Chapter 2

Free Body Diagrams – Trusses

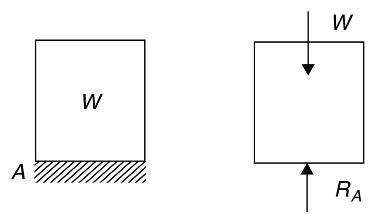
CHAPTER HIGHLIGHTS

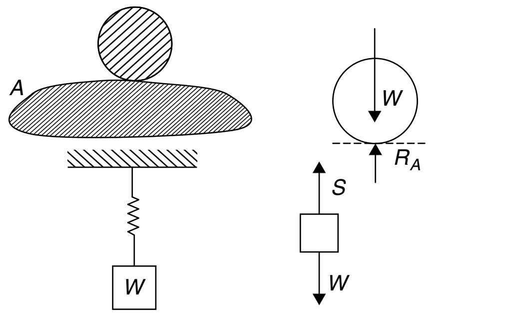
- *Free Body Diagram*
- *Composition and Resolution of Forces*
- *Resolution of a Force*
- *Equilibrium Law*
- *Internal and External Forces*
- *Superposition and Transmissibility*
- *Equilibrium of Concurrent Forces in a Plane*
- *Analysis of Roof Trusses*
- *Plane Truss*
- *Nodes*
- *Perfect Frame*
- *Supports*
- *Assumptions: Analysis of Trusses*
- *Method of Members: Analysis of Plane Frames*

Free Body Diagram

Free body diagram (FBD) 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. A general procedure for constructing a free body diagram is as follows:

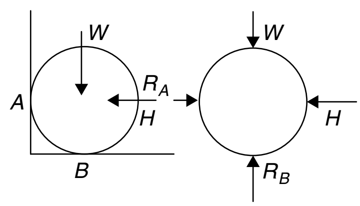
1. A sketch of the body is drawn, by removing the supporting surfaces.
2. Indicate on the sketch all the applied or active forces, which tend to set the body in motion, such as those caused by weight of the body, etc.
3. Also indicate on this sketch all the reactive forces, such as those caused by the constraints or supports that tend to prevent motion.
4. All relevant dimensions and angles; reference axes are shown on the sketch. A smooth surface is one whose friction can be neglected. Smooth surface prevents the displacement of a body normal to both the contacting surfaces at their point of contact. The reaction of a smooth surface or support is directed normal to both contacting surfaces at their point of contact and is applied at that point. Some of the examples are shown in the following figures.





We isolate the body from its supports and show all forces acting on it by vectors, both active (gravity force) and reactive (support reactions) forces.

We then consider the conditions this system of forces must satisfy in order to be in equilibrium, i.e., in order that they will have no resultant.



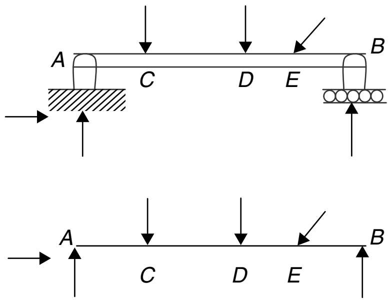


Figure 1 Beam with roller support at one end

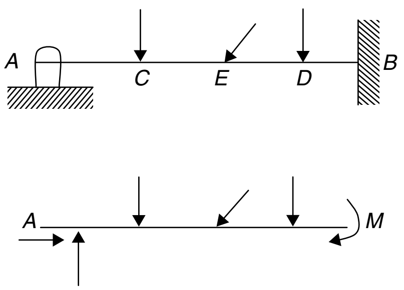
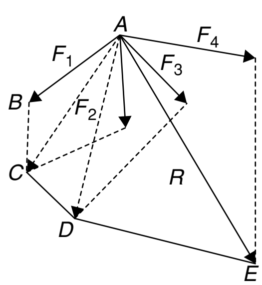
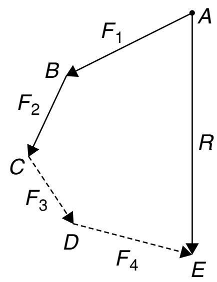


Figure 2 Beam with hinged end and fixed end

Composition and Resolution of Forces

The reduction of a given system of forces to the simplest system that will be its equivalent is called the problem of composition of forces. If several forces F_1, F_2, F_3, applied to a body at one point, all act in the same plane, then they represent a system of forces that can be reduced to a single resultant force. It then becomes possible to find this resultant by successive application of the parallelogram law. Let us consider, for example, four forces F_1, F_2, F_3, and F_4 acting on a body at point A, as shown in the following figure. To find their resultant, we begin by obtaining the resultant AC of the two forces F_1 and F_2. Combining this resultant with force F_3 we obtain the resultant AD which must be equivalent to F_1, F_2, and F_3. Finally, combining the forces AD and F_4, we obtain the resultant 'R' of the given system of forces F_1, F_2, F_3, and F_4, This procedure may be carried on for any number of given forces acting at a single point in a plane.



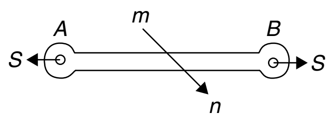


Resolution of a Force

The replacement of a single force by several components, which will be equivalent in action to the given force, is called the problem of resolution of a force. In the general case of resolution of a force into any number of coplanar components intersecting at one point on the line of action, the problem will be indeterminate unless all but two of the components are completely specified in both their magnitudes and directions.

Equilibrium Law

Two forces acting at a point can be in equilibrium only if they are equal in magnitude, opposite in direction and collinear in action. Let us consider the equilibrium of a body in the form of a prismatic bar on the ends of which two forces are acting as shown in the figure below:

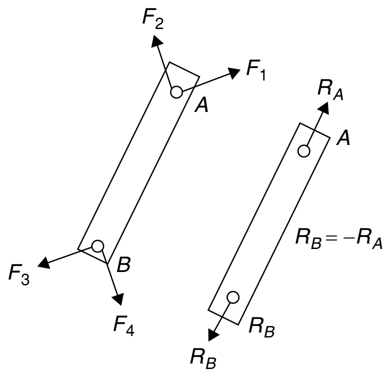


Neglecting their own weights, it follows from the principle just stated that the bar can be in equilibrium only when the forces are equal in magnitude, opposite in direction and collinear in action which means that they must act along the line joining the points of application. Considering the equilibrium of a portion of the bar 'AB' to the left of a section 'mn', we conclude that to balance, the external force S at A the portion to the right must exert on the portion to the left an equal, opposite and collinear force S as shown in the above figure.

