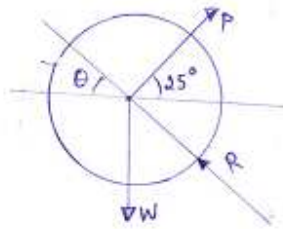
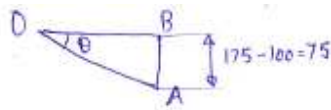


ENGINEERING MECHANICS SOLUTIONS

UNIT-I

LONG QUESTIONS

1. A roller shown in Figure 1 is mass 150 Kg. What force P is necessary to start the roller over the block A?



$$\theta = \sin^{-1}\left(\frac{75}{175}\right) = 25.37^\circ$$

$$\alpha = 90 + 25 = 115$$

$$\beta = 90 + 25.377 = 115.377$$

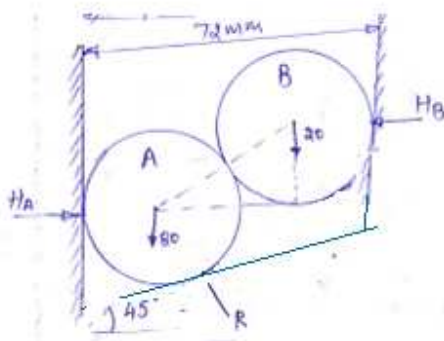
$$\gamma = 360 - (115 + 115.377) = 129.623$$

$$\frac{P}{\sin(\alpha)} = \frac{Q}{\sin(\beta)} = \frac{R}{\sin(\gamma)}$$

Putting the values we get,

$$P = 175.95 \text{ kg}$$

2.



$$\sum F_1 = 0 \quad \uparrow + \frac{R}{\sqrt{2}} - 80 - 20 = 0$$

$$\sum F_1 = 0 \rightarrow H_A - \frac{R}{\sqrt{2}} - H_B = 0$$

$$R = 100\sqrt{2} \text{ kN}$$

$$\sum M_A = 0 \rightarrow 20 \times AC - H_B \times BC = 0$$

$$H_A = \frac{R}{\sqrt{2}} + H_B = 100 + 15 = 115 \text{ kN}$$

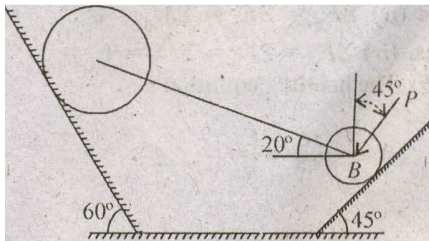
$$\text{So } H_B = 15 \text{ kN}$$

$$AC = 72 - 30 - 15 = 27 \text{ mm}$$

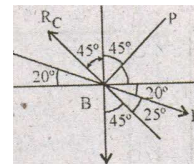
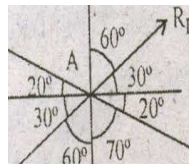
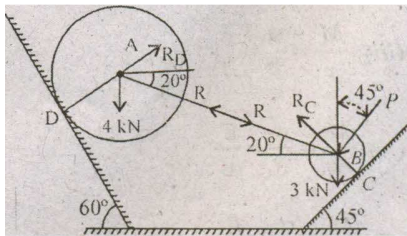
$$BC = \sqrt{45^2 - 27^2} = 36 \text{ mm}$$

H_A	115 kN
H_B	15 kN
R	$100\sqrt{2} \text{ kN}$

3. Two cylinders A and B weighing 4 kN and 3 kN, respectively, rest on smooth inclined plane as, shown in figure, They are connected by a bar of negligible weight hinged to each cylinder at its geometric centre by smooth pins. Find the force P to be applied to the smaller cylinder at 45° to the vertical to hold the system in the given position.



Ans.



Applying Lami's Theorem at 'A'.

$$\frac{4000}{\sin 130} = \frac{R}{\sin 110} = \frac{R_D}{\sin 120}$$

$$R = 4522 \text{ N}$$

$$R = 4906.7 \text{ N}$$

For equilibrium of point B, we have.

$$\sum f_x = 0,$$

$$R \cos 20^\circ - R_e \cos 45^\circ - P \cos 45^\circ = 0$$

$$4522 \cos 20^\circ - (R_e + P) \cos 45^\circ = 0$$

$$\text{or } R_e + P = 6010.31 \quad \dots (1)$$

$$\sum f_y = 0$$

$$R_c \cos 45^\circ - 3000 - R \cos 70^\circ - P \cos 45^\circ = 0.$$

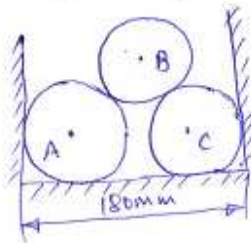
$$\text{or } R_c - P = 6430.85 \quad \dots (2)$$

Adding (1) and (2), we get

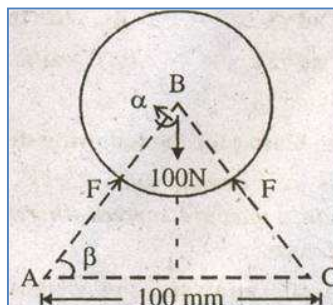
$$R_c = 6220.58 \text{ N}$$

$$P = 210.27 \text{ N Ans,}$$

4. Three cylinders A, B and C each weighing 100 N and diameter 80 mm are placed in a channel of 180 mm width as shown in Fig. 1. Determine the pressure exerted by the cylinder A and B at the point of contact.



