قسم الهندسة المدنية

Civil Eng. Dept.

المرحلة الاولى

Al-Mansour University College

1st. Stage

Engineering Mechanics

2022 – 2023

3

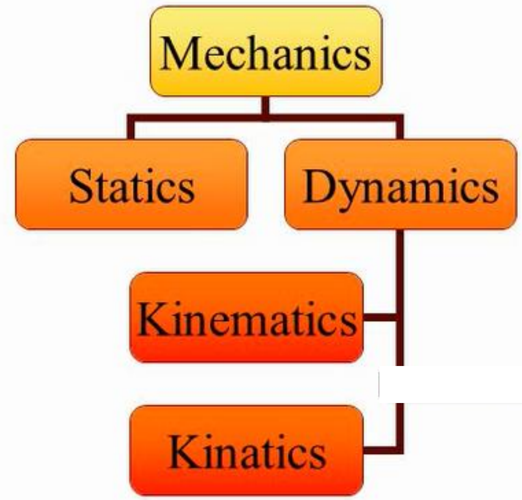
الميكانيك الهندسية

د. عبد الله سنان

Lecture 1

ENGINEERING MECHANICS
STATICS

- What is mechanics?
  - Physical science deals with the state of rest or motion of bodies under the action of force



- Why we study mechanics?
  - This science form the groundwork for further study in the design and analysis of structures

INTRODUCTION

1. **Basic Quantities**
    - Length: is used to locate the position of a point in space and thereby describe the size.
    - Time: is conceived as a succession of events .
    - Mass: is a measure of a quantity of matter that is used to compare the action of one body with that of another.
    - Force: considered as a “push” or “pull” exerted by one body on another. This interaction can occur when there is direct contact between the bodies, such as a person pushing on a wall, or it can occur through a distance when the bodies are physically separated.

2. Idealizations: Models or idealizations are used in mechanics in order to simplify application of the theory. Here we will consider three important idealizations.

- Particle. A particle has a mass, but a size that can be neglected.
- Rigid Body. A rigid body can be considered as a combination of a large number of particles in which all the particles remain at a fixed distance from one another.
- Concentrated Force. A concentrated force represents the effect of a loading which is assumed to act at a point on a body.

3. Units of Measurement

The four basic quantities—length, time, mass, and force—are not all independent from one another; in fact, they are related by Newton's second law of motion, $\mathbf{F} = m\mathbf{a}$.

Because of this, the units used to measure these quantities cannot all be selected arbitrarily. The equality $\mathbf{F} = m\mathbf{a}$. is maintained only if three of the four units, called base units, are defined and the fourth unit is then derived from the equation

- **SI Units (SI).**
- The International System of units, the SI system defines length in meters
- $W = mg \quad (g = 9.81\ m/s^2)$
- **U.S. Customary (FPS).**
- the U.S. Customary system of units, the length is measured in feet (ft), time in seconds (s), and force in pounds (lb), The unit of mass, called a slug , is derived from F = ma . Hence, 1 slug is equal to the amount of matter accelerated at 1 ft/s^2 when acted upon by a force of 1 lb ($slug = lb.s^2/ft$).
- $m = W/g \quad (g = 32.2\ ft/s^2)$

Conversion of Units.

Table below provides a set of direct conversion factors between FPS and SI units for the basic quantities.

Quantity	Unit of Measurement (FPS)	Equals	Unit of Measurement (SI)
Force	lb		4.448 N
Mass	slug		14.59 kg
Length	ft		0.3048 m

	Exponential Form	Prefix	SI Symbol
Multiple			
1 000 000 000	10^9	giga	G
1 000 000	10^6	mega	M
1 000	10^3	kilo	k
Submultiple			
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n

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د. عبد الله سنان

Structural Analysis

6

CHAPTER OBJECTIVES

- To show how to determine the forces in the members of a truss using the method of joints and the method of sections.
- To analyze the forces acting on the members of frames and machines composed of pin-connected members.

6.1 Simple Trusses

A *truss* is a structure composed of slender members joined together at their end points. The members commonly used in construction consist of wooden struts or metal bars. In particular, *planar* trusses lie in a single plane and are often used to support roofs and bridges. The truss shown in Fig. 6–1*a* is an example of a typical roof-supporting truss. In this figure, the roof load is transmitted to the truss *at the joints* by means of a series of *purlins*. Since this loading acts in the same plane as the truss, Fig. 6–1*b*, the analysis of the forces developed in the truss members will be two-dimensional.

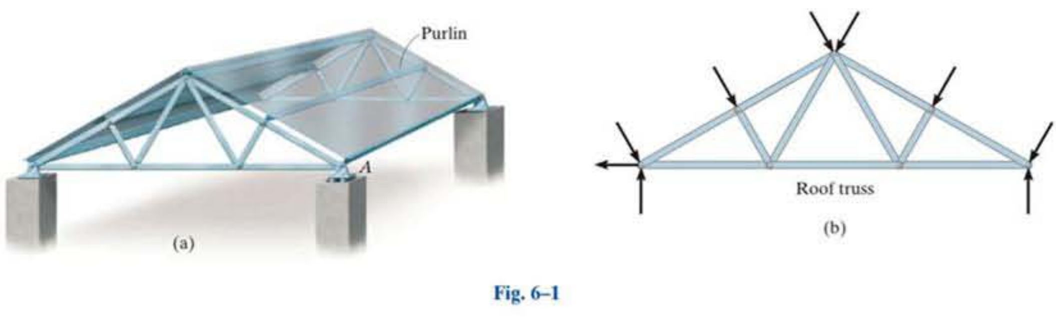


Fig. 6–1

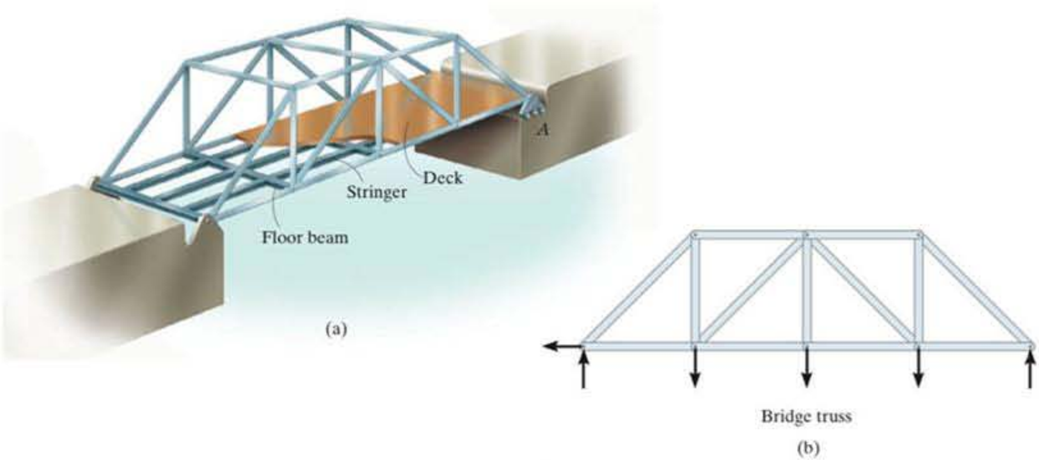


Fig. 6–2

6

In the case of a bridge, such as shown in Fig. 6–2*a*, the load on the deck is first transmitted to *stringers*, then to *floor beams*, and finally to the *joints* of the two supporting side trusses. Like the roof truss, the bridge truss loading is also coplanar, Fig. 6–2*b*.

