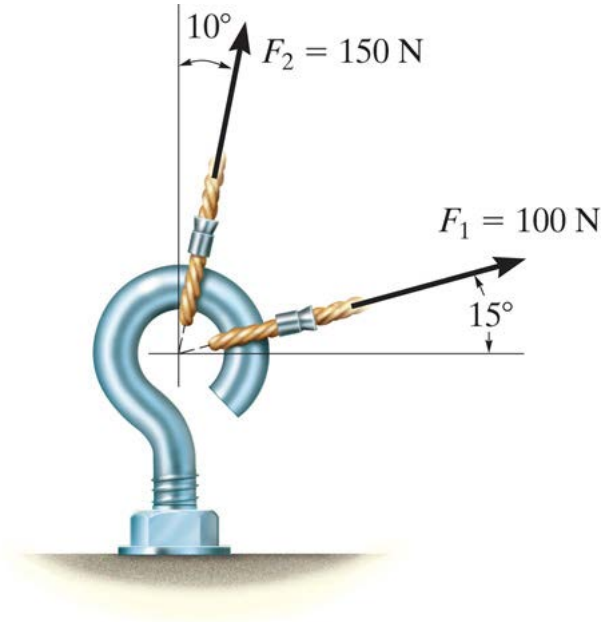
E126 Class Problems

Fall 2020

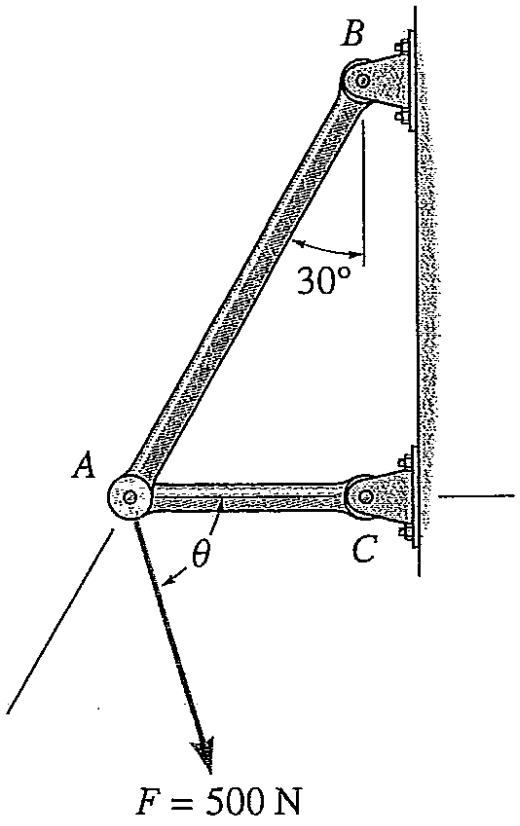
Problem 1-1:

The hook is subjected to two forces F_1 and F_2 as shown. Determine the magnitude of the resultant of these two forces and its direction measured counterclockwise from the positive x-axis.



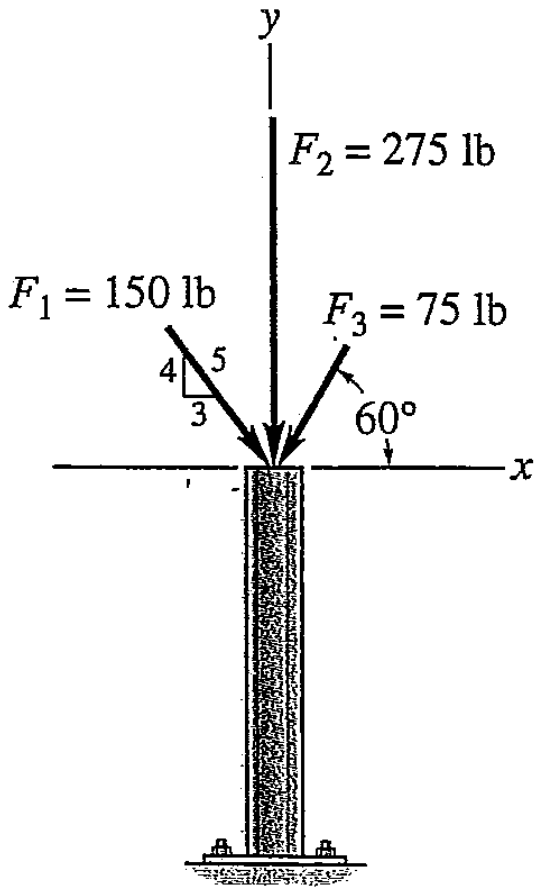
Problem 1-2:

The force acting on the frame has a magnitude of 500 N and is to be resolved into two components acting along members AB and AC. Determine the angle θ so that the component F_{AC} is directed from A toward C and has a magnitude of 400 N.



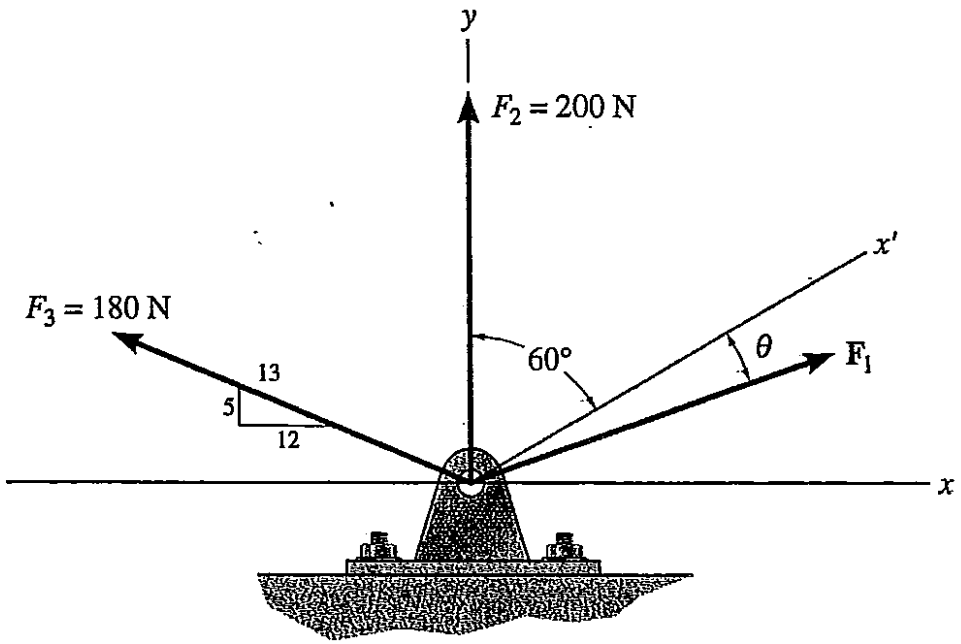
Problem 1-3:

Find the Resultant Force for all of the forces acting on the column using the components of the forces.



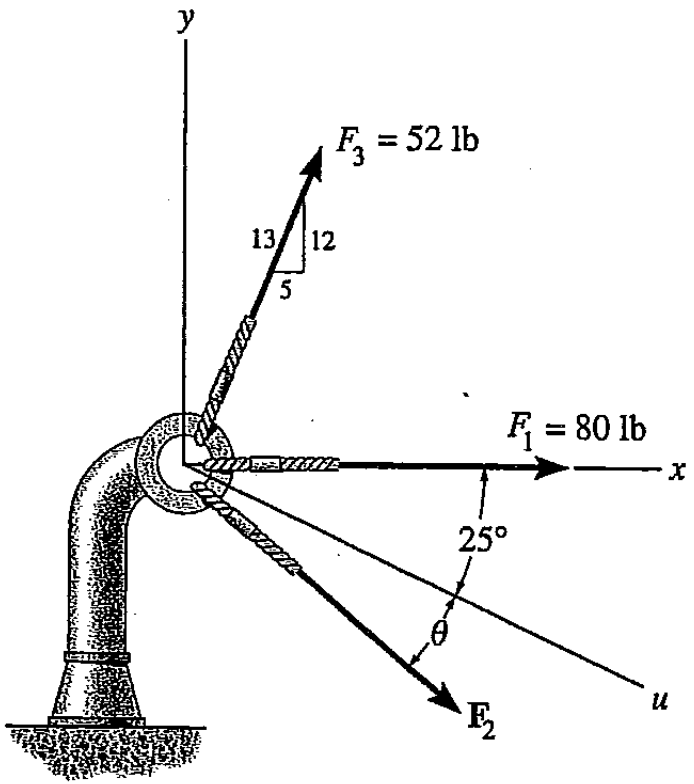
Problem 1-4:

Three forces act on a bracket as shown. Determine the magnitude and direction of θ of F_1 so that the resultant force is directed along the positive x' axis and has a magnitude of 800N.



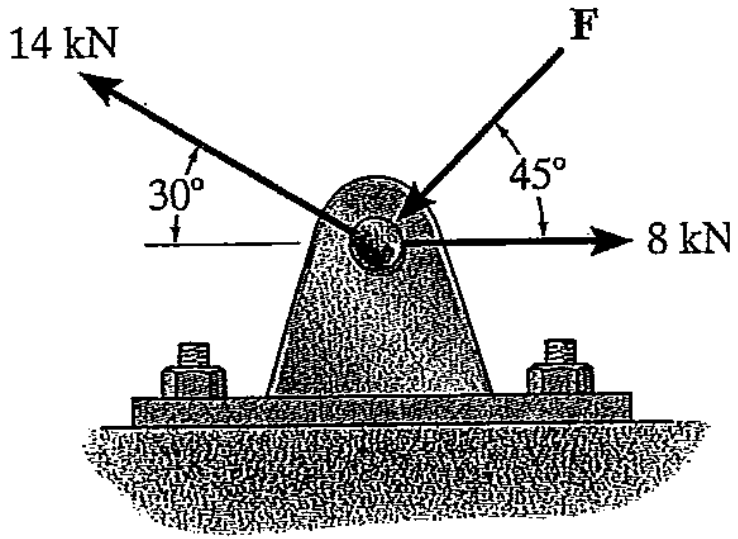
Problem 1-5:

If $F_2 = 150$ lb and $\theta = 55°$, determine the magnitude and direction (measured clockwise from the positive x-axis) of the resultant force for the 3 forces on the bracket.



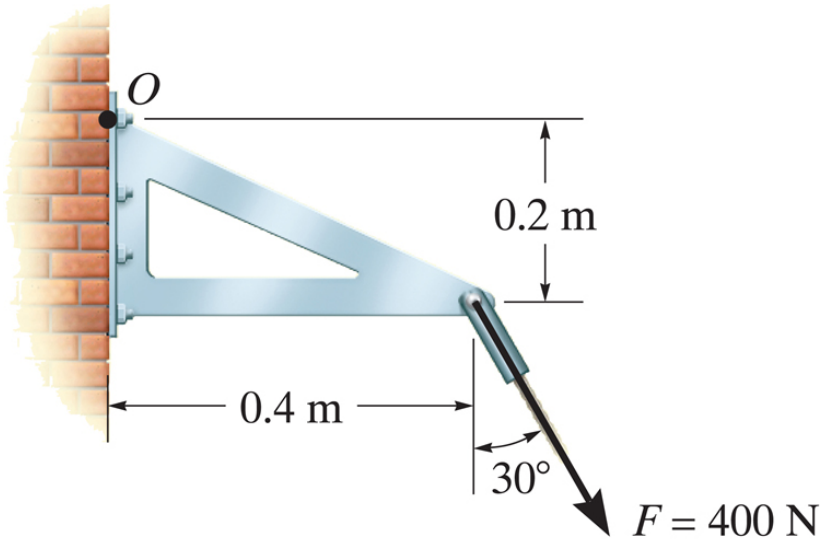
Problem 1-6:

Determine the magnitude of the force F so that the resultant of the three forces is as small as possible. What is the magnitude of the smallest resultant force?



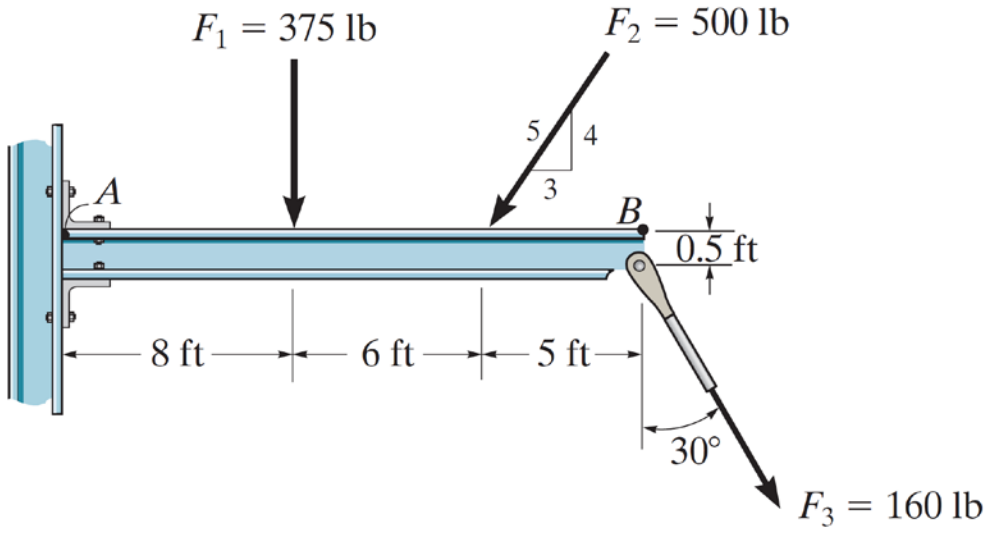
Problem 2-1:

The force F acts at the end of the angle bracket as shown. Determine the moment of the force *F* about point *O*.



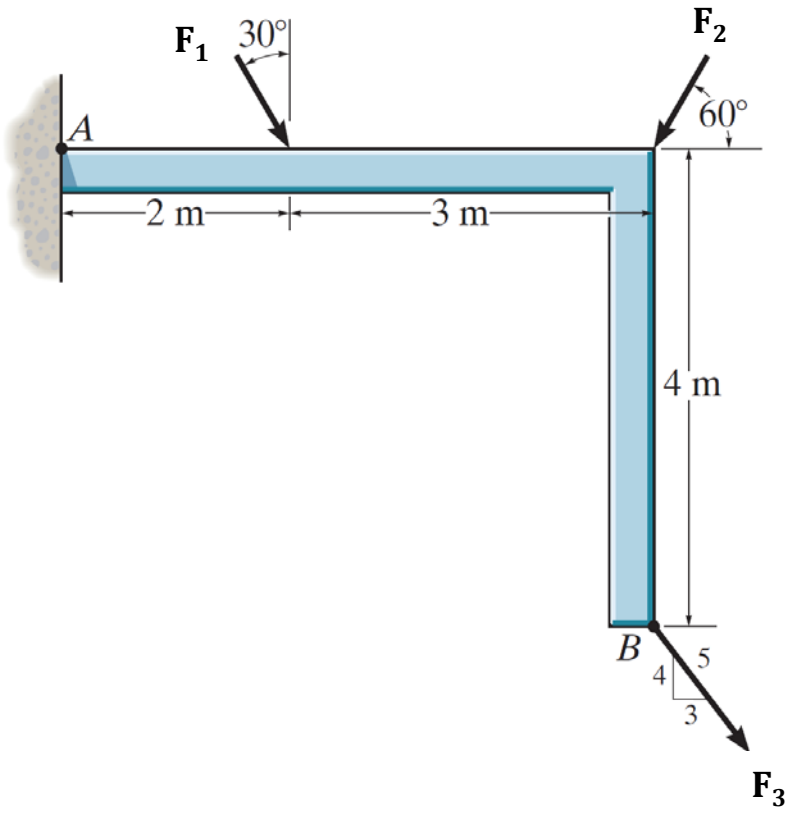
Problem 2-2:

Determine the moment about point *B* of each of the three forces acting on the beam.



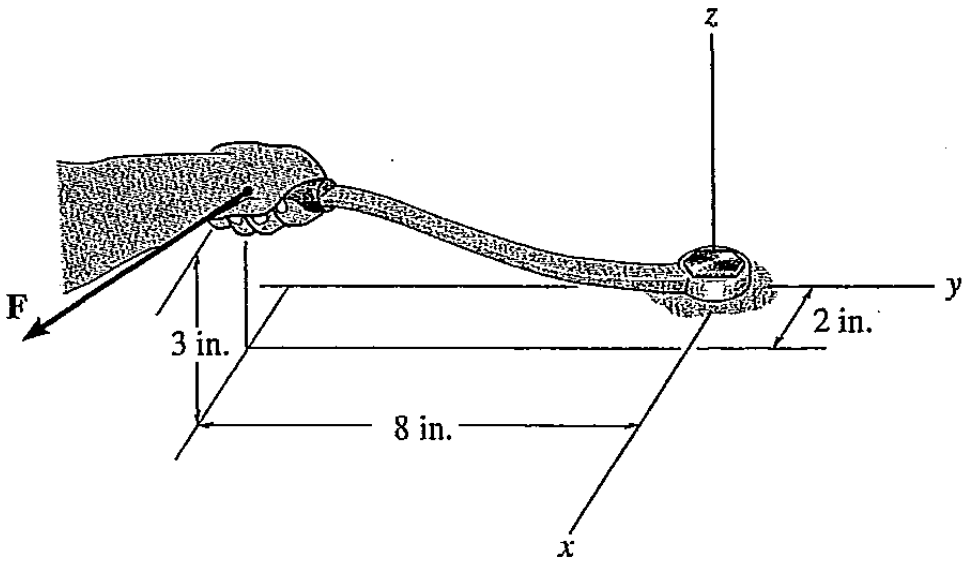
Problem 2-3:

Three forces act on the angle bracket as shown. If the resultant moment about point A has a magnitude of 4800 N-m clockwise, determine the magnitude of the force F_3 if $F_1 = 300$ N and $F_2 = 400$ N.



