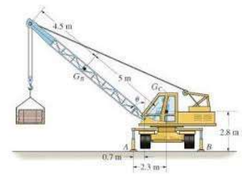

Engineering Mechanics

Dr Mohammed Shihab

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The University of Diyala
College of Engineering
Department of Civil Engineering

Module Title: Engineering Mechanics
Module Convener: Dr Mohammed Shihab
Module No: CE101

Text/Reference Books

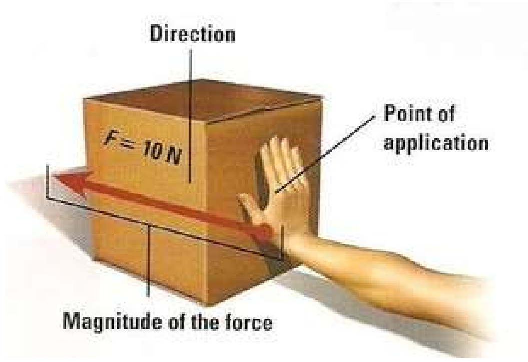
- **I. H. Shames**, Engineering Mechanics: Statics and dynamics, 4th Ed, PHI, 2002.
- **R. C. Hibbler**, *Engineering Mechani*cs: Principles of Statics and Dynamics, Pearson Press, 2006.
- **J. L. Meriam and L. G. Kraige**, Engineering Mechanics, Vol I –Statics, Vol II –Dynamics, 6thEd, John Wiley, 2008.

1. Basic Concepts

Force: A push or pull acting on a body that causes or tends to cause a change in the linear motion of the body

Characteristics of a force

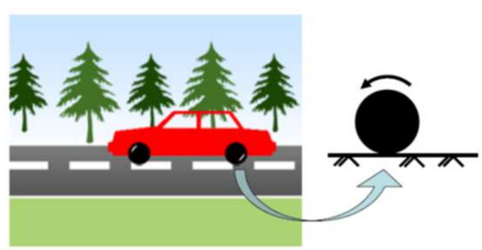
- magnitude
- direction
- point of application.
- Line of action



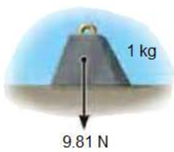
1. Basic Concepts

- **Statics:** deals with equilibrium of bodies under action of forces (bodies may be either at rest or move with a constant velocity).

- **Dynamics:** deals with motion of bodies (accelerated motion)

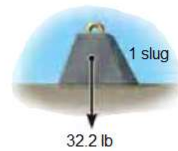


1. Basic Concepts



The International system (SI Units)

Mass: Kilogram: kg
Force: Newton: N
Length: Meter: m
Time: Second: s



US Customary Units

Mass: Slug
Force: Pound: lb
Length: Feet: ft
Time: Second: s

Conversion Factors

1 kg = 14.5939 slug | **1 slug = 0.0685218 kg**

1 N = 0.224809 lb | **1 lb = 4.44822 N**

1 m = 3.28084 ft | **1 ft = 0.3048 m**

Units Prefixes

	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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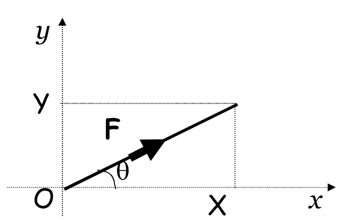
2. Composition and Resolution of Forces

- Splitting forces into their components
- Finding the resultant of two or more forces

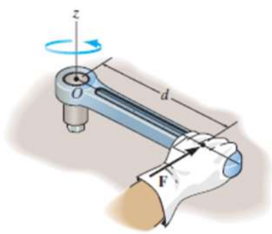
Sometimes it is necessary to resolve a force into two *components* in order to study its pulling or pushing effect in two specific directions.



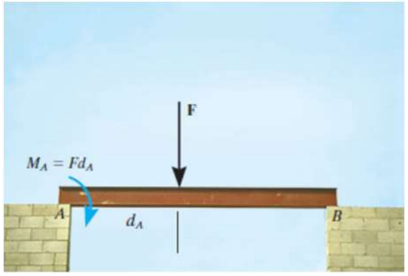
$$\boxed{\begin{aligned} OX &= F\cos\theta \\ OY &= F\sin\theta \end{aligned}}$$

3. Moment of Forces

When a force is applied to a body it will produce a tendency for the body to rotate about a point that is not on the line of action of the force. This tendency to rotate is sometimes called a *torque*, but most often it is called the moment of a force or simply the *moment*.



