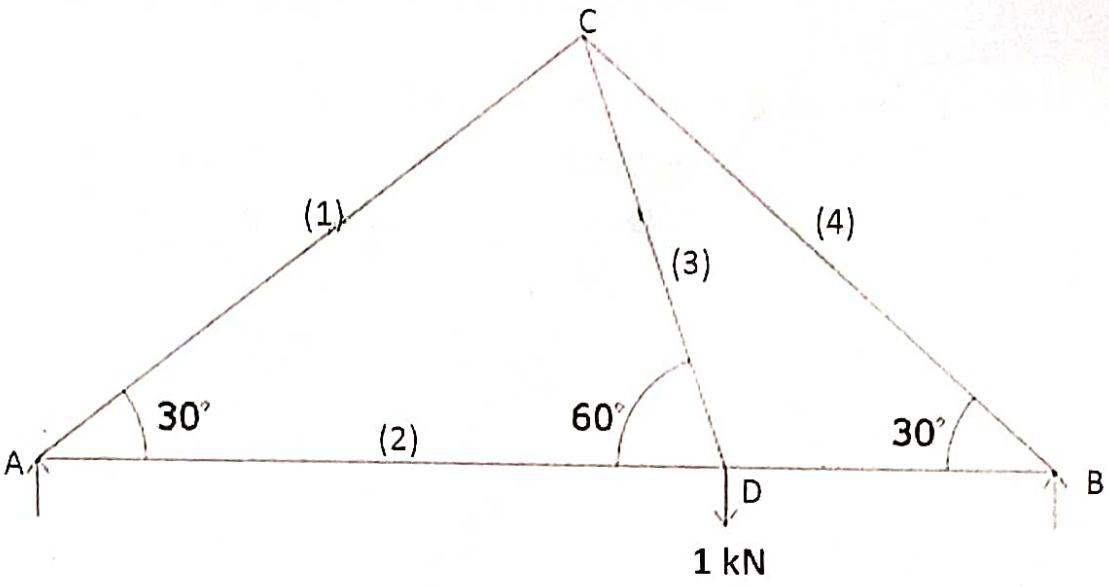
Pb 5: Find forces in all members of the truss shown in figure below.



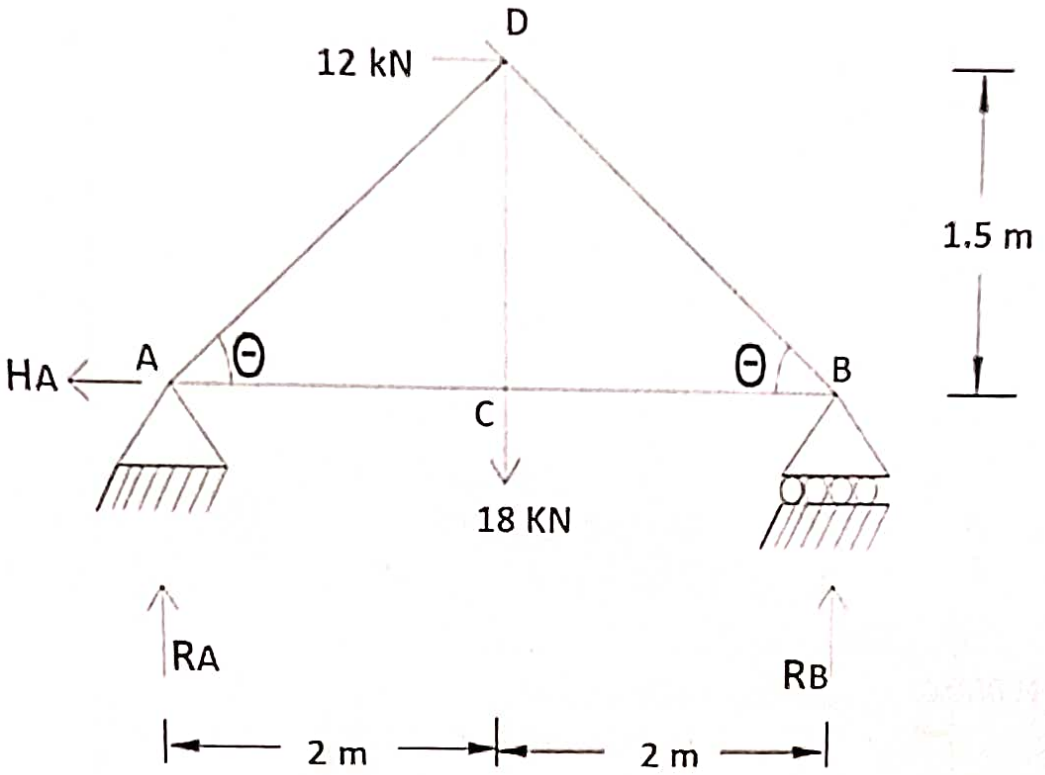
Pb 6: Find forces in all members of the truss shown in figure below.