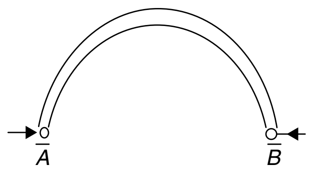
The magnitude of this internal axial force which one part of a bar in tension exerts on another part called the tensile force in the bar or simply the force in the bar, since in general it may be either a tensile force or a compressive force. Such an internal force is actually distributed over the cross sectional area of the bar and its intensity, i.e., the force per unit of cross section area is called the stress in the bar.

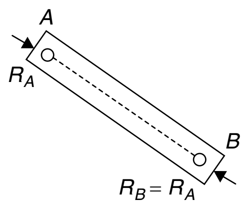
Internal and External Forces

Internal forces are the forces which hold together the particles of a body. For example, if we try to pull a body by applying two equal, opposite and collinear forces an internal force comes into play to hold the body together. Internal forces always occur in pairs and equal in magnitude, opposite in direction and collinear. Therefore, the resultant of all of these internal forces is zero and does not affect the external motion of the body or its state of equilibrium. External forces or applied forces are the forces that act on the body due to contact with other bodies or attraction forces from other separated bodies. These forces may be surface forces (contact forces) or body forces (gravity forces). Let us consider the equilibrium of a prismatic bar on each end of which two forces are acting as shown below.



Other examples of two force members held in equilibrium are shown below.





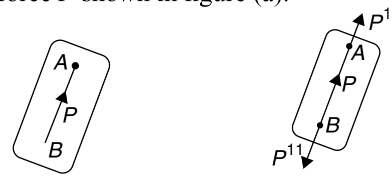
A force which is equal, opposite, and collinear to the resultant of the two given forces is known as equilibrant of the given two forces.

Superposition and Transmissibility

When two forces are in equilibrium (equal, opposite and collinear) and their resultant is zero and their combined action on a rigid body is equivalent to that—there is no force at all. A generalization of this observation gives us the third principle of statics. Sometimes,it is called the law of superposition.

Law of Superposition

The action of a given system of forces on a rigid body will in no way be changed if we add to or subtract from them another system of forces in equilibrium Let us consider now a rigid body '*AB*' under the action of a force '*P*' applied at '*A*' and acting along *BA* as shown in the figure (a). From the principles of superposition we conclude that the application at point '*B*' of two oppositely directed forces, each equal to and collinear with *P* will in no way alter the action of the given force *P*. That is, the action on the body by the three forces shown in figure (b) is same as the action on the body by the single force *P* shown in figure (a).

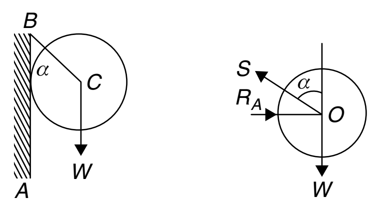


(a) (b)

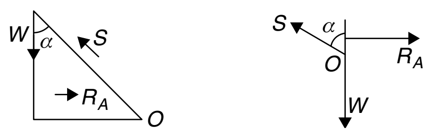
This proves that the point of application of a force may be transmitted along the line of action without changing the effect of the force on any rigid body to which it may be applied. This statement is called the theorem of transmissibility of a force.

Equilibrium of Concurrent Forces in a Plane

If a body known to be in equilibrium is acted upon by several concurrent coplanar forces then these forces or rather their free vectors, when geometrically added must form a closed polygon. This statement represents the condition of equilibrium for any system of concurrent forces in a plane. In the figure (a), we consider a ball supported in a vertical plane by a string 'BC' and a smooth wall 'AB'. The free body diagram in which the ball has been isolated from its supports and in which all forces acting upon it both active and reactive, are indicated by vectors as shown in figure (b).



(a) (b)



(c) (d)

The three concurrent forces W, S and R_A are a system of forces in equilibrium and hence their free vectors must build a closed polygon, in this case, a triangle as shown in figure (c).

If numerical data are not given, we can still sketch the closed triangle of forces and then express:

$$R_A = W\tan\alpha \quad \text{and} \quad S = W\sec\alpha$$

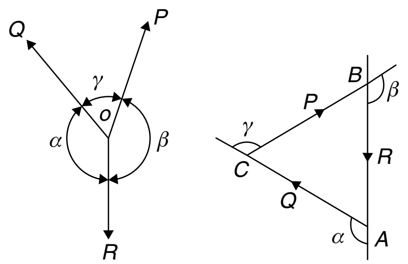
Lami's Theorem

If three concurrent forces are acting on a body, kept in equilibrium, then each force is proportional to the sine of the angle between the other two forces and the constant of proportionality is the same. Consider forces *P*, *Q* and *R* acting at a point 'O' as shown in Figure (a). Mathematically Lami's theorem is given by the following equation.

$$\boxed{\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma} = k}$$

Since the forces are in equilibrium, the triangle of forces should close. Draw the triangle of forces ΔABC, as shown in Figure (b), corresponding to the forces P, Q, and R acting at a point 'O'. From the sine rule of the triangle, we get

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



$\sin(\pi-\alpha) = \sin\alpha$
$\sin(\pi-\beta) = \sin\beta$
$\sin(\pi-\gamma) = \sin\gamma$

When feasible, the trigonometric solution, or Lami's theorem is preferable to the graphical solution since it is free from the unavoidable small errors associated with the graphical constructions and scaling.

Analysis of Roof Trusses

Definitions

Truss

A 'truss' or 'frame' or 'braced structure' is the one consisting of a number of straight bars joined together at the extremities. These bars are members of the truss.

Plane truss If the centre line of the members of a truss lies in a plane, the truss is called a plane truss or frame. If the centre line is are not lying in the same plane, as in the case of a shear leg, the frame is called a space frame.

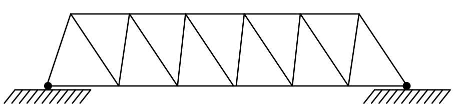


Figure 3 Plane trusses

Strut and tie A member under compression is called a strut and a member under tension is called a tie.

Loads A load is generally defined as a weight or a mass supported. Trusses are designed for permanent, intermittent or varying loads.

Nodes The joints of a frame are called as nodes. A frame is designed to carry loads at the nodes.

Perfect frame A pin joined frame which has got just the sufficient number of members to resist the loads without undergoing appreciable deformation in shape is called a perfect frame.

Supports

A truss or a framed structure is held on supports which exert reaction on the truss or framed structure that they carry. Reactions are to be considered for finding the stresses in the various members of the structures. The types of supports commonly used are

1. Simple supports
2. Pin joint and roller supports
3. Smooth surfaces
4. Fixed on encaster and fixtures

The reactions of the supports are analytically or graphically evaluated.

1. In a simply supported truss, the reactions are always vertical at the supports.
2. At a pin joint support, the reaction passes through the joint.
3. At a roller surface, the support reaction is vertically upwards at the surface.
4. The reaction at a support which has a smooth surface is always normal to the surface.

