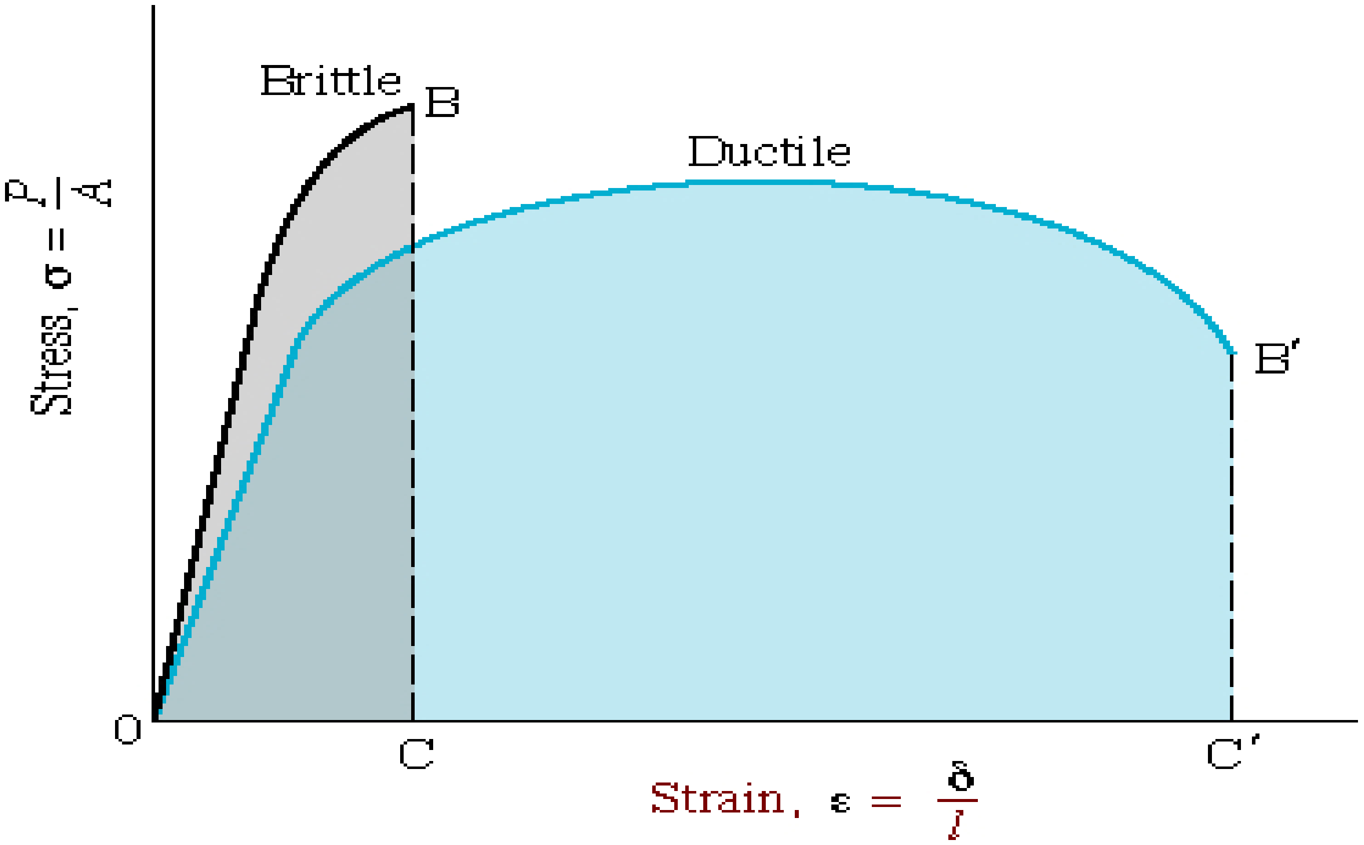
Brittle and Ductile Metal Comparison



Modulus of resilience:
the area under the linear part of the curve, measuring the stored elastic energy