Problem 2-4:

If the force $\vec{F} = \left(8\vec{\imath} - \vec{\jmath} + \vec{k}\right)$ lb is applied to the handle of the wrench as shown, determine the component of the moment of this force about the z-axis. Note this torque loosens the bolt.

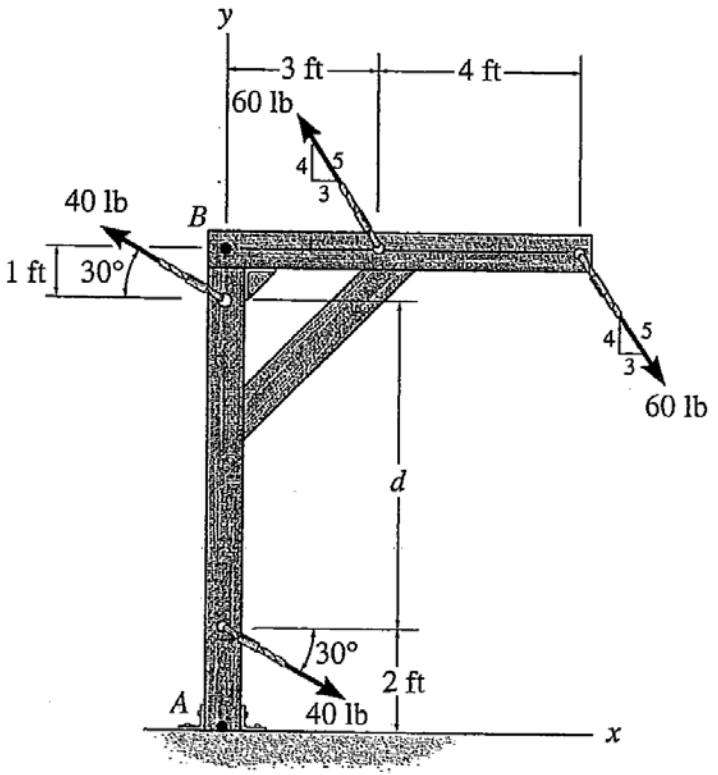


Problem 2-5:

Two couples act on the frame as shown. If $d = 4$ ft, determine the resultant couple moment in two ways:

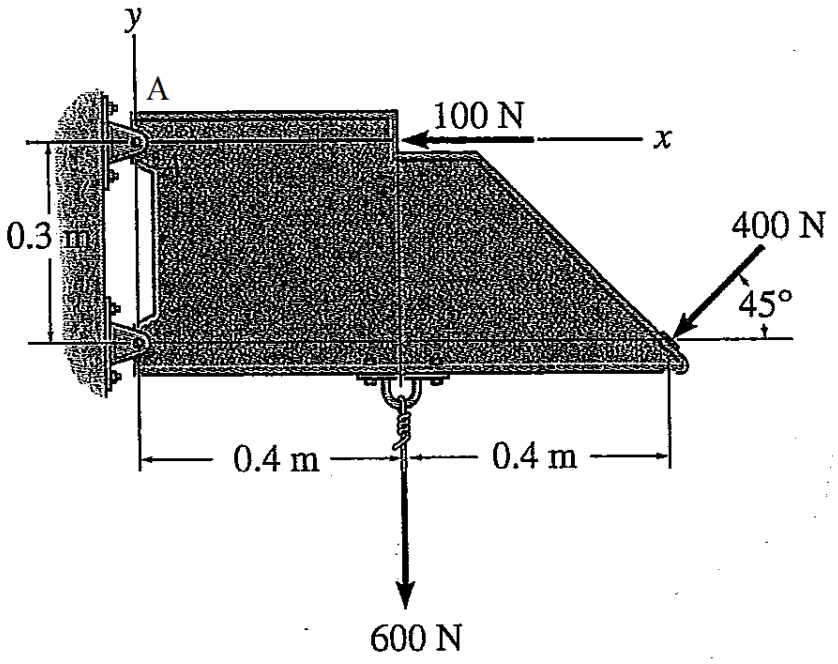
(a) by finding the moment of each couple

(b) by finding the resultant moment of the four forces



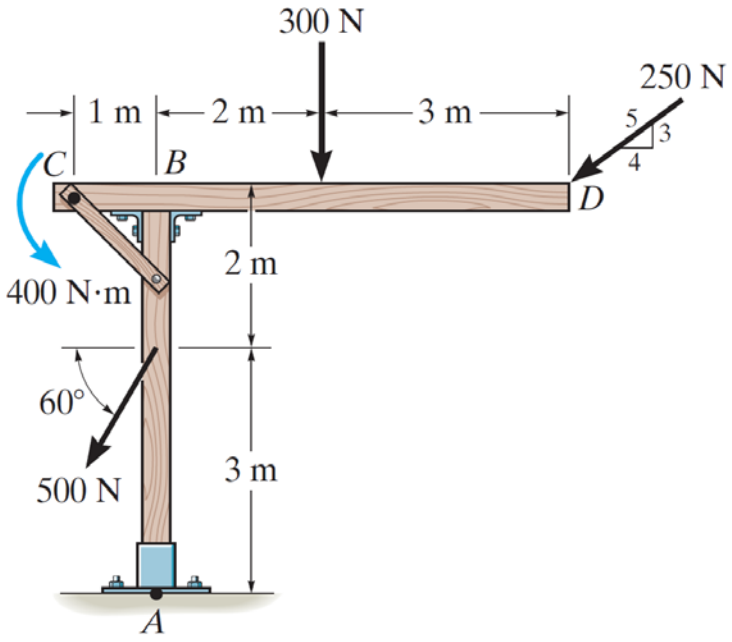
Problem 2-6:

Replace the forces acting on the brace as shown by an equivalent force and couple system acting at point *A*.



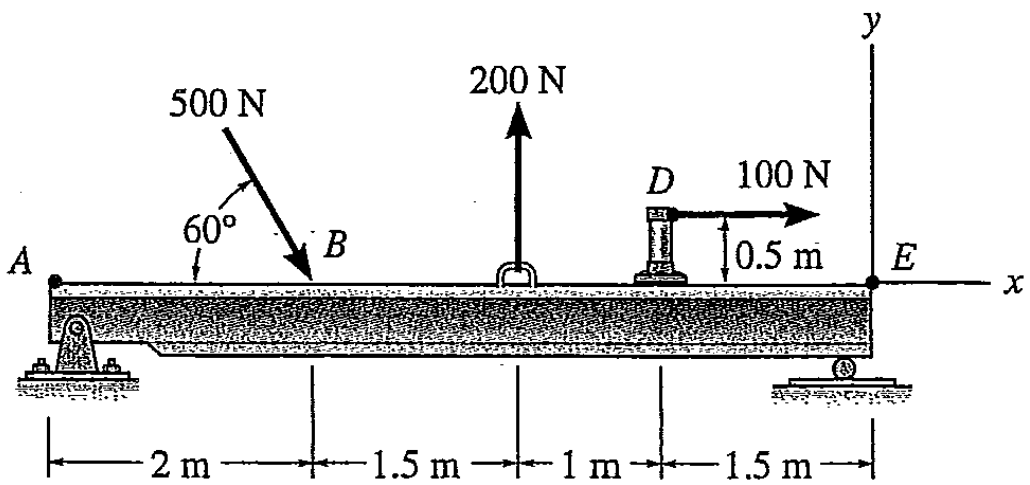
Problem 2-7:

The frame is subjected to the loading as shown. Replace this loading by an equivalent force and couple system at point A.



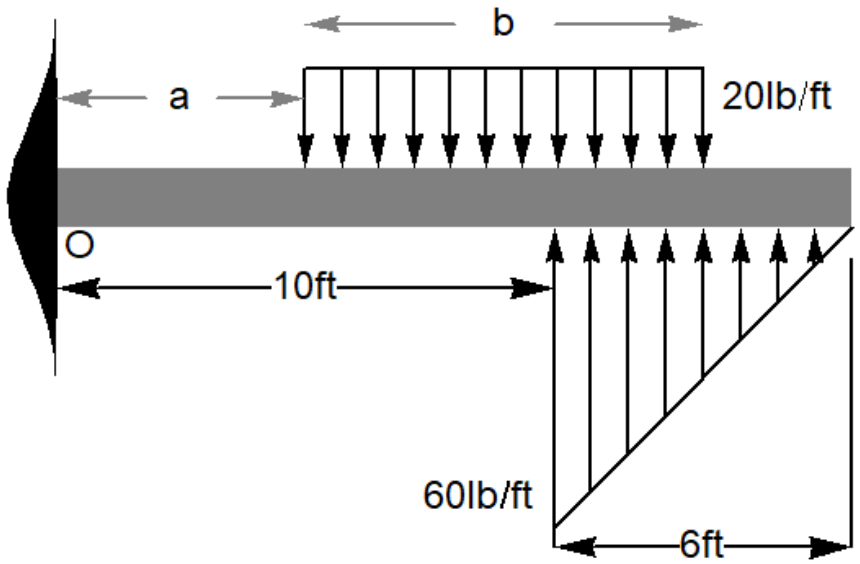
Problem 2-8:

The beam *AE* is subjected to a system of planar forces as shown. Determine the magnitude and direction of the equivalent resultant force and its location on the beam (as measured from point *E*).



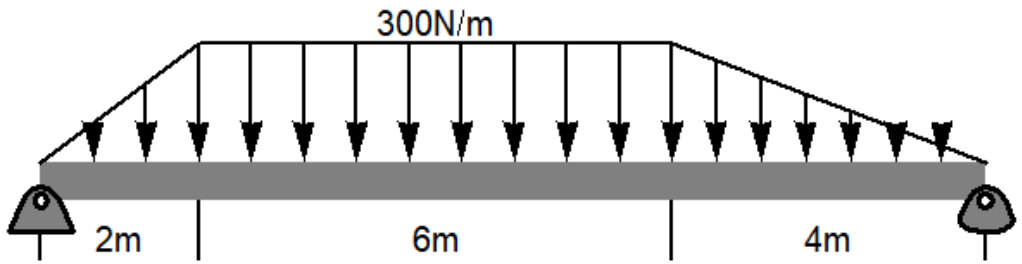
Problem 2-9:

The beam is subjected to two distributed loads as shown. Determine the lengths *a* and *b* on the beam such that the resultant force and resultant couple at the fixed support, *O*, are zero.



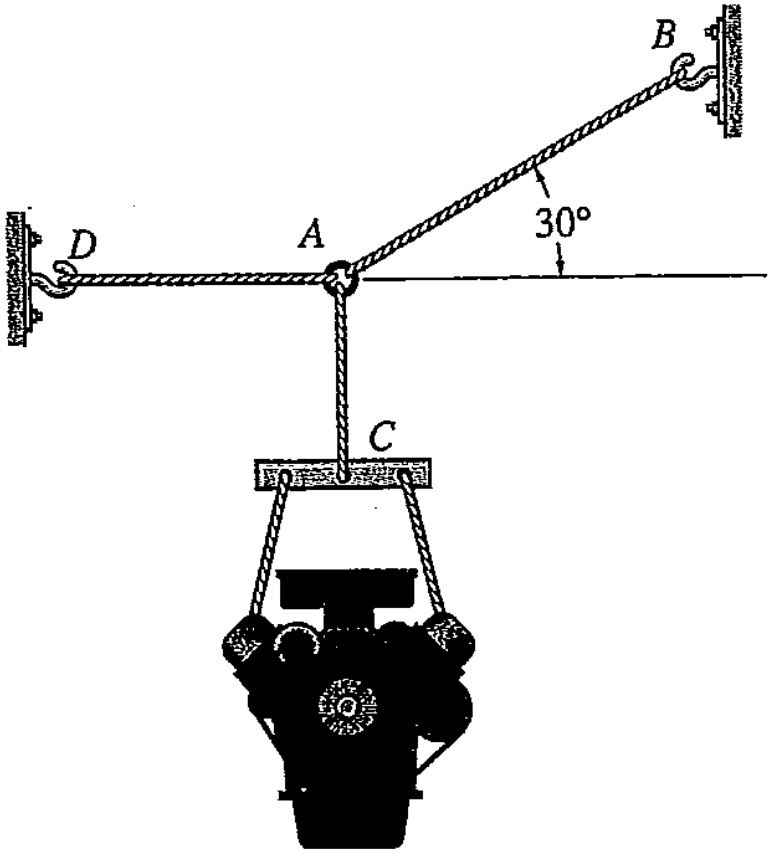
Problem 2-10:

The beam is subjected to a system of distributed loads. Determine the resultant of this system of distributed loads and locate its line of action with respect to the left support.



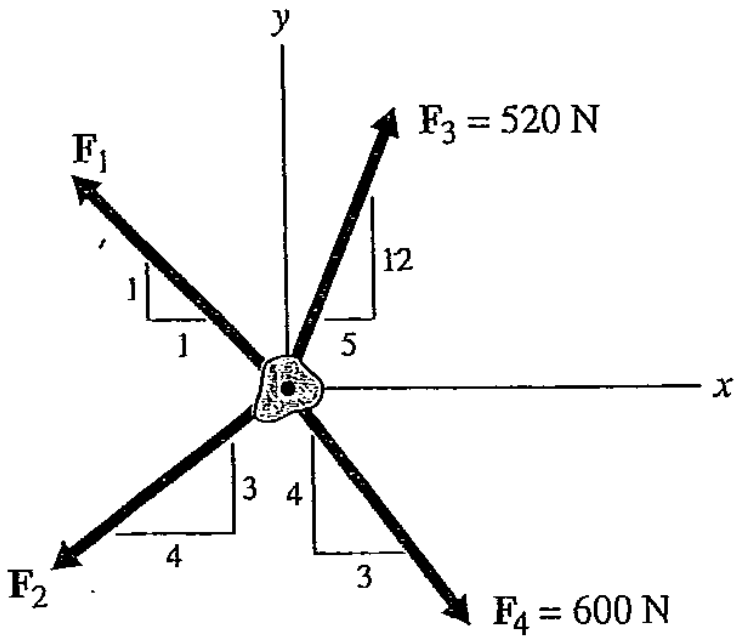
Problem 3-1:

The 250 kg engine is supported by the cables *AB*, *AC* and *AD* as shown. Determine the tension in cables *AB* and *AD* using equilibrium.



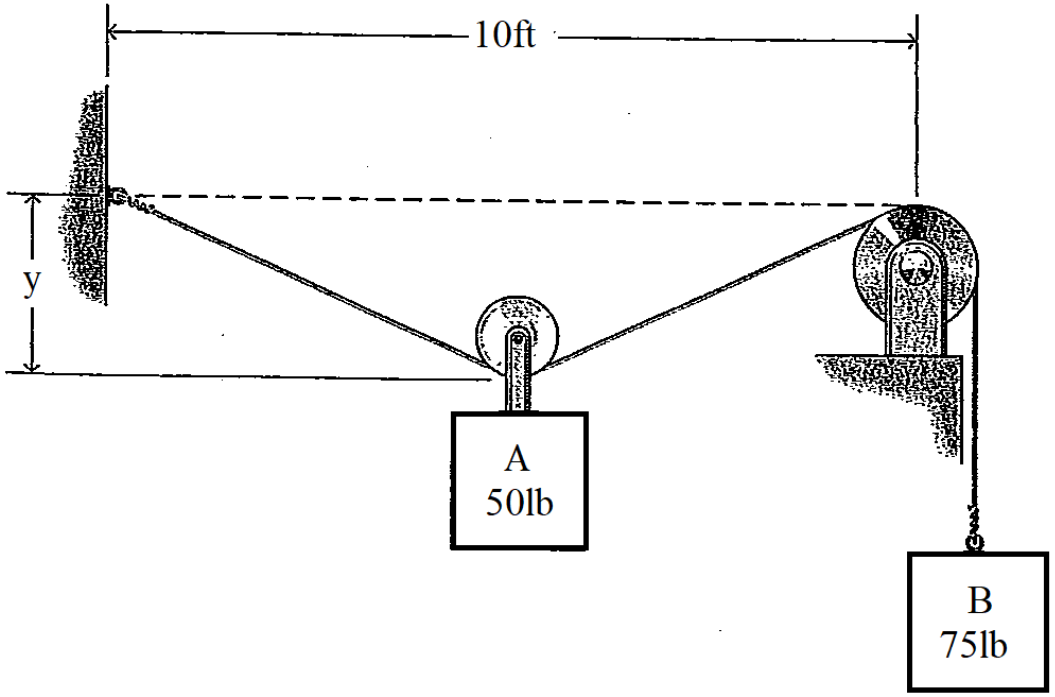
Problem 3-2:

Four forces act on a particle as shown. Determine the magnitude of the forces, F_1 and F_2 so that the particle is in equilibrium.



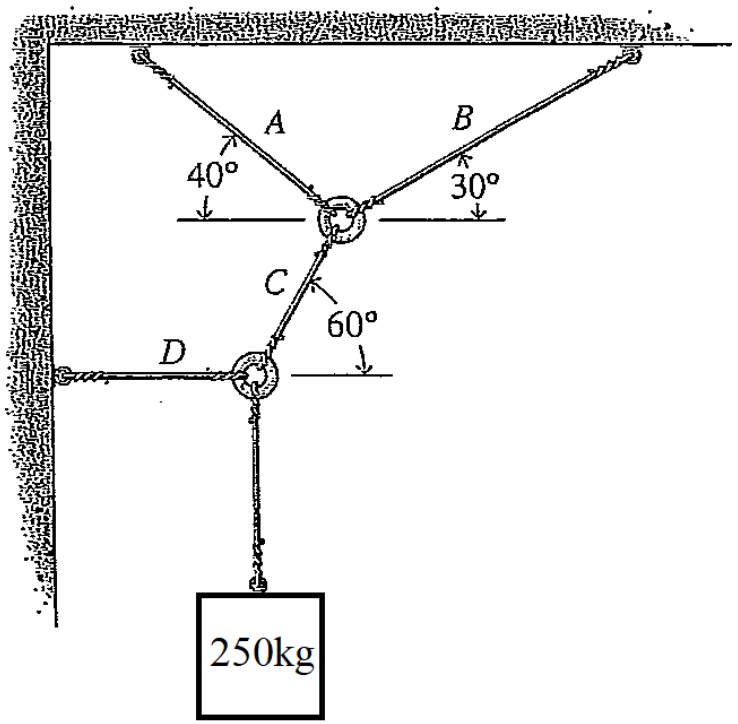
Problem 3-3:

A continuous cable is used to support two blocks as shown. The tension in the cable does not change as it passes around the small frictionless pulley. Block *A* is supported by a small wheel that is free to roll on the cable. Determine the displacement y of block *A* for equilibrium.