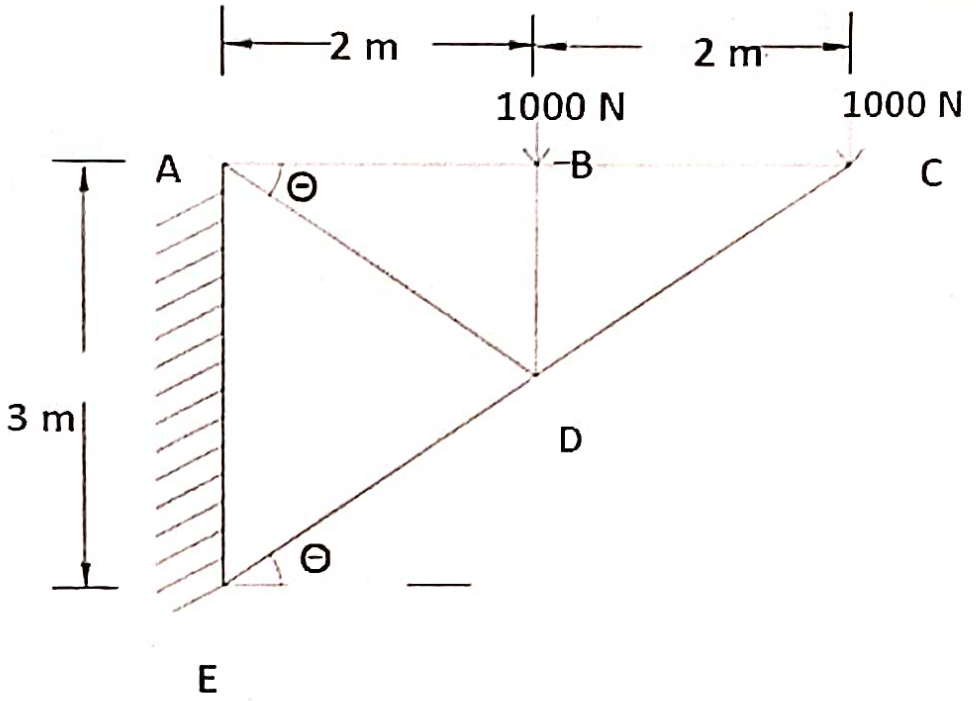
Pb 7: Find forces in all members of the truss shown in figure below.



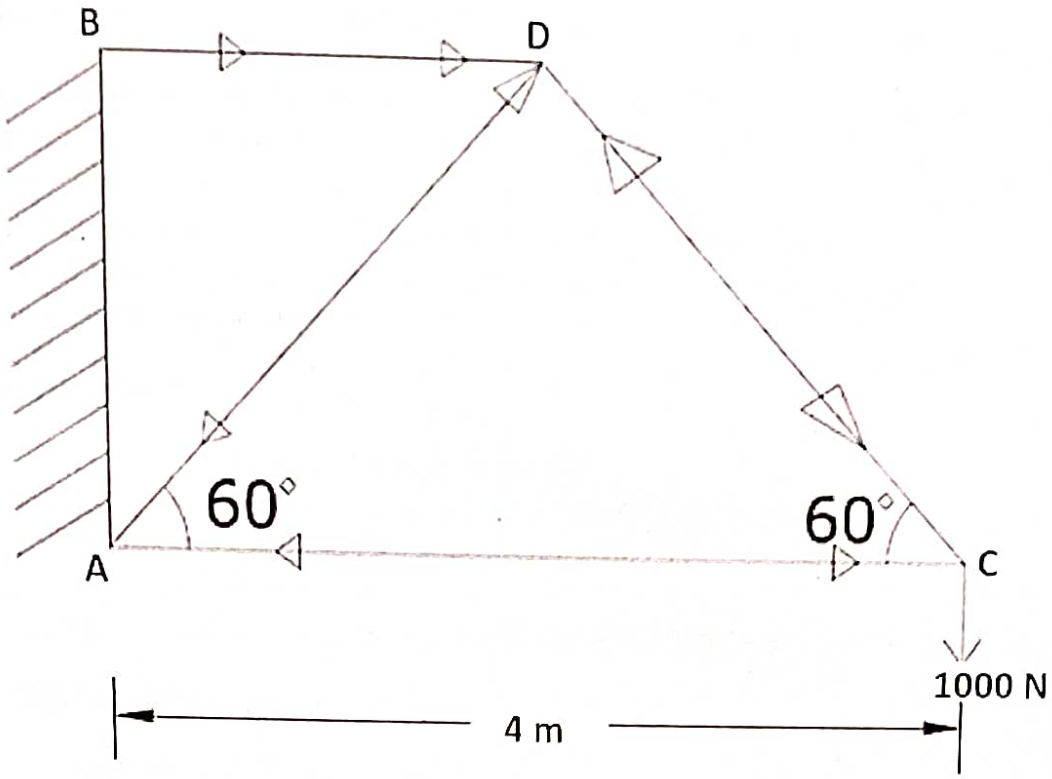
Pb 8: Find forces in all members of the truss shown in figure below.