Assumptions: Analysis of Trusses

Each truss is assumed to be composed of rigid members to be all lying in one plane. This means that co-planar force systems are involved. Forces are transmitted from one member to another through smooth pins fitting perfectly in the members. These are called two force members. Weights of the members are neglected because they are negligible in comparison to the loads.

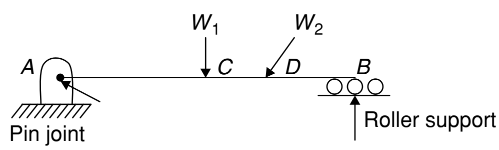


Figure 4 Pin joint and roller support

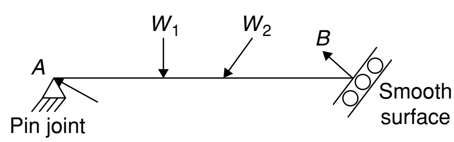


Figure 5 Pin joint and smooth surface

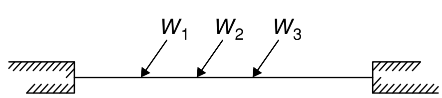


Figure 6 Fixed support

Free-body Diagram of a Truss and the Joints

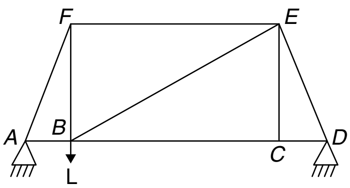


Figure 7 Truss

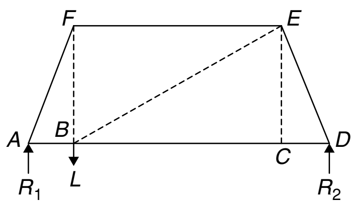


Figure 8 Free-body diagram of truss as a whole

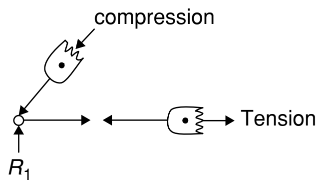
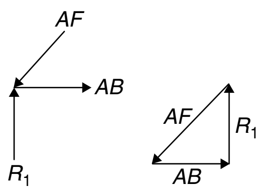
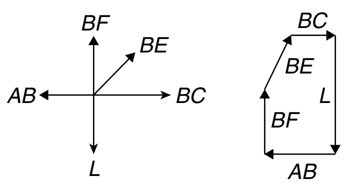


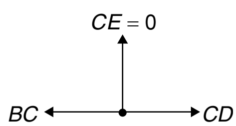
Figure 9 Free-body diagram of point A



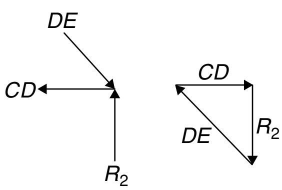
Joint A



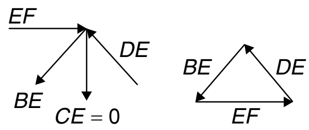
Joint B



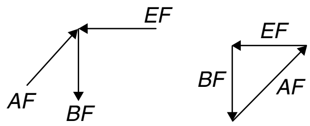
Joint C



Joint D



Joint E



Joint F

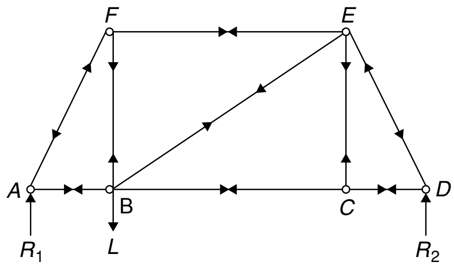


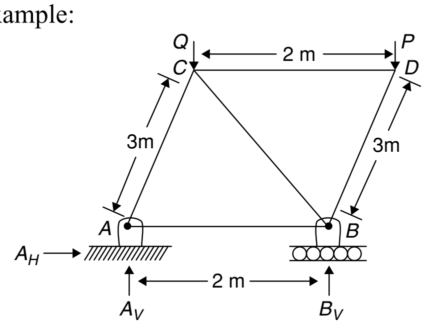
Figure 10 Free-body diagram of joints

Solution by method of joints To use this technique, draw a free-body diagram of any pin in the truss provided no more than two unknown forces act on that pin. This limitation is imposed because the system of forces is a concurrent one for which of course, only two equations are available for a solution. From one pin to another, until the unknown is found out, the procedure can be followed.

Working Rule

1. Depending on the nature of support, provide the reaction components.
   (a) For hinged support, provide horizontal and vertical reaction components.
   (b) For roller support, provide vertical reaction components only.
2. Considering the external loads affecting the truss only, apply the laws of statics at equilibrium to evaluate the support reactions.
3. Give the values of the support reactions at appropriate joints.
4. Take the joint which contains the minimum number of members (minimum number of unknowns) and apply the conditions of equilibrium to evaluate the forces in the members.

   For example:



The reaction components at A are A_H and A_V (because A is a hinged joint).

The reaction component at B is B_V only (no horizontal reaction since it is a roller).

Now evaluate the reaction components considering the external loads only i.e.,

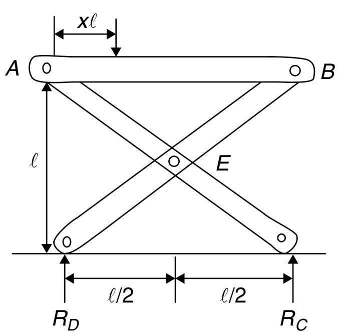
$$A_V + B_V = P + Q$$
$$A_H = 0$$

Taking algebraic sum of the moments of all forces about 'A' and equating to zero, we get two more equations. These three equations are sufficient to evaluate the support reactions. Once the support reactions are evaluated, joints can be considered one by one, to evaluate the force in the members.

Method of Members: Analysis of Plane Frames

Frames differ from trusses principally in one aspect, i.e., the action of forces are not limited to their ends only and so the members are subjected to bending also with tension or compression. In this method the members are isolated as a free body and analyzed with the forces acting on them by vectors.

Consider the folding stool with the dimensions as shown in the figure resting on a horizontal floor and a force F is acting at a distance of $x\ell$ form the end A.

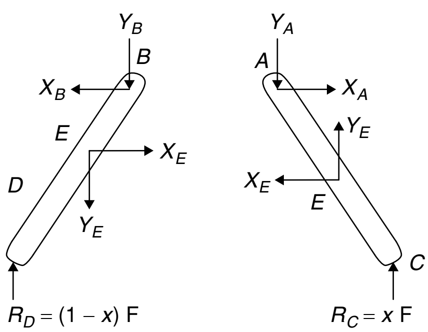


The floor is considered as smooth floor therefore the reactions at C and D are vertical.