Problem 3-4:

A 250 kg block is supported by the flexible cable system as shown. Determine the tension in cables *A*, *B*, *C* and *D*.



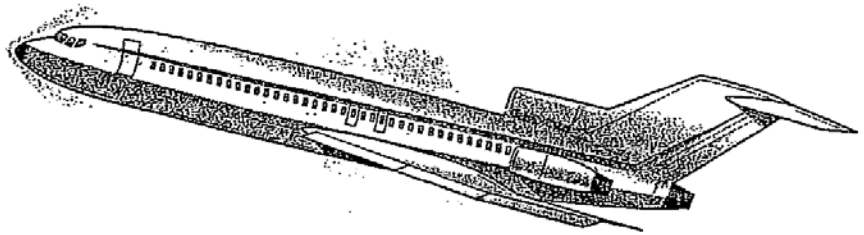
Problem 3-5:

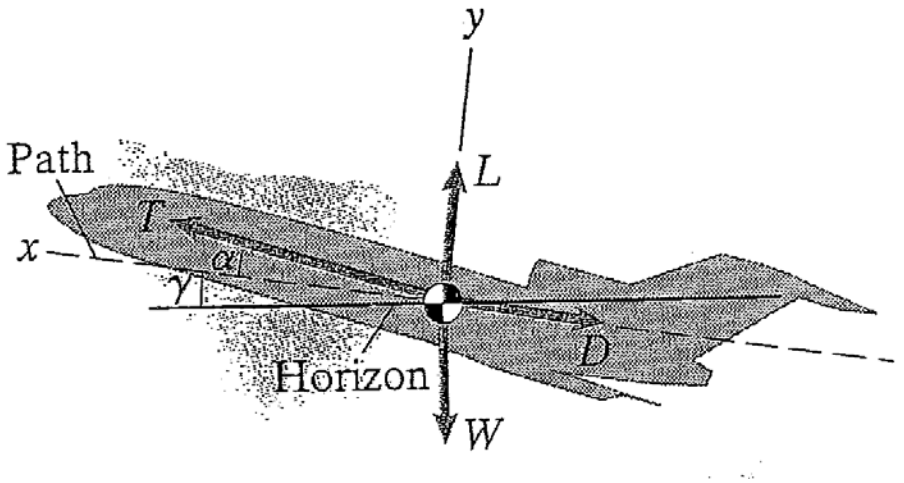
The airplane pictured is in steady flight at a constant velocity. The dashed line is the plane's path. The aerodynamic forces are resolved into the lift, L, which is perpendicular to the path and the drag, D, which is parallel to the path. The other forces acting on it are the weight, W, and the thrust, T. The flight path angle is γ and the angle of attack is α.

$$\gamma = 6°, D = 125 \text{ kN}, L = 680 \text{ kN}, m_{plane} = 7200 \text{ kg}$$

a. Determine the thrust, T, required for steady flight

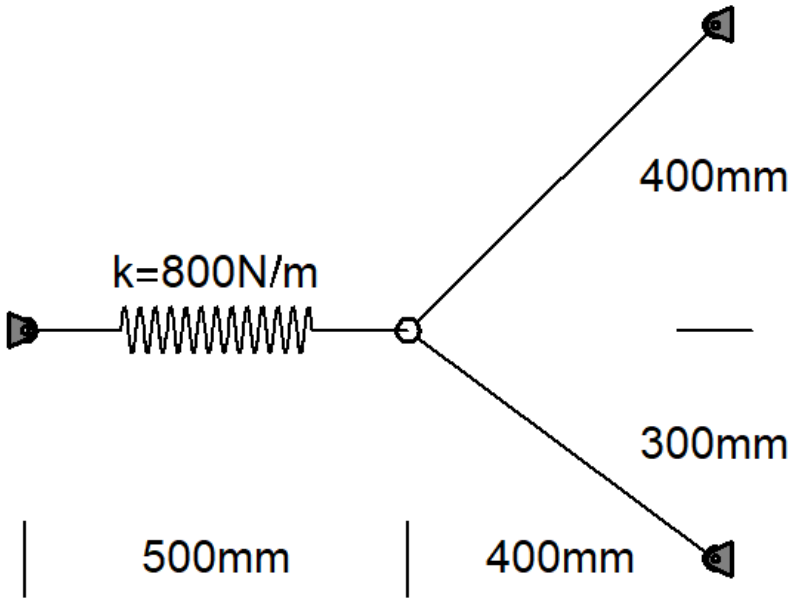
b. Find the angle of attack, α





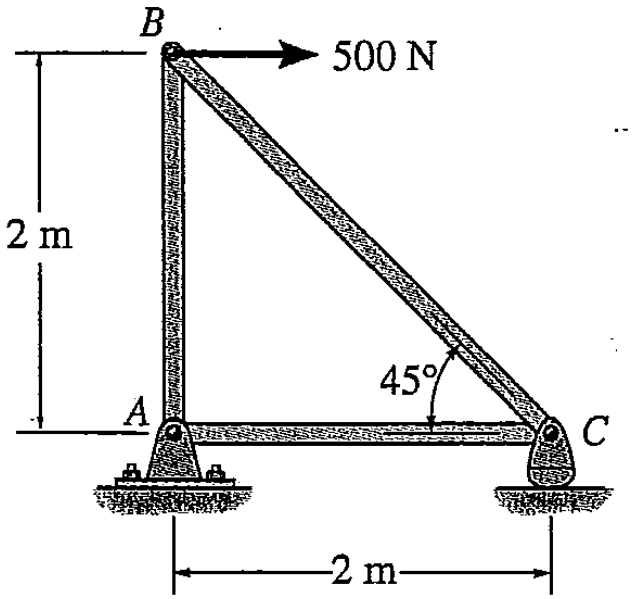
Problem 3-6:

The spring has a stiffness, $k = 800$ N/m and an unstretched length of 200 mm. Determine the force in cables *BC* and *BD* when the spring is in the position shown.



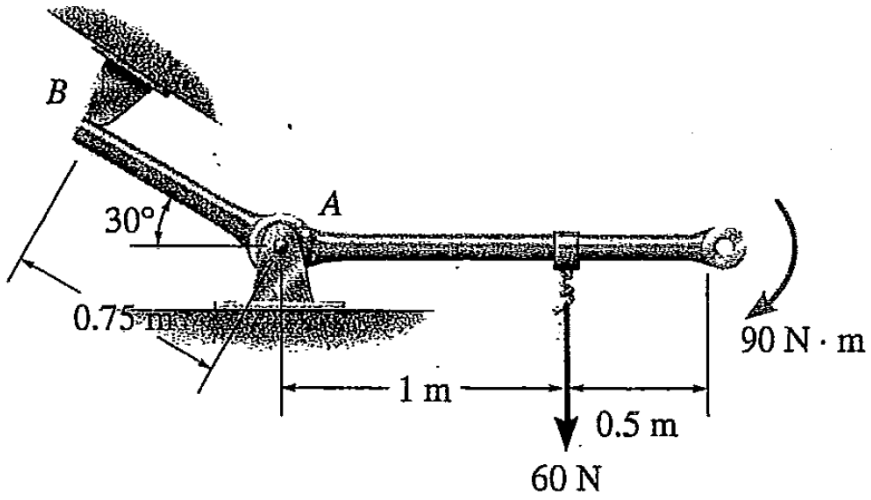
Problem 3-7:

The simple truss is loaded by a 500 N force at B, and it is supported at A and C as shown. Determine the force in each member of the truss.



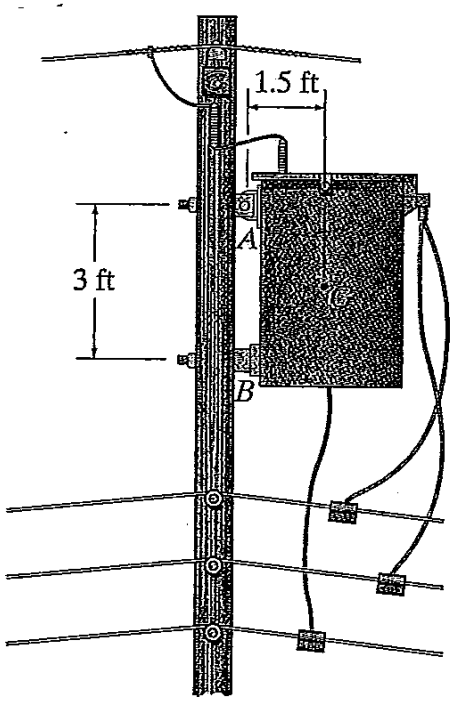
Problem 3-8:

The beam is supported by a frictionless pin at A and it rests against a smooth support at B, and it is loaded as shown. Determine the components of the reaction at A and the reaction force at B.



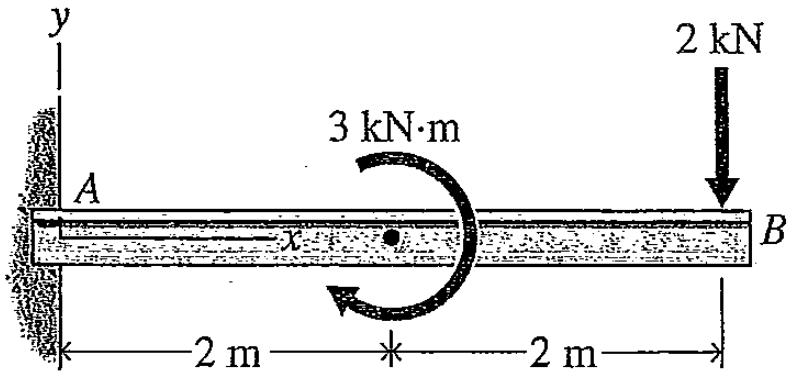
Problem 3-9:

The 300lb electrical transformer with a center of gravity, G, is supported by a pin at A and a smooth pad at B. Determine the horizontal and vertical components of the reactions at A and B.



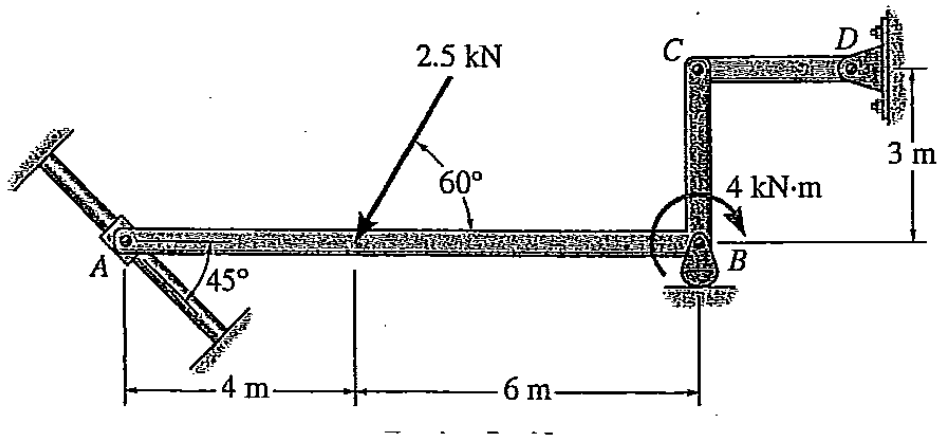
Problem 3-10:

The beam is loaded and has a fixed support at A. Find the reactions at A.



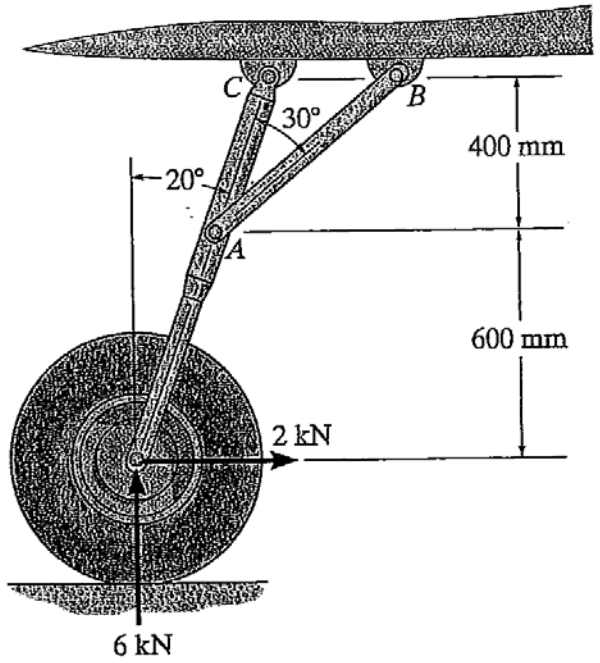
Problem 3-11:

The rod ABC is loaded as shown and it is supported by a smooth collar at A. a smooth rocker at B and a link at C. Determine the components of the reactions at the supports.



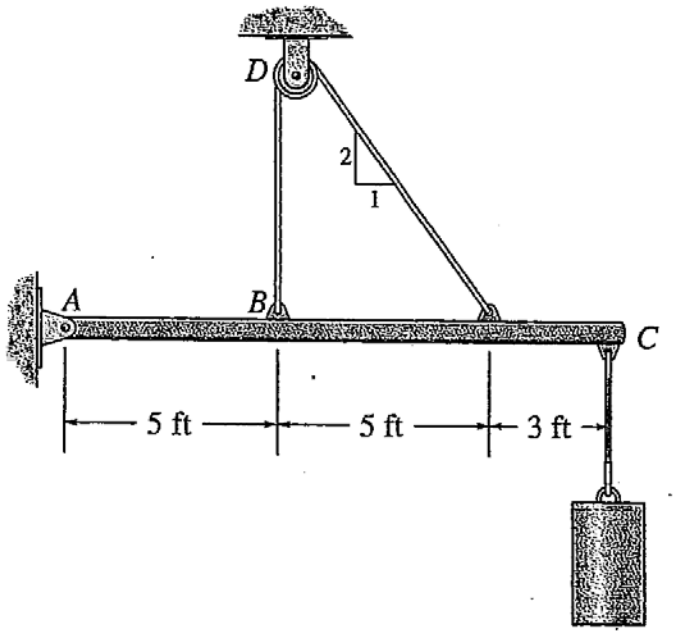
Problem 3-12:

As an airplane's brakes are applied, the nose wheel exerts two forces on the end of the landing gear as shown. Determine the horizontal and vertical components of the reaction at C and the force at in the strut AB. Joints at A, B and C are pins.



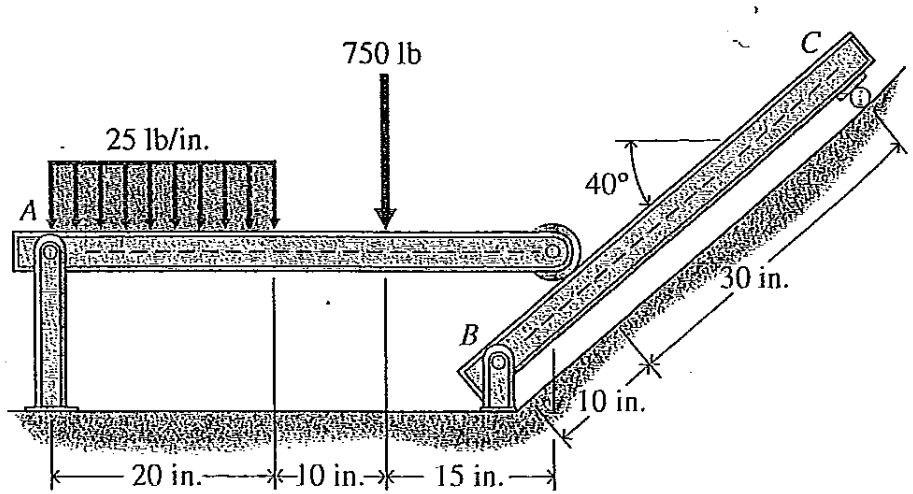
Problem 3-13:

Determine the tension in the cable and the horizontal and vertical components of reaction of the pin at A. The pulley at D is frictionless and the cylinder weighs 80lb.



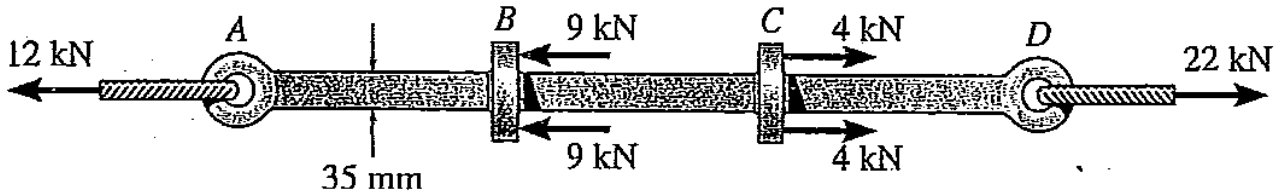
Problem 3-14:

The two beams are loaded and supported as shown. Determine the reactions at the supports A, B and C.