Pb 9: Find forces in all members of the truss shown in figure below.



Pb 10: Find forces in all members of the truss shown in figure below.



5 Rigid Bodies and Support Reaction

Q.1 Which specific Theorem/Principle/Law is used for the following situations?

a) To find location of the resultant of coplanar non-concurrent force system.
b) To convert push acting on a particle into pull.
c) Relation of force and rate of change of momentum.
d) Graphical method to find resultant of coplanar concurrent forces.
e) To find magnitude/directions of three coplanar concurrent forces in equilibrium, when few quantities are given.

Q.2 True or false:

a) Two equal like parallel forces form couple.
b) Lami's theorem is nothing but the modification of sine rule.
c) Principle of Transmissibility cannot be used for rigid body.
d) Resultant of a couple is always one.
e) If a force system is in equilibrium, then vector diagram is a closed polygon.

Q.3 Types of loading of beam.

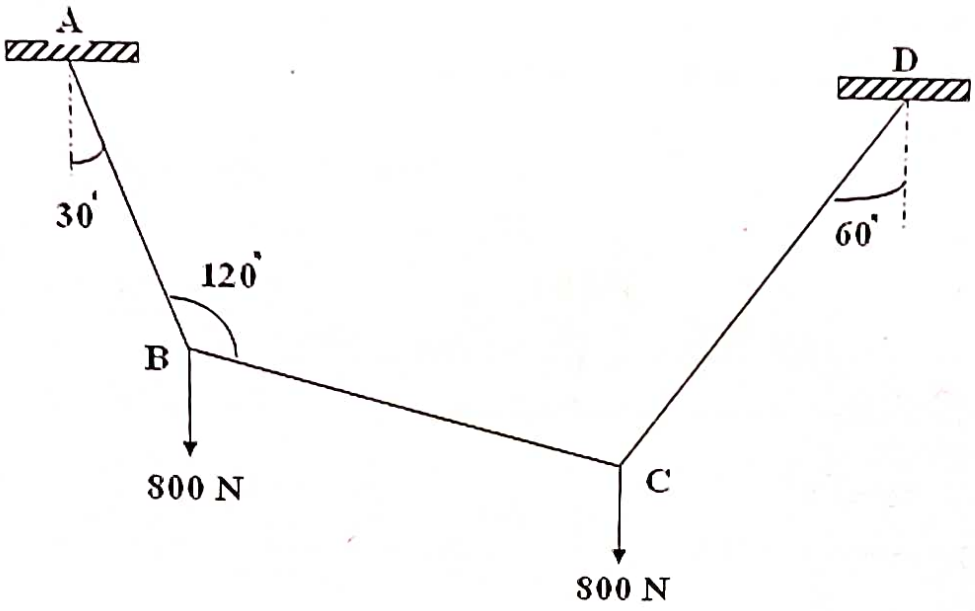
Q.4 At hinge support there are two/one reaction?

Q.5 At roller support the reaction is in which direction?

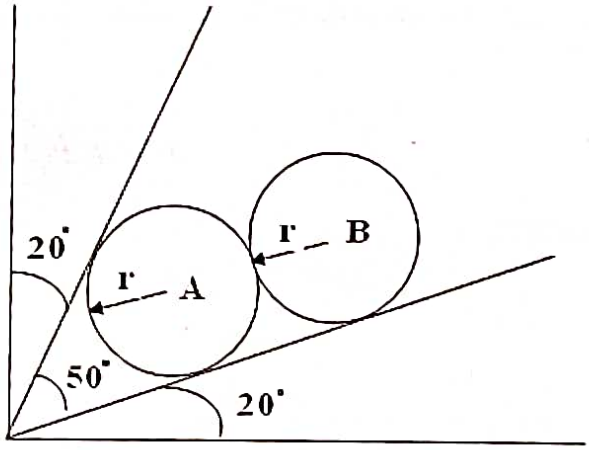
Q.6 How many types of beams are there?

Q.7 Is point load is called concentrated load or not?