When bridge or roof trusses extend over large distances, a rocker or roller is commonly used for supporting one end, for example, joint A in Figs. 6–1*a* and 6–2*a*. This type of support allows freedom for expansion or contraction of the members due to a change in temperature or application of loads.

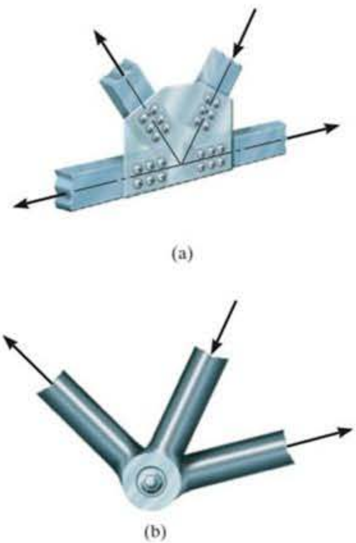


Fig. 6–3

Assumptions for Design. To design both the members and the connections of a truss, it is necessary first to determine the *force* developed in each member when the truss is subjected to a given loading. To do this we will make two important assumptions:

- ***All loadings are applied at the joints.*** In most situations, such as for bridge and roof trusses, this assumption is true. Frequently the weight of the members is neglected because the force supported by each member is usually much larger than its weight. However, if the weight is to be included in the analysis, it is generally satisfactory to apply it as a vertical force, with half of its magnitude applied at each end of the member.
- ***The members are joined together by smooth pins.*** The joint connections are usually formed by bolting or welding the ends of the members to a common plate, called a *gusset plate*, as shown in Fig. 6–3*a*, or by simply passing a large bolt or pin through each of the members, Fig. 6–3*b*. We can assume these connections act as pins provided the center lines of the joining members are *concurrent*, as in Fig. 6–3.

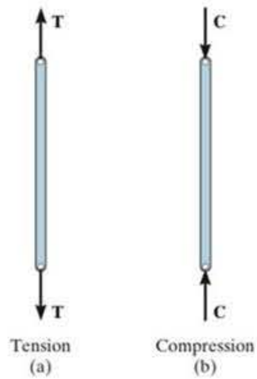


Fig. 6–4

Because of these two assumptions, *each truss member will act as a two-force member*, and therefore the force acting at each end of the member will be directed along the axis of the member. If the force tends to *elongate* the member, it is a *tensile force* (T), Fig. 6–4*a*; whereas if it tends to *shorten* the member, it is a *compressive force* (C), Fig. 6–4*b*. In the actual design of a truss it is important to state whether the nature of the force is tensile or compressive. Often, compression members must be made *thicker* than tension members because of the buckling or column effect that occurs when a member is in compression.

The use of metal gusset plates in the construction of these Warren trusses is clearly evident.

Simple Truss. If three members are pin connected at their ends they form a *triangular truss* that will be *rigid*, Fig. 6–5. Attaching two more members and connecting these members to a new joint *D* forms a larger truss, Fig. 6–6. This procedure can be repeated as many times as desired to form an even larger truss. If a truss can be constructed by expanding the basic triangular truss in this way, it is called a *simple truss*.

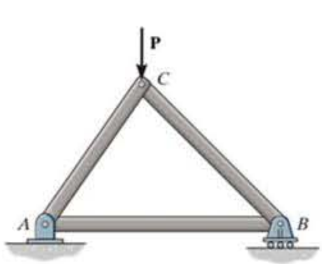


Fig. 6–5

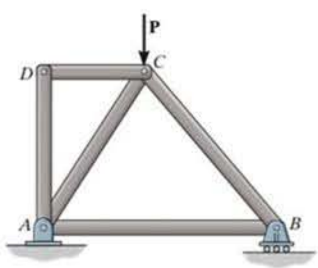


Fig. 6–6

6.2 The Method of Joints

In order to analyze or design a truss, it is necessary to determine the force in each of its members. One way to do this is to use the method of joints. This method is based on the fact that if the entire truss is in equilibrium, then each of its joints is also in equilibrium. Therefore, if the free-body diagram of each joint is drawn, the force equilibrium equations can then be used to obtain the member forces acting on each joint. Since the members of a *plane truss* are straight two-force members lying in a single plane, each joint is subjected to a force system that is *coplanar and concurrent*. As a result, only $\Sigma F_x = 0$ and $\Sigma F_y = 0$ need to be satisfied for equilibrium.

For example, consider the pin at joint B of the truss in Fig. 6–7*a*. Three forces act on the pin, namely, the 500-N force and the forces exerted by members BA and BC. The free-body diagram of the pin is shown in Fig. 6–7*b*. Here, $\mathbf{F}_{BA}$ is "pulling" on the pin, which means that member BA is in *tension;* whereas $\mathbf{F}_{BC}$ is "pushing" on the pin, and consequently member BC is in *compression.* These effects are clearly demonstrated by isolating the joint with small segments of the member connected to the pin, Fig. 6–7*c*. The pushing or pulling on these small segments indicates the effect of the member being either in compression or tension.

When using the method of joints, always start at a joint having at least one known force and at most two unknown forces, as in Fig. 6–7*b*. In this way, application of $\Sigma F_x = 0$ and $\Sigma F_y = 0$ yields two algebraic equations which can be solved for the two unknowns. When applying these equations, the correct sense of an unknown member force can be determined using one of two possible methods.

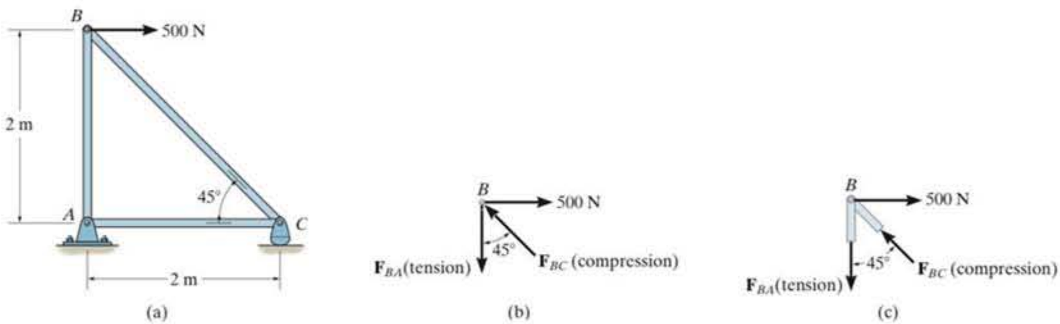


Fig. 6–7

EXAMPLE 6.2

Determine the force in each member of the truss in Fig. 6–9*a* and indicate if the members are in tension or compression.

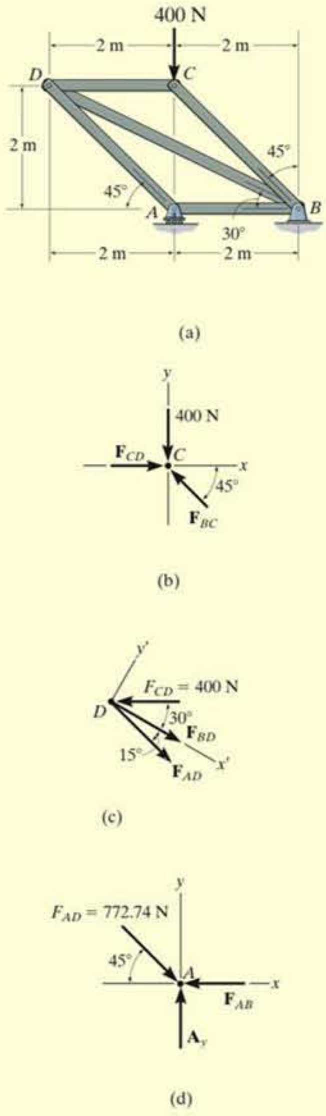


Fig. 6–9

SOLUTION

Since joint *C* has one known and only two unknown forces acting on it, it is possible to start at this joint, then analyze joint *D*, and finally joint *A*. This way the support reactions will not have to be determined prior to starting the analysis.