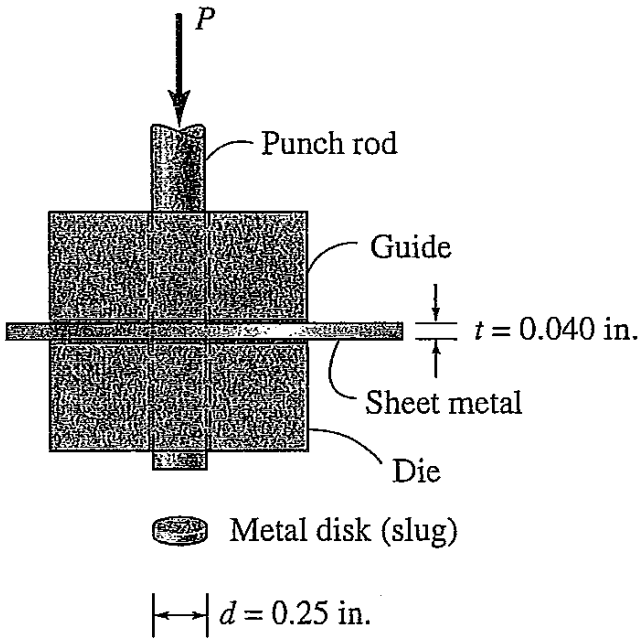
Problem 4-1:

The bar shown has a constant width of 35mm and a thickness of 10mm. Determine the maximum normal stress in the bar when it is subjected to the loading shown.



Problem 4-2:

A metal punch is used to punch holes in thin sheet metal. A force of P=1000lb is required to punch a ¼ in diameter disk out of the sheet metal that is 0.04in thick. Find the average shear stress in the sheet metal resulting from the punching operation.

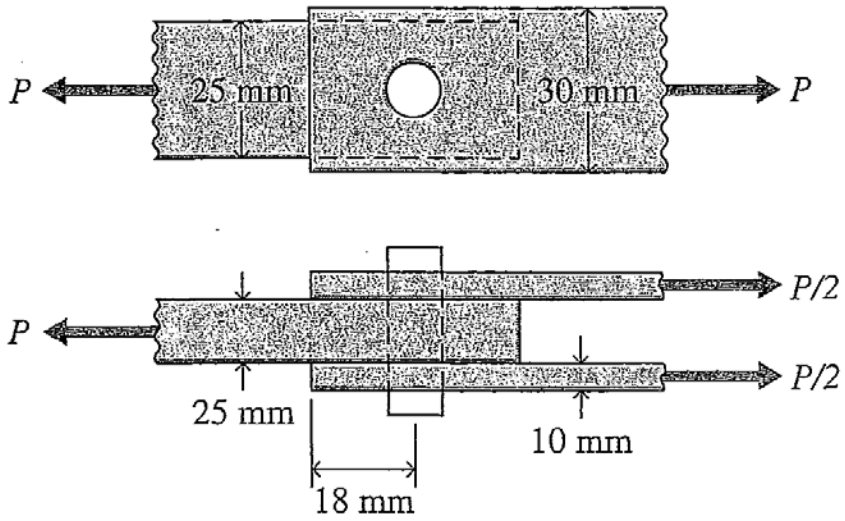


Problem 4-3:

Three plates are joined with a 12mm diameter pin as shown. Determine the maximum load, P, that can be transmitted by the joint if:

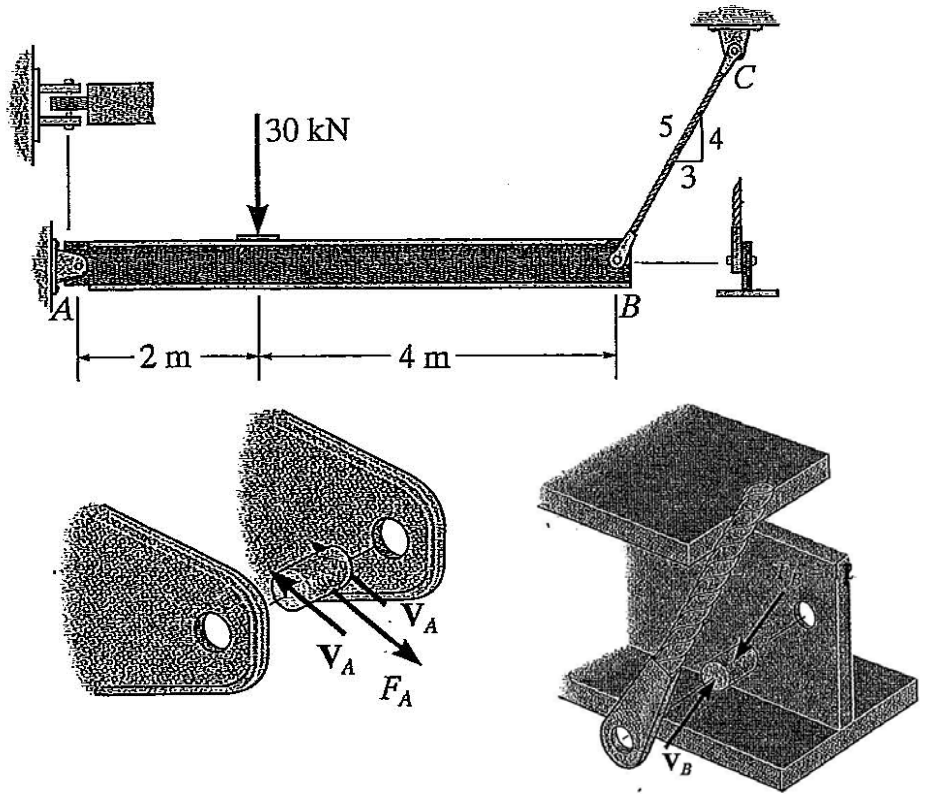
a. the maximum normal stress on the cross section at the pin be limited to 350MPa

b. the maximum shear stress on the cross section of the pin must be limited to 240MPa



Problem 4-4:

Determine the average shear stress in the 20mm diameter pin at A and the 30mm diameter pin at B that support the beam. Pin A is under double shear and Pin B is in single shear.

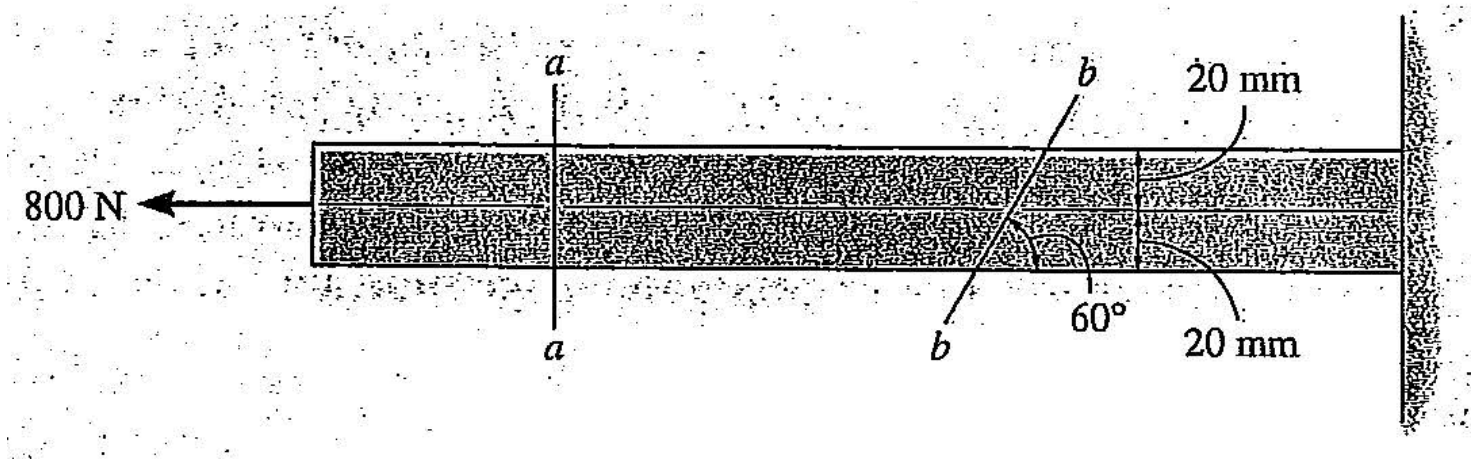


Problem 4-5:

The bar shown has a square cross section of 40mm on each side. If an external force of 800N is applied along the centroidal axis of the bar's cross section, determine the average normal stress and the average shear stress acting on the bar

a. along the plane a-a

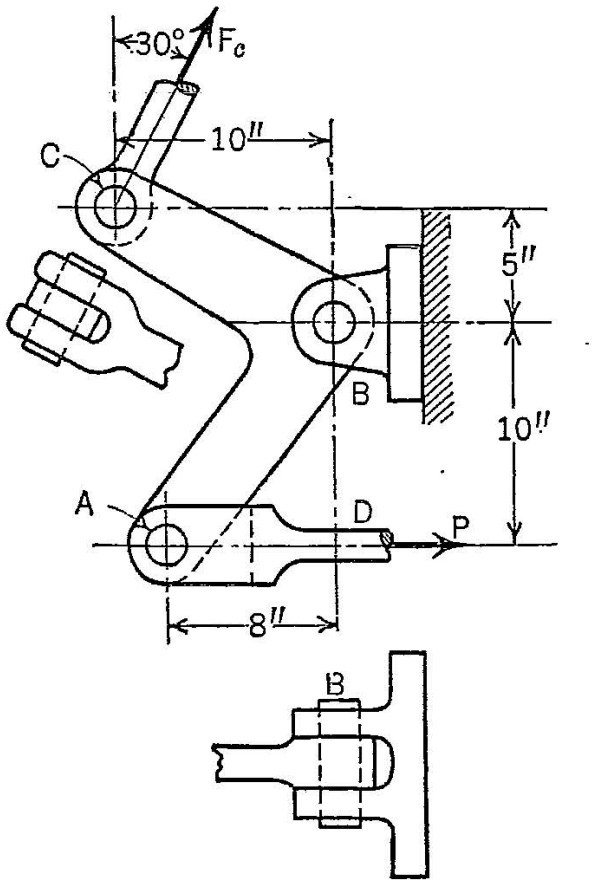
b. along the plane b-b



Problem 4-6:

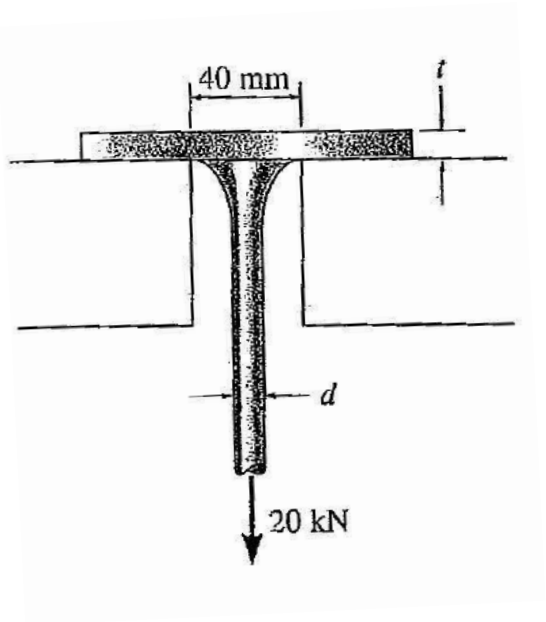
A bell-crank lever is used in various mechanisms to change the direction and magnitude of a force. Determine the size of pins B and C so that the factor of safety of each pin in shear will equal the factor of safety of the rod D in tension.

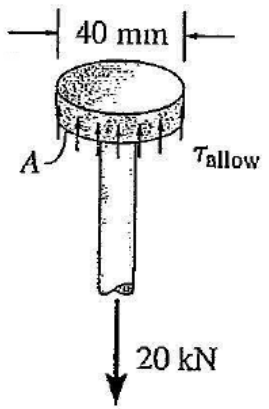
$$S_{ut} = 70kpsi, \qquad S_{su} = 50kpsi, \qquad d_D = 1.4in$$



Problem 5-1:

The suspender rod is supported at its end by a fixed connected circular disk as shown. If the rod passes through a 40mm diameter hole, determine the minimum required diameter of the rod and the thickness of the aluminum disk needed to support the 20kN rod. The rod has an allowable normal stress of 60MPa and the disk has an allowable shear stress of 35MPa.



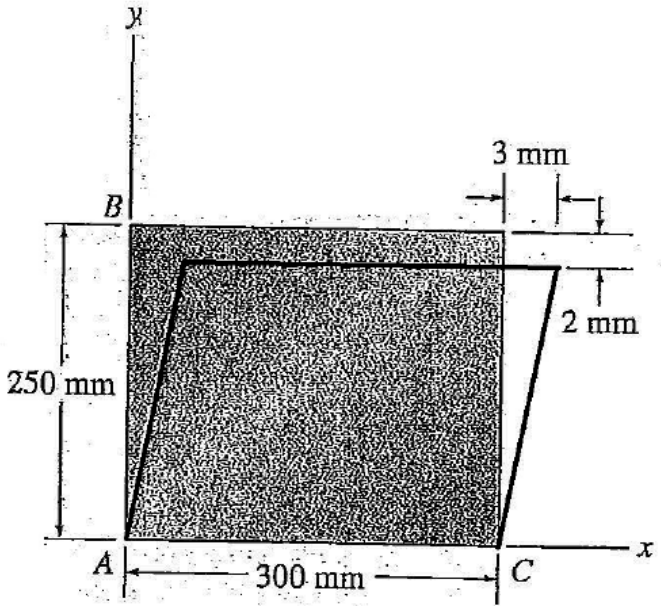


Problem 5-2:

The plate is deformed into the dashed shape shown. Assume that in this deformed shape, horizontal lines on the plate remain horizontal and their length does not change. Determine:

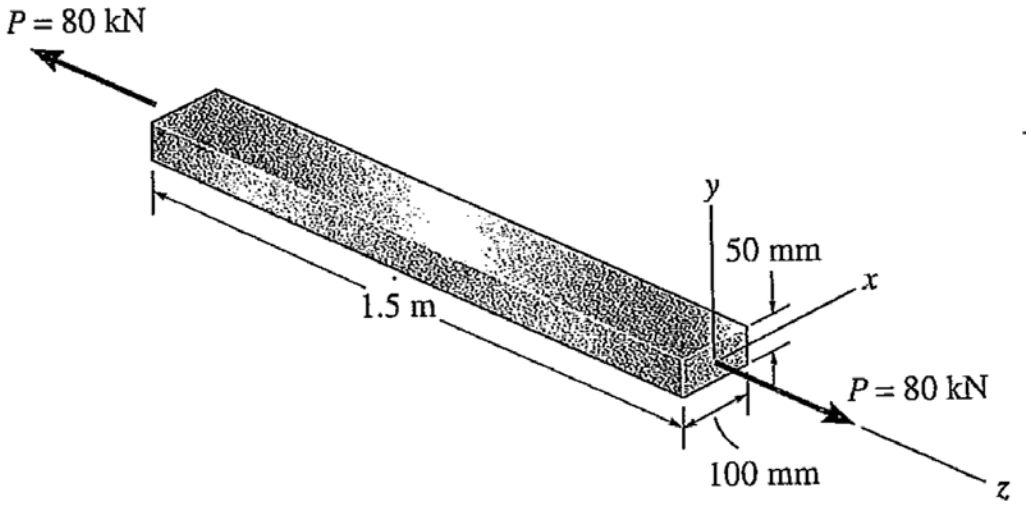
a. the average normal strain along AB

b. the average shear strain in the plate relative to the x and y axes



Problem 5-3:

A steel bar has the dimensions shown. If an axial force of P = 80 kN is applied to the bar, determine the change in its length and the change in the dimensions of its cross-section after applying the load. Use E_{st} = 200 GPa and ν_{st} = 0.3; assume elastic behavior of the material.