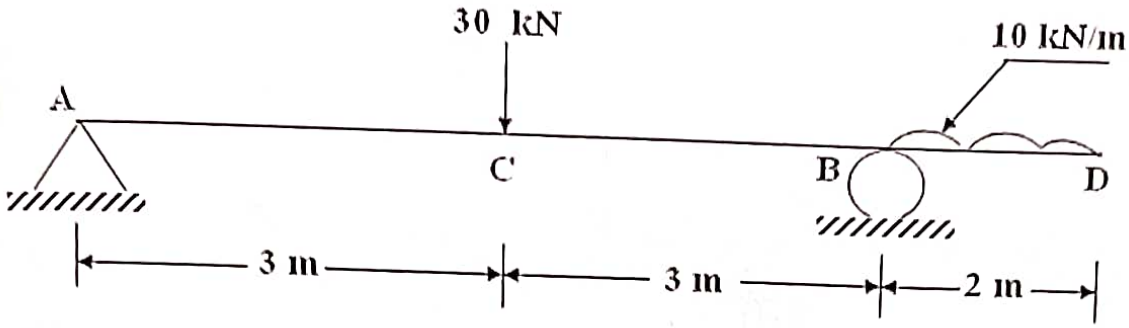
Q-1 A string ABCD attached to two fixed points A & D is carrying two equal weights of 800 N as shown. Determine the tension in AB,BC and CD of string.



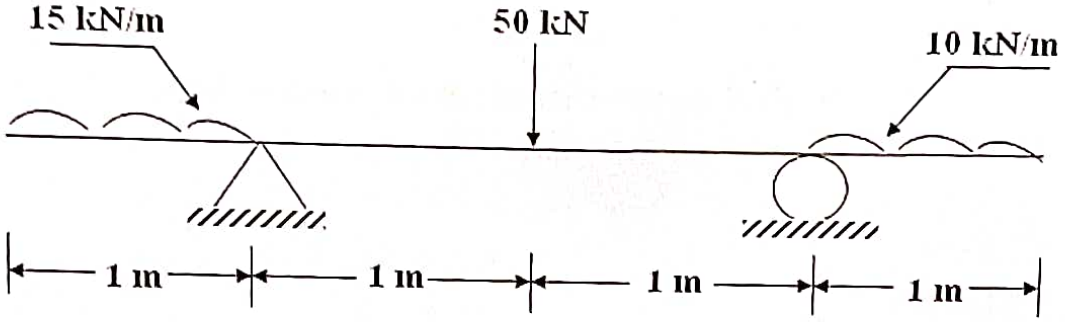
Q-2 Two Smooth balls A & B having a respective mass of 2Kg & 5 Kg respectively between the inclined plane. Determine the reaction of planes on balls. The radius of both balls is same.



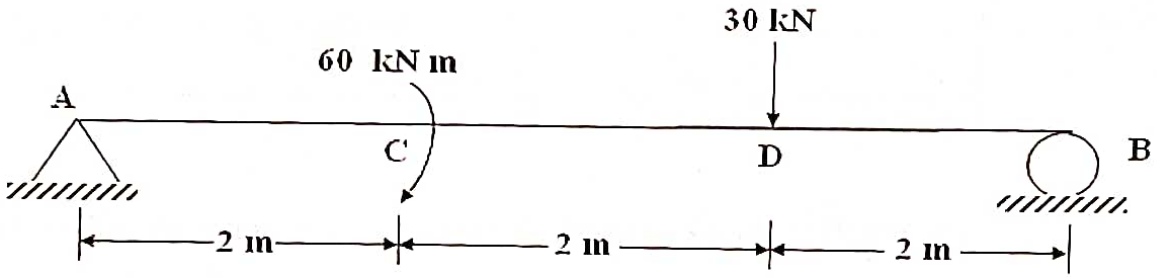
Q-3 Find the reactions at A & B.



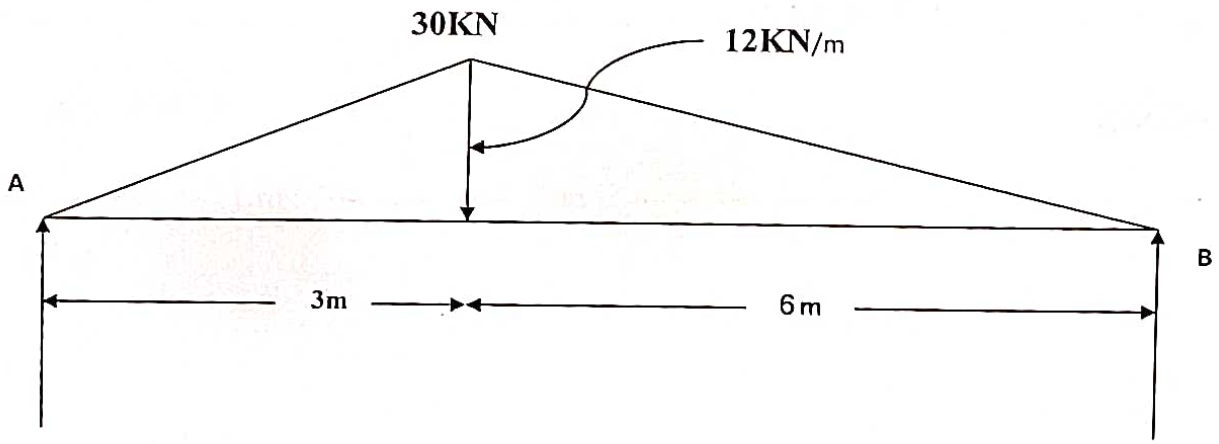
Q-4 Find the reactions at A & B.