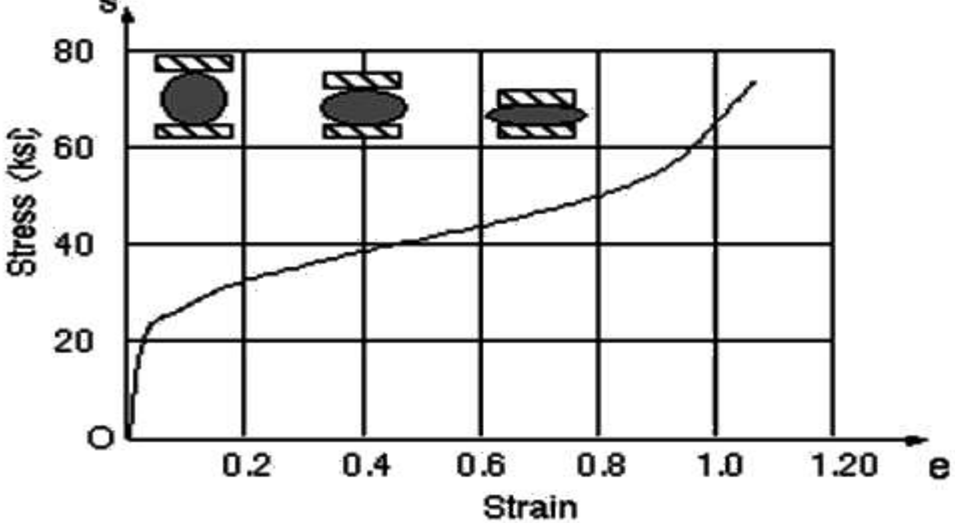
Toughness: the total area under the curve, which measures the energy absorbed by the specimen in the process of breaking

Tensile stress-strain diagrams for brittle and ductile metals loaded to fracture

Ductile Material – Materials that are capable of undergoing large strains (at normal temperature) before failure. An advantage of ductile materials is that visible distortions may occur if the loads before too large. Ductile materials are also capable of absorbing large amounts of energy prior to failure. Ductile materials include mild steel, aluminum and some of its alloys, copper, magnesium, nickel, brass, bronze and many others.

Brittle Material – Materials that exhibit very little inelastic deformation. In other words, materials that fail in tension at relatively low values of strain are considered brittle. Brittle materials include concrete, stone, cast iron, glass and plaster.

Compression Stress Strain Diagram



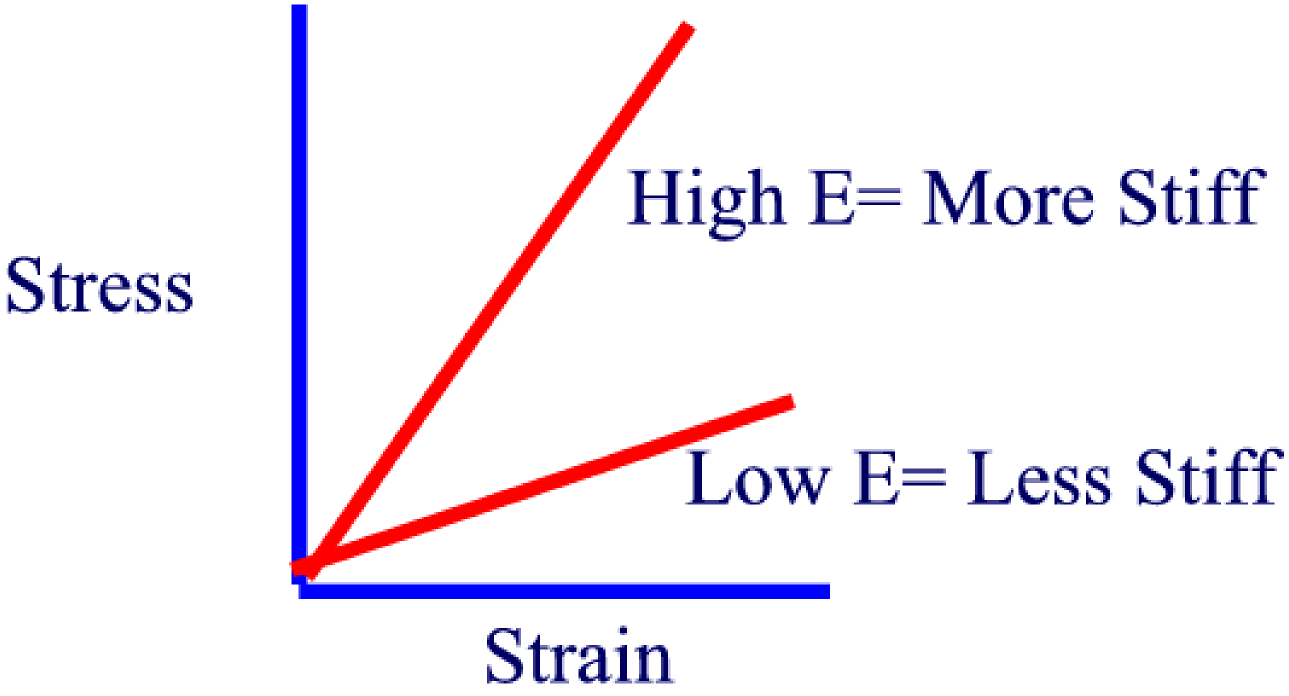
Compression stress-strain diagram for copper.