Beams are often used to bridge gaps in walls. We have to know what the effect of the force on the beam will have on the beam supports.



What do you think those impacts are at points A and B?

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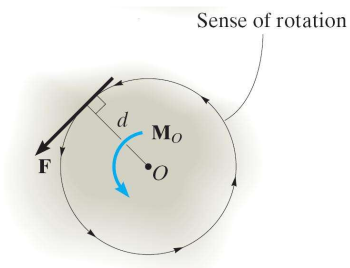
3. Moment of Forces

In the 2-D case, the magnitude of the moment is $M_o = F \times d$.



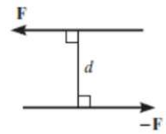
- As shown, d is the perpendicular distance from point O to the line of action of the force.

- The units of a Moment are:
  - *N·m* in the SI system
  - *ft·lbs* or *in·lbs* in the US Customary system

- The direction of M_O is either clockwise or counter-clockwise, depending on the tendency for rotation.

4. Moment of Couples

A couple is defined as two parallel forces that have the same magnitude, but opposite directions, and are separated by a perpendicular distance d. The moment is called a *couple moment*



- Since the resultant force is zero, the only effect of a couple is to produce an actual rotation, or if no movement is possible, there is a tendency of rotation in a specified direction.
- The moment of a couple, M , is defined as having a magnitude of M = F × d

where ***F*** is the magnitude of one of the forces and ***d*** is the perpendicular distance or moment arm between the forces. The ***direction*** and sense of the couple moment are determined by the right-hand rule, where the thumb indicates the axes of rotation and the fingers are curled with the sense of rotation caused by the couple forces. In all cases, M is acting perpendicular to the plane containing these forces.

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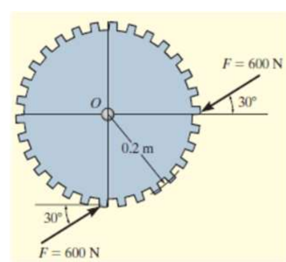
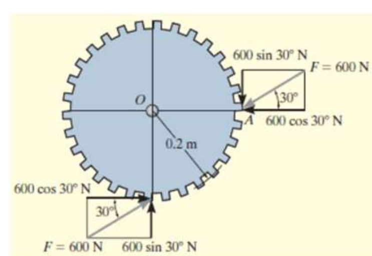
4. Moment of Couples

Example 4.1 : Determine the magnitude and direction of the couple moment for the force system shown in below.



SOLUTION

The solution requires resolving each force into its components as shown. If we consider clockwise moments as positive, we have



+ $M = \sum M$

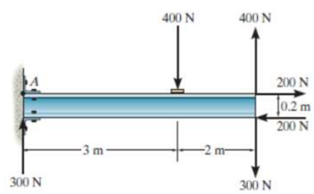
$M = -(600 \cos 30^o)(0.2\ m) + (600 \sin 30^o)(0.2\ m)$

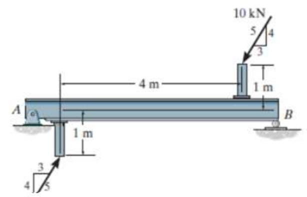
$= -43.9\ N.m \quad = 43.9\ N.m$

4. Moment of Couples

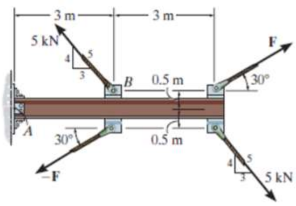
Problems:

1. Determine the resultant couple moment acting on the beams.

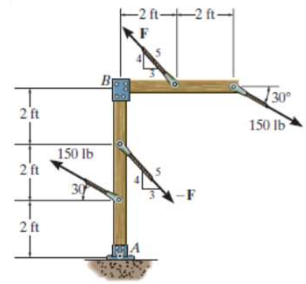




2. Determine the required magnitude of force F , if the resultant couple moment on the beam is to be zero.

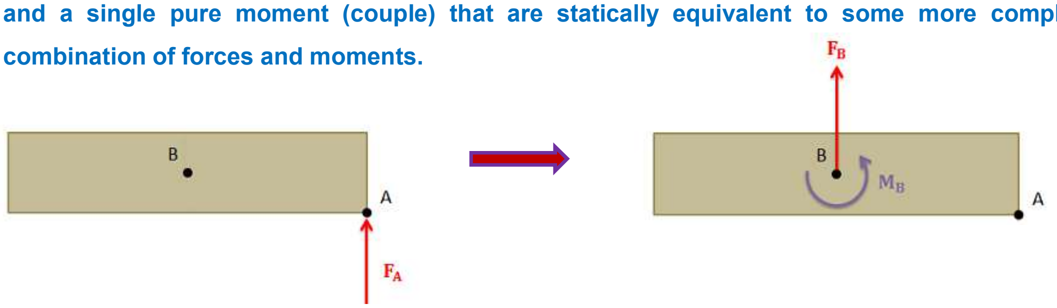


3. Determine the required magnitude of force F if the resultant couple moment on the frame is 200 lb . ft , clockwise.



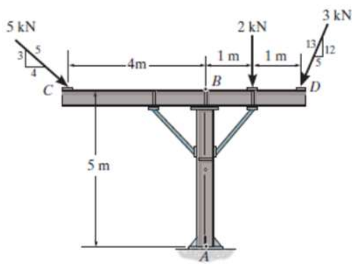
5. Resolution of forces into force and couple

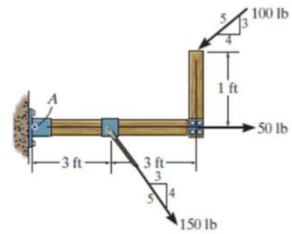
The process of transforming one force applied at one point, into a force and a couple at some other point is known as resolving a force into a force and a couple. The reason is to find the equivalent force couple system for a complex set of forces and moments. The equivalent force couple system is used to simplify more complex analysis, and consists of a single force and a single pure moment (couple) that are statically equivalent to some more complex combination of forces and moments.

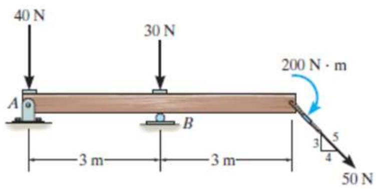


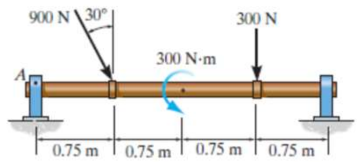
5. Resolution of forces into force and couple

Problems: **Replace the force system acting on the frame by a resultant force and couple moment at point A .**









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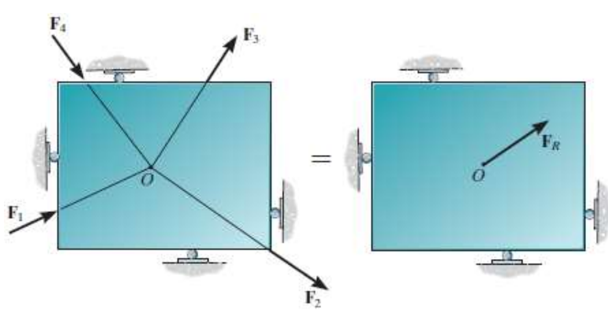
6. Resultants of force systems

- **Concurrent Force System.**

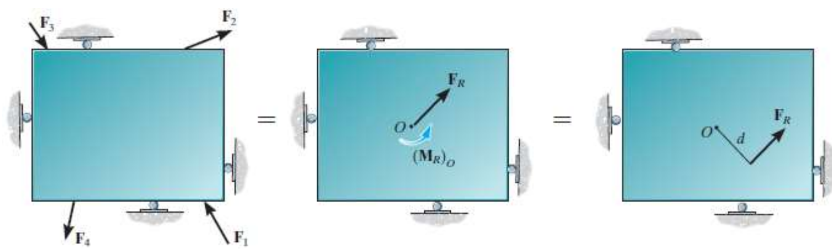
A *concurrent force system* is one in which the lines of action of all the forces intersect at a common point like *O*, then the force system produces no moment about this point. As a result, the equivalent system can be represented by a single resultant force $F_R = \sum \boldsymbol{F}$ acting at *O.*