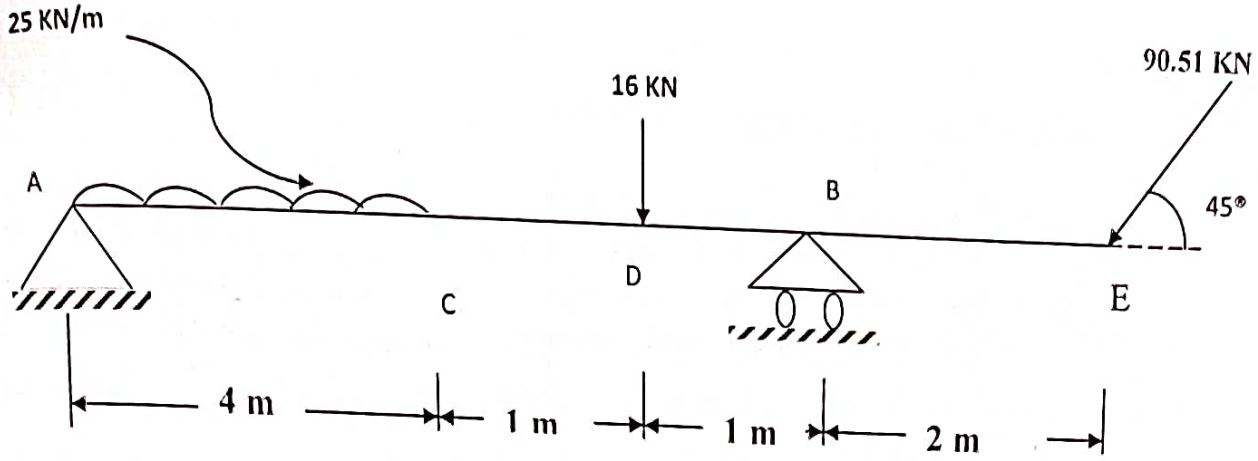
Q-5 Find the reactions at A & B.



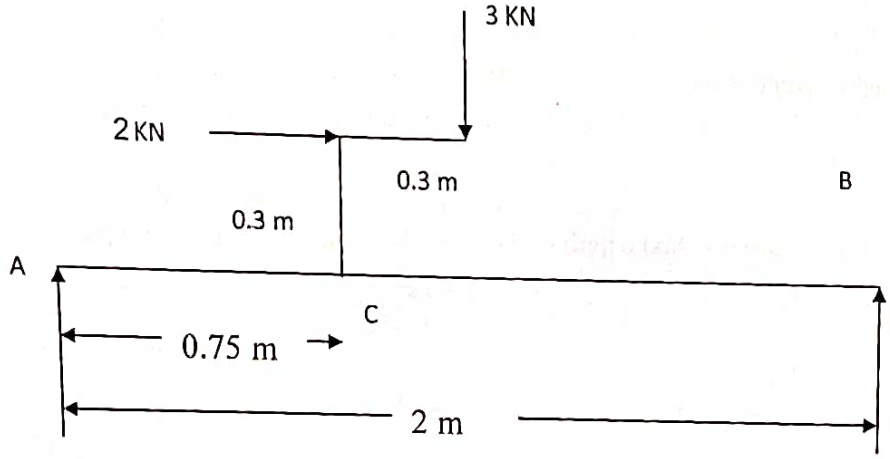
Q-6 Find the reactions at A & B.



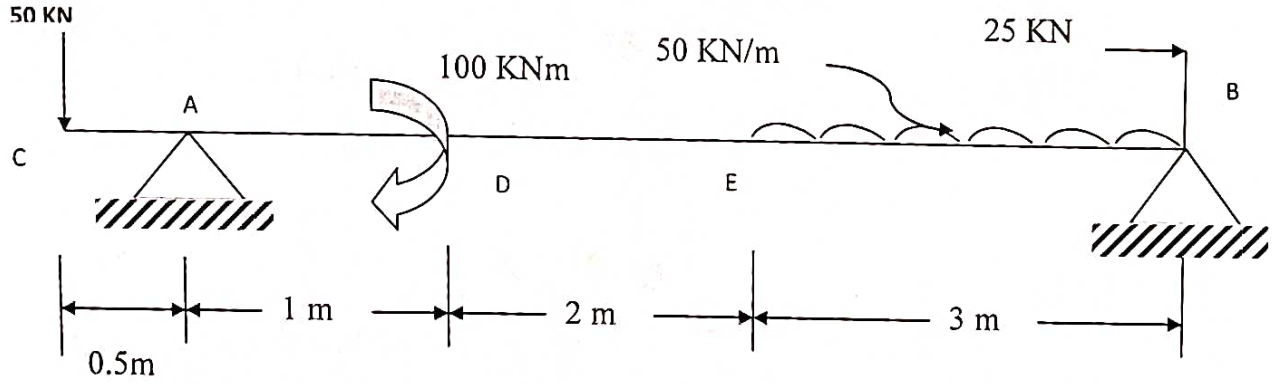
Q-7 Computer the reactions for the beam and give the name of the beam.