Joint *C*. By inspection of the force equilibrium, Fig. 6–9*b*, it can be seen that both members *BC* and *CD* must be in compression.

$$+\uparrow \Sigma F_y = 0; \qquad F_{BC} \sin 45^\circ - 400 \text{ N} = 0$$

$$F_{BC} = 565.69 \text{ N} = 566 \text{ N (C)} \qquad \textit{Ans.}$$

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad F_{CD} - (565.69 \text{ N}) \cos 45^\circ = 0$$

$$F_{CD} = 400 \text{ N (C)} \qquad \textit{Ans.}$$

Joint *D*. Using the result $F_{CD} = 400$ N (C), the force in members *BD* and *AD* can be found by analyzing the equilibrium of joint *D*. We will assume $\mathbf{F}_{AD}$ and $\mathbf{F}_{BD}$ are both tensile forces, Fig. 6–9*c*. The x', y' coordinate system will be established so that the x' axis is directed along $\mathbf{F}_{BD}$. This way, we will eliminate the need to solve two equations simultaneously. Now $\mathbf{F}_{AD}$ can be obtained *directly* by applying $\Sigma F_{y'} = 0$.

$$+\nearrow \Sigma F_{y'} = 0; \qquad -F_{AD} \sin 15^\circ - 400 \sin 30^\circ = 0$$

$$F_{AD} = -772.74 \text{ N} = 773 \text{ N (C)} \qquad \textit{Ans.}$$

The negative sign indicates that $\mathbf{F}_{AD}$ is a compressive force. Using this result,

$$+\searrow \Sigma F_{x'} = 0; \quad F_{BD} + (-772.74 \cos 15^\circ) - 400 \cos 30^\circ = 0$$

$$F_{BD} = 1092.82 \text{ N} = 1.09 \text{ kN (T)} \qquad \textit{Ans.}$$

Joint *A*. The force in member *AB* can be found by analyzing the equilibrium of joint *A*, Fig. 6–9*d*. We have

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad (772.74 \text{ N}) \cos 45^\circ - F_{AB} = 0$$

$$F_{AB} = 546.41 \text{ N (C)} = 546 \text{ N (C)} \qquad \textit{Ans.}$$

EXAMPLE 6.3

Determine the force in each member of the truss shown in Fig. 6–10*a*. Indicate whether the members are in tension or compression.

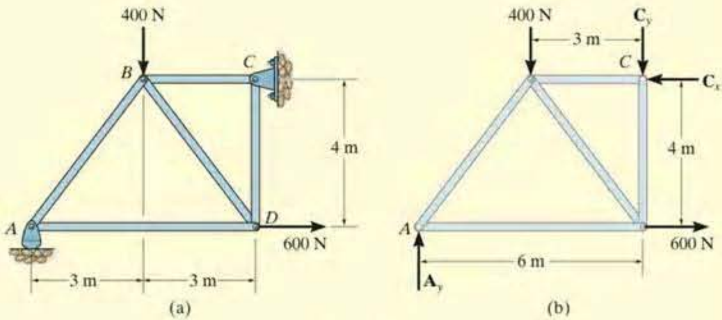


Fig. 6–10

SOLUTION

Support Reactions. No joint can be analyzed until the support reactions are determined, because each joint has more than three unknown forces acting on it. A free-body diagram of the entire truss is given in Fig. 6–10*b*. Applying the equations of equilibrium, we have

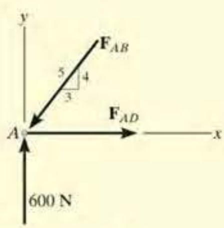
$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad 600\text{ N} - C_x = 0 \qquad C_x = 600\text{ N}$$

$$\circlearrowleft + \Sigma M_C = 0; \qquad -A_y(6\text{ m}) + 400\text{ N}(3\text{ m}) + 600\text{ N}(4\text{ m}) = 0$$

$$A_y = 600\text{ N}$$

$$+\uparrow \Sigma F_y = 0; \qquad 600\text{ N} - 400\text{ N} - C_y = 0 \qquad C_y = 200\text{ N}$$

The analysis can now start at either joint A or C. The choice is arbitrary since there are one known and two unknown member forces acting on the pin at each of these joints.



(c)

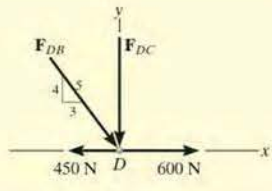
Joint A. (Fig. 6–10*c*). As shown on the free-body diagram, $\mathbf{F}_{AB}$ is assumed to be compressive and $\mathbf{F}_{AD}$ is tensile. Applying the equations of equilibrium, we have

$$+\uparrow \Sigma F_y = 0; \qquad 600\text{ N} - \tfrac{4}{5}F_{AB} = 0 \qquad F_{AB} = 750\text{ N (C)} \qquad \textit{Ans.}$$

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad F_{AD} - \tfrac{3}{5}(750\text{ N}) = 0 \qquad F_{AD} = 450\text{ N (T)} \qquad \textit{Ans.}$$

Joint *D*. (Fig. 6–10*d*). Using the result for F_{AD} and summing forces in the horizontal direction, Fig. 6–10*d*, we have

$$\xrightarrow{+} \Sigma F_x = 0; \qquad -450\text{ N} + \tfrac{3}{5}F_{DB} + 600\text{ N} = 0 \quad F_{DB} = -250\text{ N}$$



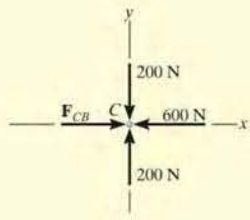
(d)

The negative sign indicates that $\mathbf{F}_{DB}$ acts in the *opposite sense* to that shown in Fig. 6–10*d*.* Hence,

$$F_{DB} = 250\text{ N (T)} \qquad \textit{Ans.}$$

To determine $\mathbf{F}_{DC}$, we can either correct the sense of $\mathbf{F}_{DB}$ on the free-body diagram, and then apply $\Sigma F_y = 0$, or apply this equation and retain the negative sign for F_{DB}, i.e.,

$$+\uparrow \Sigma F_y = 0; \qquad -F_{DC} - \tfrac{4}{5}(-250\text{ N}) = 0 \quad F_{DC} = 200\text{ N} \quad \text{(C)} \quad \textit{Ans.}$$



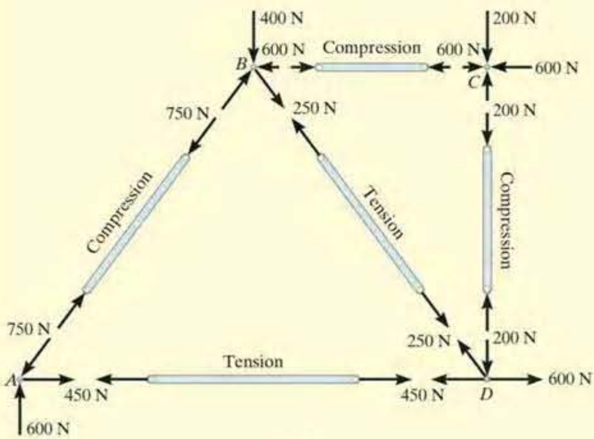
(e)

Joint *C*. (Fig. 6–10*e*).

$$\xrightarrow{+} \Sigma F_x = 0; \qquad F_{CB} - 600\text{ N} = 0 \quad F_{CB} = 600\text{ N} \quad \text{(C)} \quad \textit{Ans.}$$

$$+\uparrow \Sigma F_y = 0; \qquad 200\text{ N} - 200\text{ N} \equiv 0 \quad \text{(check)}$$

NOTE: The analysis is summarized in Fig. 6–10*f*, which shows the free-body diagram for each joint and member.