6. Resultants of force systems

- **Coplanar Force System.**

In the case of a coplanar force system, the lines of action of all the forces lie in the same plane, so the resultant force $\mathbf{F_R} = \sum \boldsymbol{F}$ of this system also lies in this plane. The moment of each of the forces about any point like **O** is directed perpendicular to this plane. Thus, the resultant moment $\mathbf{(M_R)_O}$ and resultant force $\mathbf{F_R}$ will be mutually perpendicular. The resultant moment can be replaced by moving the resultant force $\mathbf{F_R}$ a perpendicular distance **d** away from point **O** such that $\mathbf{F_R}$ produces the same moment $\mathbf{(M_R)_O}$ about point **O**. This distance **d** can be determined from the scalar equation $\mathbf{(M_R)_O = F_R \times d} = \sum \mathbf{M_O}$ or $\mathbf{d = (M_R)_O / F_R}$.



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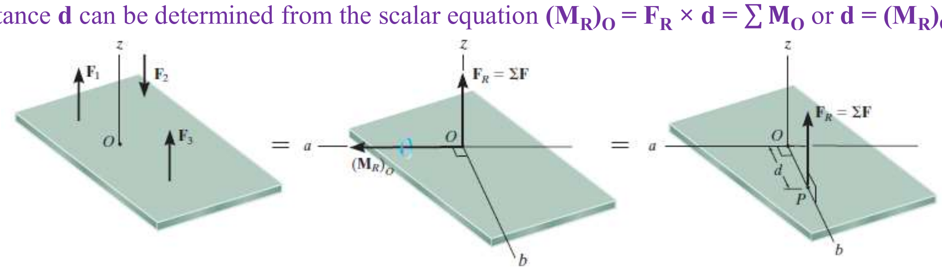
6. Resultants of force systems

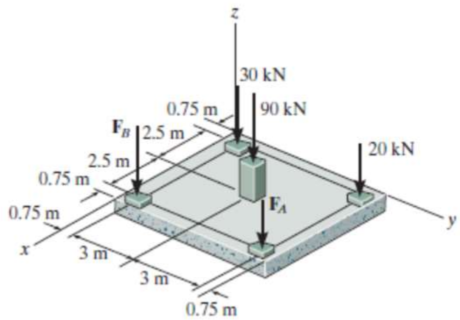
- **Parallel Force System.**

The *parallel force system* consists of forces that are all parallel. Thus, the resultant force $\mathbf{F_R} = \sum \boldsymbol{F}$ at any point like O must also be parallel to them. The moment produced by each force lies in the plane parallel to the forces and so the resultant couple moment, $\mathbf{(M_R)_O}$, will also lie in this plane, along the moment axis a since $\mathbf{F_R}$ and $\mathbf{(M_R)_O}$ are mutually perpendicular. As a result, the force system can be further reduced to an equivalent single resultant force $\boldsymbol{F_R}$, acting through point $\boldsymbol{P}$ located on the perpendicular $\boldsymbol{b}$ axis. The distance **d** can be determined from the scalar equation $\mathbf{(M_R)_O = F_R} \times \mathbf{d} = \sum \mathbf{M_O}$ or $\mathbf{d = (M_R)_O / F_R}$.

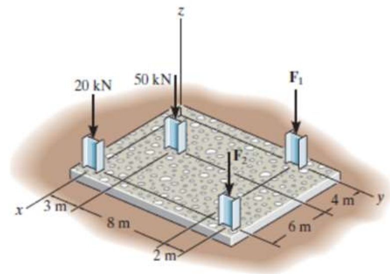


6. Resultants of force systems

Problems: 4. If the resultant force is required to act at the center of the slab, determine the magnitude of the column loadings $\mathbf{F}_A$ and $\mathbf{F}_B$ and the magnitude of the resultant force.