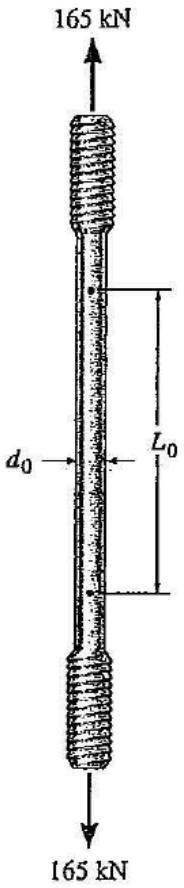
Problem 5-4:

The aluminum specimen shown has an initial diameter of 25mm and a gage length of 250mm. If a force of 165kN caused the gage length to elongate by 1.2mm, determine:

a. the modulus of elasticity

b. the change in the diameter of the specimen

$$G = 26GPa, \qquad S_y = 440MPa$$



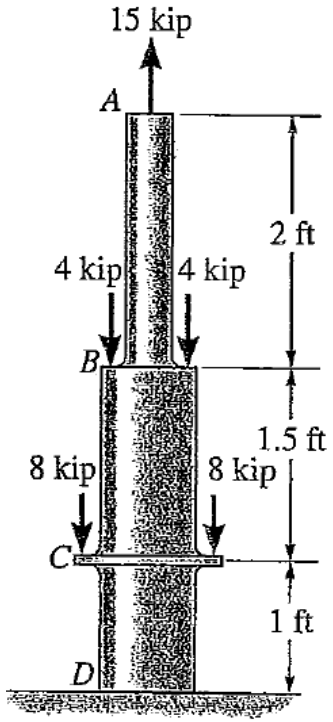
Problem 6-1:

The composite steel bar shown is made from two segments AB and BD, having cross sectional areas of $A_{AB} = 1in^2$ and $A_{BD} = 2in^2$ respectively. If the bar is subjected to the loads shown, determine:

a. the vertical displacement of point A

b. the displacement of point B relative to C

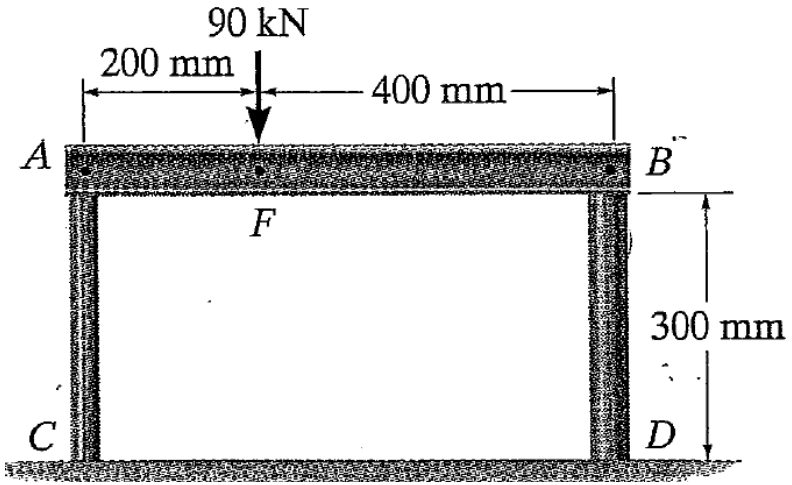
$$E_{Steel} = 29Mpsi$$



Problem 6-2:

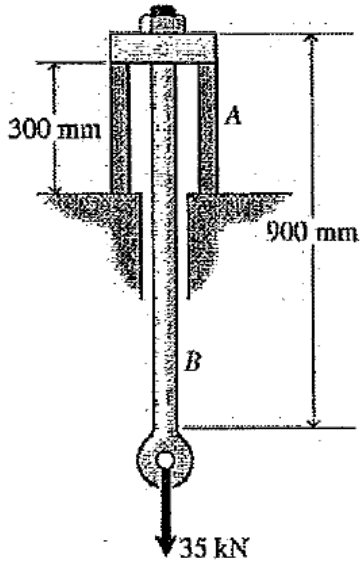
A rigid beam, AB, rests on two short posts. AC is made of steel and has a diameter of 20mm; BD is made of aluminum and has a diameter of 40mm. Find the displacement of point F if a vertical force of 90kN is applied over this point.

$$E_{steel} = 200GPa, \qquad E_{aluminum} = 70GPa$$



Problem 6-3:

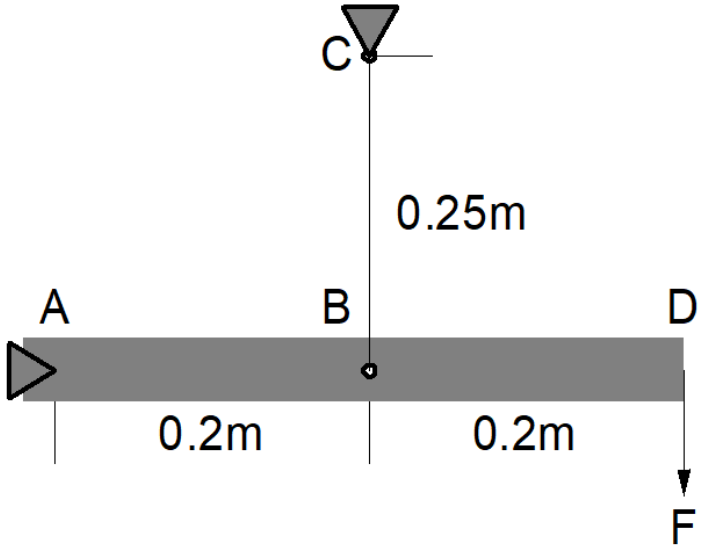
An aluminum alloy tube, A, with an outside diameter of 75mm is used to support a 25mm diameter steel rod, B, as shown. Determine the minimum thickness for the tube if the maximum deflection of the loaded end of the rod must be limited to 0.4mm. $(E_{steel} = 200GPa, E_{aluminum} = 73GPa)$



Problem 6-4:

A rigid beam, AD, is supported by a wire, BC, whose diameter is 12.5mm.

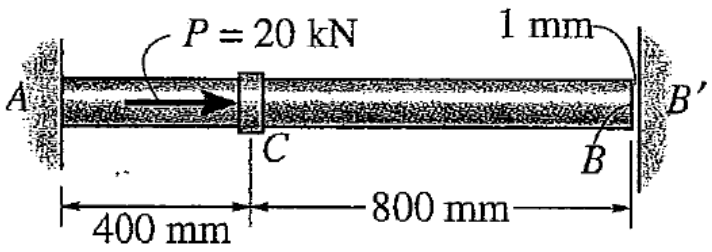
Find the elongation of BC.



Problem 6-5:

The steel rod, AB, has a diameter of 5mm. It is attached to the fixed wall at point A, and before it is loaded there is a gap of 1mm between the wall at B' and the point B of the rod. Determine the reactions at A and B' if the rod is subjected to an axial force of $P = 20kN$ as shown. Neglect the size of the collar at point C.

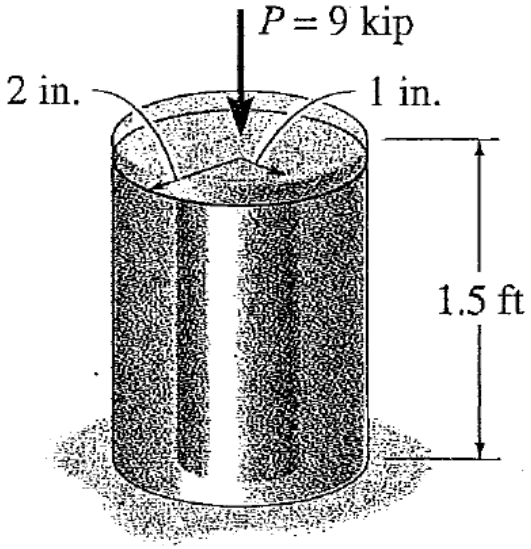
$$(E_{steel} = 200GPa)$$



Problem 6-6:

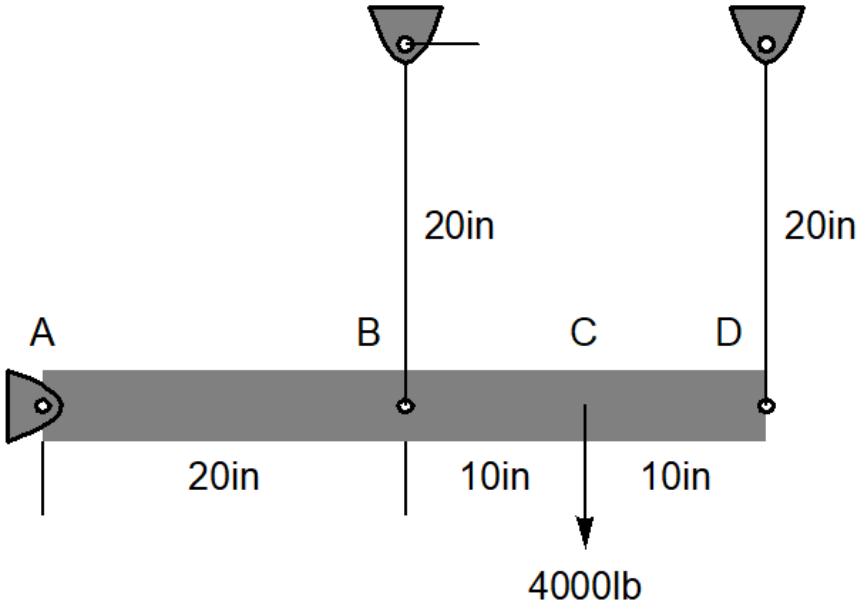
The aluminum post shown is reinforced with a brass core. If it supports an axial compressive load of 9000lbs, determine the average normal stress in the aluminum and in the brass.

$$(E_{aluminum} = 10Mpsi, E_{brass} = 15Mpsi)$$



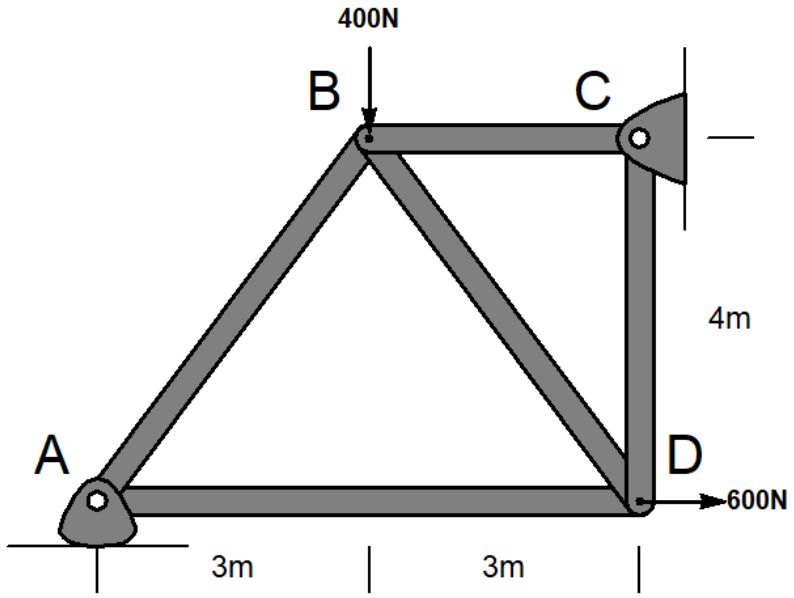
Problem 6-7:

A rigid beam is pinned at point A and supported by two cables at B and D. An applied load of 4000lb acts at point C. Determine the axial stress and deformation in the cables. The diameter of the cables is 0.1in and $E = 30Mpsi$



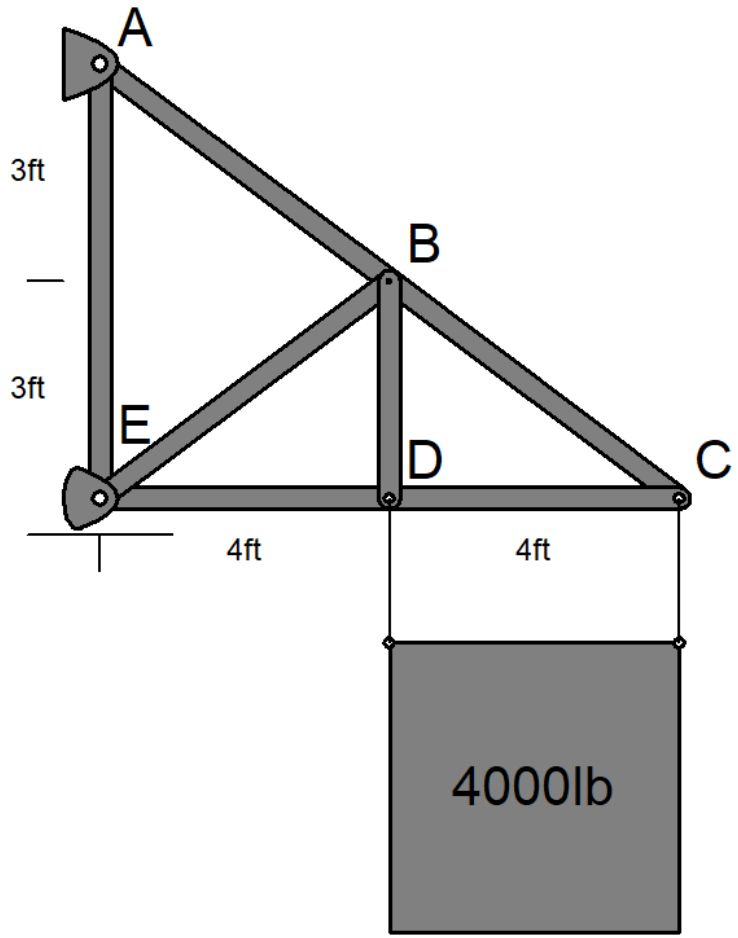
Problem 7-1:

The truss is loaded as shown with a pin at C and a roller at A. Determine the forces in all the members of the truss and state whether the members are loaded in tension or compression.



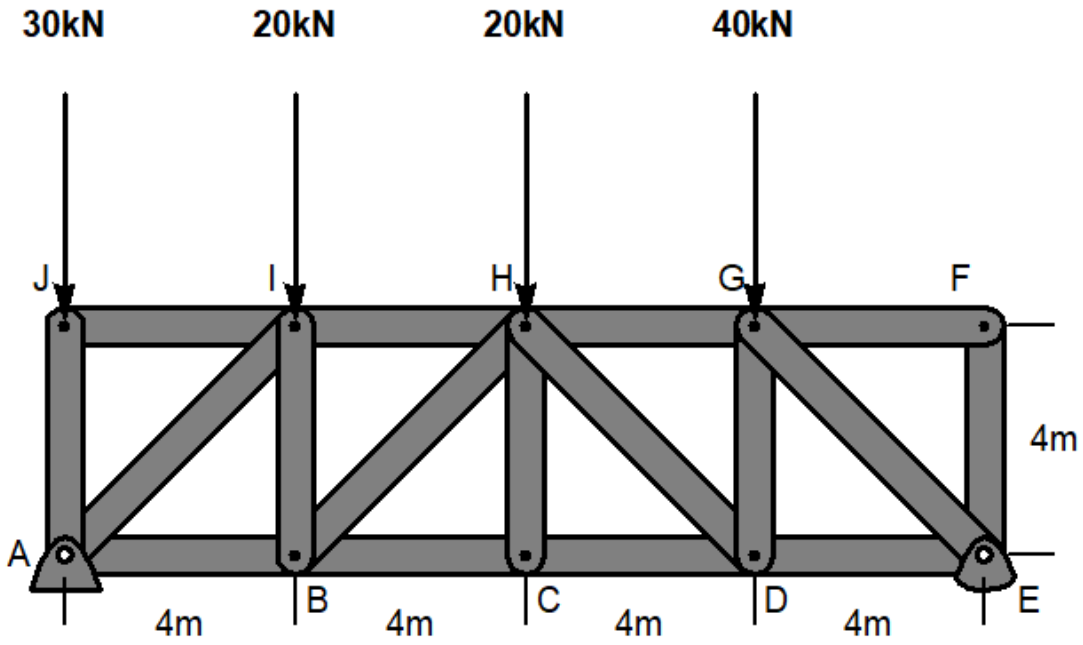
Problem 7-2:

A 4000lb crate is attached by light inextensible cables to the truss shown. Determine the forces in each member by using the Method of Joints.



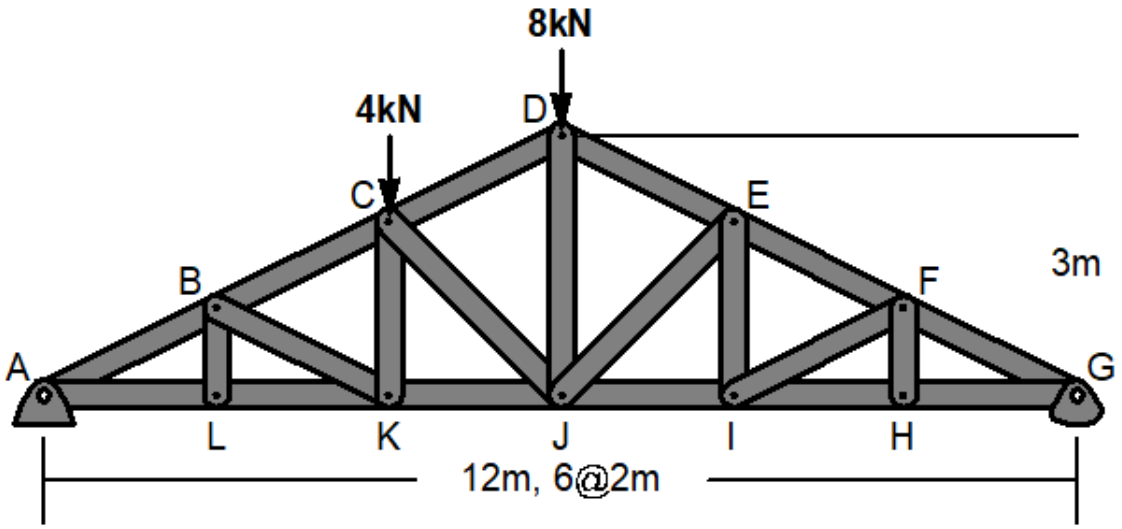
Problem 7-3:

The *Howe Truss* is loaded as shown with a pinned connection at A and a roller at E. Calculate the force members, CD, HD, and GD of the truss and state whether the members are in tension or compression.



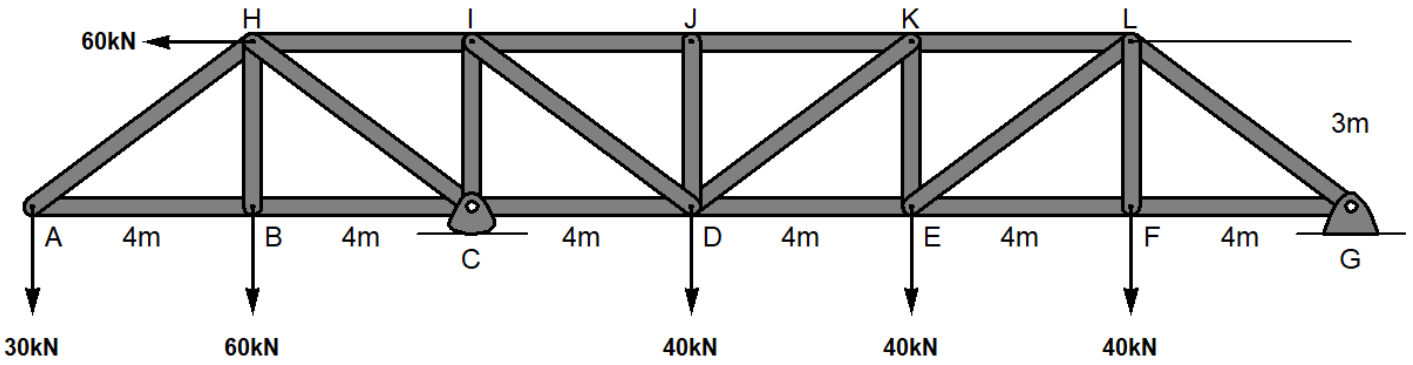
Problem 7-4:

Determine the forces in members DE and DJ of the roof truss and state whether these members are in tension or compression. Joint A is supported by a pin and joint G is a roller. Also indicate all zero force members.



