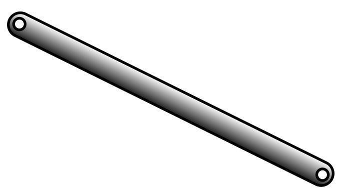
Chapter 1
Introduction- Concept of Stress

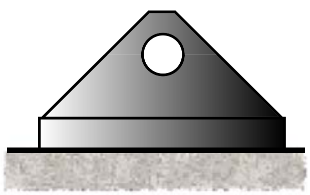
INTRODUCTION

A Review of Statics

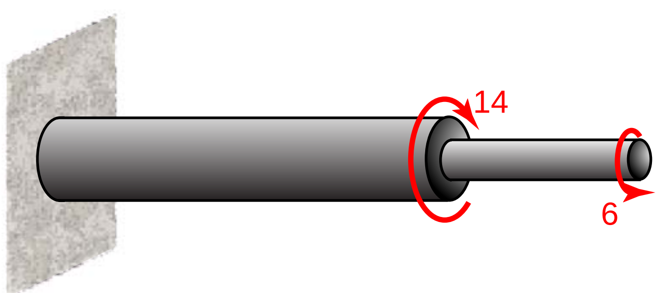
Axial Stress

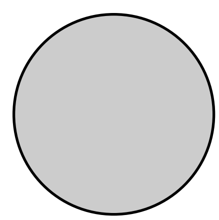


Bearing Stress

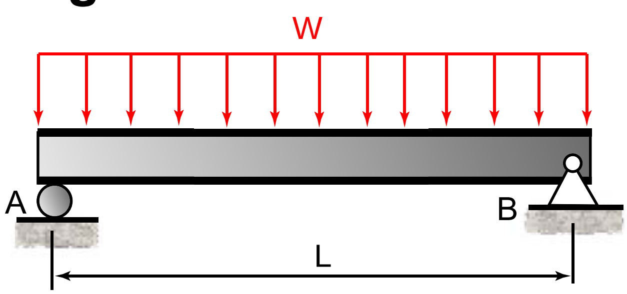


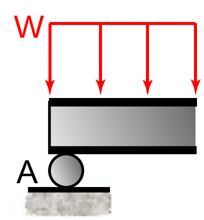
Torsional Stress



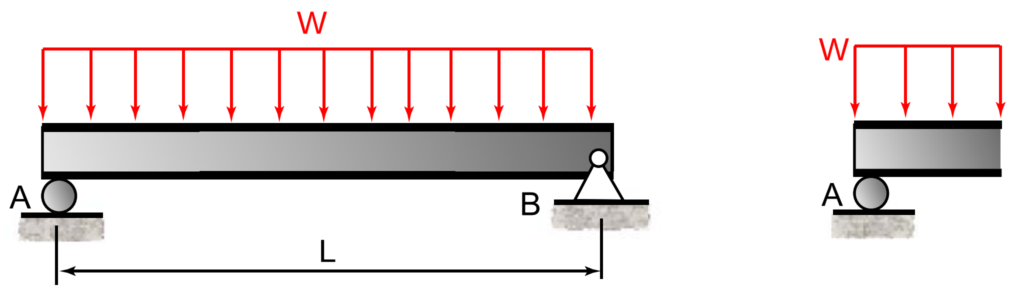


Bending Stress

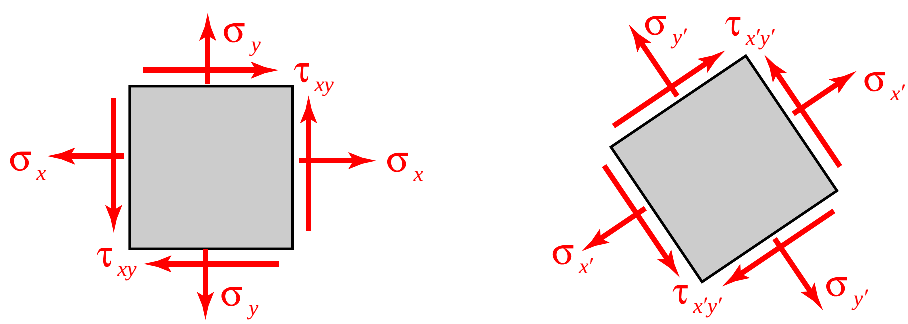




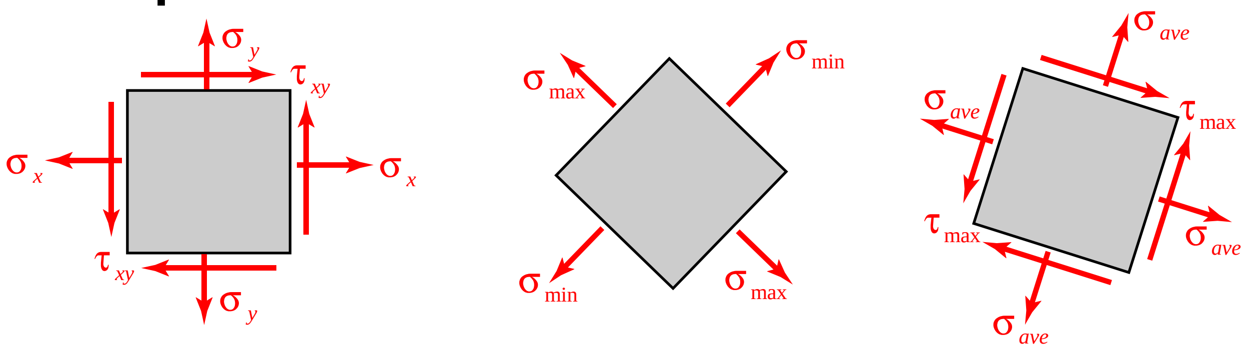
Shear Stress



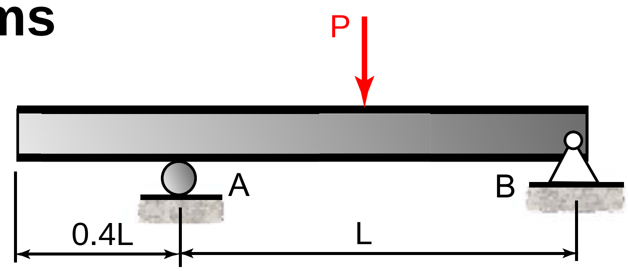
Stress and Strain



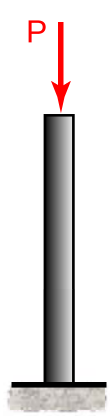
Principal Stresses



Deflection of Beams



Columns

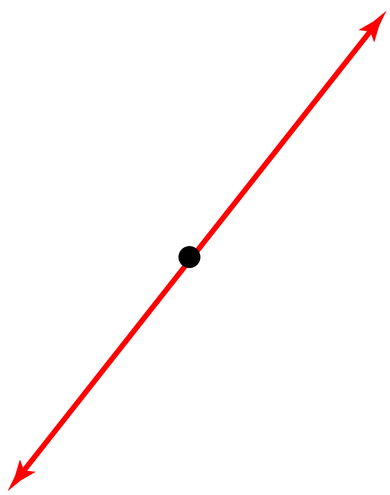


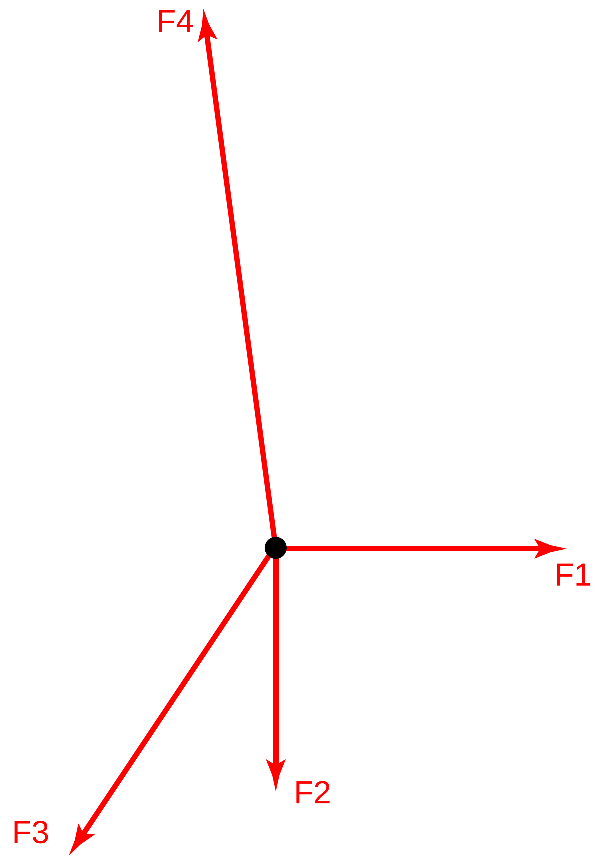
Equilibrium of a Particle

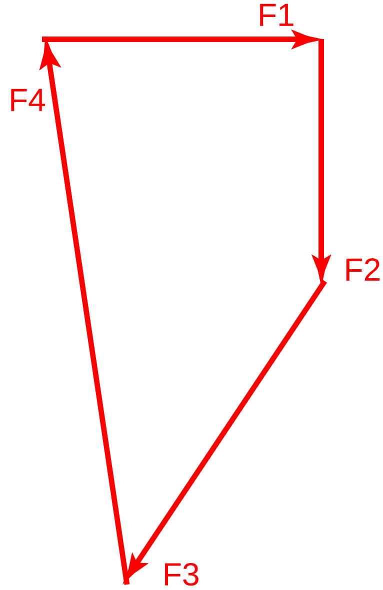