Ans. Free body diagram of the system is shown as below:



Due to symmetry, reactions of A and C on B are same,

$$\cos \beta = 50/80$$

$$\beta = 51.33^\circ$$

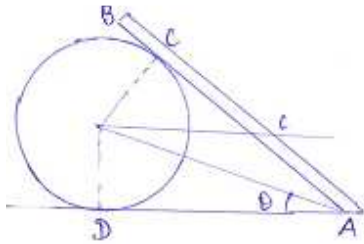
$$\alpha = 90 - 51.33 = 38.7^\circ$$

For equilibrium of B

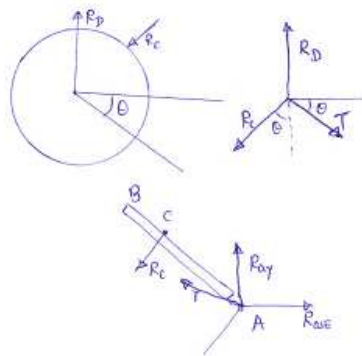
$$2 F \cos \alpha = 100 \text{ N}$$

$$\text{Or, } F = 64 \text{ N}$$

5. A smooth weightless cylinder of radius 600 mm rests on a horizontal plane and is kept from rolling by an inclined string of length 1000 mm. A bar AB of length 1500 mm and weight 1200 N is hinged at A and placed against the cylinder of negligible weight. Determine tension in the string.



Ans. From fig. $\sum M_o = 0$
 Taking moment about pint A, we get
 $R_c \times 800 - 1200 \times 750 \cos 73.72 = 0$



$$R_c = 315.37 \text{ N}$$

$$\sin \theta = 600/1000$$

$$\text{Or } \theta = 36.86^\circ$$

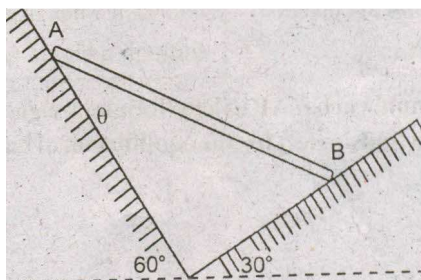
$$\text{Or } 2\theta = 73.72^\circ$$

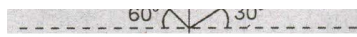
By applying Lami's Theorem,

$$\frac{R_c}{\sin (90+\theta)} = \frac{T}{\sin (180-2\theta)}$$

$$\text{Or } T = 377.86 \text{ N}$$

6. uniform bar AB of length L and weight W lie in its vertical plane with its ends resting on two smooth inclined planes OA and OB and find angle theta for the equilibrium of bar as shown in Fig.





From the geometry we obtain

the various angles

The reaction R_1 , R_2 and W of the rod should cut at same point for the equilibrium. By applying Lami's theorem at point O.

$$\frac{R_1}{\sin(150)} = \frac{R_2}{\sin(120)} = \frac{W}{\sin(90)}$$

Solving we get

$$R_1 = W/2$$

$$R_2 = 1.73 W$$

Taking moment at the centre of the rod:

Clockwise moment = Anti Clockwise moment. .

$$O1A1 = L/2 \cos \theta$$

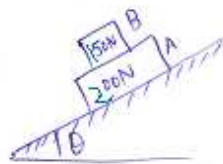
$$O1B1 = L/2 \sin \theta$$

From above, we get

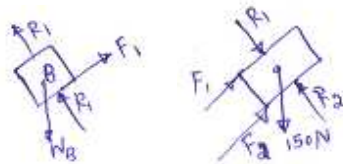
$$\tan \theta = 1/\sqrt{3}$$

$$\text{Or, } \theta = 30^\circ$$

7. Blocks A and B, of weight 150 N and 200 N, respectively rest on an inclined plane as shown in the figure. The coefficient of friction between the two blocks is 0.3 and between blocks A and inclined plane is 0.4. Find the value of θ for which either one or both the blocks start slipping. At that instant, what is the friction force between B and A? Between A and inclined plane?