Q-8 Find the support reactions for the beam as shown in figure.



Q-9 Find the support reactions for the beam as shown in figure.



6. Friction

Objective Questions:

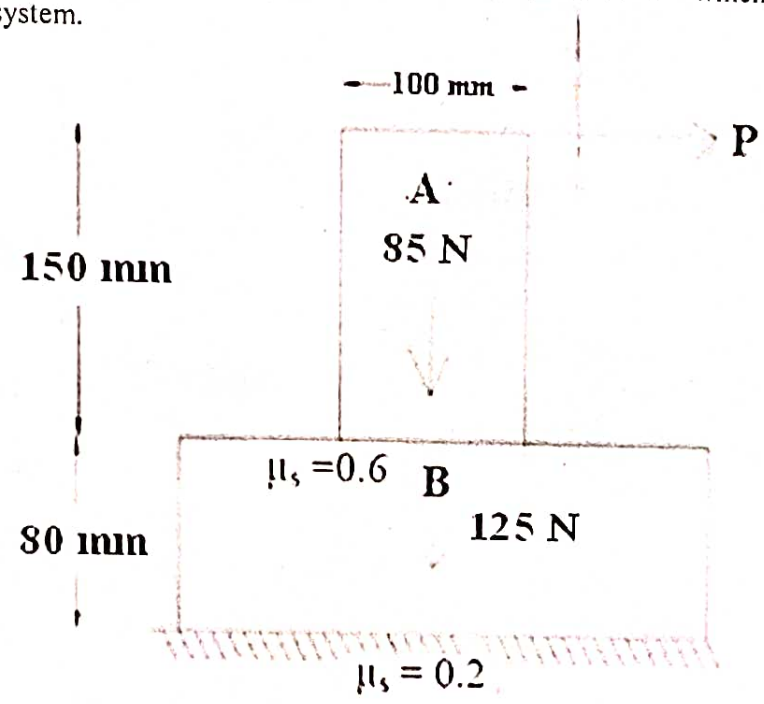
1) Angle of friction is _____ the angle of inclined plane, when solid is slide down. (less, more, equal to)
2) Rolling friction is always _____ than sliding friction. (less, more, equal to)
3) In the world there _____ frictionless surfaces. (many, none)
4) Frictional force is _____ of area of contact. (independent, depends on)
5) Angle of repose_____ angle of friction. (less, more, equal to)

Questions:

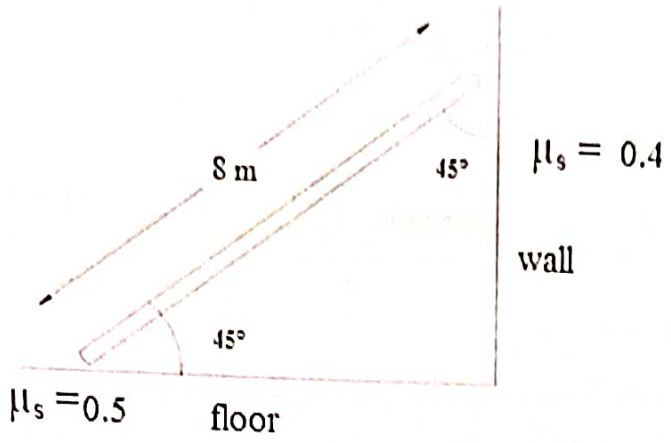
1) Define:
   (i) Angle of repose, (ii) limiting force of friction, (iii) coefficient of friction.
2) State laws of static and dynamic friction.
3) State laws of solid friction.
4) Prove that the angle of friction is equal to the angle of inclined plane, when a solid body of weight W is placed on inclined plane and is about to slide down.
5) What is wedge?
   Explain how wedge is used to raise heavy loads.
6) Derive an expression for the least force required to drag a body on rough inclined plane.

Numerical Problems:

1) Two homogeneous blocks are freely resting. Find the value of 'P' which will disturb the equilibrium of system.