Newton's First Law

If the resultant force acting on a particle is zero, the particle will remain at rest (if originally at rest) or will move with constant speed in a straight line (if originally in motion).

$$\sum F_x = 0$$
$$\sum F_y = 0$$

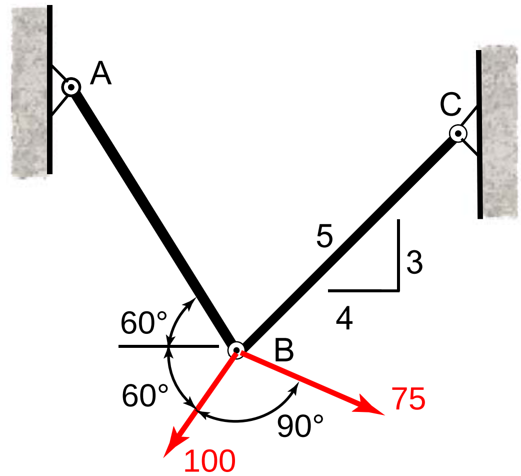






Example

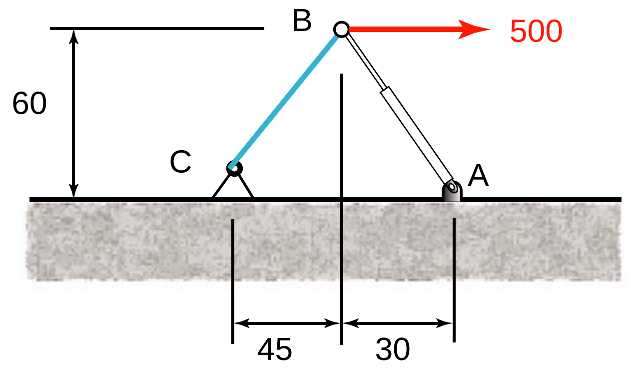
The loads are supported by two rods AB and BC as shown. Find the tension in each rod. Units: N.



Magnitude	x component	y component
100 N		
75 N		

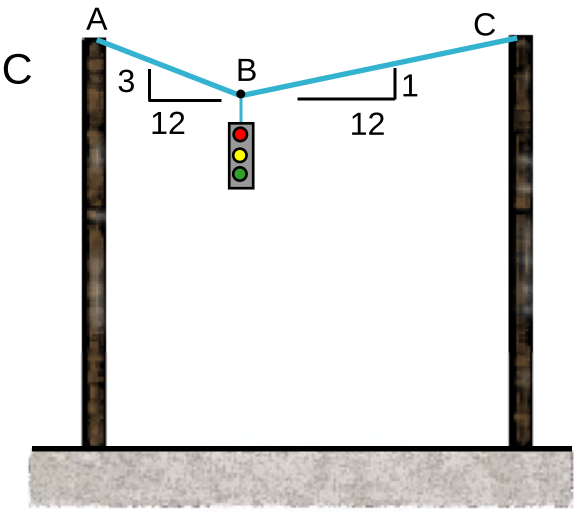
Example

Determine the forces in AB and BC.
Units: Lb, in.



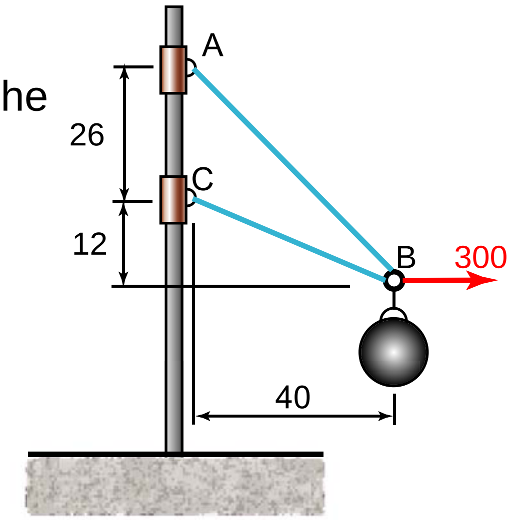
Example

Determine the forces in cables AB and BC due to the 25 lb traffic light. Units: Lb.



Example

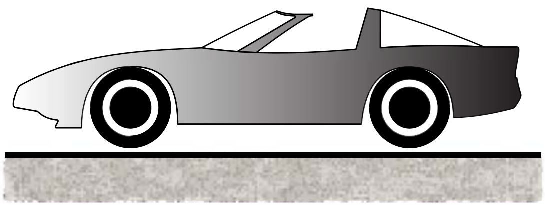
Determine the forces in wires AB and BC. The sphere weighs 100 lbs. Units: Lb, in.