∴ By taking moments at C and D.

$$R_D = (1-x)F \quad \text{and} \quad R_c = xF.$$

Now we separate the members AC and BD and analyze the forces acting on each member.



For the free body diagram BD, taking moments about B

$$Y_E\frac{\ell}{2} + X_E\frac{\ell}{2} - (1-x)F\ell = 0$$

For the free body diagram AC, taking the moments about A

$$Y_E\frac{\ell}{2} - X_E\frac{\ell}{2} + X\ell F = 0.$$

∴ $X_E = F$ and $Y_E = (1 - 2x) F$.

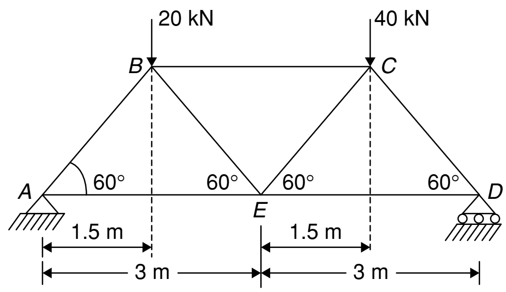
The resultant is $R_E = \sqrt{X_E^2 + Y_E^2} = F\sqrt{1+(1-2x)^2}$

∴ By knowing the numerical data for ℓ, x and the load F the unknowns R_D, R_C and R_E can be found. To find the reactions at A and B i.e., R_A and R_B take the moments about the point E for both the free body diagrams and solve for R_A and R_B.

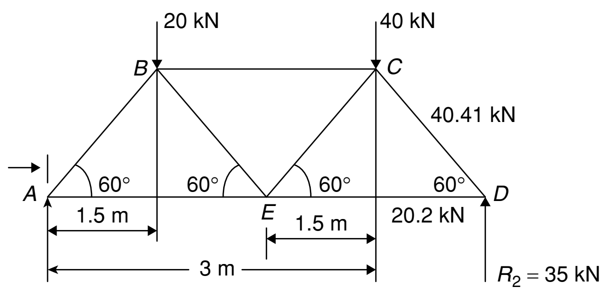
Solved Examples

Example 1: The magnitude and nature of stresses in the member ED of the truss, loaded as shown below, is

(A) 30.4 kN (T) (B) 20.2 kN (T)
(C) 18.69 kN (C) (D) 15.7 kN (T)



Solution:



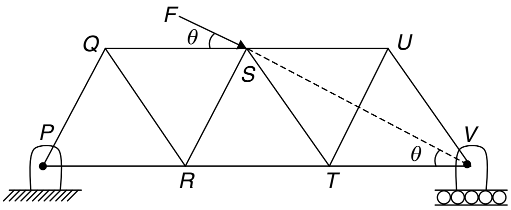
Free-body diagram

Taking moments about (A) for equilibrium, $\Sigma m_A = 0$

$$-20 \times 1.5 - 40 \times 4.5 + R_2 \times 6 = 0$$
$$6R_2 = 30 + 180$$
$$6R_2 = 210$$
$$R_2 = 35 \text{ kN}$$
$$\text{But } R_1 + R_2 = 60$$
$$\therefore R_1 = 25 \text{ kN}$$

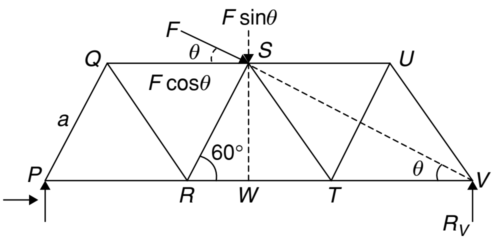
Take the joint D, force on the member CD,
$F_{CD} = 40.41$ kN because $F_{CD}\sin 60° = 35$ kN
$\therefore$ Force on $ED = F_{CD}$
$\cos 60° = 20.2$ kN (T)

Example 2: All the members of the truss shown below are of equal length and the joints are pinned smooth. It carries a load F at S whose line of action passes through V. The reaction at V is



(A) Zero
(B) Vertically upwards and equal to $F/4$
(C) Vertically upwardsand equal to $F/2$
(D) Vertically upwards and equal to F

Solution:



Let a = length of one member

From the above figure, $\sin 60° = \dfrac{SW}{SR}$.

$$SW = \frac{\sqrt{3}}{2}a \quad (\because SR = a)$$

$$\text{Also } \cos 60° = \frac{RW}{SR} \quad \Rightarrow \quad RW = \frac{a}{2},$$

$$TW = RT - RW \quad \therefore \quad a - \frac{a}{2} = \frac{a}{2}$$

$$VW = VT + TW = a + \frac{a}{2} = \frac{3}{2a}$$

$$\tan\theta = \frac{SW}{VW} = \left[\frac{\frac{\sqrt{3}a}{2}}{\frac{3a}{2}}\right] = \frac{1}{\sqrt{3}}$$

$$\theta = 30°$$

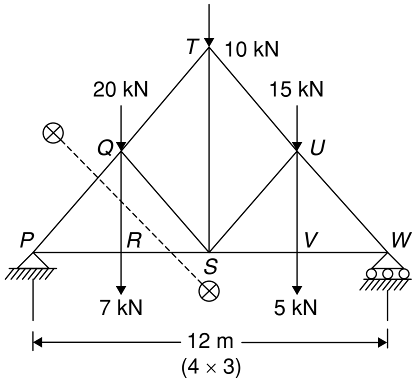
Taking moments about P for equilibrium, $\Sigma M_P = 0$

$$-F\sin\theta \times \frac{3a}{2} - F\cos\theta \times \frac{\sqrt{3}}{2}a + R_V \times 30 = 0$$

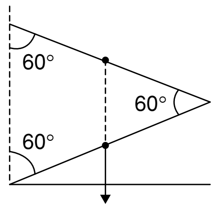
$$F \times \frac{1}{2} \times \frac{3a}{2} + F \times \frac{\sqrt{3}}{2} \times \frac{\sqrt{3}}{2}a = R_v \times 3a$$

$$R_v = F/2$$

Example 3: The force in the member RQ of the truss, as given in the figure below, is
(A) 27 kN (Tensile)
(B) 15 kN (Compressive)
(C) 20 kN (Compressive)
(D) 7 kN (Tensile)

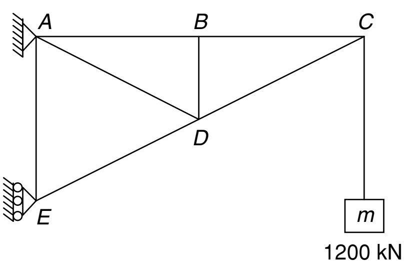


Solution:



Consider the junction R. It must be in equilibrium. The force 7 kN can be balanced only by the member Q_R.
$\therefore$ The force in the member Q_R
FQR = 7 kN (Tensile).

