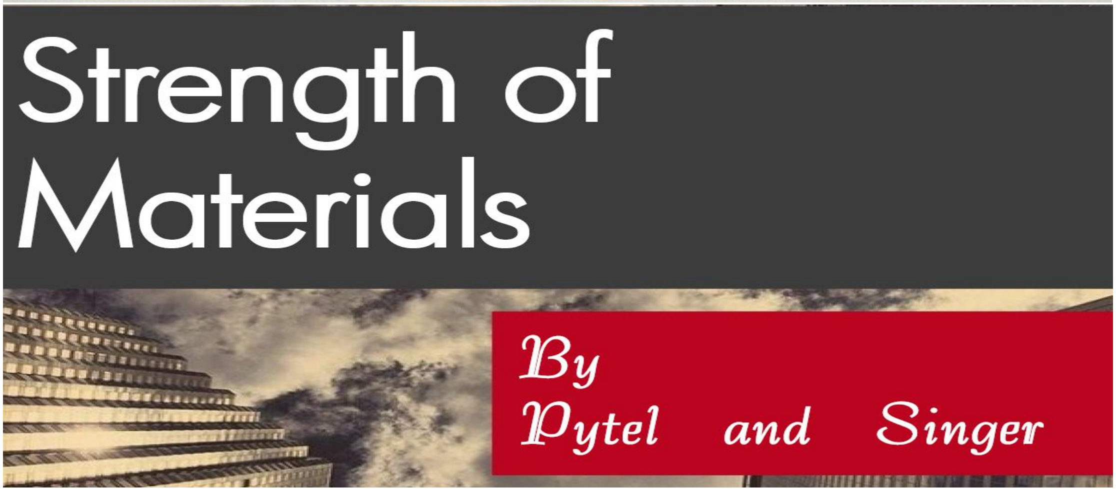
What is Strength of Materials?

- Study of **internal effects** (stresses and strains) caused by **external loads** (forces and moments) acting on a deformable body/ structure.
- **Also known as: Strength of Materials or Mechanics of Solids**
- **Determines:**
  - **1. Strength (determine by stress at failure)**
  - **2. Deformation (determined by strain)**
  - **3. Stiffness (ability to resist deformation; load needed to cause a specific deformation; determined by the stress- strain relationship)**
  - **4. Stability (ability to avoid rapidly growing deformations caused by an initial disturbance; e.g., buckling)**

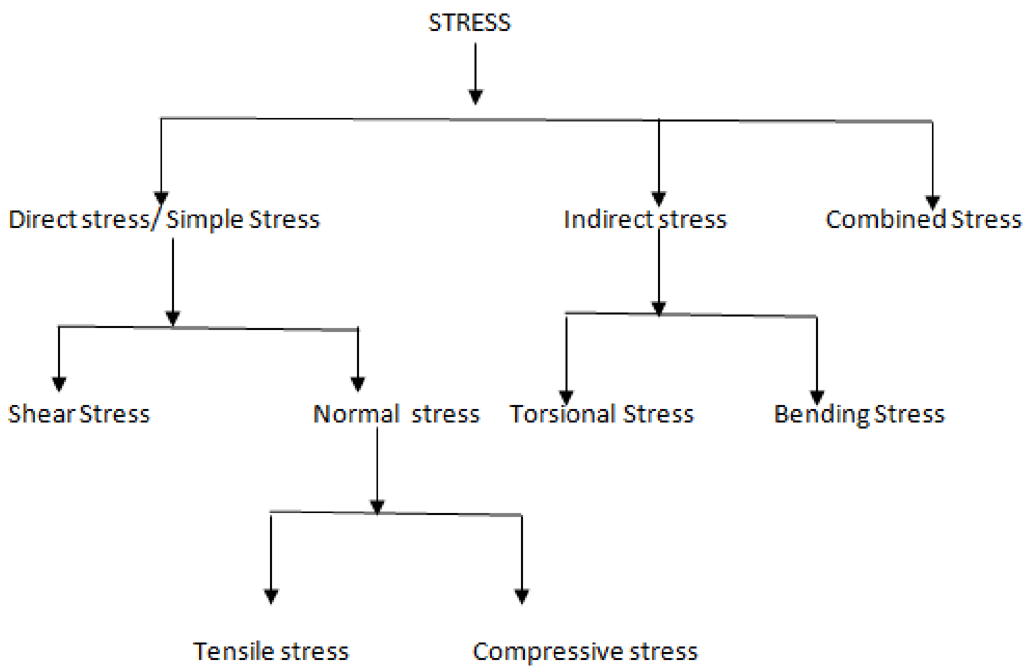
- Why we need to study this course.