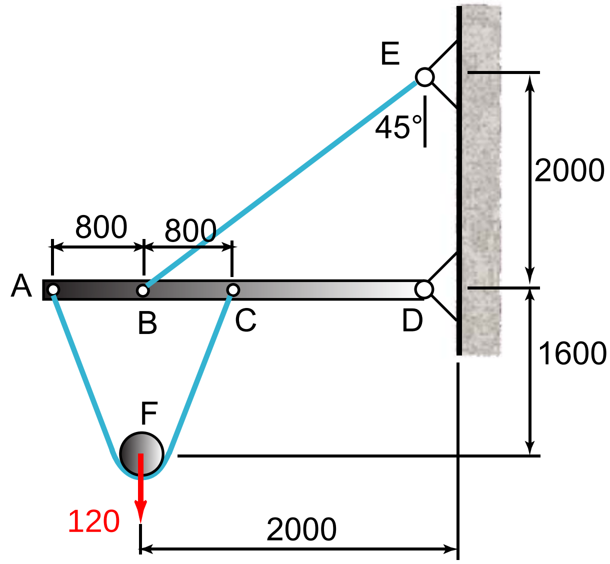


Equilibrium of Rigid Bodies

A particle remains at rest or continues to move in a straight line with uniform velocity if the resultant forces acting on it are zero, in other words:

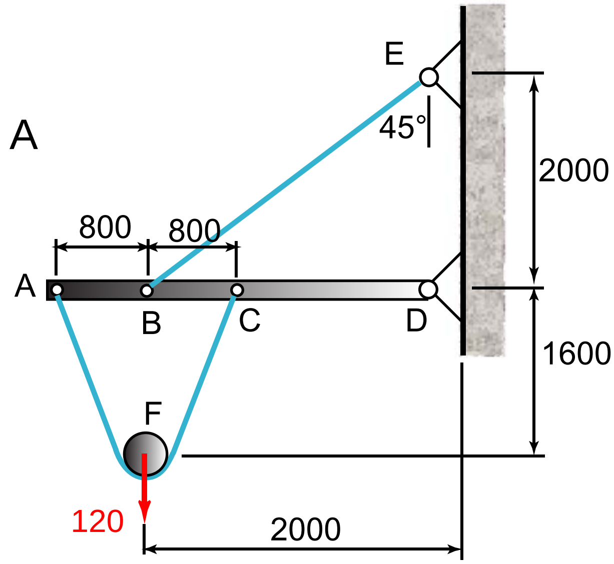
$$\sum \vec{F} = 0$$
$$\sum \vec{M} = 0$$





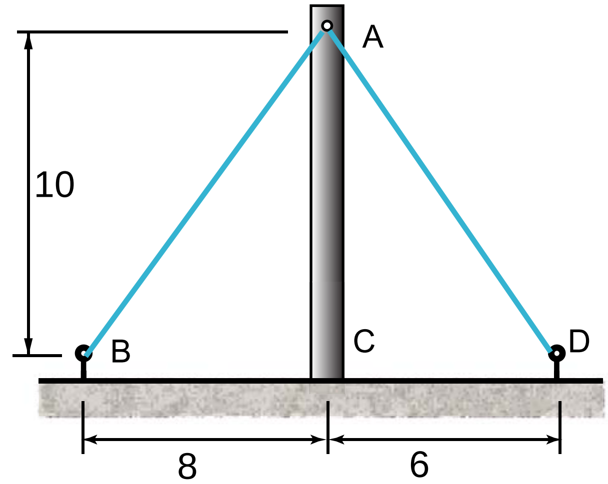
Example

Determine the reactions at D and the tension in BE. The wire connected at A and C is continuous.
Units: N, mm.



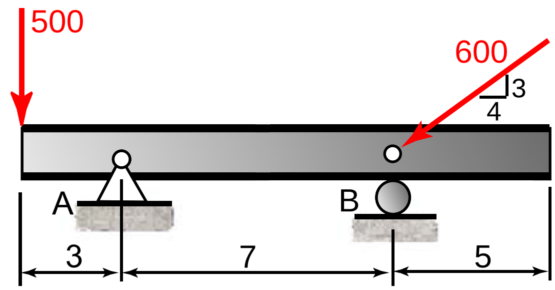
Example

The cable stays AB and AD help support pole AC. Knowing that the tension is 140 lb in AB and 40 lb in AD, determine the reactions at C. Units: Lb, ft.



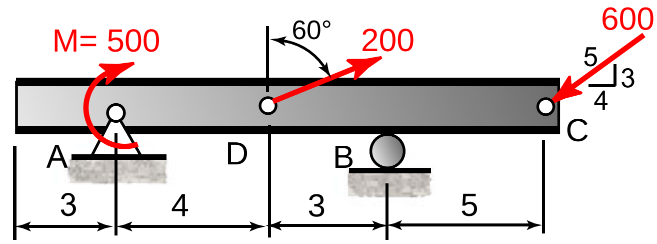
Example

Determine the reactions at supports A and B.
Units: Lb, ft.



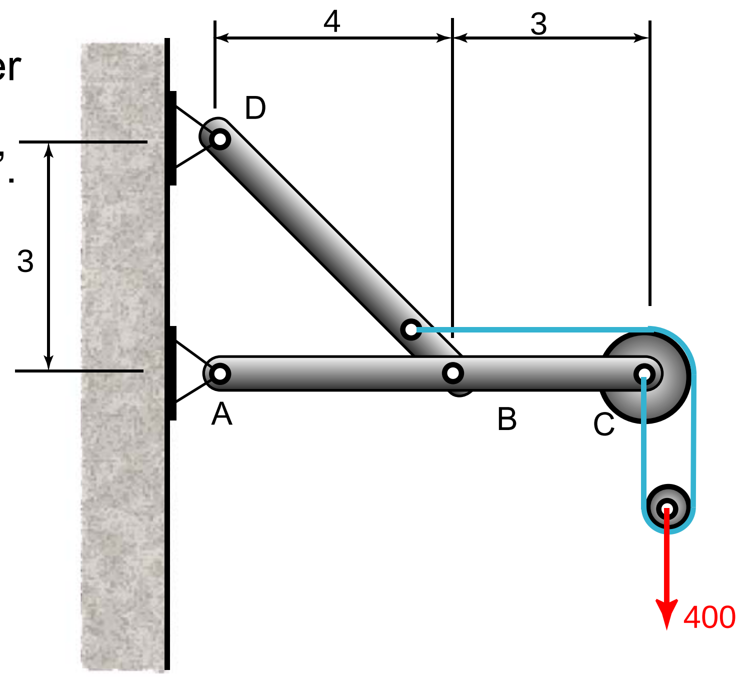
Example

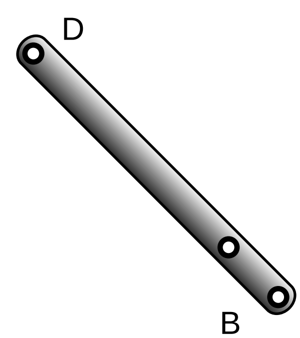
Determine the reactions at A and B. Units: Lb, ft.

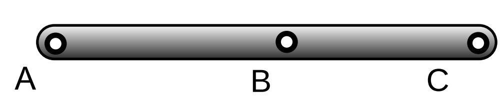


Example

Determine the forces on member ABC. The radius of the small pulley is 2.5" and the larger is 5”. Units: Lb, ft.