5. The building slab is subjected to four parallel column loadings. Determine the equivalent resultant force and specify its location (**x, y**) on the slab. Take $\mathbf{F}_1$ **= 20 kN**, $\mathbf{F}_2$ **= 50 kN**.



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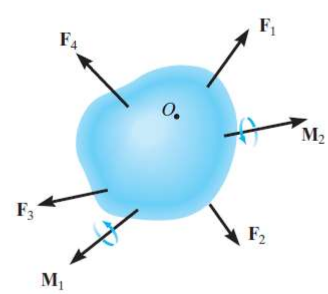
7. Equilibrium

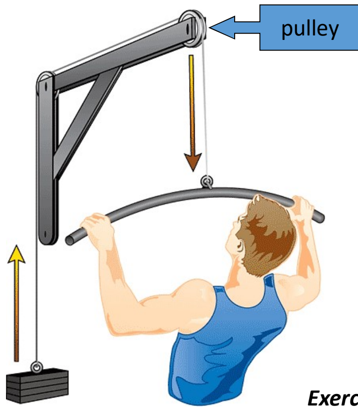
- Statics deals primarily with the description of the force conditions necessary and sufficient to maintain the equilibrium of engineering structures.
- When a body is in equilibrium, the resultant of all forces acting on it is zero. Thus, the resultant force **R** and the resultant couple **M** are both zero, and we have the equilibrium equations.
  - $F_R = \sum \boldsymbol{F} = 0$
  - $(M_R)_O = \sum \mathbf{M}_O = 0$
- These requirements are both necessary and sufficient conditions for equilibrium.



7. Equilibrium

7.4 Pulleys

A pulley wheel is a mechanism which helps move or lift objects.

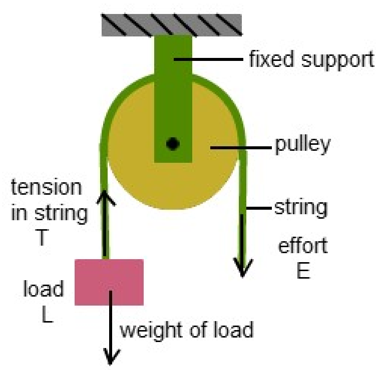


Exercise machine

7. Equilibrium

7.4 Pulleys

Parts of a Pulley System

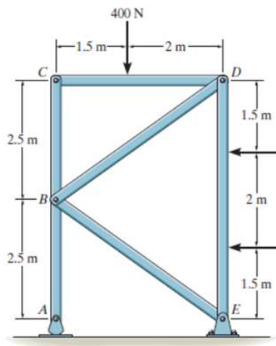


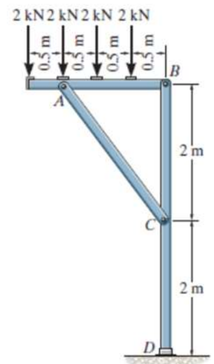
Notice that the pulleys change the direction of the applied force.

7. Equilibrium

Problems:

4. **Determine the horizontal and vertical components of the reactions at A and E.**





5. **Determine the horizontal and vertical components of force and the moment at point D.**

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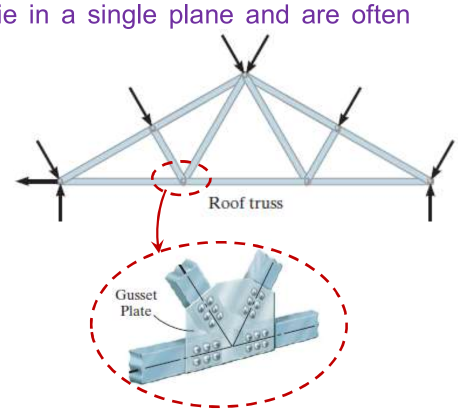
7. Equilibrium

7.5 Truss

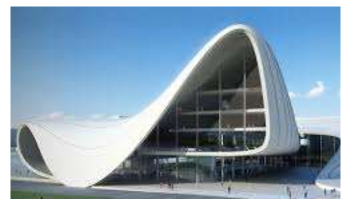
A truss is a structure composed of slender members joined together at their end points. The members commonly used in construction consist of wooden struts or metal bars. In particular, planar trusses lie in a single plane and are often used to support roofs and bridges.