Stresses

Stresses are expressed as the ratio of the applied force divided by the resisting area or it is the expression of force per unit area to structural members that are subjected to external forces and/or induced forces. Stress is the lead to accurately describe and predict the elastic deformation of a body.

Simple stress can be classified as normal stress, shear stress, and bearing stress. **Normal stress** develops when a force is applied perpendicular to the cross-sectional area of the material. If the force is going to pull the material, the stress is said to be **tensile stress** and **compressive stress** develops when the material is being compressed by two opposing forces. **Shear stress** is developed if the applied force is parallel to the resisting area. Example is the bolt that holds the tension rod in its anchor. Another condition of shearing is when we twist a bar along its longitudinal axis. This type of shearing is called torsion. Another type of simple stress is the **bearing stress**; it is the contact pressure between two bodies.



Stress

Stress is the expression of force applied to a unit area of surface. It is measured in psi (English unit) or in MPa (SI unit). Stress is the ratio of force over area.

Stress = force / area

Simple Stresses

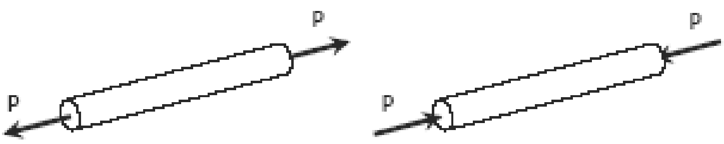
There are three types of simple stress namely; normal stress, shearing stress, and bearing stress.

Normal Stress

The resisting area is perpendicular to the applied force, thus normal. There are two types of normal stresses; tensile stress and compressive stress. Tensile stress applied to bar tends the bar to elongate while compressive stress tend to shorten the bar.

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

Where P is the applied normal load in Newton and A is the area in mm^2. The maximum stress in tension or compression occurs over a section normal to the load.



Bar in Tension Bar in Compression

Ex: A hollow steel tube with an inside diameter of 100 mm must carry a tensile load of 400 kN Determine the outside diameter of the tube if the stress is limited to 120 MN/m^2.

$P = \sigma A$

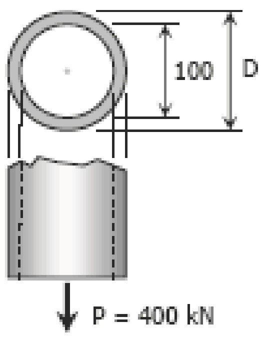
where:

$P = 400\ kN = 400\ 000\ N$

$\sigma = 120\ MPa$

$A = \frac{1}{4}\pi D^2 - \frac{1}{4}\pi(100^2)$

$= \frac{1}{4}\pi(D^2 - 10\ 000)$



thus,

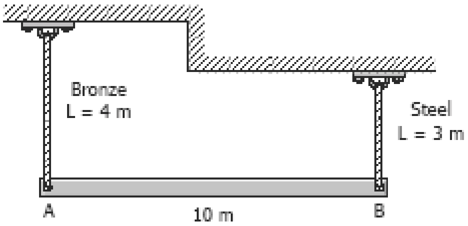
$400\ 000 = 120[\frac{1}{4}\pi(D^2 - 10\ 000)]$