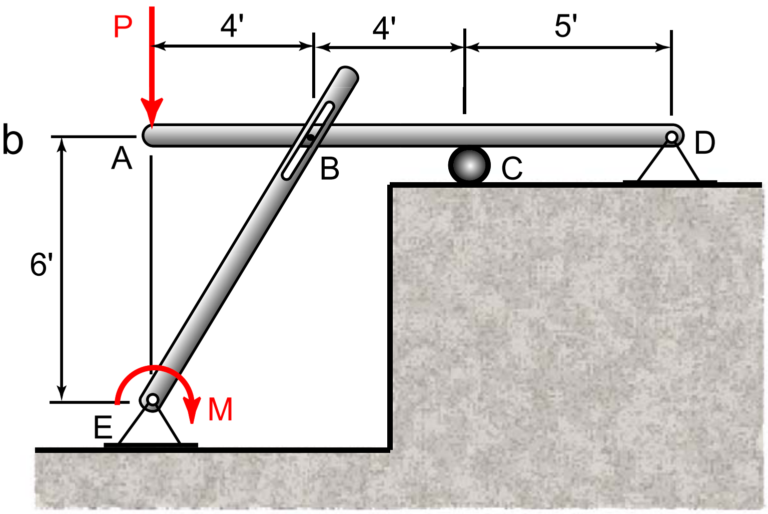


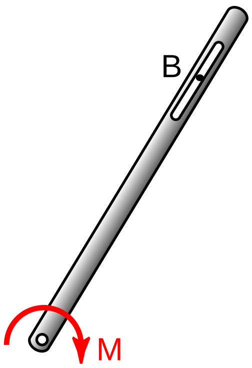


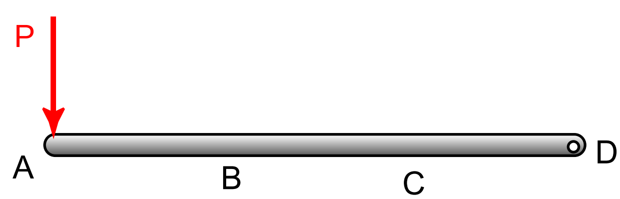


Example

Determine the forces on member ABCD due to P= 500 lb and M= 700 ft-lb. Units: Lb, ft.

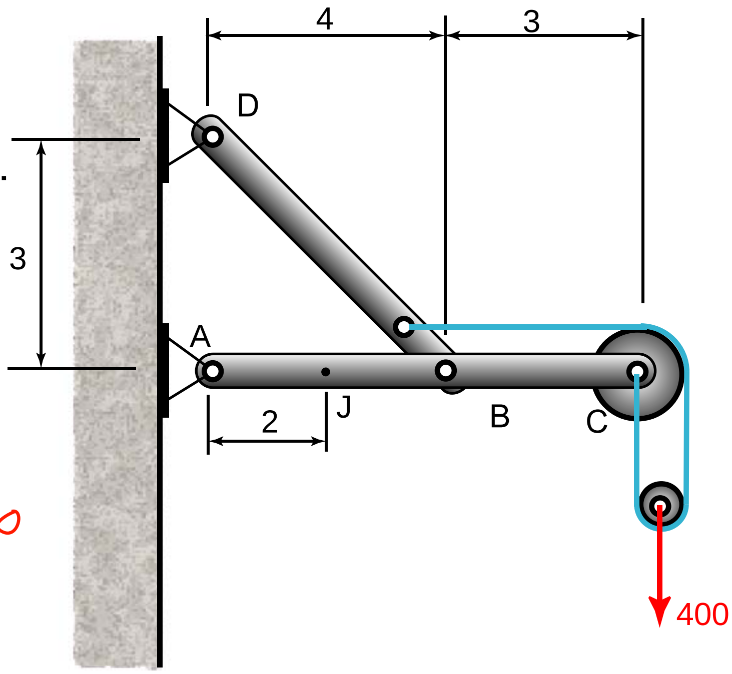




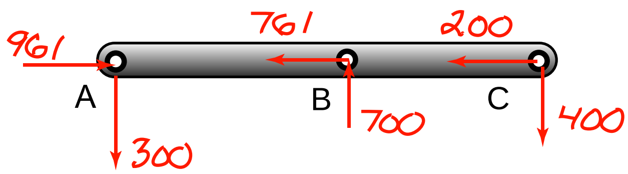


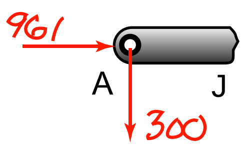
Example

Determine the internal forces at point J. The radius of the small pulley is 2.5" and the larger is 5”. Units: Lb, ft.



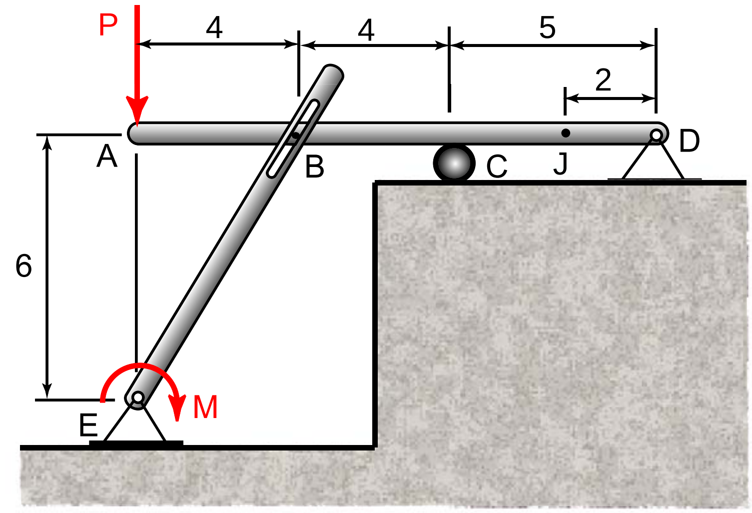
Recall from a previous solution:



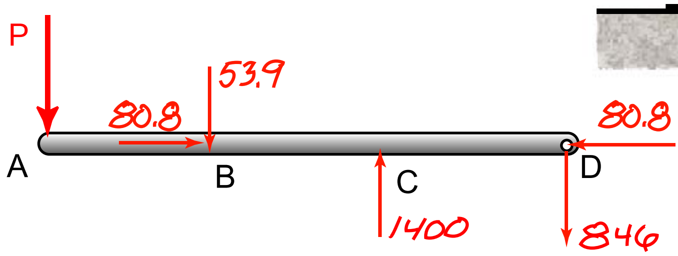


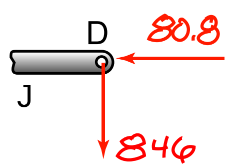
Example

Determine the internal forces at point J due to P= 500 lb and M= 700 ft-lb. Units: Lb, ft.