(f)

*The proper sense could have been determined by inspection, prior to applying $\Sigma F_x = 0$.

6.3 Zero-Force Members

Truss analysis using the method of joints is greatly simplified if we can first identify those members which support *no loading*. These *zero-force members* are used to increase the stability of the truss during construction and to provide added support if the loading is changed.

The zero-force members of a truss can generally be found *by inspection* of each of the joints. For example, consider the truss shown in Fig. 6–11*a*. If a free-body diagram of the pin at joint A is drawn, Fig. 6–11*b*, it is seen that members AB and AF are zero-force members. (We could not have come to this conclusion if we had considered the free-body diagrams of joints F or B simply because there are five unknowns at each of these joints.) In a similar manner, consider the free-body diagram of joint D, Fig. 6–11*c*. Here again it is seen that DC and DE are zero-force members. From these observations, we can conclude that *if only two members form a truss joint and no external load or support reaction is applied to the joint, the two members must be zero-force members.* The load on the truss in Fig. 6–11*a* is therefore supported by only five members as shown in Fig. 6–11*d*.

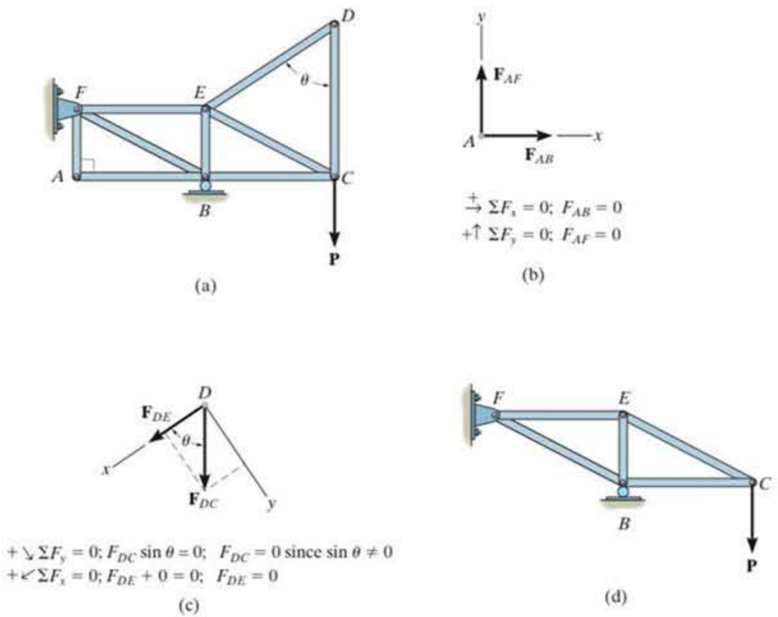
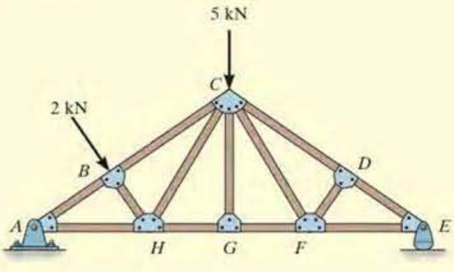


Fig. 6–11

EXAMPLE 6.4

Using the method of joints, determine all the zero-force members of the *Fink roof truss* shown in Fig. 6–13*a*. Assume all joints are pin connected.

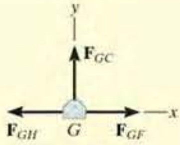


(a)

Fig. 6–13

SOLUTION

Look for joint geometries that have three members for which two are collinear. We have

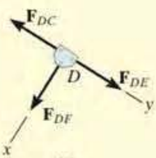


(b)

Joint G. (Fig. 6–13*b*).

$+\uparrow\Sigma F_y = 0;$ $\quad F_{GC} = 0$ *Ans.*

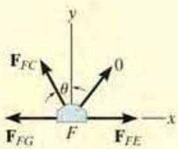
Realize that we could not conclude that GC is a zero-force member by considering joint C, where there are five unknowns. The fact that GC is a zero-force member means that the 5-kN load at C must be supported by members CB, CH, CF, and CD.



(c)

Joint D. (Fig. 6–13*c*).

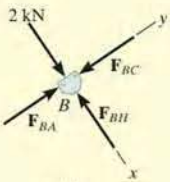
$+\swarrow\Sigma F_x = 0;$ $\quad F_{DF} = 0$ *Ans.*



(d)

Joint F. (Fig. 6–13*d*).

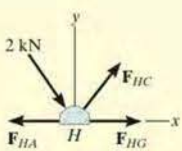
$+\uparrow\Sigma F_y = 0;$ $\quad F_{FC}\cos\theta = 0$ $\quad$ Since $\theta \neq 90°$, $\quad F_{FC} = 0$ *Ans.*



(e)

NOTE: If joint B is analyzed, Fig. 6–13*e*,

$+\searrow\Sigma F_x = 0;$ $\quad 2\text{ kN} - F_{BH} = 0 \quad F_{BH} = 2\text{ kN}$ $\quad$ (C)

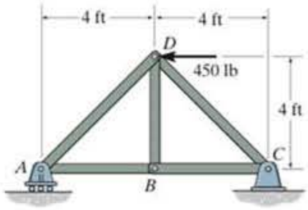


(f)

Also, F_{HC} must satisfy $\Sigma F_y = 0$, Fig. 6–13*f*, and therefore HC is *not* a zero-force member.

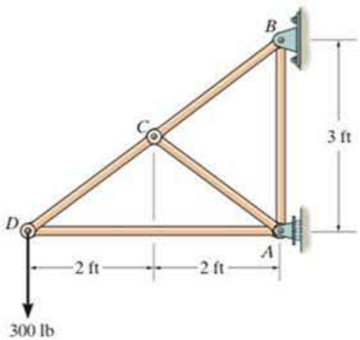
FUNDAMENTAL PROBLEMS

F6–1. Determine the force in each member of the truss. State if the members are in tension or compression.



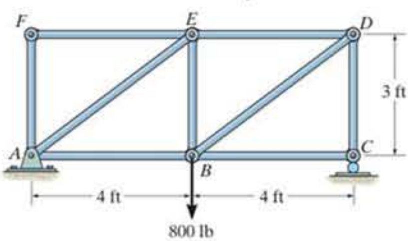
F6–1

F6–2. Determine the force in each member of the truss. State if the members are in tension or compression.



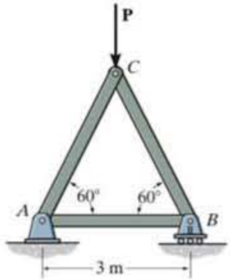
F6–2

F6–3. Determine the force in members AE and DC. State if the members are in tension or compression.