Stress-strain diagrams for compression have different shapes from those for tension. Ductile metals such as steel, aluminum, and copper have proportional limits in compression very close to those in tension, hence the initial regions of their compression stress-strain diagrams are very similar to the tension diagrams. When yielding begins, the behavior is quite different.

In a tension test, the specimen is being stretched, necking may occur, and ultimately fracture takes place. When a small specimen of ductile material is compressed, it begins to bulge outward on the sides and become barrel shaped. With increasing load, the specimen is flattened out, thus offering increased resistance to further shortening (which means the stress-strain curve goes upward

Linear Elasticity, Hooke's Law and Poisson's Ratio

Hooke's Law: $\sigma_x = E\varepsilon_x$,

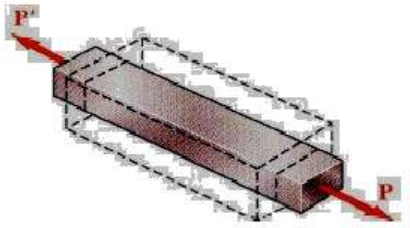


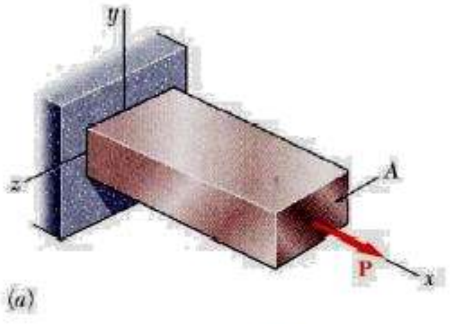
Isotropic – Isotropic materials have elastic properties that are independent of direction. Most common structural materials are isotropic.

Anisotropic – Materials whose properties depend upon direction.

An important class of anisotropic materials is fiber-reinforced composites.

Homogeneous – A material is homogeneous if it has the same composition at every point in the body. A homogeneous material may or may not be isotropic





Design for Axial Loads and Direct Shear

Analysis: Given the structure and loads, determine stresses and strains.

Design: Given the loads and allowable stresses, determine the properties of the structure.

Design for axial loads and direct shear entails finding the required area to carry the loads

$$\text{Required area} = \frac{\text{Load to be transmitted}}{\text{Allowable stress}} \quad \text{(i.e., Strength Consideration)}$$

Other design considerations include

- **Stiffness**: Designing the structure to resist changes in shape.
- **Stability**: Designing the structure to resist buckling under compressive loads.
- **Optimization**: Designing the best structure to meet a particular goal.