- **The truss load is always applied at the joints.**

7. Equilibrium

7.5 Truss



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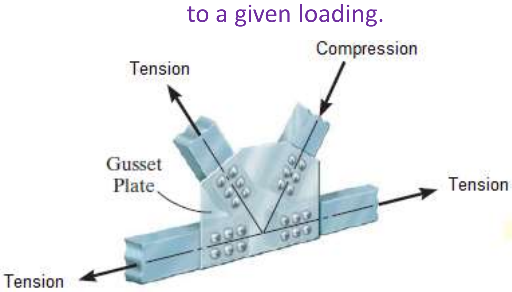
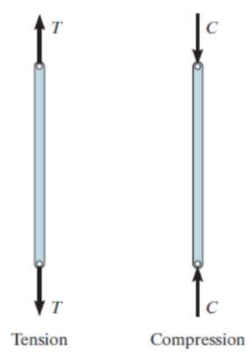
7. Equilibrium

7.5 Truss

- 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.





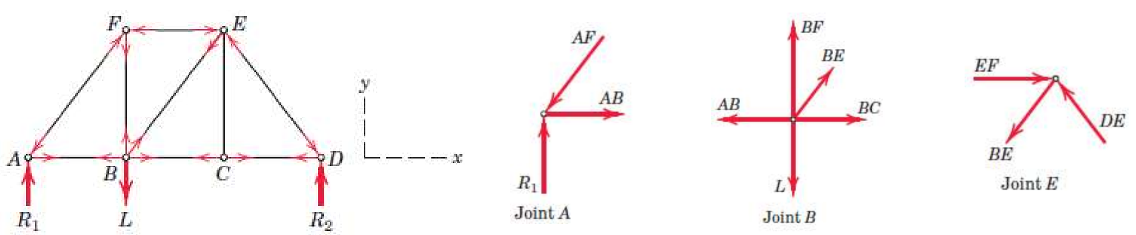
- **We usually assume that the connection is a pin joint**

7. Equilibrium

7.5.1 Analysis of Truss using The Method of Joints

- This method for finding the forces in the members of a truss consists of satisfying the conditions of equilibrium for the forces acting on the connecting pin of each joint. The method therefore deals with the equilibrium of **concurrent forces**, and only two independent equilibrium equations are involved.

$$\sum Fx \rightarrow + = 0 \qquad \sum Fy \uparrow + = 0$$



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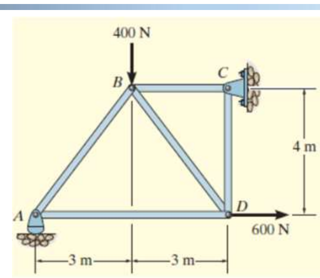
7. Equilibrium

Example 7.6: Determine the force in each member of the truss shown. Indicate whether the members are in tension or compression



SOLUTION

Step One: Draw a FBD of the entire truss and determine the support reactions.

$\sum Fx \rightarrow + = 0$

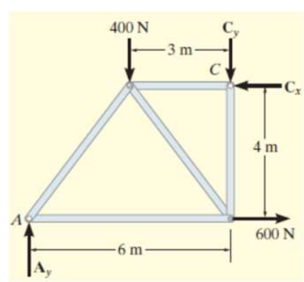
$600\ N - C_x = 0 \quad \Rightarrow C_x = 600\ N \leftarrow$

$\sum M_C \circlearrowright + = 0$

$-(400\ N)(3\ m) - 600\ N\ (4\ m) + A_y\,(6\ m) = 0 \qquad \Rightarrow A_y = 600\ N \uparrow$

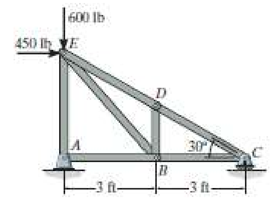
$\sum Fy \uparrow + = 0$

$600\ N - 400\ N - C_y = 0 \quad \Rightarrow \quad C_y = 200\ N \downarrow$



7. Equilibrium

Example 7.9: **Determine the force in each member of the truss.**
State if the members are in tension or compression.



SOLUTION

7. Equilibrium

7.5.1 Analysis of Truss using The Method of Sections

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. 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.”