Ans:



From the fig.

$$R_1 = 200 \cos \theta$$

$$F_1 = 200 \sin \theta$$

$$F_1 = \mu R_1$$

$$200 \sin \theta = \mu \times 200 \cos \theta$$

$$\tan \theta = 0.3$$

$$\theta = 16.7^\circ \text{ Ans}$$

$$F_1 = 200 \sin 16.7$$

$$F_1 = 57.47 \text{ N Ans.}$$

$$R_2 - R_1 = 150 \cos \theta$$

$$F_2 - R_2 = 150 \sin \theta$$

$$F_2 = 350 \sin \theta$$

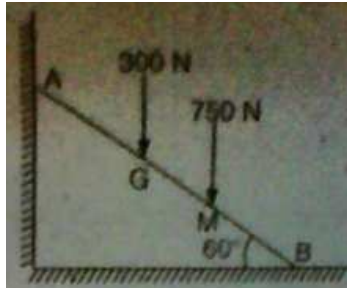
$$R_2 = 350 \cos \theta$$

$$F_2 = 350 \sin 16.7$$

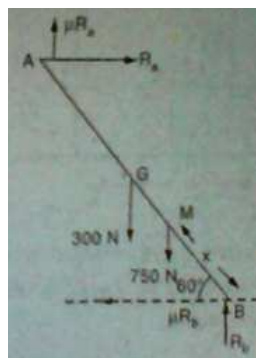
$$F_2 = 100.6 \text{ N}$$

Body B will slide at $\theta = 16.7^\circ$

8 A ladder 6 m long weighting 300 N is resting against a wall at an angle of 60° to the horizontal plane as shown in fig. 3. A man weighing 750 N climbs the ladder from position B towards A. At what position along the ladder from the bottom of the ladder does he induce slipping? The coefficient of friction for both the wall and the ground with the ladder is 0.2.



Ans. Draw the FBD for ladder



Let x be the distance man climbs on ladder for equilibrium from point B.

$$\sum f_x = 0, \quad R_a - \mu R_b = 0 \quad R_a = 0.2 R_b \dots (1)$$

$$\sum f_y = 0, \quad R_b + \mu R_a - 300 - 750 = 0$$

$$R_b = 1009.6 \text{ N}, \quad R_a = 201.92 \text{ N}$$

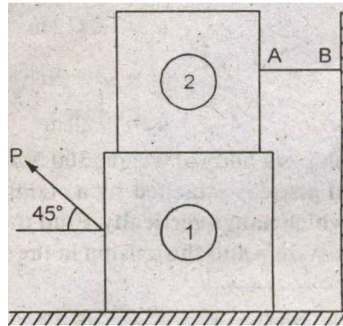
For finding out distance x take moment about B.

$$\sum M_o = 0, \quad 750 x \cos 60^\circ + 300 x 3 \cos 60^\circ - \mu R_a 6 \sin 60^\circ -$$

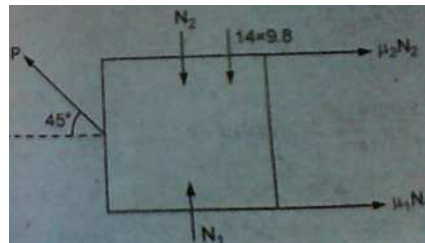
$$R_a x 6 \cos 60^\circ = 0$$

$$x = 1.92 \text{ m}$$

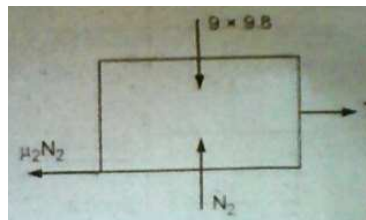
9. Block 2 rests on block 1 and is attached by horizontal rope AB on the wall as shown in fig. What force P is necessary to cause motion of the block 1 to impend? The coefficient of friction between the blocks is $1/4$ and between the floor and block 1 is $1/3$. Mass of the blocks 1 and 2 are 14 kg and 9 kg respectively.



Ans:
 $M_1 = 14\text{kg}$,
 $m_2 = 9\text{kg}$
 FBD of block 2



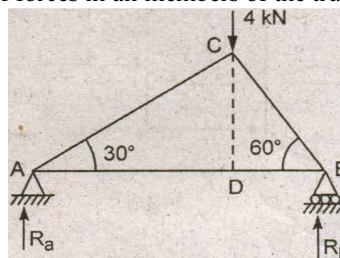
$\sum f_x = 0$ $T = \mu_2 \times N_2$
 $\sum f_y = 0$ $N_2 = 9 \times 9.8$
 FBD of block 1



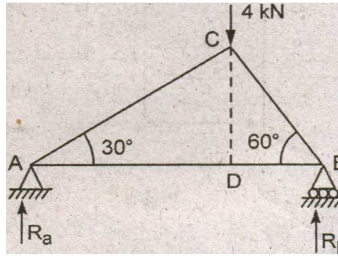
$\sum f_x = 0$; $P \cos 45^\circ = \mu_1 \times N_1 + \mu_2 N_2$ (3)
 $\sum f_y = 0$; $P \sin 45^\circ + N_1 = N_2 + 14 \times 9.8$ (4)
 By solving all. equations
 $P = 103.183\text{N}$

UNIT-II

1. Determine the magnitude and nature of forces in all members of the truss shown in Fig.



Ans:



For equilibrium of truss consider it fully as free body

$$R_a + R_b = 4$$

$$\sum M = 0$$

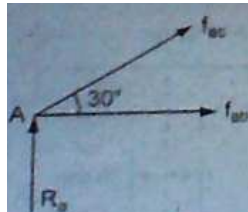
$$4 \times AD = R_b \times AB$$

Putting the value we get,

$$R_b = 3 \text{ kN}$$

$$R_a = 1 \text{ kN}$$

FBD of Joint A



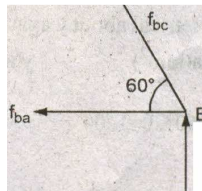
$$\sum f_x = 0 ; f_{ac} \cos 30^\circ + f_{ab} = 0$$

$$\sum f_y = 0 ; f_{ac} \sin 30^\circ + R_a = 0$$

$$f_{ac} = -2 \text{ kN (C)}$$

$$f_{ab} = 1.732 \text{ kN (T)}$$

Joint B

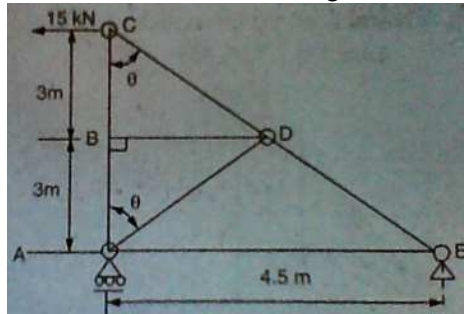


$$\sum f_x = 0 ; f_{bc} \cos 60^\circ + f_{ba} = 0$$

$$\sum f_y = 0 ; f_{bc} \sin 60^\circ + R_b = 0$$

$$f_{bc} = -1.155 \text{ kN (C)}$$

2.. Determine the force in all the members of the truss shown in Fig.



Ans:

First consider whole truss as a free body

$$\sum f_x = 0, R_{ex} = 15 \text{ kN}$$

$$\sum f_y = 0, R_{ey} + R_a = 0$$

$$\sum M_o = 0, R_a \times 4.5 = 1.5 \times 6$$

$$R_a = 20 \text{ kN}$$

$$R = -20 \text{ kN}$$

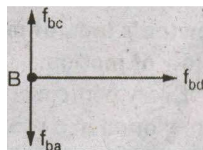
Joint C

$$\sum f_x = 0, f_{cd} \sin 36.87 - 15 = 0$$

$$\sum f_y = 0, f_{cb} + f_{cd} \cos 36.87 = 0$$

$$f_{cd} = 25 \text{ kN (T),}$$

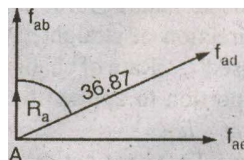
Joint B



$$f_{ba} = f_{bc} = -20 \text{ kN (c)}$$

$$f_{bd} = 0 \text{ kN}$$

Joint A



$$\sum f_y = 0$$

$$f_{ab} + R_a + f_{ad} \cos 36.87 = 0$$

$$-20 + 20 + f_{ad} \cos 36.87 = 0$$

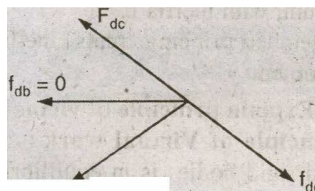
$$f_{ad} = 0$$

$$\sum f_x = 0$$

$$f_{ac} + f_{ad} \sin 36.87 = 0$$

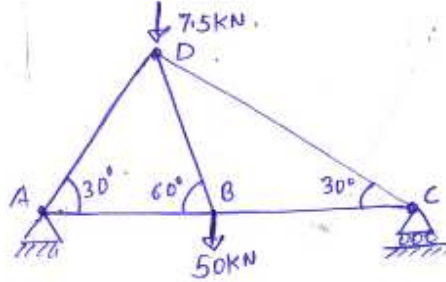
$$f_{ac} = 0$$

Joint D

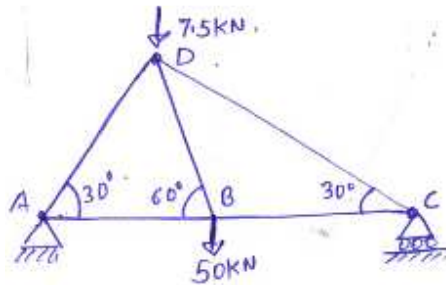


$$F_{dc} = F_{de} = 25 \text{ kN (T)}$$

3.. Determine the forces and their nature in each member of truss loaded as shown in fig.



Ans.



The reaction at the supports can be determined by considering equilibrium of the entire truss.