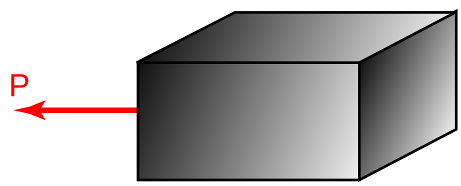


Recall from a previous solution:





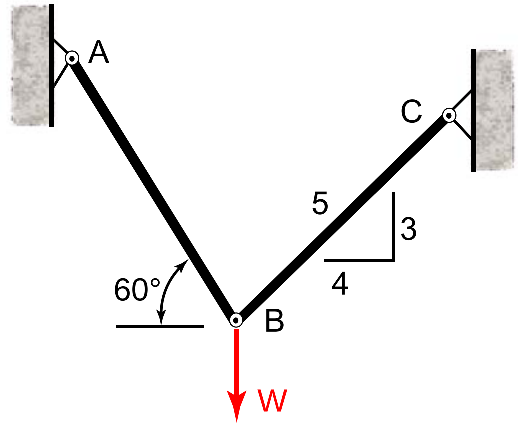
NORMAL STRESS



$$\sigma = \frac{P}{A}$$

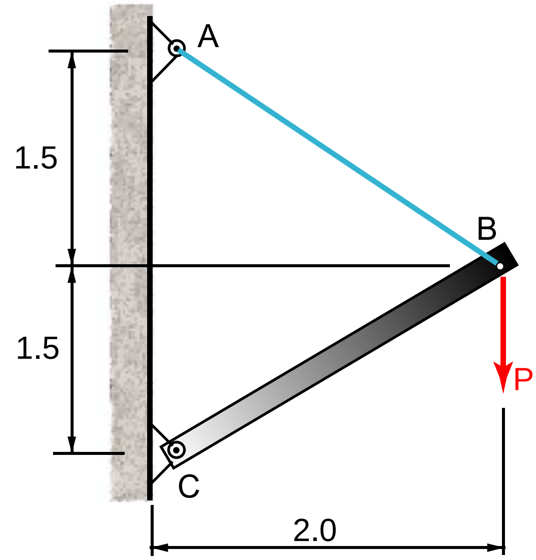
EXAMPLE

The 80-kg lamp is supported by two rods AB and BC as shown. If AB has a diameter of 10 mm and BC has a diameter of 8 mm, determine which rod is subjected to the greater normal stress?



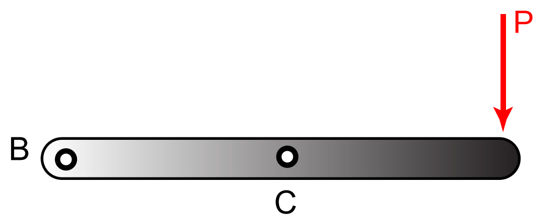
Example

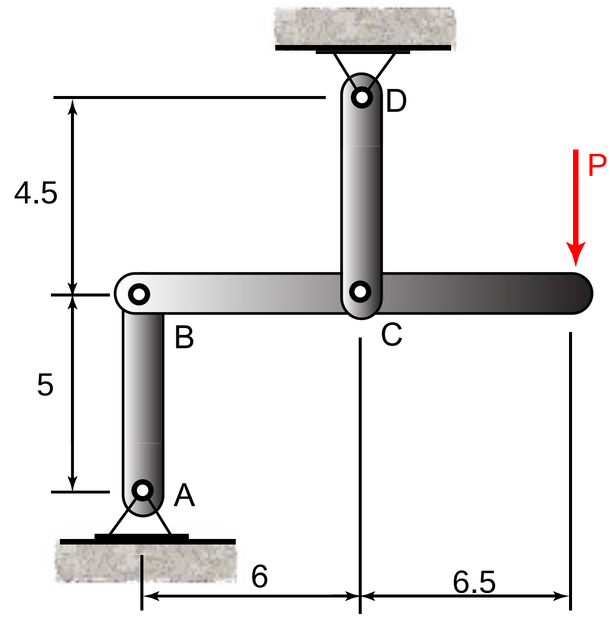
A strut and cable assembly ABC supports a vertical load P= 1.8 kN. The cable has an effective cross-sectional area of 12000 sq. mm and the strut has an area of 25000 sq. mm. Calculate the normal stress in the cable and strut, and indicate whether they are in tension or compression. Units: m



Example

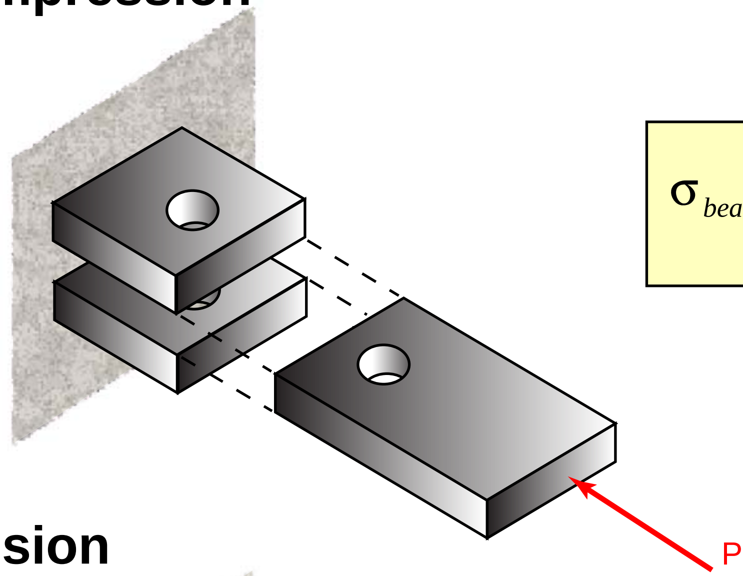
Bar AB has a cross-section of .25"x4" and CD is .60"x4". With a load of 2-k at the end, what is the axial stress in link AB and CD.
Note: The units of “k” means 1000 lbs, often referred to as “kips”.
Units: K, ft.