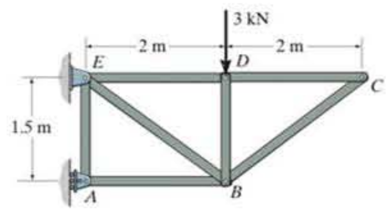
F6–3

F6–4. Determine the greatest load P that can be applied to the truss so that none of the members are subjected to a force exceeding either 2 kN in tension or 1.5 kN in compression.



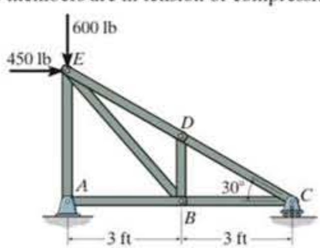
F6–4

F6–5. Identify the zero-force members in the truss.



F6–5

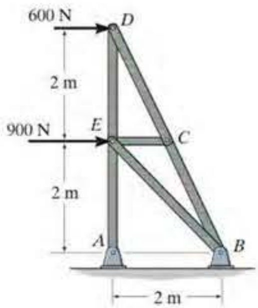
F6–6. Determine the force in each member of the truss. State if the members are in tension or compression.



F6–6

PROBLEMS

•6–1. Determine the force in each member of the truss, and state if the members are in tension or compression.

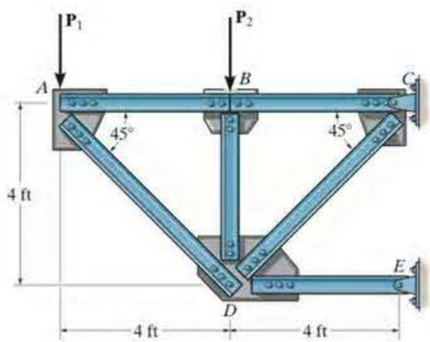


Prob. 6–1

6

6–2. The truss, used to support a balcony, is subjected to the loading shown. Approximate each joint as a pin and determine the force in each member. State whether the members are in tension or compression. Set $P_1 = 600$ lb, $P_2 = 400$ lb.

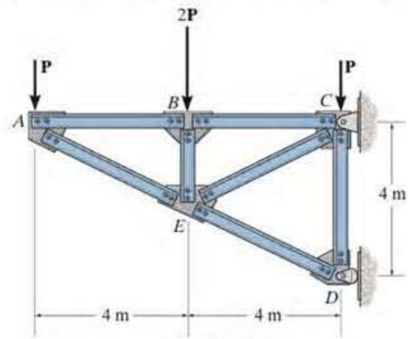
6–3. The truss, used to support a balcony, is subjected to the loading shown. Approximate each joint as a pin and determine the force in each member. State whether the members are in tension or compression. Set $P_1 = 800$ lb, $P_2 = 0$.



Probs. 6–2/3Prob. 6–1

*6–4. Determine the force in each member of the truss and state if the members are in tension or compression. Assume each joint as a pin. Set $P = 4$ kN.

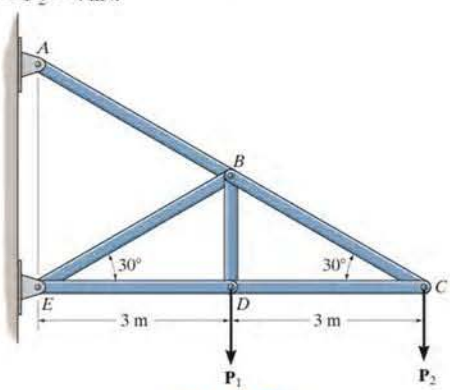
•6–5. Assume that each member of the truss is made of steel having a mass per length of 4 kg/m. Set $P = 0$, determine the force in each member, and indicate if the members are in tension or compression. Neglect the weight of the gusset plates and assume each joint is a pin. Solve the problem by assuming the weight of each member can be represented as a vertical force, half of which is applied at the end of each member.



Probs. 6–4/5

6–6. Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 2$ kN and $P_2 = 1.5$ kN.

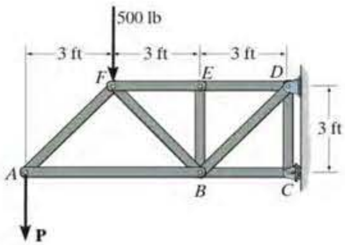
6–7. Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = P_2 = 4$ kN.



Probs. 6–6/7

*6–8. Determine the force in each member of the truss, and state if the members are in tension or compression. Set $P = 800$ lb.

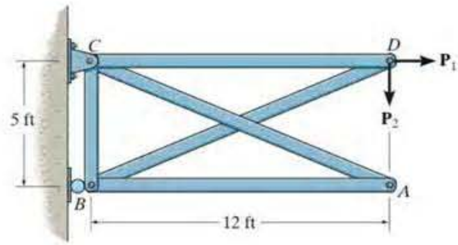
•6–9. Remove the 500-lb force and then determine the greatest force P that can be applied to the truss so that none of the members are subjected to a force exceeding either 800 lb in tension or 600 lb in compression.



Probs. 6–8/9

*6–12. Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 240$ lb, $P_2 = 100$ lb.

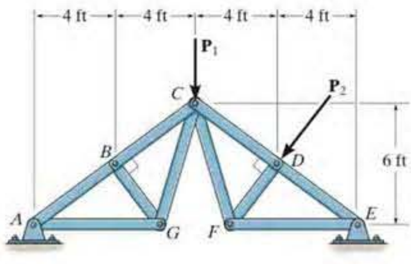
•6–13. Determine the largest load P_2 that can be applied to the truss so that the force in any member does not exceed 500 lb (T) or 350 lb (C). Take $P_1 = 0$.



Probs. 6–12/13

6–10. Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 800$ lb, $P_2 = 0$.

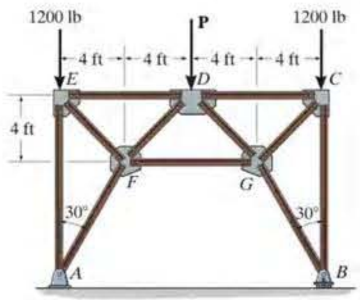
6–11. Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 600$ lb, $P_2 = 400$ lb.



Probs. 6–10/11

6–14. Determine the force in each member of the truss, and state if the members are in tension or compression. Set $P = 2500$ lb.

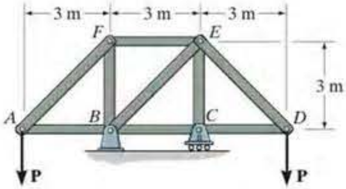
6–15. Remove the 1200-lb forces and determine the greatest force P that can be applied to the truss so that none of the members are subjected to a force exceeding either 2000 lb in tension or 1500 lb in compression.



Probs. 6–14/15

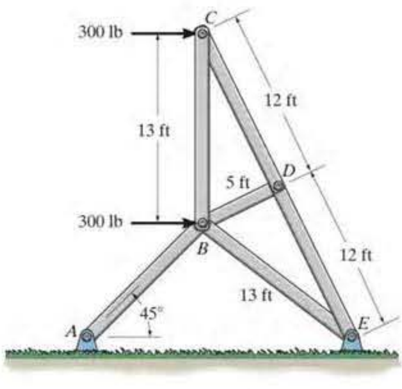
*6–24. Determine the force in each member of the truss, and state if the members are in tension or compression. Set $P = 4$ kN.