Allowable Stress and allowable Load

Factors to be considered in design includes :

- **functionality,**
- **strength,**
- **appearance,**
- **economics and**
- **environmental protection.**

Factor of safety considerations:

- uncertainty in material properties
- uncertainty of loadings
- uncertainty of analyses
- number of loading cycles
- types of failure
- maintenance requirements and deterioration effects
- importance of member to integrity of whole structure
- risk to life and property
- influence on machine function

The factor of safety must be greater than one to avoid failure

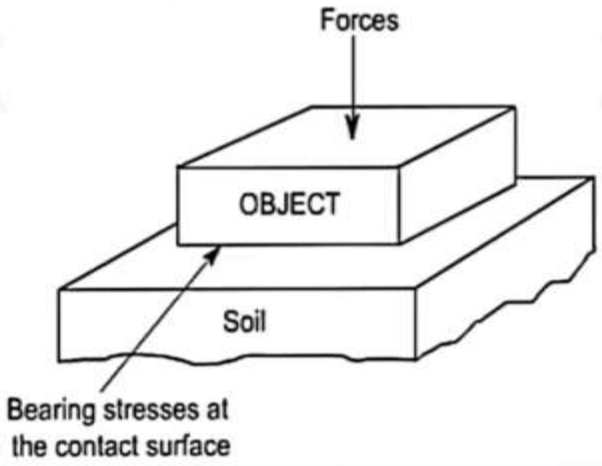
Factor of Safety = $n = \dfrac{Actual\ strength}{Required\ strength}$

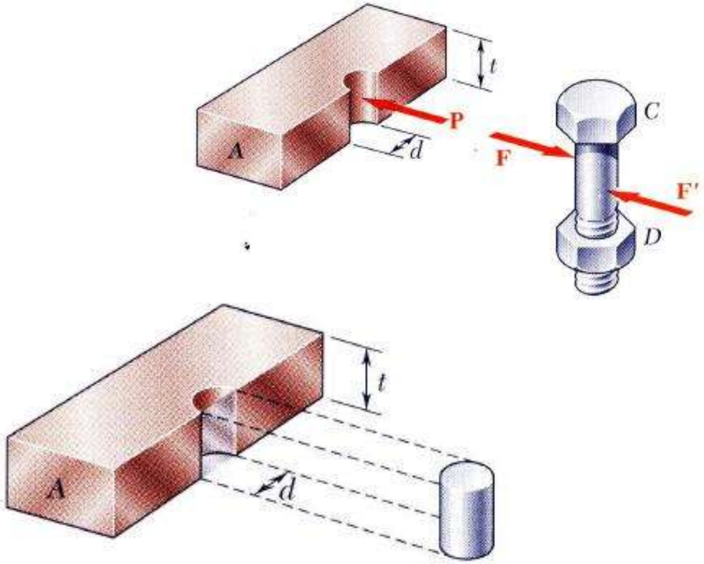
The allowable load = (Permissible load or safe load) = (Allowable stress) (Area)

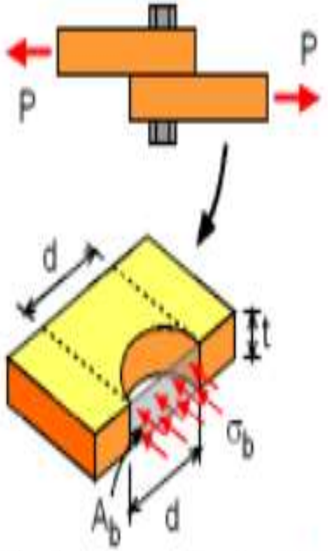
$$P_{allow} = \sigma_{allow} A$$

Bearing Stress

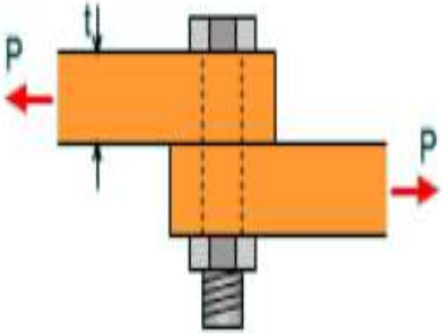
- When one object presses against another, it is referred to a bearing stress (They are in fact the compressive stresses) as shown in Figure (3.5).