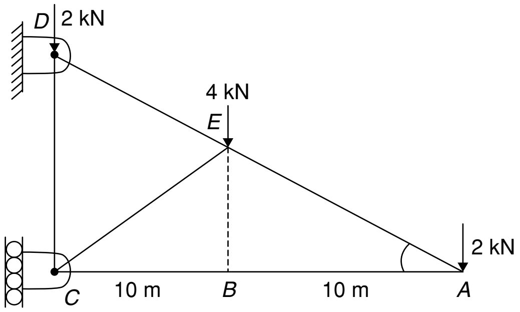
Example 4: The figure is a pin jointed plane truss loaded at the point C by hanging a weight of 1200 kN. The member DB of the truss is subjected to a load of



(A) Zero
(B) 500 kN in compression
(C) 1200 kN in compression
(D) 1200 kN in tension

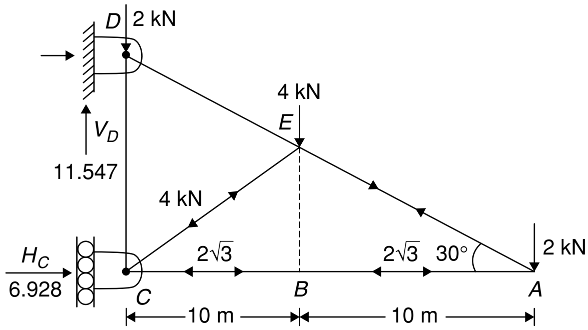
Solution:
Member DB is perpendicular to AC. Resolving the vertical component of the forces at B, we observe that no force can be present in member DB.

Example 5: Find the force in the member EC of the truss shown in the figure



(A) 8 kN (B) 4 kN
(C) 3.5 kN (D) 2 kN

Solution:

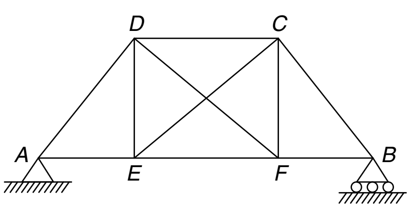


Equating vertical forces $V_D = 8$
Taking moment about D,
$-2 \times 20 - 4 \times 10 + H_C \times 11.54 = 0$
$80 = 11.54\, H_C$
$\therefore\ H_C = 6.928$ kN
Consider the equilibrium of joint A
$F_{AE}\sin 30° = 2$
$F_{AE} = 4$ kN (T)
$F_{AE}\cos 30° = F_{BA}$

$$\frac{4\sqrt{3}}{2} = 2\sqrt{3}F_{BA}$$

$F_{BE} = 0,\ F_{CB} = 2\sqrt{3}$
Consider point C
Net horizontal force $= 6.928 - 2\sqrt{3}$
$= 3.463$ kN
It is to be balanced by the force on EC
$F_{EC}\cos 30 = 3.463$
$\therefore\ F_{EC} = 4$ kN.

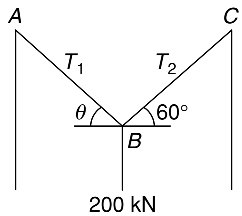
Example 6: The type of truss, shown in the figure below, is



(A) Perfect (B) Deficient
(C) Redundant (D) None of above

Solution: The number of joints, $J = 6$
The number of member, $n = 10$
Then, $2j - 3 = 2 \times 6 - 3 = 9$
Since $n > (2j - 3)$, it is a redundant truss.

Example 7: A weight 200 kN is supported by two cables as shown in the figure.



The tension in the cable AB will be minimum when the angle θ is:
(A) 0° (B) 30°
(C) 90° (D) 120°

Solution:

$$\frac{T_1}{\sin 150} = \frac{T_2}{\sin(90° + \theta)} = \frac{200\text{ kN}}{\sin 180° - (\theta + 60)}$$

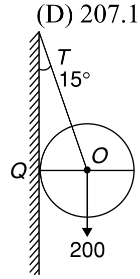
$$T_1 = \frac{200\sin 30°}{\sin(120° - \theta)}$$

$$= \frac{200\sin 30°}{\sin[120° - \theta]} \quad (\because \sin 30° = \sin 150°)$$

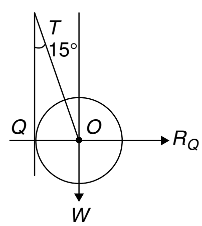
T_1 is minimum when $\dfrac{1}{\sin(120° - \theta)}$ is minimum, i.e., $\sin(120° - \theta)$ is maximum.

$$\sin(120° - \theta) = 1$$
$$120° - \theta = 90°$$
$$\theta = 30°.$$

Example 8: A 200 kN weight is hung on a string as shown in the figure below. The tension T is:
(A) 200 kN (B) 300 kN
(C) 160 kN (D) 207.1 kN



Solution:
The three forces T, R_B and 200 kN are in equilibrium at point O.

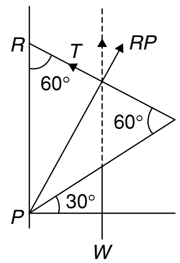


$$\frac{T}{\sin 90} = \frac{W}{\sin(90°+15°)}$$

$$T = W\frac{\sin 90}{\sin 105} = \frac{200\times 1}{0.965} = 207.1 \text{ kN}$$

Example 9: A uniform beam PQ pinned at P and held by a cable at Q. If the tension in the cable is 5 kN then weight of the beam and reaction at P on the beam are respectively

(A) 10 kN and 8.86 kN (B) 5 kN and 13 kN
(C) 10 kN and 10 kN (D) 15 kN and 13 kN



Solution:

Let ω be the weight of the beam and R_P be the reaction in the beam at P. Since it is the case of 3 forces forming a system in equilibrium all the three forces must be either concurrent or parallel; in this case, they are to be concurrent.

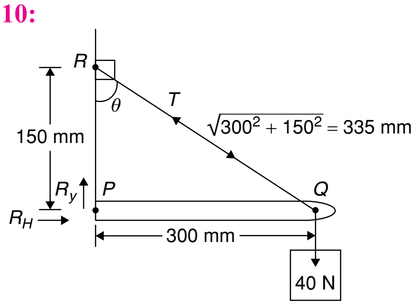
$$\frac{W}{\sin 90} = \frac{T}{\sin 150} = \frac{R_P}{\sin 120}$$

$$\frac{W}{1} = \frac{T}{0.5} = \frac{R_P}{0.886}$$

$$W = \frac{5\times 1}{0.5} = 10 \text{ kN}$$

$R_P = 8.86$ kN.