•6–25. Determine the greatest force P that can be applied to the truss so that none of the members are subjected to a force exceeding either 1.5 kN in tension or 1 kN in compression.



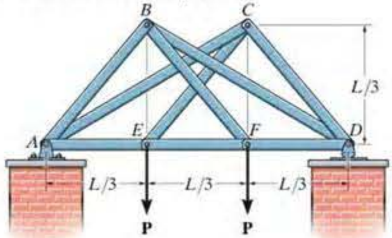
Probs. 6–24/25

6–26. A sign is subjected to a wind loading that exerts horizontal forces of 300 lb on joints B and C of one of the side supporting trusses. Determine the force in each member of the truss and state if the members are in tension or compression.



Prob. 6–26

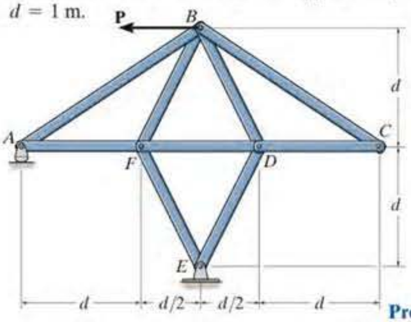
6–27. Determine the force in each member of the double scissors truss in terms of the load P and state if the members are in tension or compression.



Prob. 6–27

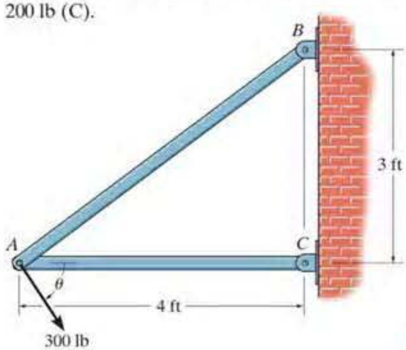
*6–28. Determine the force in each member of the truss in terms of the load P, and indicate whether the members are in tension or compression.

•6–29. If the maximum force that any member can support is 4 kN in tension and 3 kN in compression, determine the maximum force P that can be applied at joint B. Take $d = 1$ m.



Probs. 6–28/29

6–30. The two-member truss is subjected to the force of 300 lb. Determine the range of θ for application of the load so that the force in either member does not exceed 400 lb (T) or 200 lb (C).



Prob. 6–30

6.4 The Method of Sections

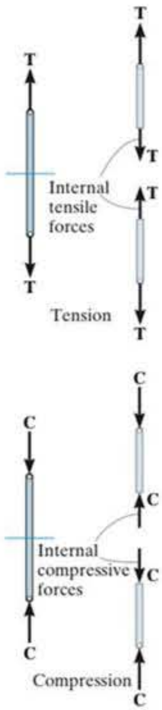
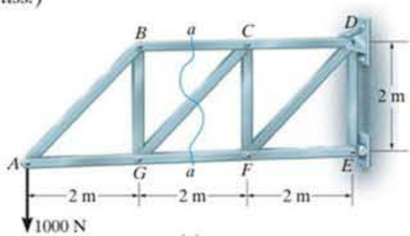


Fig. 6–14

When we need to find the force in only a few members of a truss, we can analyze the truss using the *method of sections*. It is based on the principle that if the truss is in equilibrium then any segment of the truss is also in equilibrium. For example, consider the two truss members shown on the left in Fig. 6–14. If the forces within the members are to be determined, then an imaginary section, indicated by the blue line, can be used to cut each member into two parts and thereby "expose" each internal force as "external" to the free-body diagrams shown on the right. Clearly, it can be seen that equilibrium requires that the member in tension (T) be subjected to a "pull," whereas the member in compression (C) is subjected to a "push."

The method of sections can also be used to "cut" or section the members of an entire truss. If the section passes through the truss and the free-body diagram of either of its two parts is drawn, we can then apply the equations of equilibrium to that part to determine the member forces at the "cut section." Since only *three* independent equilibrium equations ($\Sigma F_x = 0$, $\Sigma F_y = 0$, $\Sigma M_O = 0$) can be applied to the free-body diagram of any segment, then we should try to select a section that, in general, passes through not more than *three* members in which the forces are unknown. For example, consider the truss in Fig. 6–15*a*. If the forces in members BC, GC, and GF are to be determined, then section aa would be appropriate. The free-body diagrams of the two segments are shown in Figs. 6–15*b* and 6–15*c*. Note that the line of action of each member force is specified from the *geometry* of the truss, since the force in a member is along its axis. Also, the member forces acting on one part of the truss are equal but opposite to those acting on the other part—Newton's third law. Members BC and GC are assumed to be in *tension* since they are subjected to a "pull," whereas GF in *compression* since it is subjected to a "push."

The three unknown member forces $\mathbf{F}_{BC}$, $\mathbf{F}_{GC}$, and $\mathbf{F}_{GF}$ can be obtained by applying the three equilibrium equations to the free-body diagram in Fig. 6–15*b*. If, however, the free-body diagram in Fig. 6–15*c* is considered, the three support reactions $\mathbf{D}_x$, $\mathbf{D}_y$ and $\mathbf{E}_x$ will have to be known, because only three equations of equilibrium are available. (This, of course, is done in the usual manner by considering a free-body diagram of the *entire truss*.)



(a)

When applying the equilibrium equations, we should carefully consider ways of writing the equations so as to yield a *direct solution* for each of the unknowns, rather than having to solve simultaneous equations. For example, using the truss segment in Fig. 6–15*b* and summing moments about C would yield a direct solution for $\mathbf{F}_{GF}$ since $\mathbf{F}_{BC}$ and $\mathbf{F}_{GC}$ create zero moment about C. Likewise, $\mathbf{F}_{BC}$ can be directly obtained by summing moments about G. Finally, $\mathbf{F}_{GC}$ can be found directly from a force summation in the vertical direction since $\mathbf{F}_{GF}$ and $\mathbf{F}_{BC}$ have no vertical components. This ability to *determine directly* the force in a particular truss member is one of the main advantages of using the method of sections.*

As in the method of joints, there are two ways in which we can determine the correct sense of an unknown member force:

- The correct sense of an unknown member force can in many cases be determined "by inspection." For example, $\mathbf{F}_{BC}$ is a tensile force as represented in Fig. 6–15*b* since moment equilibrium about G requires that $\mathbf{F}_{BC}$ create a moment opposite to that of the 1000-N force. Also, $\mathbf{F}_{GC}$ is tensile since its vertical component must balance the 1000-N force which acts downward. In more complicated cases, the sense of an unknown member force may be *assumed*. If the solution yields a *negative* scalar, it indicates that the force's sense is *opposite* to that shown on the free-body diagram.
- *Always assume* that the unknown member forces at the cut section are *tensile* forces, i.e., "pulling" on the member. By doing this, the numerical solution of the equilibrium equations will yield *positive scalars for members in tension and negative scalars for members in compression.*

*Notice that if the method of joints were used to determine, say, the force in member GC, it would be necessary to analyze joints A, B, and G in sequence.

The forces in selected members of this Pratt truss can readily be determined using the method of sections.

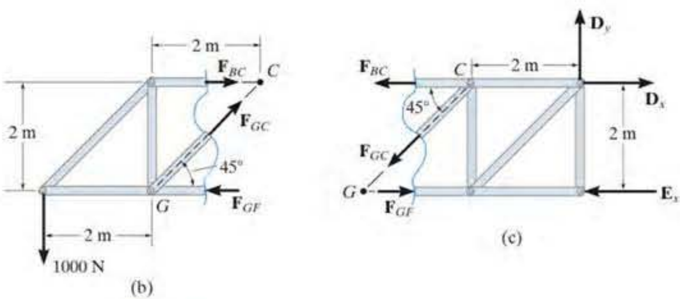


Fig. 6–15

6

Simple trusses are often used in the construction of large cranes in order to reduce the weight of the boom and tower.