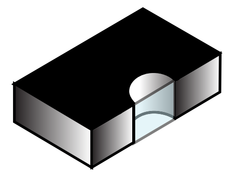


STRESSES IN CONNECTIONS

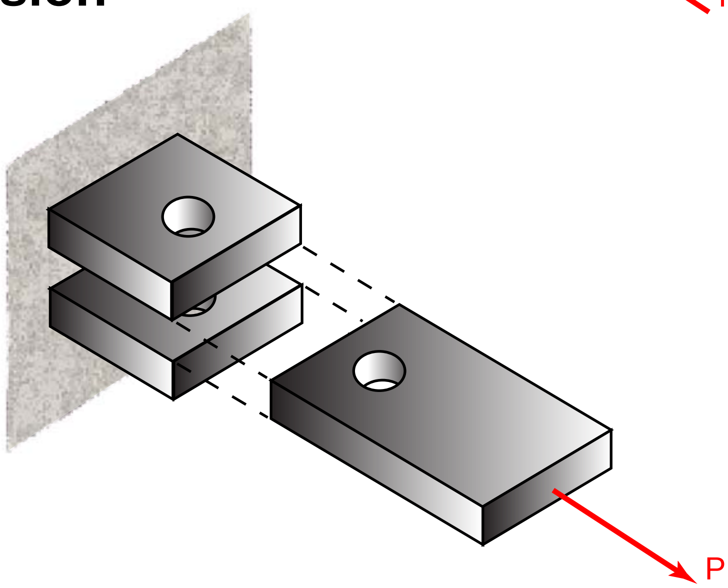
Compression

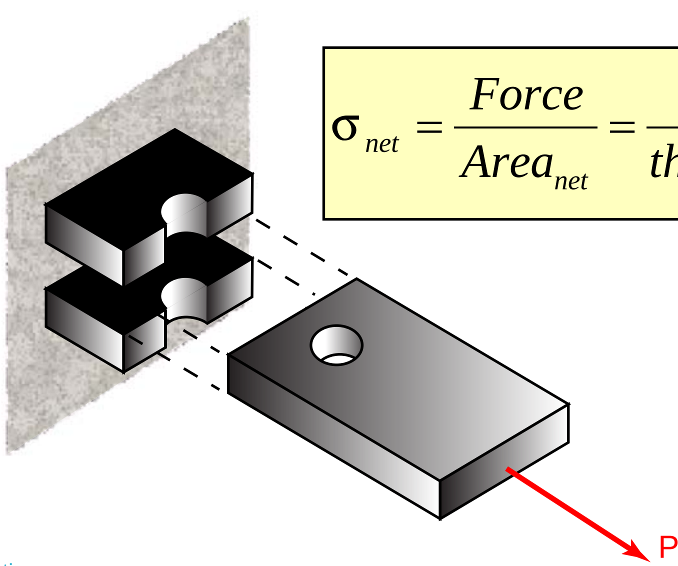


$$\sigma_{bearing} = \frac{Force}{thk_{plate}\,dia_{bolt}}$$



Tension

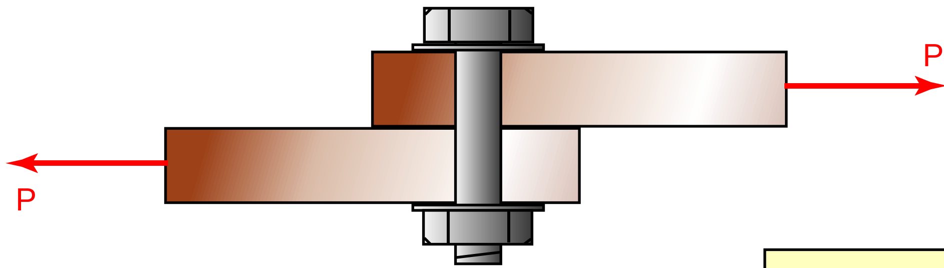




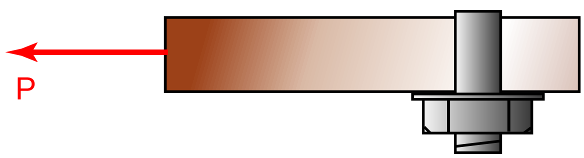
$$\sigma_{net} = \frac{Force}{Area_{net}} = \frac{Force}{thk_{plate}(width_{plate} - dia_{bolt})}$$

SHEAR STRESSES IN BOLTS

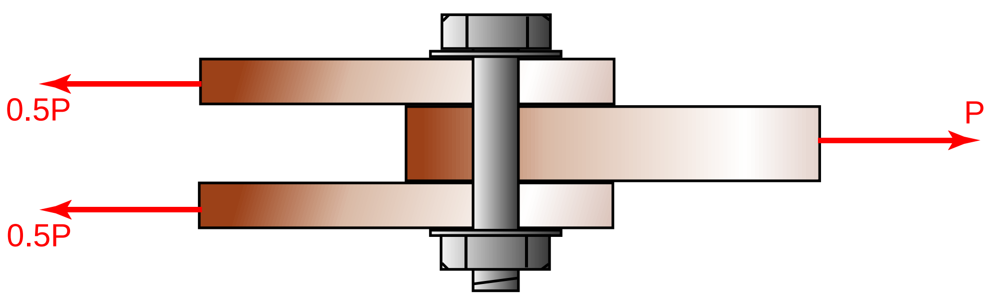
Single Shear



$$\tau_{ave} = \frac{Force_{bolt}}{A_{bolt}}$$



Double Shear



NUMERICAL ACCURACY

Numerical accuracy depends on:

-accuracy of the given data

-the accuracy of the computations

Example

I want to measure the area of my house and I'm so cheap I can't afford a tape measure. But my foot is approximately 1 foot (no pun intended) long. So I measure the length and width of the house accordingly (47.5 by 26.5 foot lengths). Find the area.

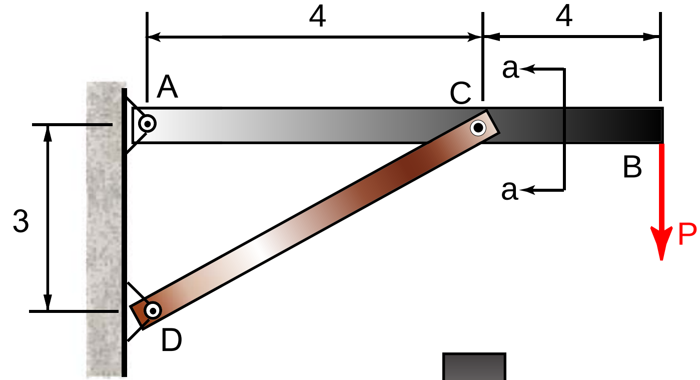
Trial and Error Solutions

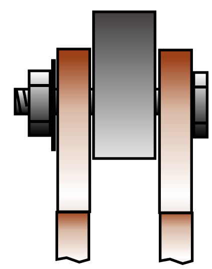
Example

Find x given: $0=73.6 - 100\sin(x) - 45\cos(x)$

Example

A beam AB is supported by a strut CD and carries a load P= 2500 lb. The strut, which consists of two bars, is connected to the beam by a bolt passing through each of the bars at joint C. (a) If the allowable average shear stress in the bolt is 14,000 psi, what is the minimum required diameter d of the bolt? (b) If the allowable bearing stress on the strut is 20 ksi and the thickness of the strut is 0.25 inches, find the minimum diameter. Units: Lbs, ft.