Example 10:



A mass of 40 N is suspended from a weight less bar PQ which is supported by a cable QR and a pin at P. At P on the bar, the horizontal one vertical component of the reaction, respectively, are

(A) 80 N and 0 N (B) 75 N and 0 N
(C) 60 N and 80 N (D) 55 N and 80 N

Solution:

$$\theta = \cos^{-1}\frac{150}{335} = 63.4°$$

Resolving the vertical components of the forces at Q,

$40 = T\cos 63.4°$

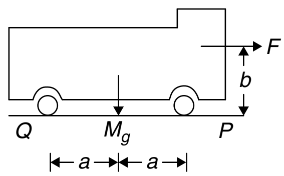
$$T = \frac{40}{\cos 63.4}$$

$T = 89.336$ N

Resolving the vertical components of the forces at P, $R_y = 0$

Resolving the horizontal component of the forces at RQP, $R_H = T\sin 63.4 = 80$ N

Example 11: A truck of weight M_g is shown in figure below. A force F (pull) is applied as shown. The reaction at the front wheels at location P is



(A) $\frac{M_g}{2a} + \frac{Fb}{2}$ (B) $\frac{M_g}{a} + \frac{Fb}{2}$
(C) $\frac{M_g}{2} + \frac{Fb}{2a}$ (D) $\frac{M_g}{2a} + \frac{F}{2}$

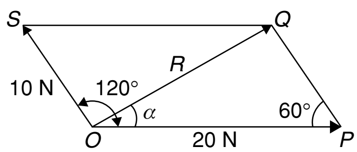
Solution:

Taking moment about Q,

$$\Sigma M_Q = 0 = R_P \times 2a - M_g \times a - F\times b$$

$$R_P = \frac{M_g\times a + F\times b}{2a} = \frac{M_g}{2} + \frac{Fb}{2a}.$$

Direction for questions 12 to 13: All the forces acting on a particle situated at the point of origin of a two dimensional reference frame. One force has magnitude of 20 N acting in the positive x direction. Where as the other has a magnitude of 10 N at an angle of 120° with force directed away from the origin with respect to the positive direction to the direction of 20 N:



Example 12: The value of the resultant force, R, will be

(A) 18 N (B) 20 N
(C) 15 N (D) 21 N

Solution:

$$R = \sqrt{20^2 + 10^2 + 2\times 20\times 5\times \cos 120°}$$

$$= \sqrt{500 - 100} = 20 \text{ N}$$

Example 13: The value of α made by the resultant force with the horizontal force will be:

(A) 25.65 (B) 13
(C) 14.5 (D) 15

Solution:

From triangle OQP

$$\frac{10}{\sin\alpha} = \frac{R}{\sin 60} = \frac{20}{0.866} = 23.09$$

$$\sin\alpha = \frac{10}{23.09} = 0.433$$

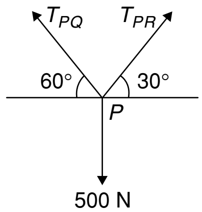
$$\alpha = 25.65.$$

Exercises

Practice Problems I

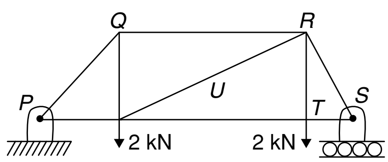
Direction for questions 1 to 10: Select the correct alternative from the given choices.

1. If point P is in equilibrium under the action of the applied forces, then the values of the tensions T_{PQ} and T_{PR} are respectively



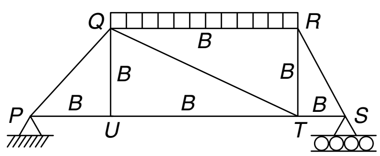
(A) 250 N and $250\sqrt{3}$ N
(B) $250\sqrt{3}$ N and 250 N
(C) $300\sqrt{3}$ N and 300 N
(D) 280 N and $280\sqrt{3}$ N

2. For the loading of a truss shown in the figure below (length of member PU = length of member UT = length of member TS), the reaction at S (R_S) is



(A) 2 kN (B) 3 kN
(C) 2.57 kN (D) 4 kN

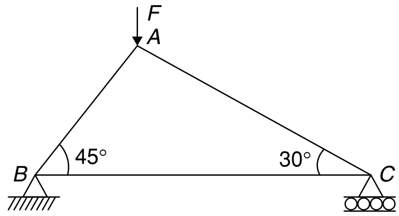
3. A truss consists of horizontal members (PU, UT, TS, QR) and vertical members (UQ, TR) all having a length B each.



The members PQ, TQ and SR are inclined at 45° to the horizontal. If an uniformly distributed load 'F' per unit length is present on the member QR of the truss shown in the figure above, then the force in the member UT is

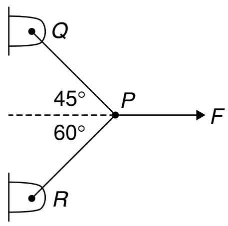
(A) $\dfrac{FB}{2}$ (B) FB
(C) 0 (D) $\dfrac{2FB}{3}$

4. Consider the truss ABC loaded at A with a force F as shown in the figure below.



The tension in the member BC is
(A) 0.5 F (B) 0.63 F
(C) 0.73 F (D) 0.87 F

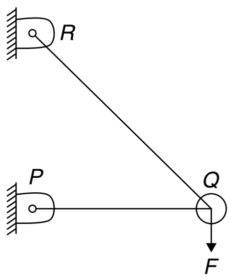
Direction for questions 5 and 6: Two steel members PQ and QR each having cross sectional area of 200 mm^2 are subjected to a horizontal force F as shown in figure. All the joints are hinged.



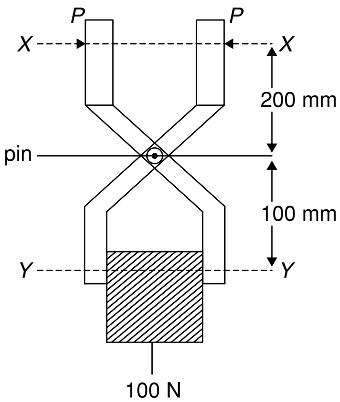
5. If F= 1 kN the magnitude of the vertical reaction force developed at the point R in kN is
(A) 0.543 kN (B) 2 kN
(C) 0.634 kN (D) 1 kN

6. The maximum value of the force F in kN that can be applied at P such that the axial stress in any of the truss members does not exceed 100 Pa is
(A) 22.3 kN (B) 54 kN
(C) 43.6 kN (D) 43.28 kN

7. Bars PQ and QR, each of negligible mass support a load F as shown in the figure below. In this arrangement, it can be deciphered that



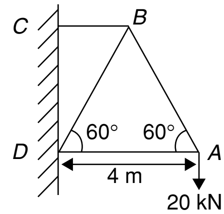
(A) Bar PQ is subjected to bending but bar QR is not subjected to bending.
(B) Bars PQ and QR are subjected to bending
(C) Neither bar PQ nor bar QR is subjected to bending.
(D) Bar QR is subjected to bending but bar PQ is not subjected to bending.