Procedure for Analysis

The forces in the members of a truss may be determined by the method of sections using the following procedure.

Free-Body Diagram.

- Make a decision on how to "cut" or section the truss through the members where forces are to be determined.
- Before isolating the appropriate section, it may first be necessary to determine the truss's support reactions. If this is done then the three equilibrium equations will be available to solve for member forces at the section.
- Draw the free-body diagram of that segment of the sectioned truss which has the least number of forces acting on it.
- Use one of the two methods described above for establishing the sense of the unknown member forces.

Equations of Equilibrium.

- Moments should be summed about a point that lies at the intersection of the lines of action of two unknown forces, so that the third unknown force can be determined directly from the moment equation.
- If two of the unknown forces are *parallel*, forces may be summed *perpendicular* to the direction of these unknowns to determine *directly* the third unknown force.

EXAMPLE 6.6

Determine the force in member CF of the truss shown in Fig. 6–17a. Indicate whether the member is in tension or compression. Assume each member is pin connected.

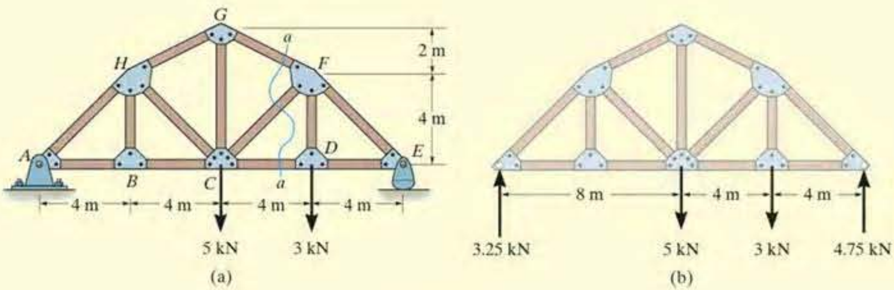
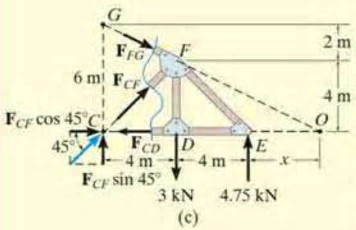


Fig. 6–17

6

SOLUTION

Free-Body Diagram. Section aa in Fig. 6–17a will be used since this section will "expose" the internal force in member CF as "external" on the free-body diagram of either the right or left portion of the truss. It is first necessary, however, to determine the support reactions on either the left or right side. Verify the results shown on the free-body diagram in Fig. 6–17b.



The free-body diagram of the right portion of the truss, which is the easiest to analyze, is shown in Fig. 6–17c. There are three unknowns, F_{FG}, F_{CF}, and F_{CD}.

Equations of Equilibrium. We will apply the moment equation about point O in order to eliminate the two unknowns F_{FG} and F_{CD}. The location of point O measured from E can be determined from proportional triangles, i.e., $4/(4 + x) = 6/(8 + x)$, $x = 4$ m. Or, stated in another manner, the slope of member GF has a drop of 2 m to a horizontal distance of 4 m. Since FD is 4 m, Fig. 6–17c, then from D to O the distance must be 8 m.

An easy way to determine the moment of $\mathbf{F}_{CF}$ about point O is to use the principle of transmissibility and slide $\mathbf{F}_{CF}$ to point C, and then resolve $\mathbf{F}_{CF}$ into its two rectangular components. We have

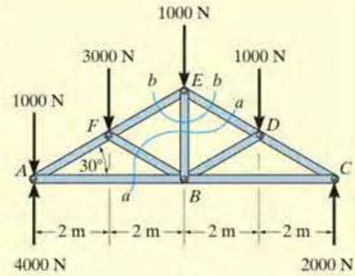
$\circlearrowleft + \Sigma M_O = 0;$

$$-F_{CF} \sin 45^\circ (12 \text{ m}) + (3 \text{ kN})(8 \text{ m}) - (4.75 \text{ kN})(4 \text{ m}) = 0$$

$$F_{CF} = 0.589 \text{ kN} \quad \text{(C)} \qquad \textit{Ans.}$$

EXAMPLE 6.7

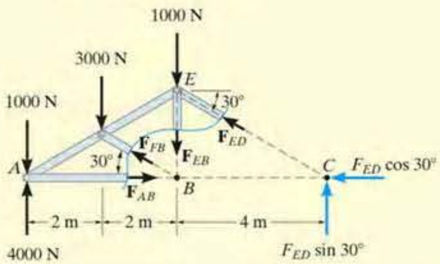
Determine the force in member EB of the roof truss shown in Fig. 6–18a. Indicate whether the member is in tension or compression.



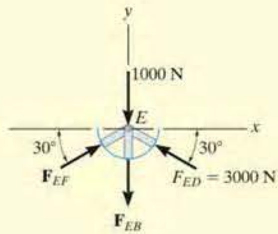
(a)

SOLUTION

Free-Body Diagrams. By the method of sections, any imaginary section that cuts through EB, Fig. 6–18a, will also have to cut through three other members for which the forces are unknown. For example, section aa cuts through ED, EB, FB, and AB. If a free-body diagram of the left side of this section is considered, Fig. 6–18b, it is possible to obtain $\mathbf{F}_{ED}$ by summing moments about B to eliminate the other three unknowns; however, $\mathbf{F}_{EB}$ cannot be determined from the remaining two equilibrium equations. One possible way of obtaining $\mathbf{F}_{EB}$ is first to determine $\mathbf{F}_{ED}$ from section aa, then use this result on section bb, Fig. 6–18a, which is shown in Fig. 6–18c. Here the force system is concurrent and our sectioned free-body diagram is the same as the free-body diagram for the joint at E.



(b)



(c)

Fig. 6–18

Equations of Equilibrium. In order to determine the moment of $\mathbf{F}_{ED}$ about point B, Fig. 6–18b, we will use the principle of transmissibility and slide the force to point C and then resolve it into its rectangular components as shown. Therefore,

$$\circlearrowleft+\Sigma M_B = 0; \qquad 1000\text{ N}(4\text{ m}) + 3000\text{ N}(2\text{ m}) - 4000\text{ N}(4\text{ m}) + F_{ED}\sin 30°(4\text{ m}) = 0$$

$$F_{ED} = 3000\text{ N} \quad \text{(C)}$$

Considering now the free-body diagram of section bb, Fig. 6–18c, we have

$$\xrightarrow{+}\Sigma F_x = 0; \qquad F_{EF}\cos 30° - 3000\cos 30°\text{ N} = 0$$

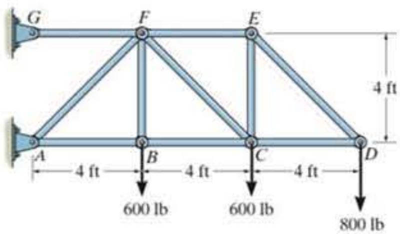
$$F_{EF} = 3000\text{ N} \quad \text{(C)}$$

$$+\uparrow\Sigma F_y = 0; \qquad 2(3000\sin 30°\text{ N}) - 1000\text{ N} - F_{EB} = 0$$

$$F_{EB} = 2000\text{ N} \quad \text{(T)} \qquad \textit{Ans.}$$

FUNDAMENTAL PROBLEMS

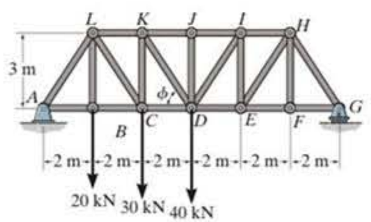
F6–7. Determine the force in members BC, CF, and FE. State if the members are in tension or compression.