From the figure.

$$AB \sin 30^\circ = BD$$

$$AB = 2 BD = 2X$$

$$BD = BC = X$$

$$\sum f_y = 0$$

$$R_A + R_C = 57.5 \text{ kN}$$

$$\sum M_o = 0$$

$$7.5 \times 2X \cos 30 + 50 \times 2X = R_C \times 3X$$

$$\text{Or, } R_C = 37.08 \text{ kN}$$

$$R_A = 20.42 \text{ kN}$$

$$F_{AD} = -20.42 / \sin 30 = -40.84 \text{ kN (C)}$$

$$F_{AB} = +40.84 \times \sqrt{3} / 2 = 35.36 \text{ kN (T)}$$

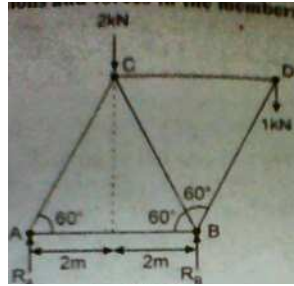
$$F_{CD} = -74.16 \text{ kN (C)}$$

$$F_{BC} = +74.16 \times \sqrt{3} / 2$$

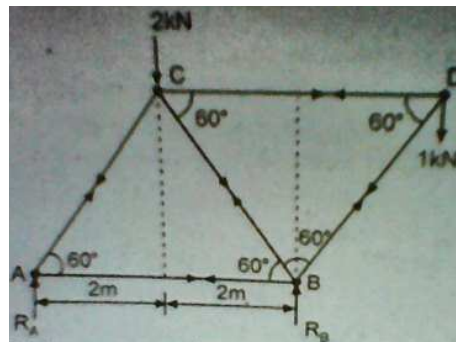
$$= 64.221 \text{ kN}$$

$$F_{BD} = 50 / \sin 60 = 57.71 \text{ kN (T)}$$

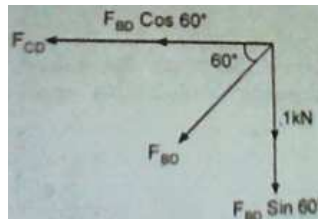
4. A truss is loaded as shown in Fig. 6. Find the reactions and forces in the members of truss.



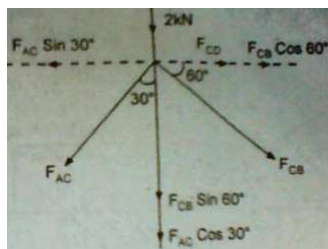
Ans:



For Equilibrium conditions
 $\sum f_y = 0,$
 $R_A + R_B = 2 + 1 = 3$
 Taking moment about A
 $\sum M_A = 0,$
 $1 \times 6 - R_B \times 4 + 2 \times 2 = 0$
 $R_B = 2.5 \text{ kN}$
 $R_A = 0.5 \text{ kN}$
 Consider point D



$\sum f_y = 0,$
 $F_{BD} \sin 60 = -1$
 $F_{BD} = -1.155 \text{ kN}$
 $\sum f_h = 0,$
 $F_{CD} = -F_{BD} \sin 60$
 $F_{CD} = 0.577 \text{ kN}$
 Consider Point C



$\sum f_y = 0,$

$$F_{CB} \sin 60^\circ + F_{AC} \cos 30^\circ = -2$$

$$0.866 F_{CB} + 0.866 F_{AC} = -2$$

$$\sum f_h = 0,$$

$$F_{AC} \sin 30^\circ - F_{CB} \cos 60^\circ = 0$$

$$0.5 F_{AC} - 0.5 F_{CB} = 0.577$$

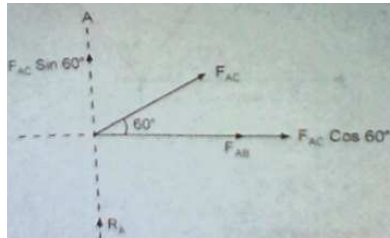
... (ii)

From equations (i) and (ii)

$$F_{AC} = -0.577 \text{ kN (comp.) Ans.}$$

$$F_{CB} = -1.731 \text{ kN (comp.) Ans.}$$

Consider point 'A'

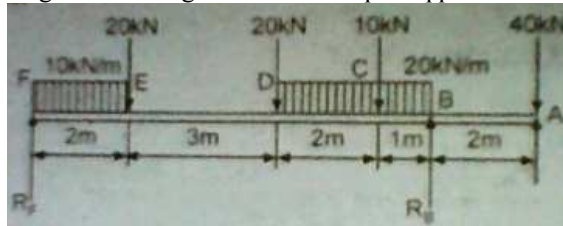


$$F_{AB} = -F_{AC} \times \cos 60^\circ$$

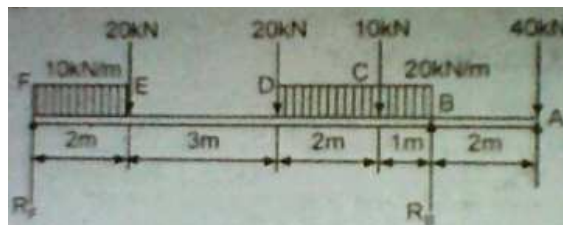
$$F_{AB} = +0.577 \times \cos 60^\circ$$

$$F_{AB} = 0.2885 \text{ kN (Tensile)}$$

5. Draw the shear force and bending moment diagrams for the simple supported beam as shown in Fig.



Ans:



For equilibrium conditions

$$\sum f_y = 0,$$

$$R_B + R_F = 70$$

Taking moment about point 'F'

$$R_B \times 8 = 40 \times 10 + 20 \times 1 \times 7.5 + 10 \times 7 + 20 \times 2 \times 6 + 20 \times 5 + 20 \times 2 + 10 \times 2 \times 1$$

$$R_B = 127.5 \text{ kN}$$

$$R_F = 42.5 \text{ kN}$$

Shear force diagram:

Shear force at point 'F' = 42.5 kN

Shear force at just left of point 'E'

$$= 42.5 - 10 \times 2 = 22.5 \text{ kN}$$

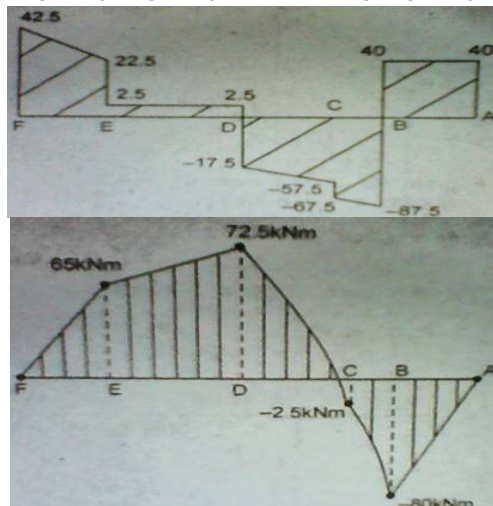
Shear force at point 'E'

$$= 42.5 - 10 \times 2 - 20 = 2.5 \text{ kN}$$

Shear force at just left of point 'D' = 2.5 kN

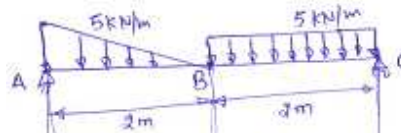
Shear force at point 'D'

$= 2.5 - 20 = -17.5 \text{ kN}$
 Shear force at just left of point 'C'
 $= -17.5 - 20 \times 2 = -57.5 \text{ kN}$
 Shear force at point 'C'
 $= -57.5 - 10 = -67.5 \text{ kN}$
 Shear force at just left of point 'B'
 $= -67.5 - 20 \times 1 = -87.5 \text{ kN}$
 Shear force at point 'B'
 $= -87.5 + (R_B = 127.5) = 40 \text{ kN}$
 Shear force at point 'A' = $40 - 40 = 0$
 Bending moment diagram:
 Bending moment at point 'F' = 0
 Bending moment at point 'E'
 $= 42.5 \times 2 - 10 \times 2 \times 1 = 65 \text{ kN-m}$
 Bending moment at point 'D'
 $= 42.5 \times 5 - 10 \times 2 \times 4 - 20 \times 3 = 72.5 \text{ kN-m}$
 Bending moment of point C
 $= 42.5 \times 7 - 10 \times 2 \times 6 - 20 \times 5 - 20 \times 2 - 20 \times 2 \times 1 = -2.5 \text{ kN-m}$
 Bending moment at point B
 $= 42.5 \times 8 - 10 \times 2 \times 7 - 20 \times 6 - 20 \times 3 - 20 \times 3 \times 2 - 10 \times 1 - 20 \times 1 \times 0.5 = -80 \text{ kN-m}$
 Bending moment at A
 $= 42.5 \times 10 - 10 \times 2 \times 9 - 20 \times 8 - 20 \times 5 - 20 \times 4 \times 2 - 10 \times 3 - 20 \times 1 \times 2.5 + 127.5 \times 2 = 0 \text{ kN-m}$

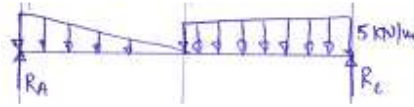


SFD and BMD

6. For the simply supported beam as shown in figure, draw shear force and bending moment diagrams after finding the equations for shear force and bending moment.



Ans. Total load
 $RA + RB = 5 \times 2 + 5$
 $= 10 + 5 = 15 \text{ kN}$
 $\sum M_0 = 0,$



Taking moment about point A we get,

$$5 \times \frac{2}{3} + 10 \times 3 = 4R_B$$

$$R_B = 8.33 \text{ kN}$$

$$R_A = 6.67 \text{ kN}$$

$$SF_A = + R_A = 6.67 \text{ kN}$$

$$SF_0 = - 8.33 + 5x \quad 0 \leq x \leq 2$$

at distance 0

$$= - 8.33 + 5 \times 0$$

$$= - 8.33 \text{ kN}$$

at distance 2.

$$= - 8.33 + 5 \times 2$$

$$= - 8.33 + 10$$

$$= - 1.67 \text{ kN}$$

with the help of load, draw the SFD shown in fig.