8. 

The figure shows a pair of pin jointed gripper tongs holding an object weighing 1000 N. The co-efficient of friction (μ) at the gripping surface is 0.1. xx is the line of action of the input force P and yy is the line of application of gripping force. If the pin joint is assumed to be frictionless, then the magnitude of the force P required to hold the weight is:

(A) 500 N (B) 1000 N
(C) 2000 N (D) 2500 N

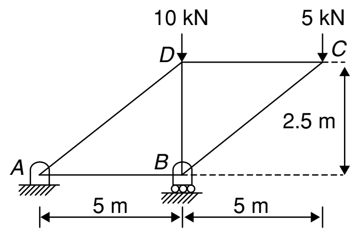
9. A cantilever truss of 4 m span is loaded as shown in the figure.



Determine the farce in member BC

(A) 32.1 kN (B) 11.55 kN
(C) 46.2 kN (D) 23.1 kN

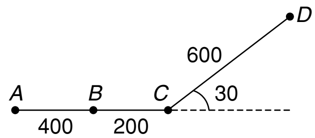
10. In the figure shown below, the force in the member BD is,



(A) 5 kN (B) 10 kN
(C) 15 kN (D) 20 kn

Practice Problems 2

Direction for questions 1, 2 and 3: Two collinear forces of magnitudes 400 N and 200 N act along with a force 600 N, acting at an angle of 30° with the former forces, as shown below:



1. The resultant force is

(A) 1512 N (B) 1424 N
(C) 1342 N (D) 1108 N

2. The angle made by the resultant force with the former forces is

(A) 15° (B) 18°
(C) 22° (D) 26°

3. If the forces 200 N and 600 N are collinear and acts at 30° with the force 400 N, then the resultant force shall be

(A) 1812 N (B) 1526 N
(C) 1423 N (D) 1164 N

Direction for questions 4 to 6: Select the correct alternative from the given choices.

4. A force of 500 N is acting on a body. The magnitude of the force to be acted on the same body at 120° with the first force, so that the net force on the body is still 500 N acting along the bisector of 120°, is

(A) 300 N (B) 500 N
(C) 750 N (D) 100 N

5. P and Q are two forces acting at a point and their resultant force is R. When Q is doubled the resultant force is doubled. If again the resultant force is doubled when Q is reversed, then $P : Q : R$ is:

(A) $\sqrt{2}:\sqrt{3}:\sqrt{2}$ (B) $1:\sqrt{3}:\sqrt{2}$
(C) $\sqrt{3}:\sqrt{2}:\sqrt{6}$ (D) $\sqrt{3}:\sqrt{5}:\sqrt{2}$

6. A force of 200 N is acting at a point making an angle of 30° with the horizontal. The components of this force along the x and y directions, respectively, are:

(A) 173.2 N and 100 N (B) 200 N and 130 N
(C) 250 N and 180.2 N (D) 135.5 N and 160 N

Direction for questions 7 and 8: A small block of weight 200 N is placed on an inclined plane which makes an angle $\theta = 30°$ with the horizontal.

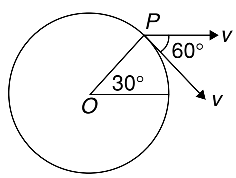
7. The component of the weight perpendicular to the inclined plane is

(A) 160.2 N (B) 173.2 N
(C) 140.2 N (D) 183.2 N

8. The component of the weight perpendicular to the inclined plane is

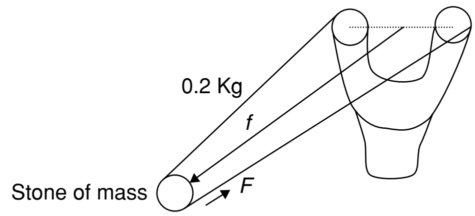
(A) 70 N (B) 78 N
(C) 98 N (D) 100 N

9. A circular disk of radius 20 mm rolls without slipping at a velocity v. The magnitude of the velocity at the point P is



(A) $\sqrt{3}v$ (B) $\sqrt{3}\frac{v}{2}$
(C) $\frac{v}{2}$ (D) $\frac{2v}{\sqrt{3}}$

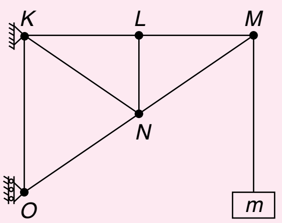
10. A stone with a mass of 0.2 kg is catapulted as shown in the figure below. The total force F_x (in N) exerted by the rubber band as a function of the distance x (in m) is given by $F_x = 300\,x^2$. If the stone is displaced by 0.2 m from the unstretched position (x = 0) of the rubber band, the energy stored in the rubber band is



(A) 0.02 J (B) 0.3 J
(C) 0.8 J (D) 10 J

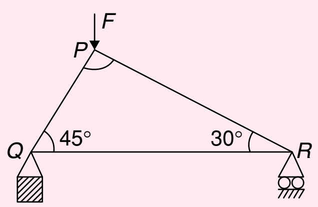
Previous Years' Questions

1. The figure shows a pin-jointed plane truss loaded at the point M by hanging a mass of 100 kg. The member LN of the truss is subjected to a load of: **[2004]**



(A) 0 N
(B) 490 N in compression
(C) 981 N in compression
(D) 981 N in tension

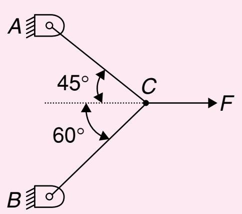
2. Consider a truss PQR loaded at P with a force F as shown in the figure. The tension in the member QR is: **[2008]**



(A) 0.5F (B) 0.63F
(C) 0.73F (D) 0.87F

Direction for questions 3 and 4: Two steel truss members, AC and BC, each having cross sectional area of 100 mm^2, are subjected to a horizontal force F as shown in figure. All the joints are hinged.