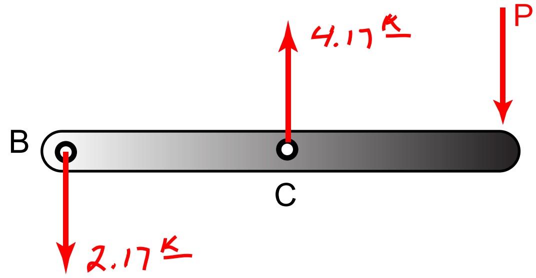


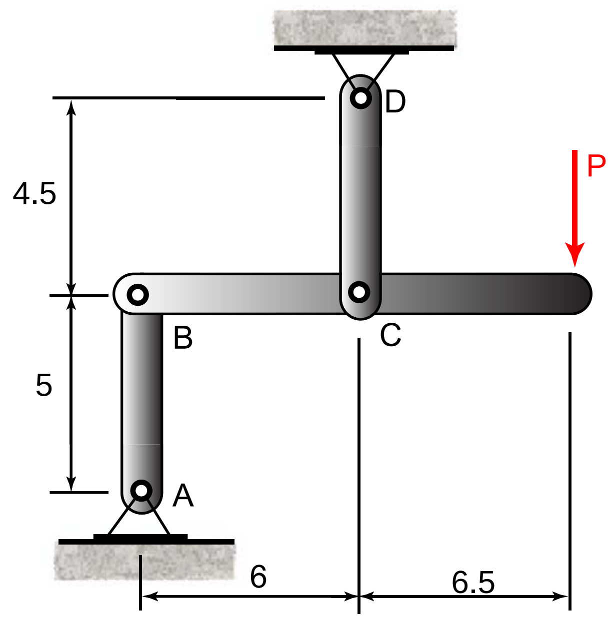
Section a-a

Example

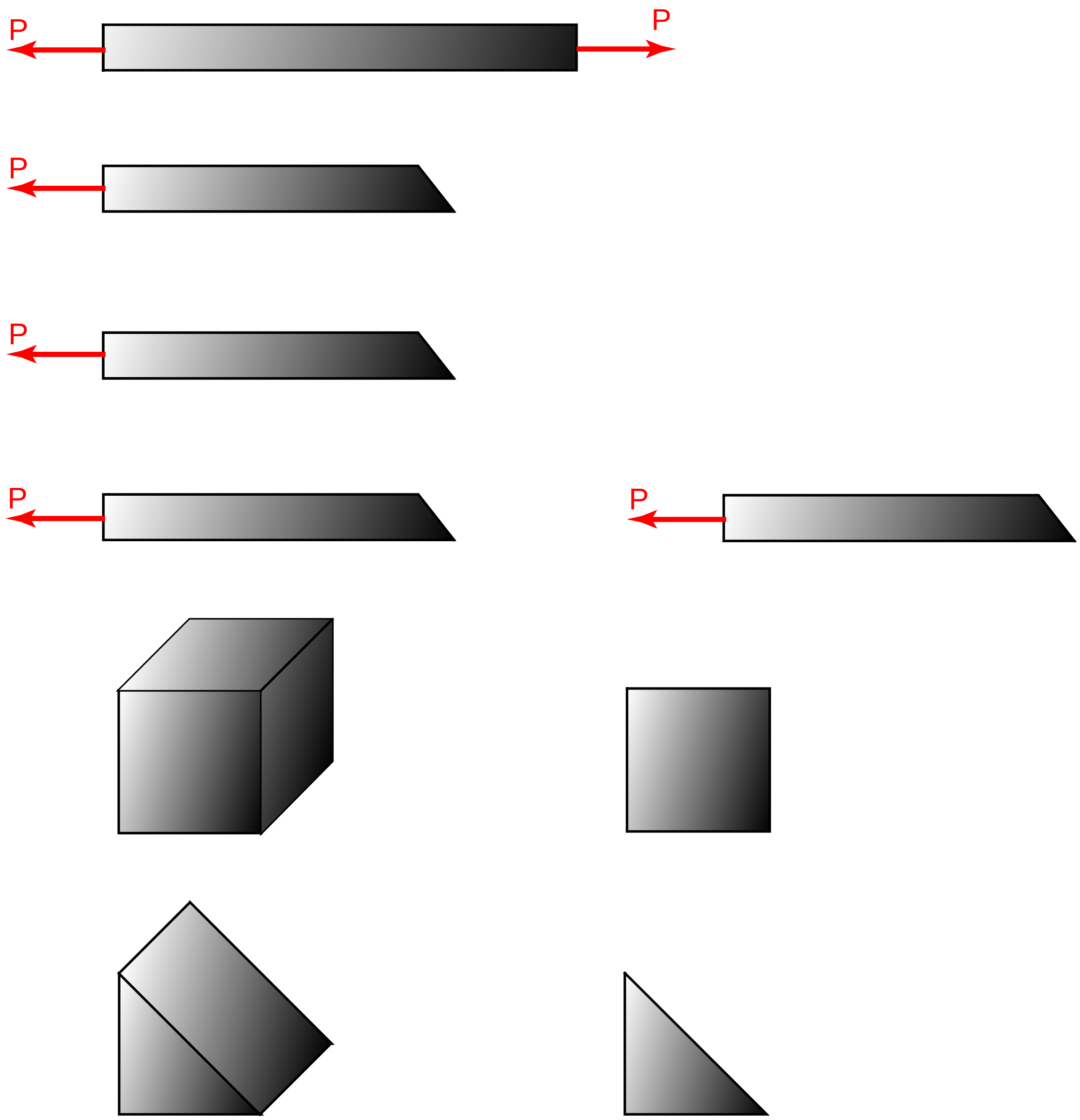
Bar AB has a cross-section of .25"x4". (a) With a load of 2-k at the end, what is the maximum bolt size at B based on a maximum net stress of 24,000 psi in member AB. (b) If the bolt has a shear stress allowable of 21,600 psi and a bearing stress allowable of 32,400 psi, find the minimum bolt size at joint B. Note: The units of "k" means 1000 lbs, often referred to as "kips". Units: Lbs, ft.

Recall from a previous solution:





STRESSES ON INCLINED SECTIONS



$$\sigma_\theta = \sigma_x \cos^2\theta$$

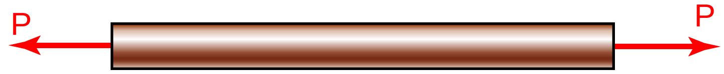
$$\sigma_{max} = \sigma_x \ @\theta = 0°$$

$$\tau_\theta = -\sigma_x \sin\theta \cos\theta$$

$$\tau_{max} = \frac{\sigma_x}{2} \ @\theta = 45°$$

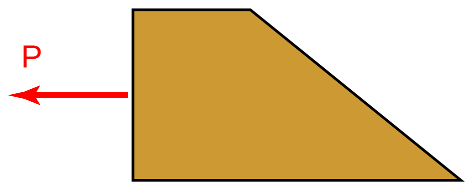
Example

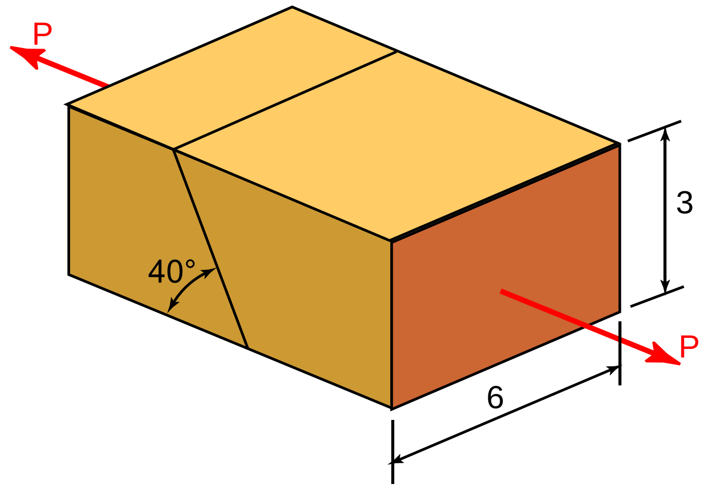
A circular steel rod is to carry a tensile load P= 140 kN. The allowable stresses in tension and shear are 120 MPa and 55 MPa, respectively. What is the minimum required diameter d of the rod?