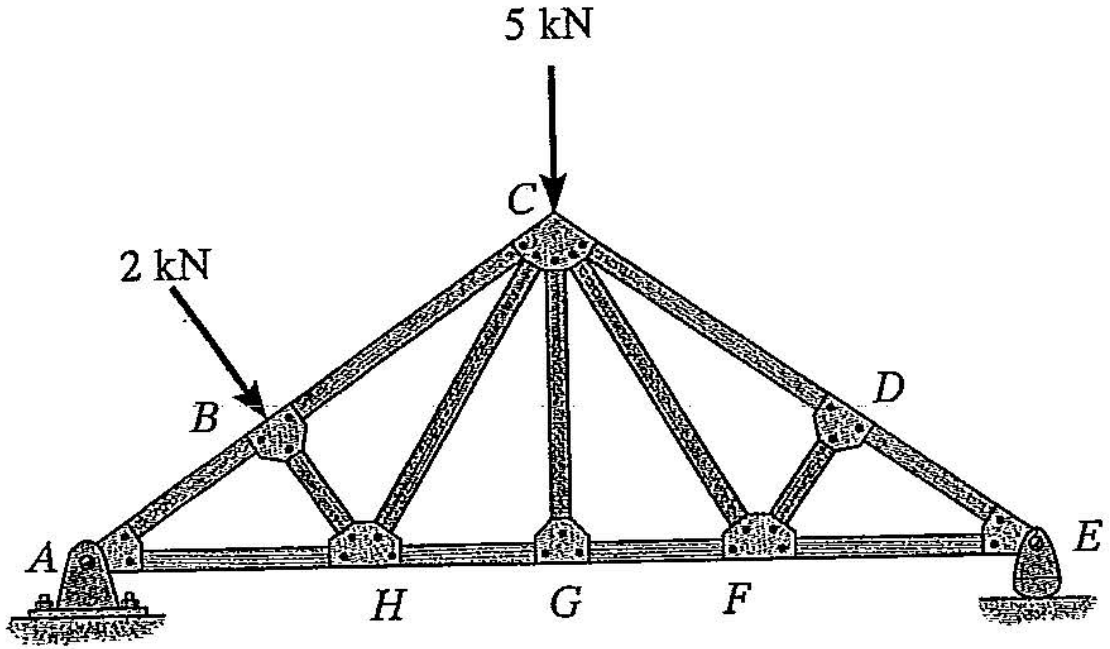
Problem 7-5:

For the truss pictured below, find the forces in the following members: HC, BC, JD, KD and LF



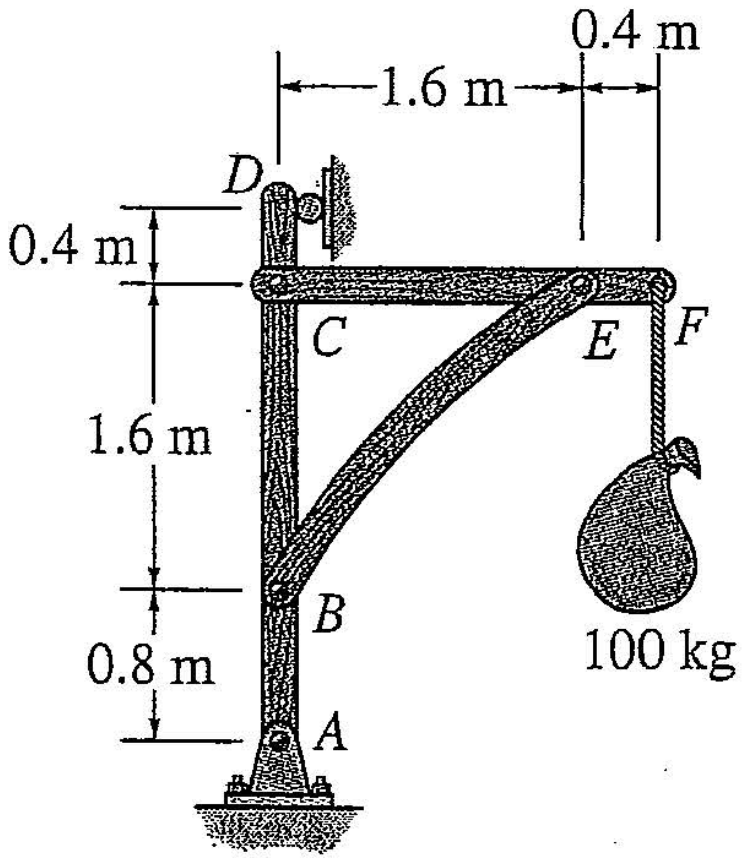
Problem 7-6:

Find all zero-force members in the truss shown.



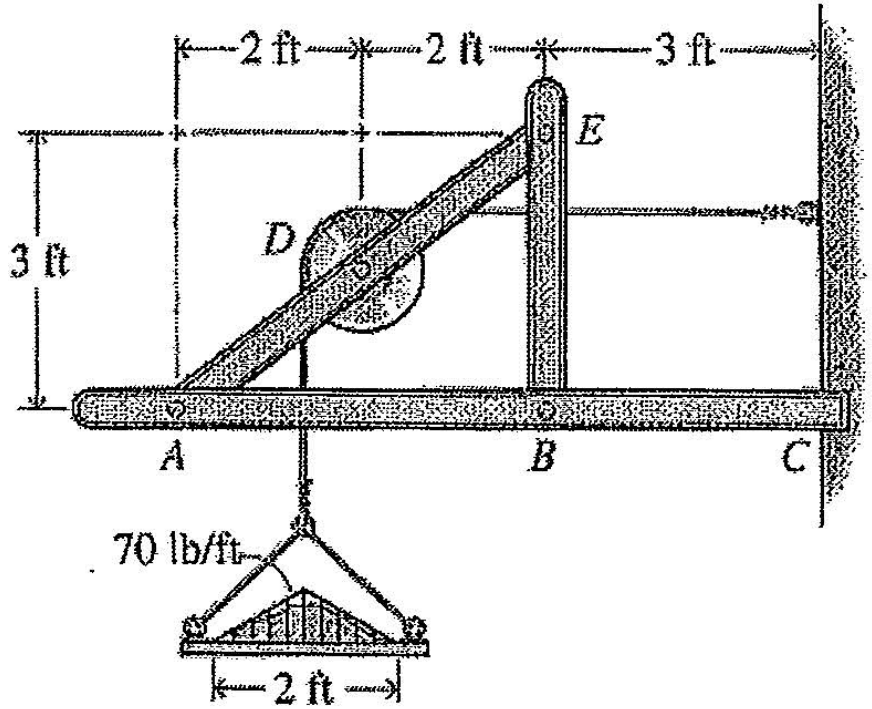
Problem 8-1:

Determine the horizontal and vertical components of the force at point C exerted on member ABCD of the frame shown.



Problem 8-2:

The hoist pulley structure is rigidly attached to the wall at point C. A load of sand hangs from the cable that passes around the 1ft diameter frictionless pulley at point D. The weight of the sand can be treated as a triangular distributed load with a maximum intensity of 70lb/ft. Determine all force acting on member ABC.

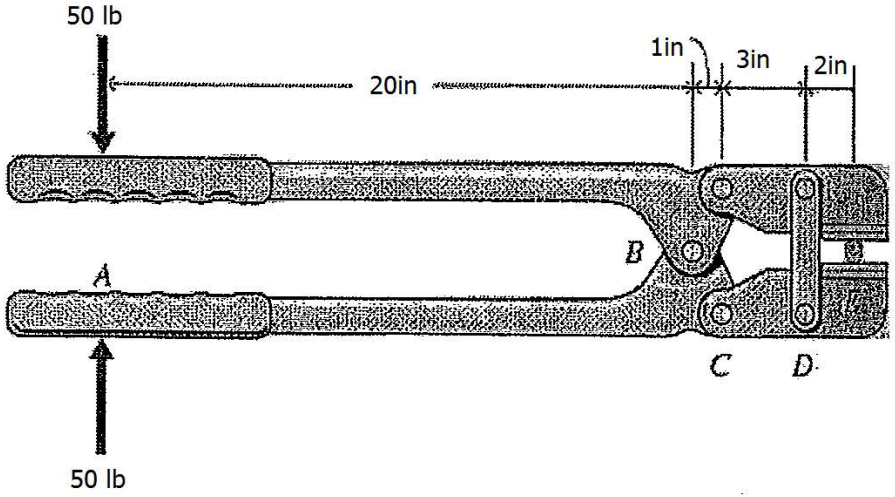


Problem 8-3:

Two 50lb forces are applied to the handles of the bolt cutter as shown. Determine:

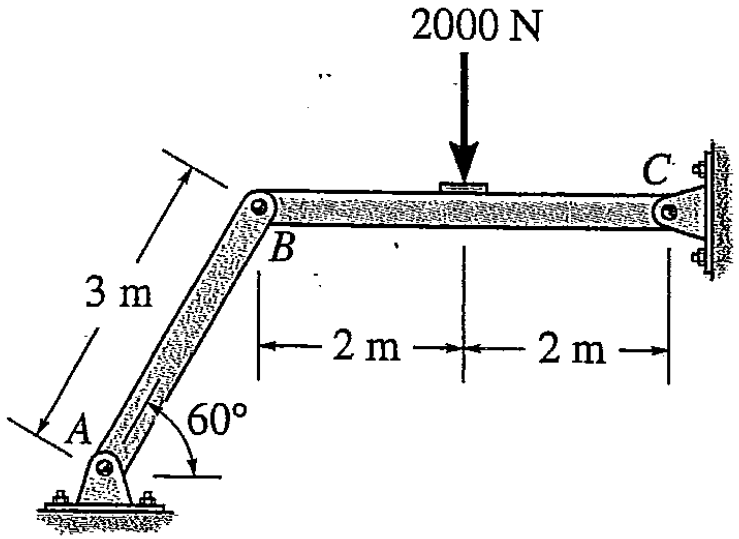
a.) all the forces acting on the handle ABC

b.) the force exerted on the bolt at point E.



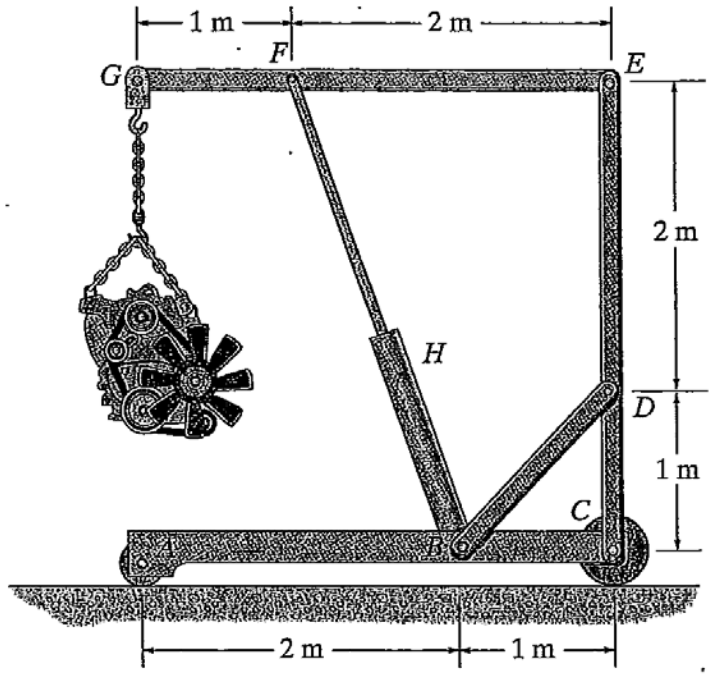
Problem 8-4:

For the frame shown determine the horizontal and vertical components of the reactions at pins A and C.



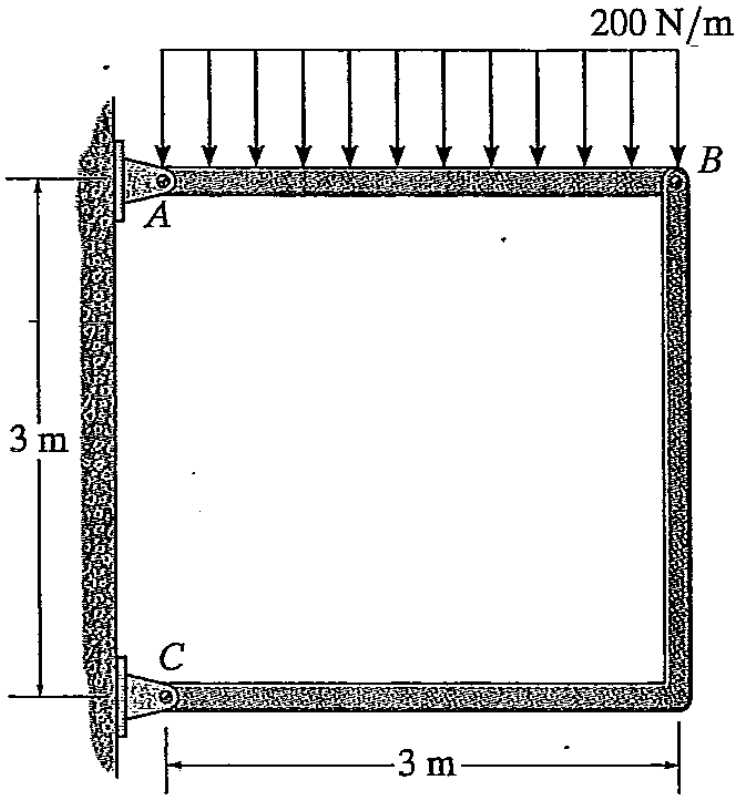
Problem 8-5:

The hoist supports the 125kg engine. Find the forces in members DB and FB.



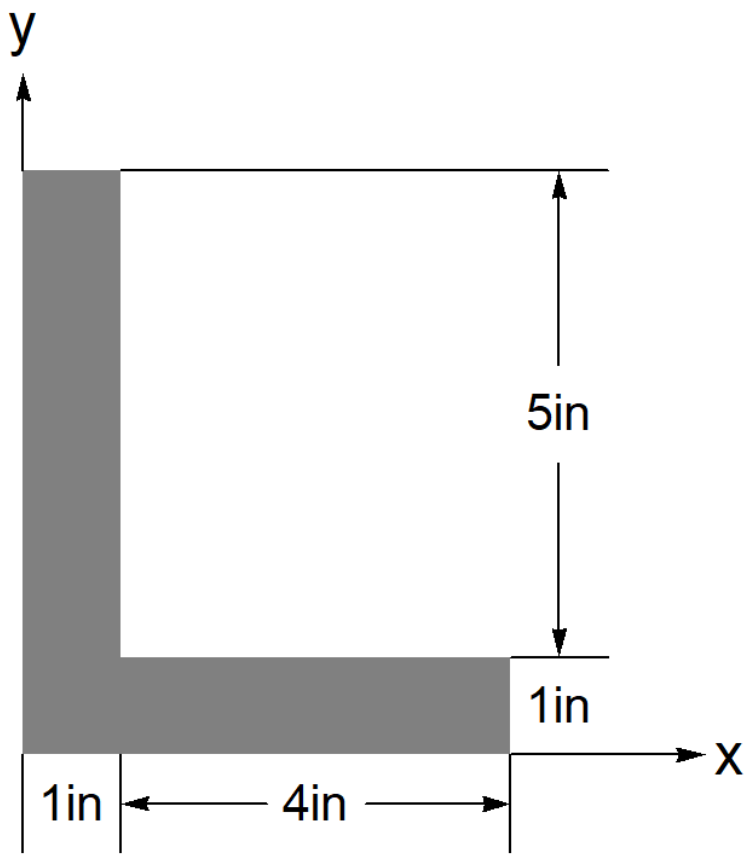
Problem 8-6:

Determine the horizontal and vertical reactions at pins A and C of the frame.



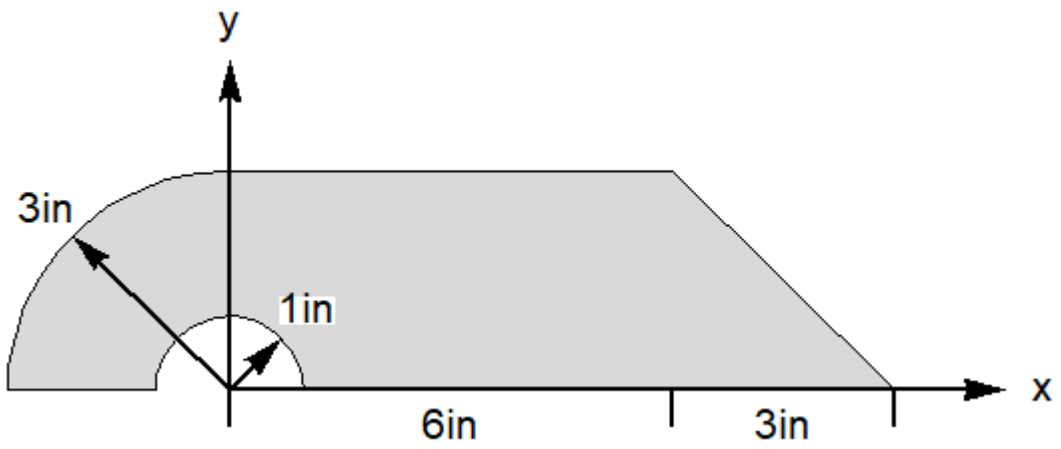
Problem 9-1:

Determine the locations of the centroid $(\bar{x}, \bar{y})$ for the area shown with respect to the axes shown.



Problem 9-2:

Determine the locations of the centroid $(\bar{x}, \bar{y})$ for the area shown with respect to the axes shown.