3. If F = 1 kN, the magnitude of the vertical reaction force developed at the point B in kN is: **[2012]**

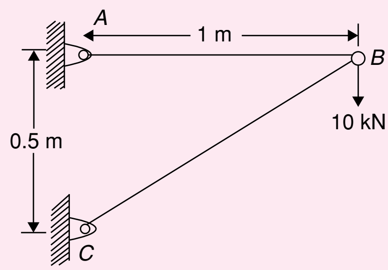


(A) 0.63 (B) 0.32
(C) 1.26 (D) 1.46

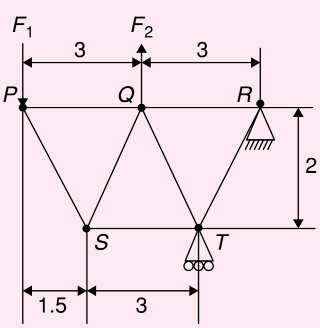
4. The maximum force F in kN that can be applied at C such that the axial stress in any of the truss members DOES NOT exceed 100 MPa is: **[2012]**

(A) 8.17 (B) 11.15
(C) 14.14 (D) 22.30

5. A two member truss ABC is shown in the figure. The force (in kN) transmitted in member AB is ____ **[2014]**

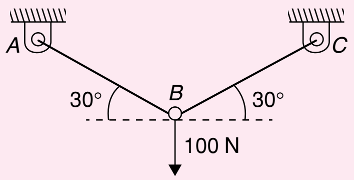


6. For the truss shown in the figure, the forces F_1 and F_2 are 9 kN and 3 kN, respectively. The force (in kN) in the member QS is (All dimensions are in m): **[2014]**

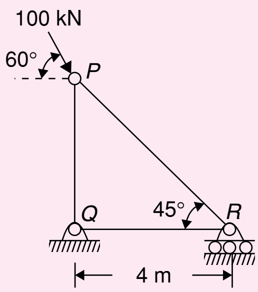


(A) 11.25 tension
(B) 11.25 compression
(C) 13.5 tension
(D) 13.5 compression

7. Two identical trusses support a load of 100 N as shown in the figure. The length of each truss is 1.0 m; cross-sectional area is 200 mm^2, Young's modulus E = 200 GPa. The force in the truss AB (in N) is ______ **[2015]**



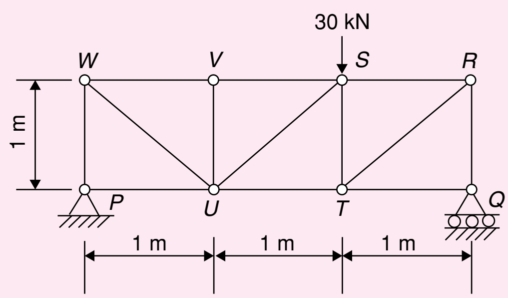
8.



For the truss shown in figure, the magnitude of the force in member PR and the support reaction at R are respectively **[2015]**

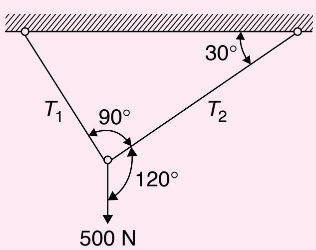
(A) 122.47 kN and 50 kN
(B) 70.71 kN and 100 kN
(C) 70.71 kN and 50 kN
(D) 81.65 kN and 100 kN

9. For the truss shown in the figure, the magnitude of the force (in kN) in the member SR is: **[2015]**



(A) 10 (B) 14.14
(C) 20 (D) 28.28

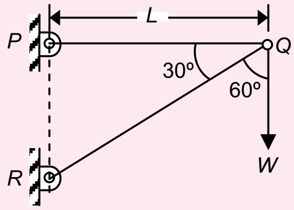
10. A weight of 500 N is supported by two metallic ropes as shown in the figure. The values of tensions T_1 and T_2 are respectively. **[2015]**



(A) 433 N and 250 N
(B) 250 N and 433 N
(C) 353.5 N and 250 N
(D) 250 N and 353.5 N

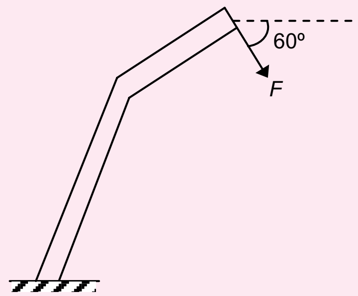
11. A two-member truss PQR is supporting a load W. The axial forces in members PQ and QR are respectively. **[2016]**

(A) $2W$ tensile and $\sqrt{2}W$ compressive
(B) $\sqrt{3}W$ tensile and $2W$ compressive



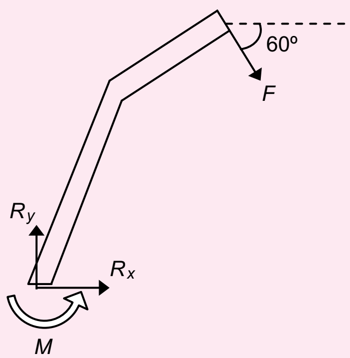
(C) $\sqrt{3}W$ compressive and $2W$ tensile
(D) $2W$ compressive and $\sqrt{3}W$ tensile

12. A force F is acting on a bent bar which is clamped at one end as shown in the figure. **[2016]**

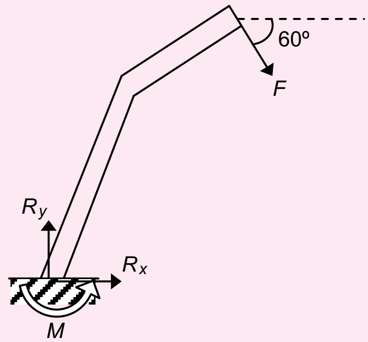


The CORRECT free body diagram is

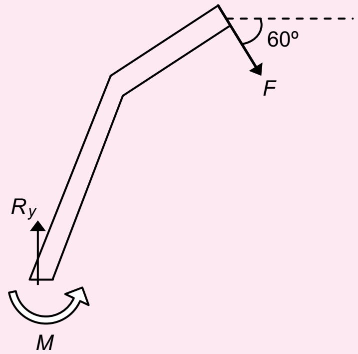
(A)



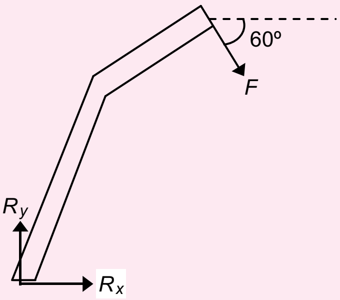
(B)



(C)



(D)



Answer Keys

Exercises

Practice Problems 1

1. B	**2.** A	**3.** A	**4.** B	**5.** C	**6.** A	**7.** A	**8.** D	**9.** A	**10.** C

Practice Problems 2

1. C	**2.** A	**3.** D	**4.** B	**5.** A	**6.** A	**7.** B	**8.** D	**9.** A	**10.** C

Previous Years' Questions

1. A	**2.** B	**3.** A	**4.** B	**5.** 18 to 22	**6.** A	**7.** 100	**8.** C	**9.** C	**10.** A
11. B	**12.** A								