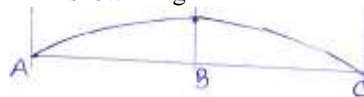
For BMD- when the Beam is simply supported at end point B.M. will be zero.

$$BMA = BMB = 0$$

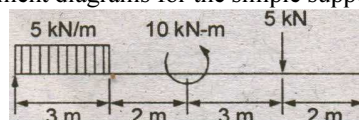
$$M = 8.33x - \frac{5}{2}x^2 \quad 0 \leq x \leq 2$$

$$M = 8.33x - 10(x-1) - 1 - 25(x-2)^2 \quad 2 \leq x \leq 4$$

with help of BM load we will draw the BMD show in fig



7. Draw the shear force and bending moment diagrams for the simple supported beam as shown in fig.



Ans.

$$\sum f_y = 0$$

$$R_a + R_b = 15 + 5 = 20 \text{ KM}$$

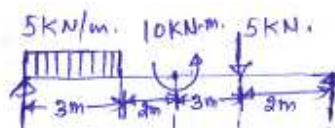
Taking moment about point A

$$\sum M_o = 0$$

$$15 \times 1.5 + 10 + 5 \times 8 - R_b \times 10 = 0$$

$$R_b = 7.25 \text{ kN}$$

$$R_a = 12.75 \text{ kN}$$



Calculation for the shear force diagram. Value of S F

Just before A₁ SF_A = 0

Just at A, $SF_A = +RA = 12.75 \text{ KN}$

We get two values at A = 0 and 12.75

At-point E $SF_E = RA - 5 \times 3$

= 12.75-5

=-2.25KN

Between points A and C Since there is UDL b/w points A and E, Hence an inclined line is drawn

Now our aim is to find out the distance of that point where shear force changes its sign. Let it will be 'y' from point A.

$SF_y = RA - 5 \times y$

$Y = 2.55 \text{ m}$

$SF_D = 12.75 - 5 \times 3$

Single-valued C = -2.25

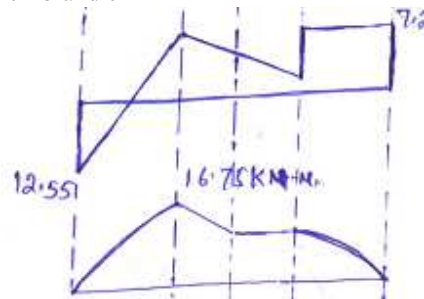
$SF_c = 12.75 - 5 \times 3 = -2.25$

Between point D and C

$SF_D = 12.75 - 5 \times 3 - 5 = -7.25$

Just-at $SF_D = 12.75 - 5 \times 3 - 5 + 10 = +2.75$

We get two values at B = - 7.25 and 0



Now for the BM diagram

$BMA = 0 \text{ kN-m}$

$BM = 12.75 \times 2.55 - 5 \times 2.55 \times 2.55/2$

=+ 16.25 kN-m

$BMD = 12.75 \times 5 - 10(2 + 1.5) = 28.75 \text{ kN-m}$

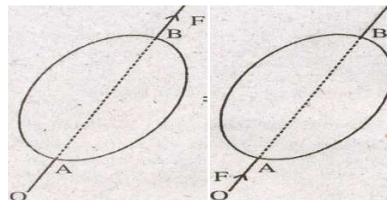
$BM_C = 12.75 \times 7 - 10 \times (3 + 2 + 15) = 24.25 \text{ kN-m}$

$BMB = 12.75 \times 8 - 10(2 + 3 + 2 + 1.5) = 17.00 \text{ KN-m}$

UNIT-I

SHORT QUESTION

1. Principle of Transmissibility of a Force. It states that the condition of equilibrium or of motion of rigid body will remain unchanged if the point of application of a force acting on the rigid body is transmitted to act at any other point along its line of action. A force F acting on the rigid body at point B having the line of action AB, can be replaced by the same force F but acting at the point A provided this new point A lies along the line of action AB of the force.



In other words, the force F acting at point A can be transmitted to act any other point B along its line of action without changing its effect on the rigid body. Next consider a prismatic bar AB which is acted upon by two equal and opposite coaxial forces P and P' as shown in Fig.

Varignon's Theorem: It is also known as principle of moments: it states that "The algebraic sum of the moments of a system of coplanar forces about a moment centre in their plane is equal to the moment of their resultant force about the same moment centre.

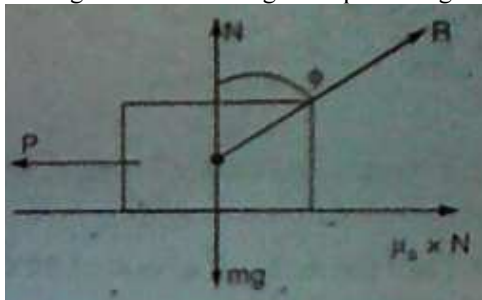
$$F_1 \times X_1 + F_2 \times X_2 + F_3 \times X_3 = R \times X$$

F_1, F_2, F_3 are the forces and R is the resultant.

5. Angle of Friction (ϕ): It is defined as the angle made by the resultant of the normal reaction and the limiting force of friction (f) with the normal reaction R .

$$\tan \phi = F/R = \mu .$$

Angle of repose: It is the maximum inclination of an inclined at which body starts moving due to its own weight. In limiting condition this angle is equal to angle of friction.