Example

Two wooden rectangular members with a cross section of 3"x6" are joined by the simple glued 40° scarf splice shown. Knowing that the maximum allowable shearing stress in the glue splice is 90 psi and 120 psi in tension, determine the largest load P which can be safely applied. Units: Lbs, in.





DESIGN CONSIDERATIONS

Ultimate Strength

$$\sigma_U = \frac{P_U}{A}$$

Factor of Safety

$$\text{Factor of safety} = \text{F.S.} = \frac{\text{ultimate load}}{\text{allowable load}}$$

$$\text{Factor of safety} = \text{F.S.} = \frac{\text{ultimate stress}}{\text{allowable stress}}$$

Determination:

-Variations that may occur in the properties of the member under considerations.

-The number of loading cycles that may be expected during the life of the structure or machine.

-The type of loadings that are planned for the future in the design, or that may occur in the future.

-The type of failure that may occur.

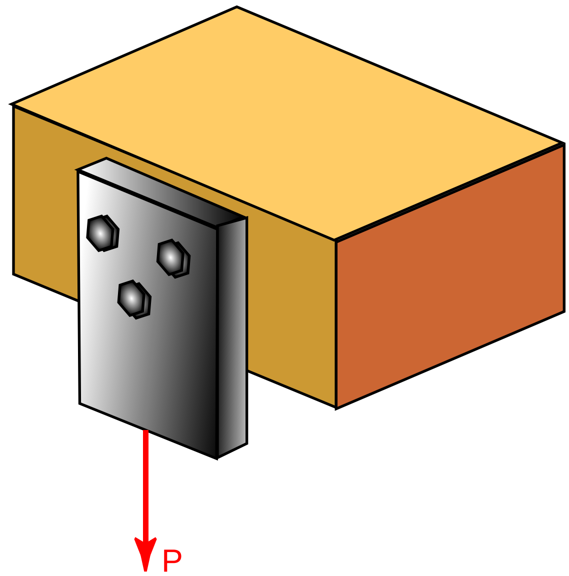
-Uncertainty due to methods of analysis.

-Deterioration that may occur in the future because of poor mainte-ance or because of unpreventable natural causes.

-The importance of a given member to the integrity of the whole structure.

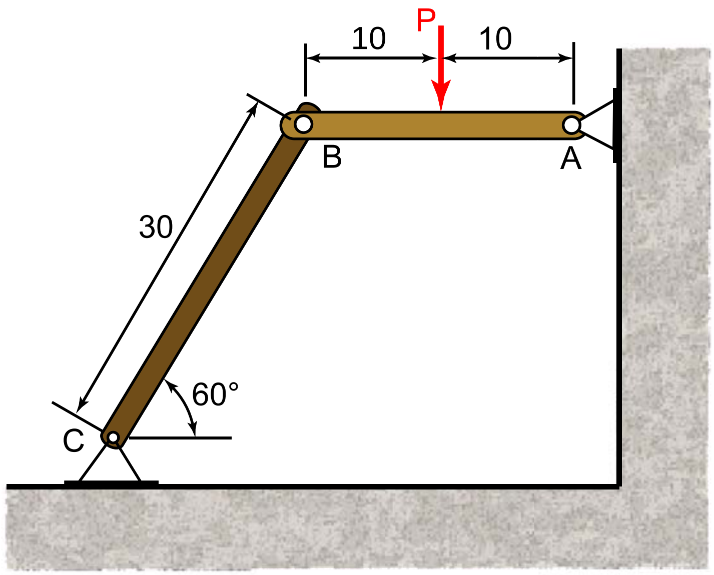
Example

Three steel bolts are to be used to attach the steel plate shown to a wooded beam. Knowing that the plate will support a 24-kip load, that the ultimate shearing stress for the bolt is 52 ksi, and a factor of safety of 3.37 is desired, determine the required diameter of the bolt.



Example

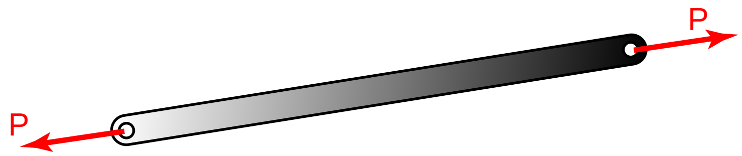
A 5/8” bolt is used at C to connect to the wooden member BC that has a cross-sectional area of 5.25 in². Knowing that the utimate shearing stress is 58 ksi for the bolt and that the ultimate normal stress is 7.2 ksi for member BC, determine the allowable load P if an overall factor of safety of 3.0 is desired. Units: Kips, in.



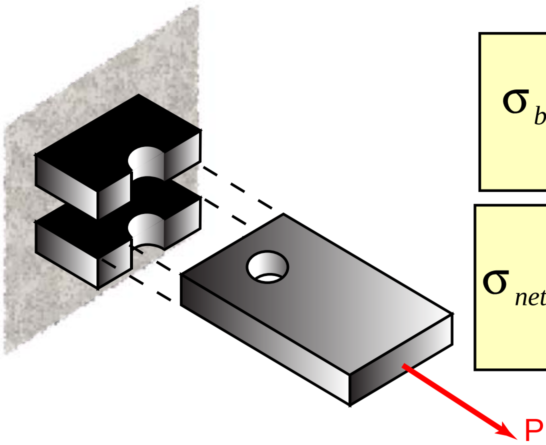
SUMMARY

Normal Stress

$$\sigma = \frac{P}{A}$$



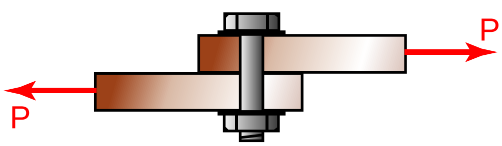
Stresses in Connections

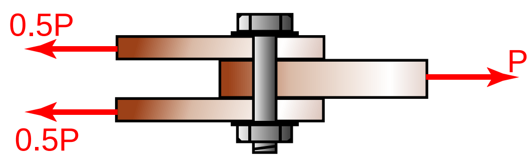


$$\sigma_{bearing} = \frac{Force}{thk_{plate} dia_{bolt}}$$

$$\sigma_{net} = \frac{Force}{Area_{net}} = \frac{Force}{thk_{plate}(width_{plate} - dia_{bolt})}$$

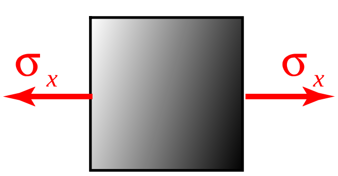
Shear Stresses in Bolts





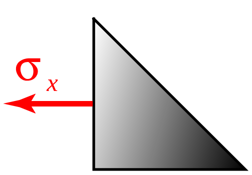
$$\tau_{ave} = \frac{Force_{bolt}}{A_{bolt}}$$

Stresses on Inclined Sections



$$\sigma_\theta = \sigma_x \cos^2\theta$$

$$\sigma_{\max} = \sigma_x \ @\theta = 0°$$



$$\tau_\theta = -\sigma_x \sin\theta \cos\theta$$

$$\tau_{\max} = \frac{\sigma_x}{2} \ @\theta = 45°$$