F6–7

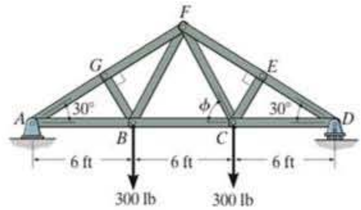
F6–8. Determine the force in members LK, KC, and CD of the Pratt truss. State if the members are in tension or compression.

F6–9. Determine the force in members KJ, KD, and CD of the Pratt truss. State if the members are in tension or compression.



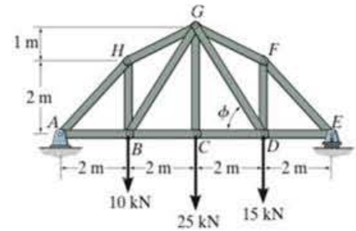
F6–8/9

F6–10. Determine the force in members EF, CF, and BC of the truss. State if the members are in tension or compression.



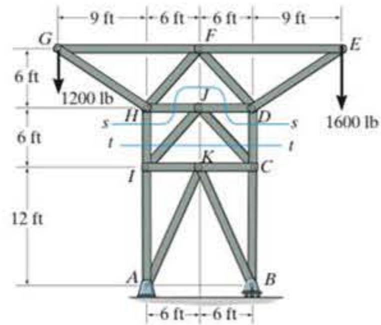
F6–10

F6–11. Determine the force in members GF, GD, and CD of the truss. State if the members are in tension or compression.



F6–11

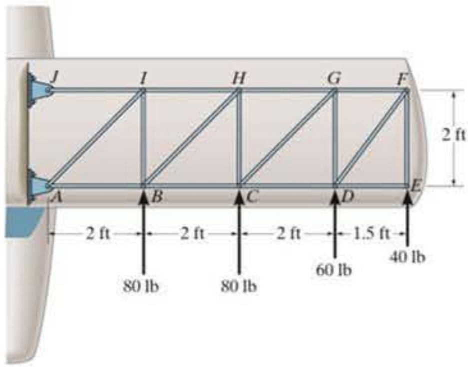
F6–12. Determine the force in members DC, HI, and JI of the truss. State if the members are in tension or compression.



F6–12

PROBLEMS

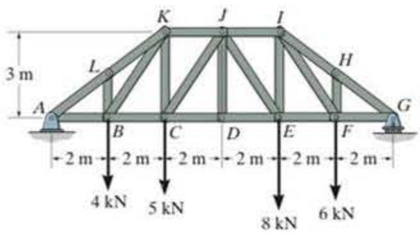
6–31. The internal drag truss for the wing of a light airplane is subjected to the forces shown. Determine the force in members *BC*, *BH*, and *HC*, and state if the members are in tension or compression.



Prob. 6–31

6–34. Determine the force in members *JK*, *CJ*, and *CD* of the truss, and state if the members are in tension or compression.

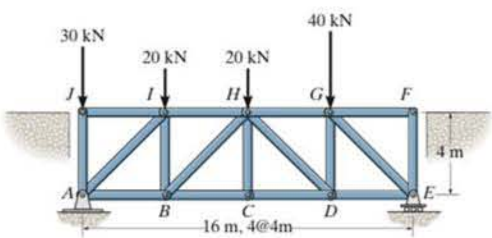
6–35. Determine the force in members *HI*, *FI*, and *EF* of the truss, and state if the members are in tension or compression.



Probs. 6–34/35

*6–32. The *Howe bridge truss* is subjected to the loading shown. Determine the force in members *HD*, *CD*, and *GD*, and state if the members are in tension or compression.

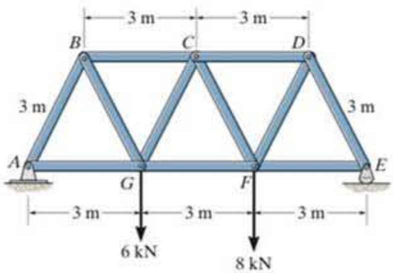
•6–33. The *Howe bridge truss* is subjected to the loading shown. Determine the force in members *HI*, *HB*, and *BC*, and state if the members are in tension or compression.



Probs. 6–32/33

*6–36. Determine the force in members *BC*, *CG*, and *GF* of the *Warren* truss. Indicate if the members are in tension or compression.

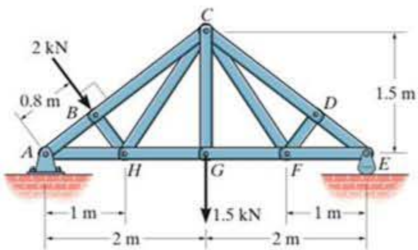
•6–37. Determine the force in members *CD*, *CF*, and *FG* of the *Warren truss*. Indicate if the members are in tension or compression.



Probs. 6–36/37

6–46. Determine the force developed in members BC and CH of the roof truss and state if the members are in tension or compression.

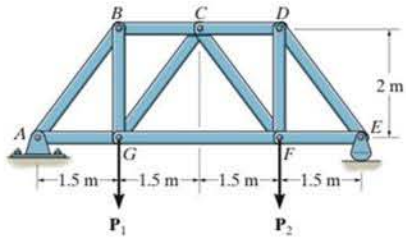
6–47. Determine the force in members CD and GF of the truss and state if the members are in tension or compression. Also indicate all zero-force members.



Probs. 6–46/47

6–50. Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 20$ kN, $P_2 = 10$ kN.

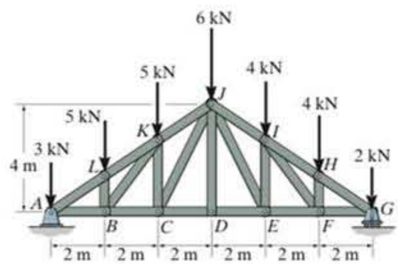
6–51. Determine the force in each member of the truss and state if the members are in tension or compression. Set $P_1 = 40$ kN, $P_2 = 20$ kN.



Probs. 6–50/51

*__6–48.__ Determine the force in members IJ, EJ, and CD of the *Howe* truss, and state if the members are in tension or compression.

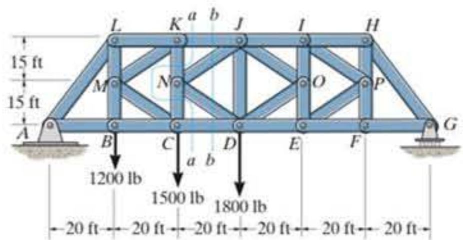
•**6–49.** Determine the force in members KJ, KC, and BC of the *Howe* truss, and state if the members are in tension or compression.



Probs. 6–48/49

*__6–52.__ Determine the force in members KJ, NJ, ND, and CD of the *K truss*. Indicate if the members are in tension or compression. *Hint:* Use sections *aa* and *bb*.

•**6–53.** Determine the force in members JI and DE of the *K truss*. Indicate if the members are in tension or compression.



Probs. 6–52/53