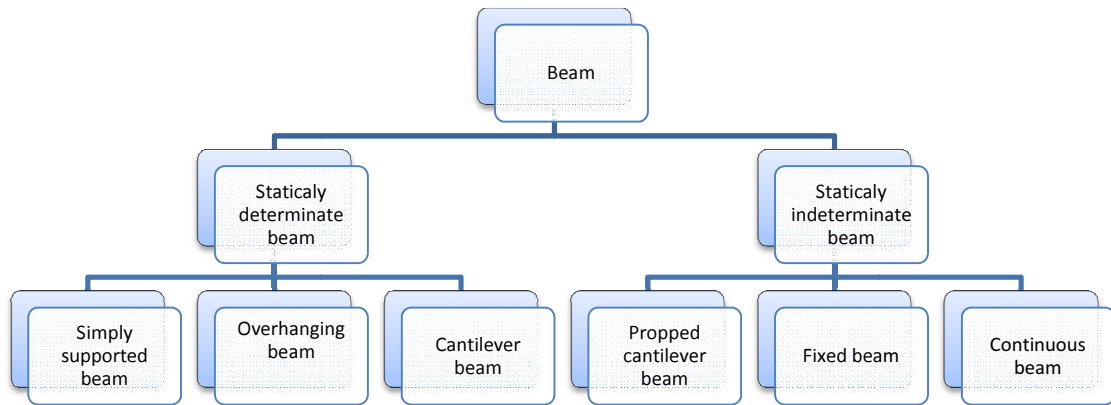
7. **Laws of static friction** : If the two surfaces, which are in contact are at rest, the force experienced by one surface is called static friction' following are the coulomb's laws for static (Dry) friction:

1. Frictional force is always acting .in opposite direction in which body tends to move.
2. Frictional force is directly proportional to normal reaction.
3. Frictional force is equal to the net force acting in direction of motion.
4. Frictional force is independent of the surface area in contact.
5. Frictional force depends upon the nature or roughness of surface.

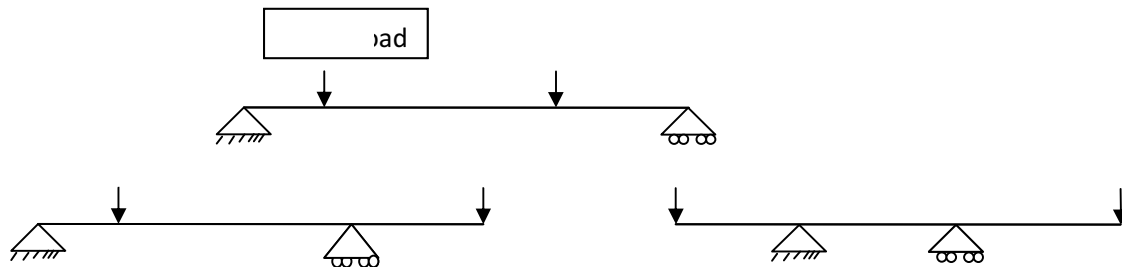
UNIT-II

SHORT QUESTION

1.



Simply supported beam: When a beam is made to freely rest on supports which may be knife edges or rollers is called simply supported beam.

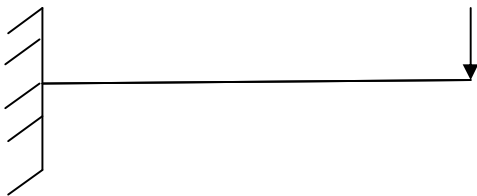


Overhanging Beam: A beam having one or both ends extended over the supports is called a overhang beam.

One side overhang

Both side overhang

Cantilever Beam: In cantilever beam one end is fixed or built in and other end is free to deflect.



4. The point at which bending moment changes its sign is called point of contraflexure. At this point bending moment is zero point of contraflexure and point inflection is same.

5. Assumptions:

- I. The truss is statically determinate and perfect one and thus follow, $m = 2j - 3$.
- II. The joints of truss are assumed to be pin connections and frictionless.
- III. The members of the truss are straight two force members with the forces acting at the joints only.
- IV. The weights of the members are negligibly small unless otherwise mentioned.

6. Analysis of truss: Analysis of truss means finding out axial forces in different members of truss. These forces may be compressive members of truss. These forces may be compressive or tensile in nature.

We can analyze truss by

(1) Graphical method: Finding out forces in different members by drawing funicular polygons and bow's notation.

(2) Analytical Method;

(a) Method of joints: Draw the free body diagram for each and every joint. Direction of axial forces in the line of members. By applying necessary condition of equilibrium we can get axial forces in members. It is for finding out forces in all members.

(b) Method of Sections: It is for finding out forces in some specified members. Take a section plane which will cut only three members where forces are unknown including specified members. Draw the FBD for either side and apply condition of equilibrium for finding out unknowns
Method of section is preferred when forces in some of the member are required and also preferred when method of joint fails to proceed.