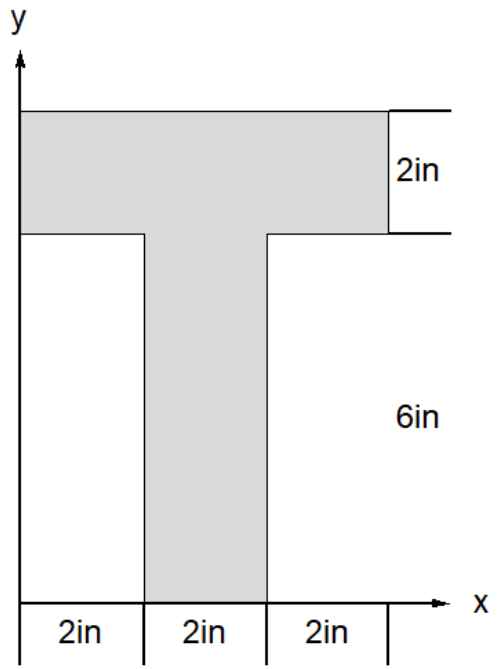
Problem 9-3:

Find the moment of inertia (2nd moment of area):

a.) with respect to the x-axis

b.) with respect to the y-axis

c.) with respect to the neutral axis parallel to the x-axis

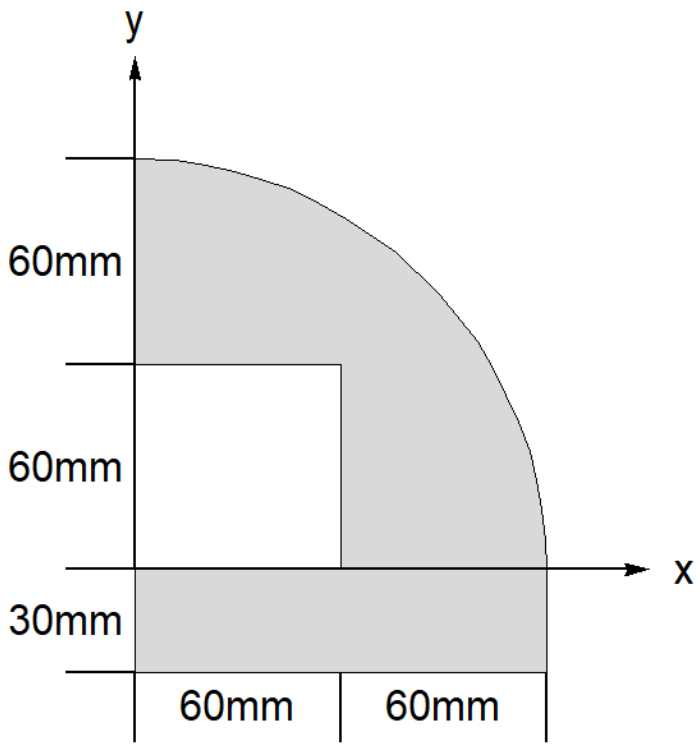


Problem 9-4:

Find the moment of inertia (2nd moment of area) with respect to:

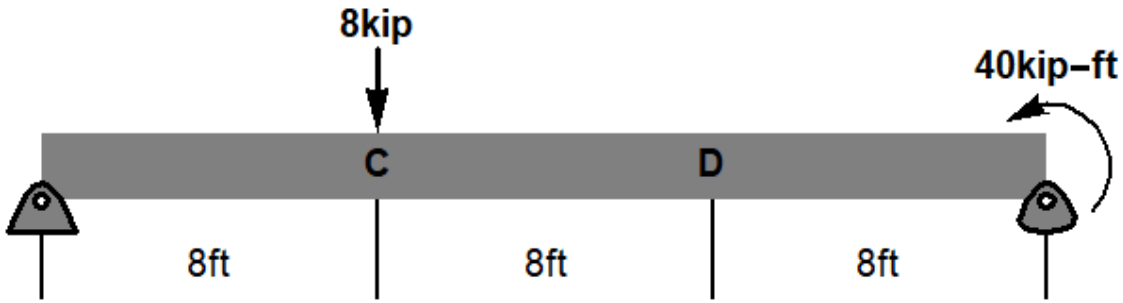
a.) x-axis

b.) y-axis



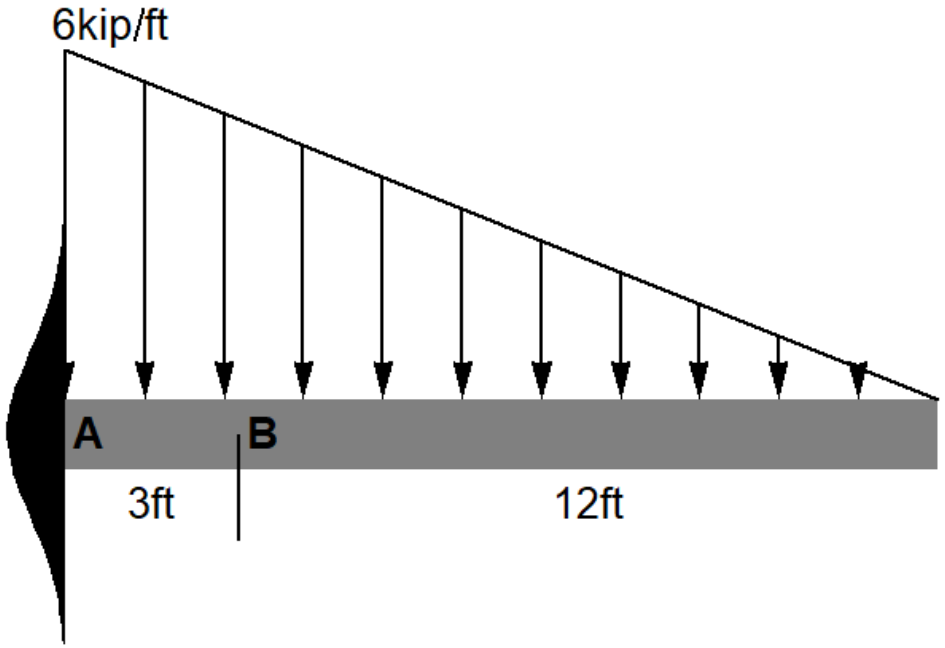
Problem 10-1:

Determine the internal normal force, shear force and bending moment in the points at C and D. Point C is located just to the right of the 8000lb load.



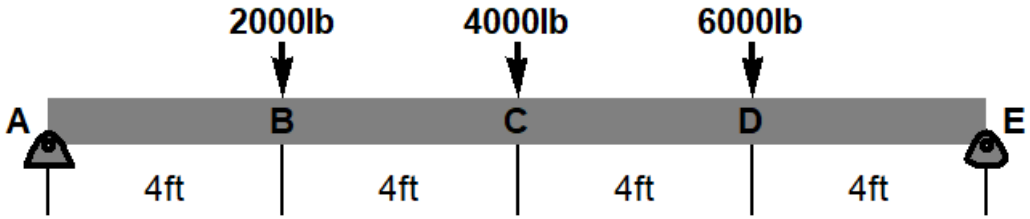
Problem 10-2:

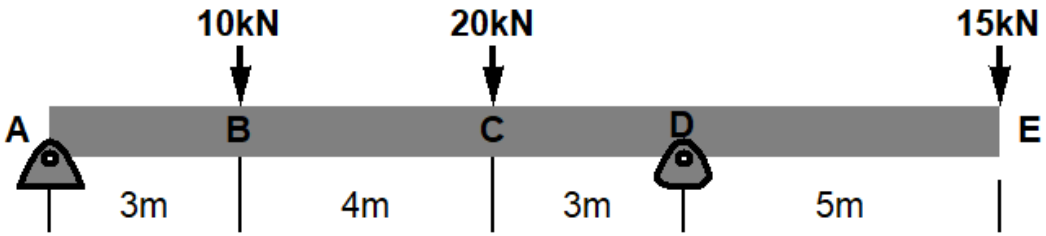
Determine the internal normal force, shear force and bending moment in the cantilever beam at point B.



Problem 10-3

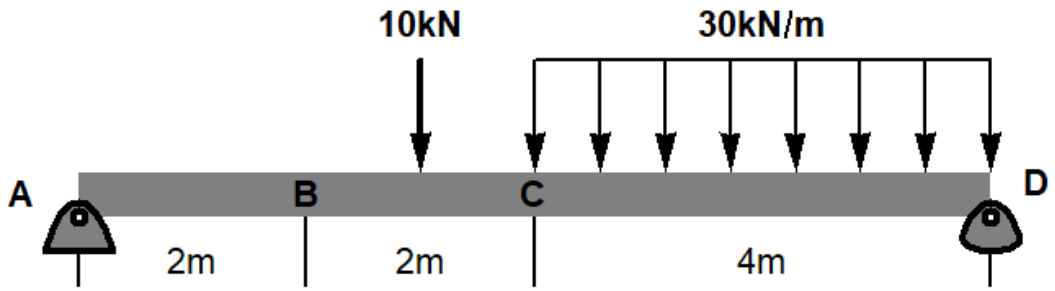
Draw shear force and bending moment diagrams for the two beams pictured below.

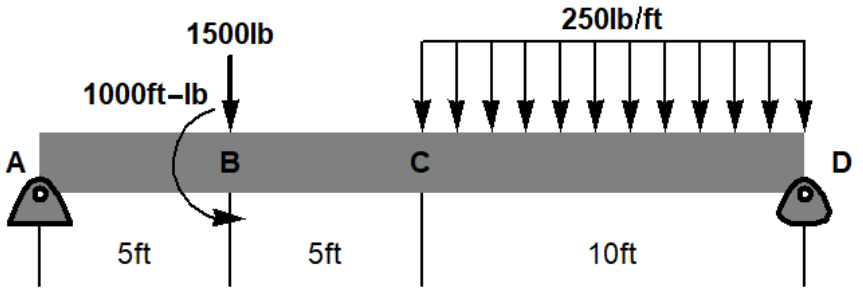




Problem 10-4

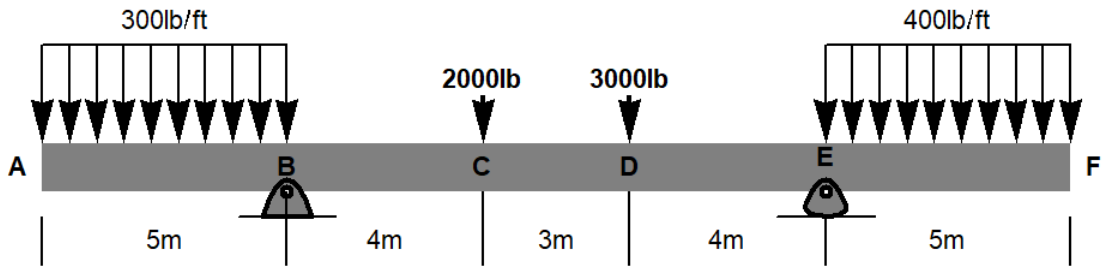
Draw the shear force and bending moment diagrams for the following beams.





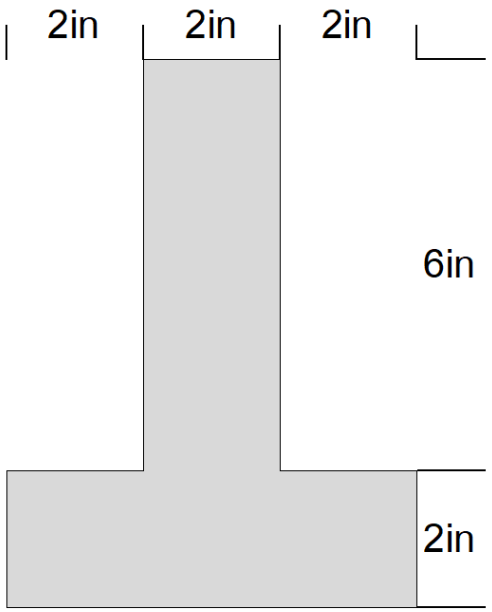
Problem 10-5

Draw Shear Force and Bending Moment Diagrams for the following beam.



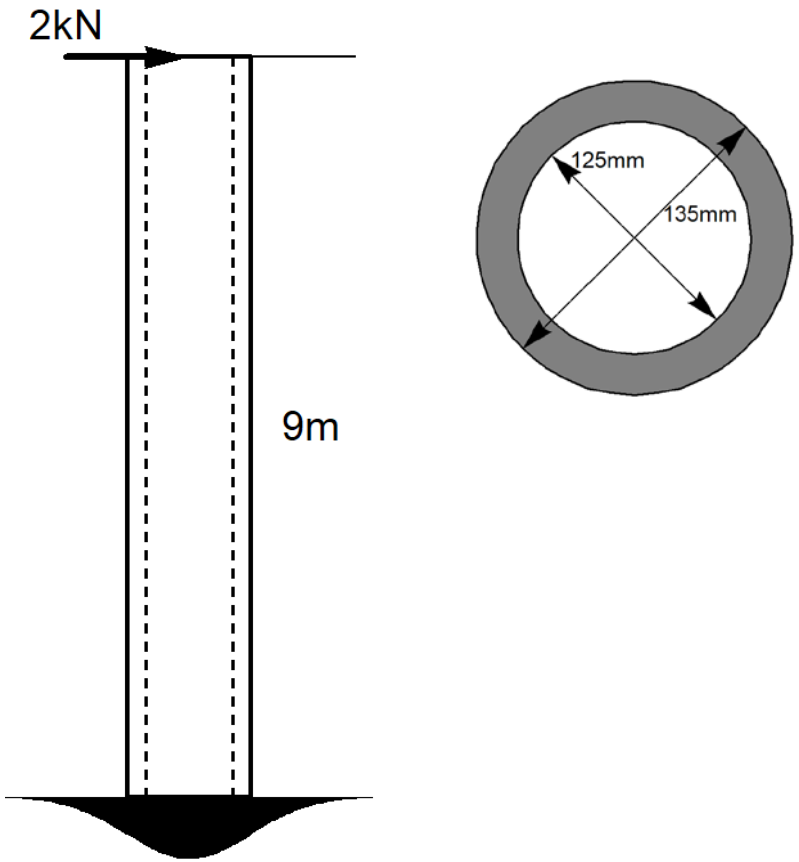
Problem 11-1:

A beam having a cross sectional area as shown is subjected to a bending moment of 5000ft-lb. Determine the maximum flexural (bending) stress produced by this moment and identify its location.



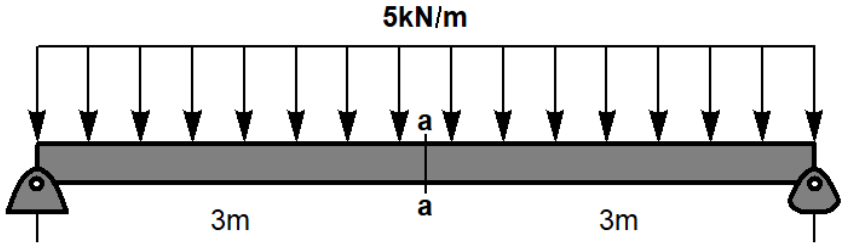
Problem 11-2:

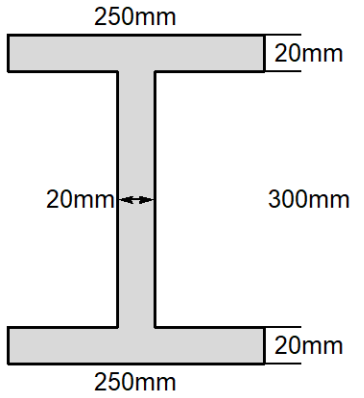
A 9m long flagpole having a hollow circular cross section is fixed at the base while it is subjected to a horizontal load of 2kN at the top as shown. Determine the maximum bending stress and identify its location.



Problem 11-3:

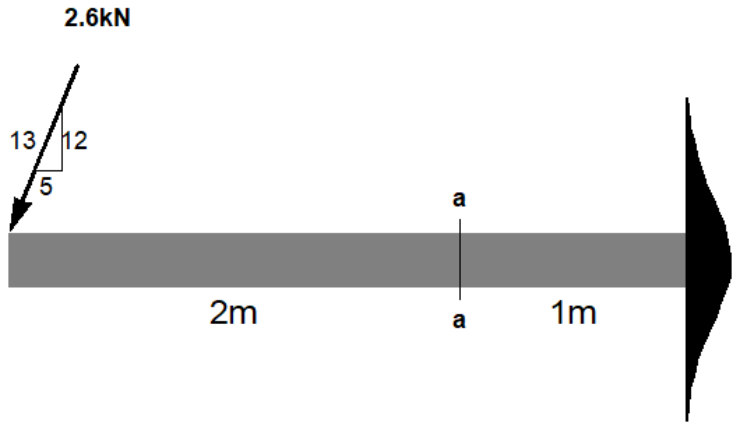
The I-beam shown is simply-supported and it is subjected to a uniform distributed load. Determine the bending stress acting at points B and D on the cross section at section a-a.

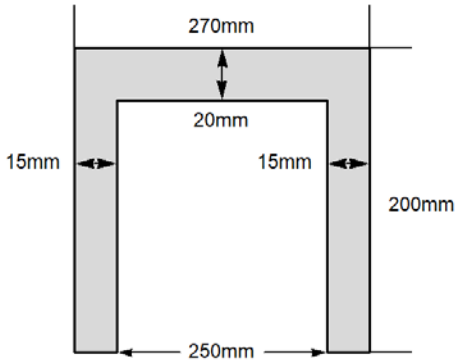




Problem 11-4:

The beam to the right has a cross sectional area in the shape of a channel. Find the maximum bending stress that occurs in the beam at Section a-a. Locate the centroid as shown and $I_{NA} = 42.26 * 10^6 mm^4$





Problem 12-1:

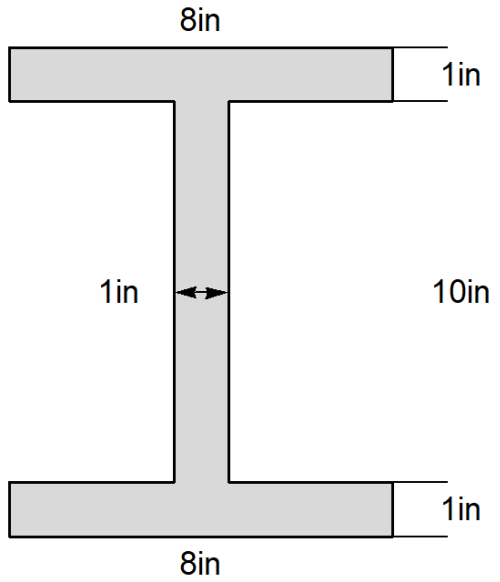
A cross section of a beam is shown. The shear force acting on the section is $V = 16{,}000lb$ and the bending moment is $M = 568{,}000$in-lb.