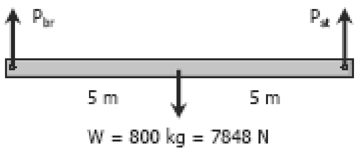
$400\ 000 = 30\pi D^2 - 300\ 000\pi$

$D^2 = \dfrac{400\ 000 + 300\ 000\pi}{30\pi}$

$D = \mathbf{119.35\ mm}$

Ex2: A homogeneous 800 kg bar AB is supported at either end by a cable as shown in Fig. Calculate the smallest area of each cable if the stress is not to exceed 90 MPa in bronze and 120 MPa in steel.





By symmetry:

$P_{br} = P_{st} = \frac{1}{2}(7848)$

$= 3924$ N

For bronze cable:

$P_{br} = \sigma_{br} A_{br}$

$3924 = 90 A_{br}$

$A_{br} = 43.6$ **mm²**

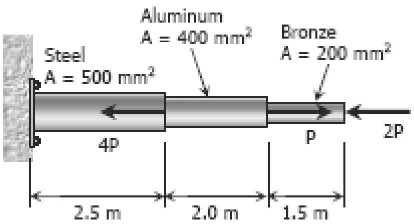
For steel cable:

$P_{st} = \sigma_{st} A_{st}$

$3924 = 120 A_{st}$

$A_{st} = 32.7$ **mm²**

107: An aluminum rod is rigidly attached between a steel rod and a bronze rod as shown in Fig. Axial loads are applied at the positions indicated. Find the maximum value of P that will not exceed a stress in steel of 140 MPa, in aluminum of 90 MPa, or in bronze of 100 MPa.



For bronze:

$\sigma_{br} A_{br} = 2P$

$100(200) = 2P$

$P = 10\ 000$ N

For aluminum:

$\sigma_{al} A_{al} = P$

$90(400) = P$

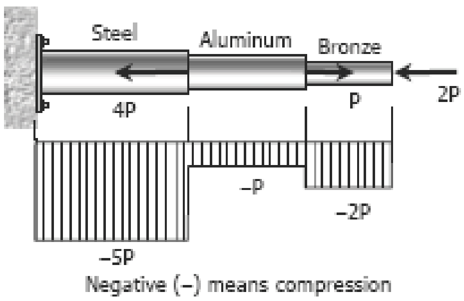
$P = 36\ 000$ N

For Steel:

$\sigma_{st} A_{st} = 5P$

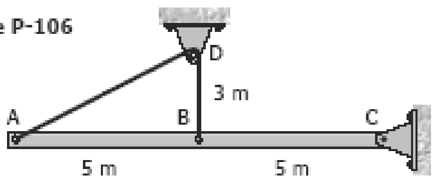
$P = 14\ 000$ N

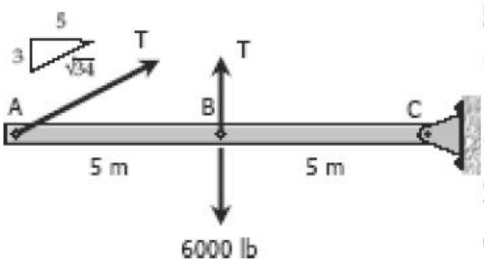
For safe P, use $P = 10\ 000$ N = **10 kN**



106: The homogeneous bar shown in Fig., is supported by a smooth pin at C and a cable that runs from A to B around the smooth peg at D. Find the stress in the cable if its diameter is 0.6 inch and the bar weighs 6000 lb.