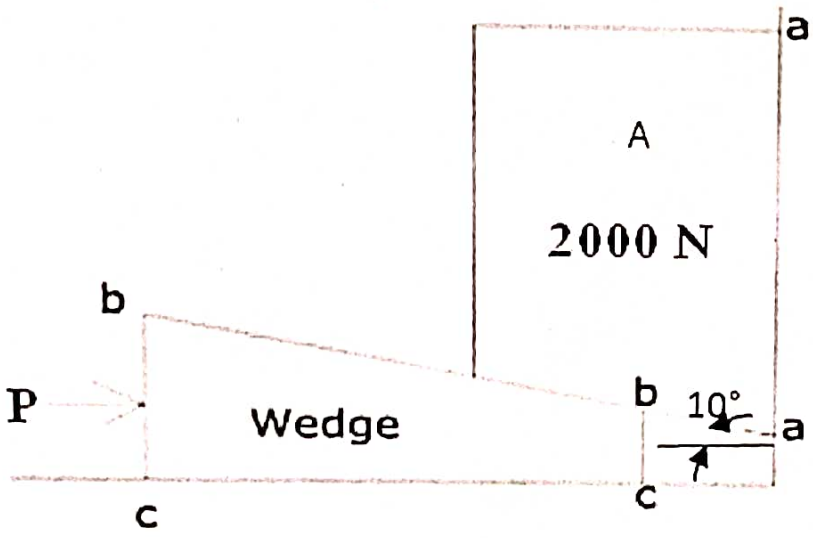


2) A ladder of 8 m rests against a wall making an angle of 45 and coefficient of friction between ladder and wall is 0.4 and ladder and floor is 0.5. If a man whose weight is one half that of ladder ascends it, how high wills he climbs, when ladder slips?

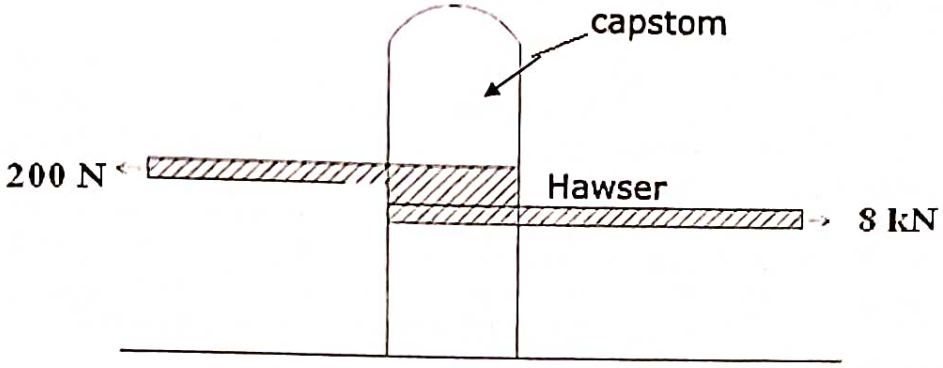


3) A ladder of 15 m length rests against a vertical wall making an angle of 60 and coefficient of friction between ladder and wall is 0.3 and ladder and floor is 0.25. A man weighing 500 N climbs the ladder, how long will he be able to climb before the ladder slips? Find the necessary weight to put at bottom of ladder so as to be sufficient to permit the man to go to the top. Weight of ladder is 850 N.

Calculate the force 'P' required to raise the Block 'B' of weight 1000 N (weight of wedge is negligible). μ_{cc} =0.4, μ_{bb} = 0.2,μ_{aa} = 0.3



4) A hawser thrown from a ship to a pier is wrapped two full turns around capstan. The tension is in hawser 7.5 kN exerting a force of 150 N on its free end to keep hawser from slipping. Calculate coefficient of friction between hawser and capstan.



7. Mechanical Vibrations

Objective Questions:

1. Amplitude and period of vibrations are related to each other. Give your view in a line.
2. Are vibrations undesirable in machines? Give reasons in a sentence.
3. For a spring-mass system, give maximum velocity and acceleration expressions.
4. For a single degree of freedom, spring mass system differential equation of motion, show how mass and stiffness control the displacements.
5. Give examples/applications from day-to-day life of : free vibration, damped vibration and forced vibration.
6. How the vibrations of a particle and a rigid body are different from each other. Consider a single degree of freedom spring-mass and an oscillating square plate.
7. Is damping responsible for change in frequency of a spring-mass system?
8. Principle of conservation of energy gives the same answer as the solution of differential equation of vibration for a spring-mass system. Give your comment.
9. What is resonance? Does it result in destruction every time it is encountered?
10. Why the displacements are sinusoidal in case of free vibrations, whereas the same are exponentially decreasing in case of damped vibrations?

Questions:

1. Describe the terms: vibration, free vibration, forced vibration.
2. Explain how energy is conserved in case of oscillation of a rigid body.
3. State how Free Vibrations of a rigid body as different from a simple pendulum.