Determine:

a.) the maximum shear stress

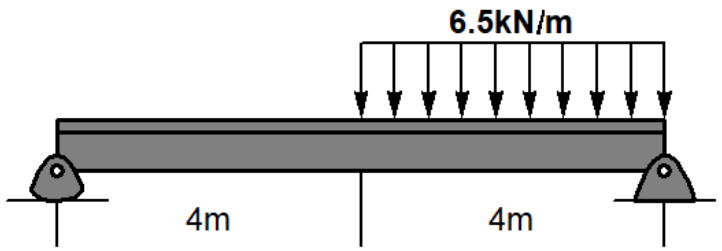
b.) the shear stress at the junction of the web and flange

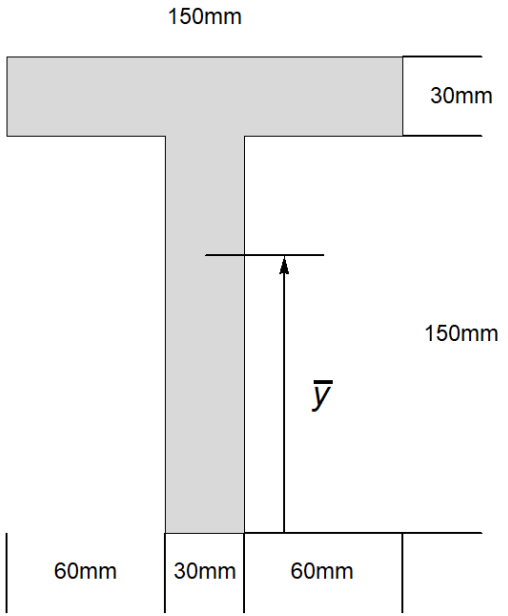
c.) the variation in the shear stress through the cross section



Problem 12-2:

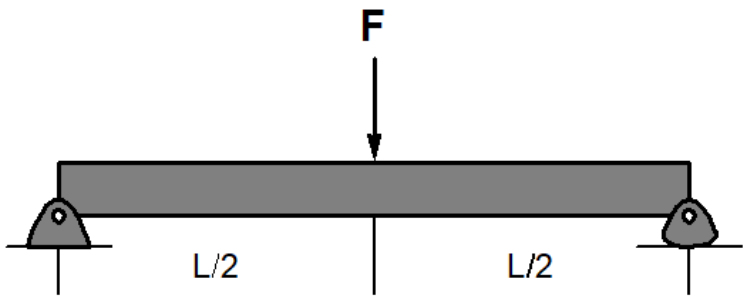
The beam shown has a T shaped cross section, made from two boards glued together. The location of the centroid is shown. Find the maximum shear stress in the glue that is necessary to hold the boards together where they are joined. Also verify $I_{NA} = 27 * 10^6 mm^4$

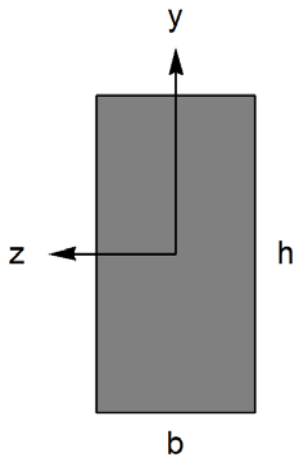




Problem 12-3:

Consider the beam loading as shown. Show that the ratio of maximum shear stress (τ_{max}) to maximum bending stress (σ_{max}) is given by $\frac{\tau_{max}}{\sigma_{max}} = \frac{h}{2L}$





Cross section

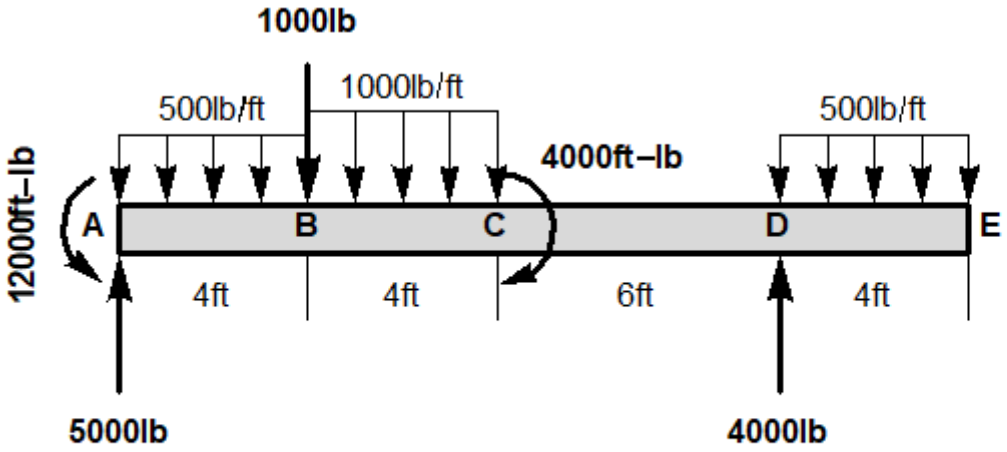
Problem 12-4:

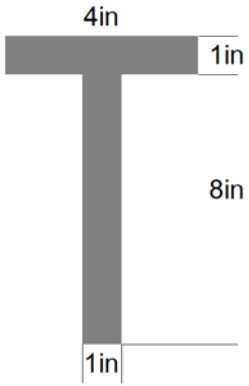
For the simply supported beam loaded as shown and with a cross section as shown, determine:

a.) the maximum tensile flexural stress in the beam

b.) the maximum compressive flexural stress in the beam

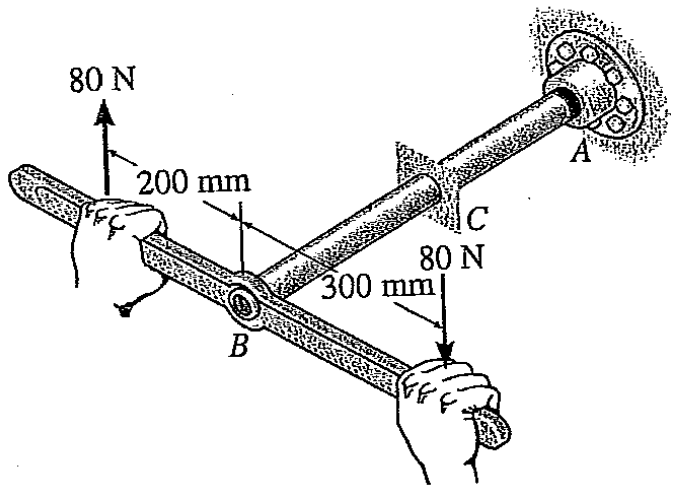
c.) the shear stress at a point 3in down from the top of the cross section at the x-location where the beam is subjected to the maximum shear force





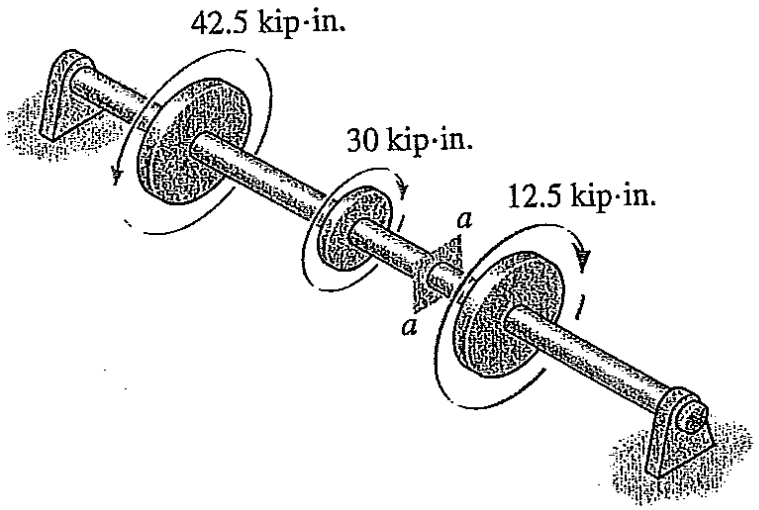
Problem 13-1:

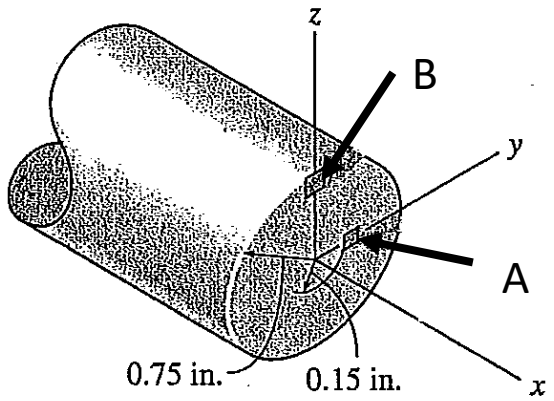
The pipe shown has an inner diameter of 80mm and an outer diameter of 100mm. If its end is tightened against the support at point A using a torque wrench at point B, determine the shear stress developed in the material at the inner and outer walls along the central portion of the pipe at point C when the 80N forces are applied to the handle as shown.



Problem 13-2:

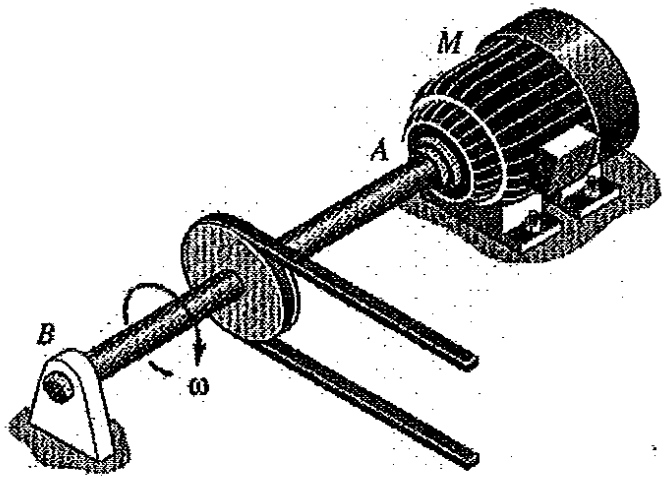
The shaft is supported by two bearings and it is subjected to three torques as shown. Determine the shear stress developed at points A and B located at points A and B located on the section a-a of the shaft.





Problem 13-3:

A solid steel shaft, AB, is used to transmit 5hp from the motor M to a pulley as shown. If the shaft rotates at 175rpm and the steel has an allowable shear stress of 14.5kpsi, determine the required diameter of the shaft to the nearest 1/8in.

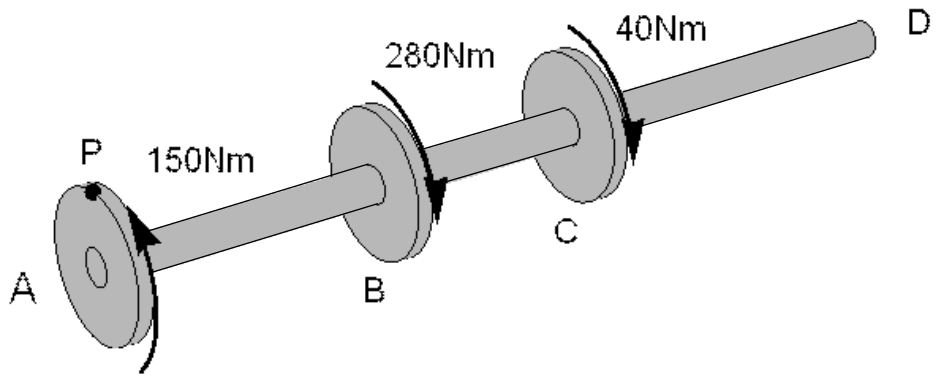


Problem 13-4:

A hollow shaft has an inner diameter of 30mm and an outer diameter of 42mm and it is used to transmit 90kW of power. Determine the frequency of rotation (in Hz) so that the shear stress cannot exceed 50MPa.

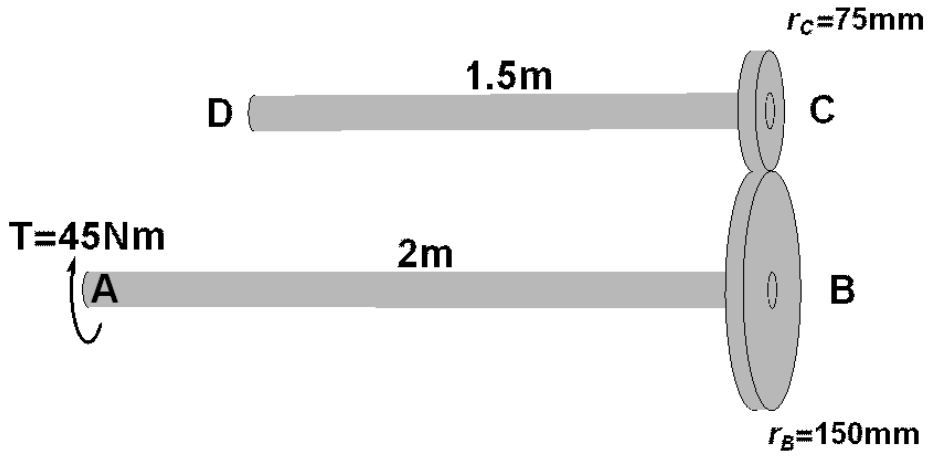
Problem 13-5:

Three gears are attached to a shaft with a fixed end at point D (no rotation). If the shaft has a diameter of 14mm, determine the displacement of point P on gear A. The shear modulus of elasticity of steel is $G = 80GPa$.



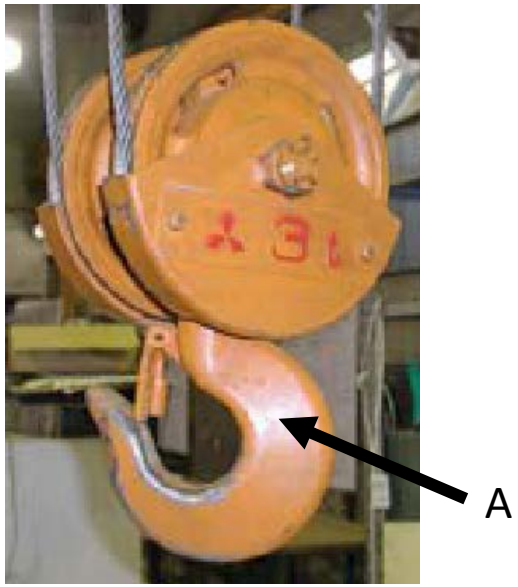
Problem 13-6:

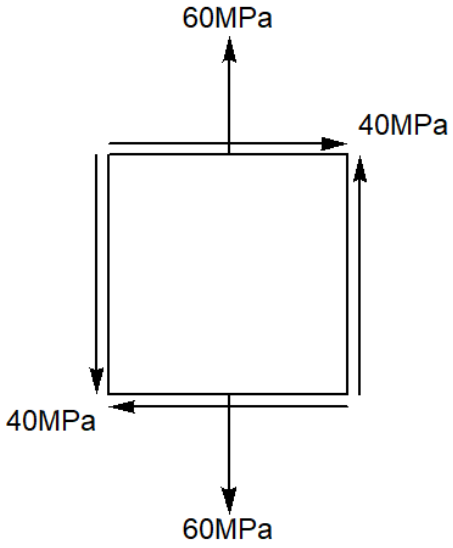
Two solid steel shafts are coupled together using gears as shown. Determine the angle of twist of end A of shaft AB when a torque of 45Nm is applied. Assume that the shaft AB is free to rotate and the shaft CD is fixed at point D (no rotation). Each shaft has a diameter of 20mm and a shear modulus of 80GPa.



Problem 14-1:

A crane hook is loaded and the state of plane stress at point A. Using Mohr's circle represent the state of stress at point A in terms of the principal stresses.





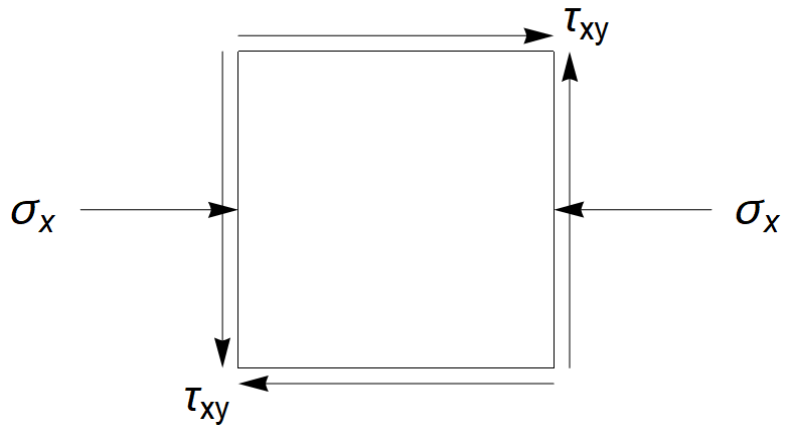
Problem 14-2:

The propeller shaft of a ship is a hollow circular tube with outside diameter of 18in and an inside diameter of 10in. The shaft is subjected to a torque of 2000kip-in and an axial force of 1000lb. The state of plane stress at a point on the outside surface is represented on the planar stress element as shown. Using Mohr's circle Find:

a.) the maximum tensile stress

b.) the maximum compressive stress

c.) the maximum shear stress



Problem 14-3:

The cantilevered rectangular bar is subjected to the force of 5000lb as shown. Determine the principal stresses at point B in section a-a. The cross section is also pictured below.