Figure P-106





$\Sigma M_C = 0$

$5T + 10\left(\frac{3}{\sqrt{34}}T\right) = 5(6000)$

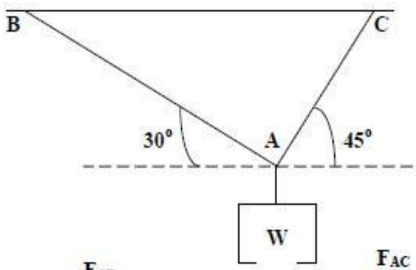
$T = 2957.13$ lb

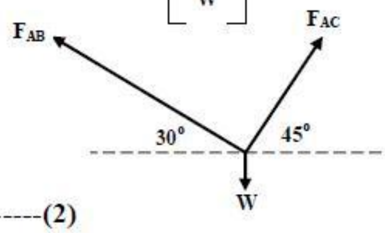
$T = \sigma A$

$2957.13 = \sigma\left[\frac{1}{4}\pi(0.6^2)\right]$

$\sigma =$ **10 458.72 psi**

Ex4: Determine the largest weight (W) which can be supported by the two wires as shown in fig. The stresses in wires AB and AC are not to exceed 100 MPa and 150 MPa respectively. The cross-sectional areas of the two wires are 400mm2 for wire AB and 200mm2 for wire AC.





Free-body diagram

$\sum F_x = 0$ **(Equilibrium state)**

$$F_{AB} Cos\,30 = F_{AC} Cos\,45$$

$$F_{AB} = F_{AC} \frac{Cos\,45}{Cos\,30} = \frac{\frac{1}{\sqrt{2}}}{\frac{\sqrt{3}}{2}} = \frac{\sqrt{2}}{\sqrt{3}}$$

$$F_{AB} = \sqrt{\frac{2}{3}} F_{AC} \text{ -------(1)}$$

$$F_{AB} = 0.8165 F_{AC}$$

$$\sum F_y = 0 \longrightarrow W = F_{AB} Sin\,30^o + F_{Ac} Sin\,45^o \text{ -----(2)}$$

Sub (1) in (2) :

$$W = 0.8165 F_{AC} Sin 30^o + F_{AC} Sin 45^o$$

$$\sigma = \frac{F}{A} \longrightarrow F_{AC} = \sigma_{AC} * A_{AC} = 150*10^6 * 200*10^{-6} = 30kN$$

$$W = 0.8165 * 30 * 10^3 Sin\,30^o + 30 * 10^3 Sin\,45^o$$

$$(W = 33.5kN)$$

Homework

113: Find the stresses in members BC, BD, and CF for the truss shown in Fig. Indicate the tension or compression. The cross sectional area of each member is 1600 mm^2.

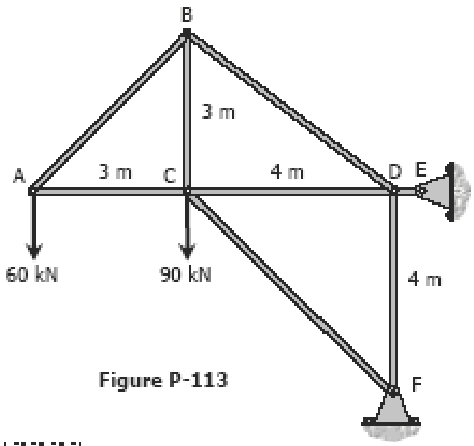


Figure P-113

114: The homogeneous bar ABCD shown in Fig., is supported by a cable that runs from A to B around the smooth peg at E, a vertical cable at C, and a smooth inclined surface at D. Determine the mass of the heaviest bar that can be supported if the stress in each cable is limited to 100 MPa. The area of the cable AB is 250 mm^2 and cable at C is 300 mm^2.

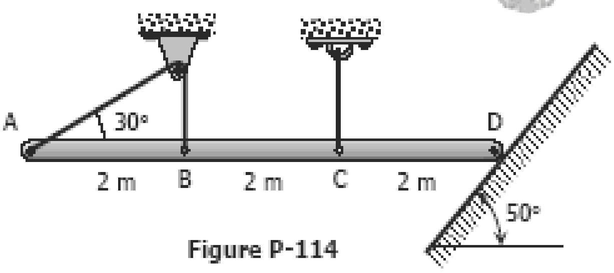


Figure P-114