Numerical Problems:

1) A 50-kg block moves vertical guides as shown in figure 1. The block is pulled 40 mm down from its equilibrium position and released. For each spring arrangement, determine the period of the vibration, the maximum velocity of the block, and the maximum acceleration of the block.

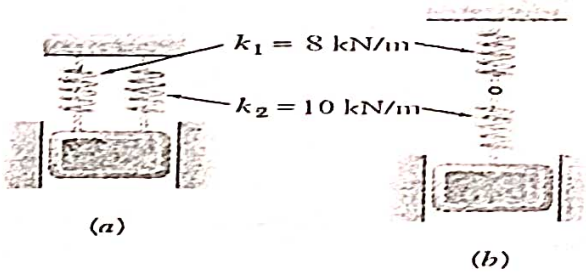


FIGURE: 1

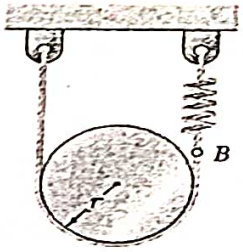


FIGURE: 2

2) A cylinder of weight W = 100 N and radius r = 10 cm is suspended from a looped cord as shown in figure 2. One end of the cord is attached directly to a rigid support, while the other end is attached to a spring of constant k = 25 N/mm. Determine the period and natural frequency of the cylinder.

3) Determine the period of small oscillations of cylinder of radius r which rolls without slipping inside a curved surface of radius R as shown in figure 3.

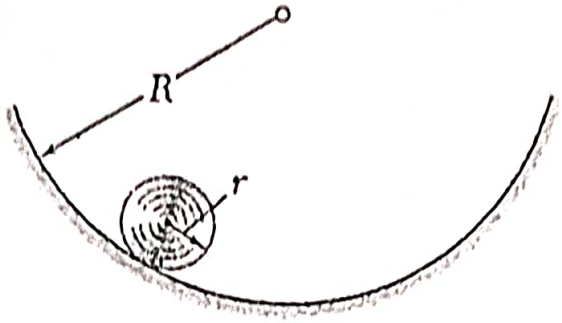


FIGURE: 3

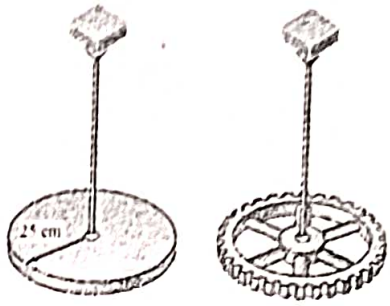


FIGURE: 4

4) A circular disk, weighing 15 kg and radius 25cm is suspended from a wire as shown in figure 4. The disk is rotated (thus twisting the wire) and then released; the period of the torsional vibration is observed to be 1.13 s. A gear is then suspended from the same wire, and the period of torsional vibration for the gear is observed to be 1.93 s. Assuming that the moment of the couple exerted by the wire is proportional to the angle of twist, determine (a) the torsional spring constant of the wire, (b) the centroidal moment of inertia of the gear, (c) the maximum angular velocity reached by the gear if it is rotated through 90° and released.

5) A motor weighing 200 kg is supported by four springs, each having a constant of 150 KN/m. The unbalance of the rotor is equivalent to a weight of 0.05 kg located 15 cm from the axis of rotation. Knowing that the motor is constrained to move vertically, determine (a) the speed in rpm at which resonance will occur, (b) the amplitude of the vibration of the motor at a speed of 1200 rpm.

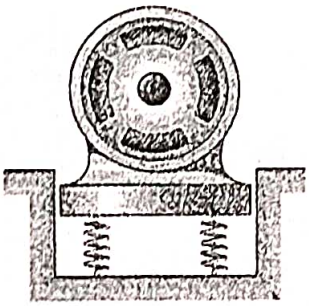


FIGURE: 5

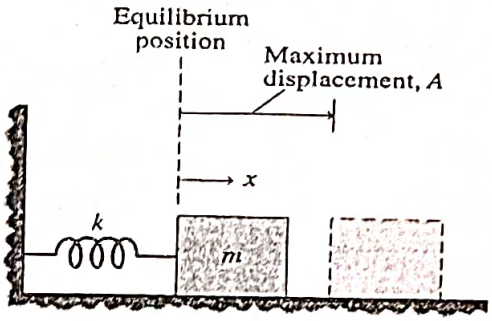


FIGURE: 6

6) Consider the spring/mass system as shown in figure 6. Let the spring constant be k = 400 N/m and the mass m = 1 kg. The mass is given as initial displacement x_0 = 0.15 m and an initial velocity v_0 = 5.0 m/s to the right.
   a. Determine the amplitude, the phase angle and the total energy of the vibration.
   b. Derive formulas for the position, velocity, and acceleration of the vibrating mass as a function of time t.