Bearing Stress Due to a Bolt



Bearing Stress

The average bearing stress is the force pushing against a structure divided by the area. Exact bearing stress is more complicated but for most applications, the following equation works well for the average,

$$\sigma_b = P/A_b$$

This relationship can be further refined by using the width and height of the bearing area as

$$\sigma_b = \frac{P}{dt}$$

2-إجهاد القص Shear stress: يعرف بانه الاجهاد الذي يكون بنفس مستو المقطع العرضي للمادة وينشا من تطبيق القوة بشكل موازي للمقطع العرضي للمادة، ويرمز له بالرمز tau (τ).

ملاحظة1: إجهاد القص ناتج من قوة القص shear force (V) وليس القوة العمودية normal force (P) لذلك إجهاد القص يعطى بالقانون التالي: $\tau = \frac{V}{Area}$.

ملاحظة2: بعض الاربطة و المساند مثل (hinge ، pin ، clevis) تخضع لقوة قص من الجانبين وبالتالي ينتج عنها ما يسمى بالقص المزدوج (double shear) وبالتالي سيكون إجهاد القص مضاعف ($2 \times \tau$) لذلك عند الحل إما أن نضرب الإجهاد الناتج بـ2 أو نقسم القوة على 2 ($V = \frac{P}{2}$)، أي سيكون القانون في حالة الـdouble shear كالتالي: $2 \times \tau = \frac{P}{A}\ or \gg \tau = \frac{\frac{P}{2}}{A} = \frac{V}{A}$

ملاحظة3: في حالة وجود بعض الإربطة مثل (bracket ، rivet) سيكون هناك فقط قوة قص من جانب واحد مما ينتج عنها إجهاد قص مفرد (single shear) وبالتالي لا داعي لقسمة القوة $V = P$.

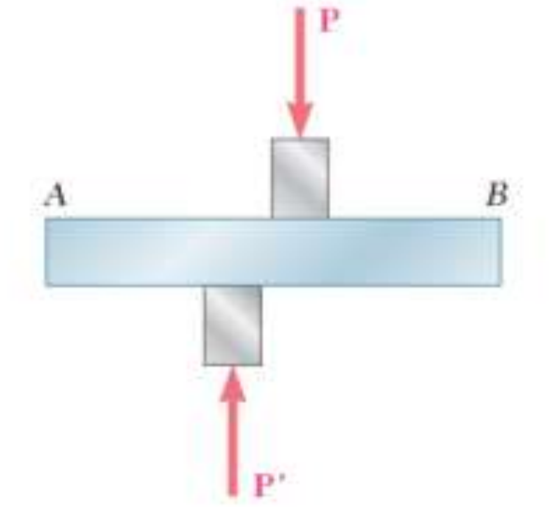
ملاحظة4: المساحة Area (A) هي مساحة المقطع (cross-sectional area) وليس مساحة الشكل الكلي إي إذا كان الشكل إسطواني سيكون القطع له دائري لذلك نستخدم مساحة الدائرة ($A = \pi r^2\ or \gg \frac{\pi d^2}{4}$)،

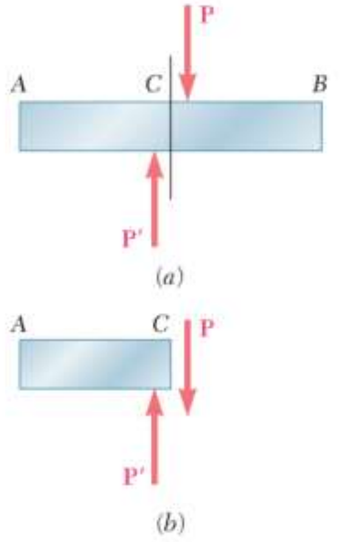
وحسب الشكل المعطى بالسؤال

Shearing Stress

The type of stress is obtained when transverse forces *P* and *P ′* are applied to a member *AB* (Fig. 1.). Passing a section at *C* between the points of application of the two forces (Fig. 1.a), we obtain the diagram of portion *AC* shown in Fig. 1.b. We conclude that internal forces must exist in the plane of the section, and that their resultant is equal to *P*. These elementary internal forces are called shearing forces, and the magnitude *P* of their resultant is the shear in the section. Dividing the shear *P* by the area *A* of the cross section, we obtain the average shearing stress in the section. Denoting the shearing stress by the Greek letter *τ* (tau), we write

$$\tau = V/A$$



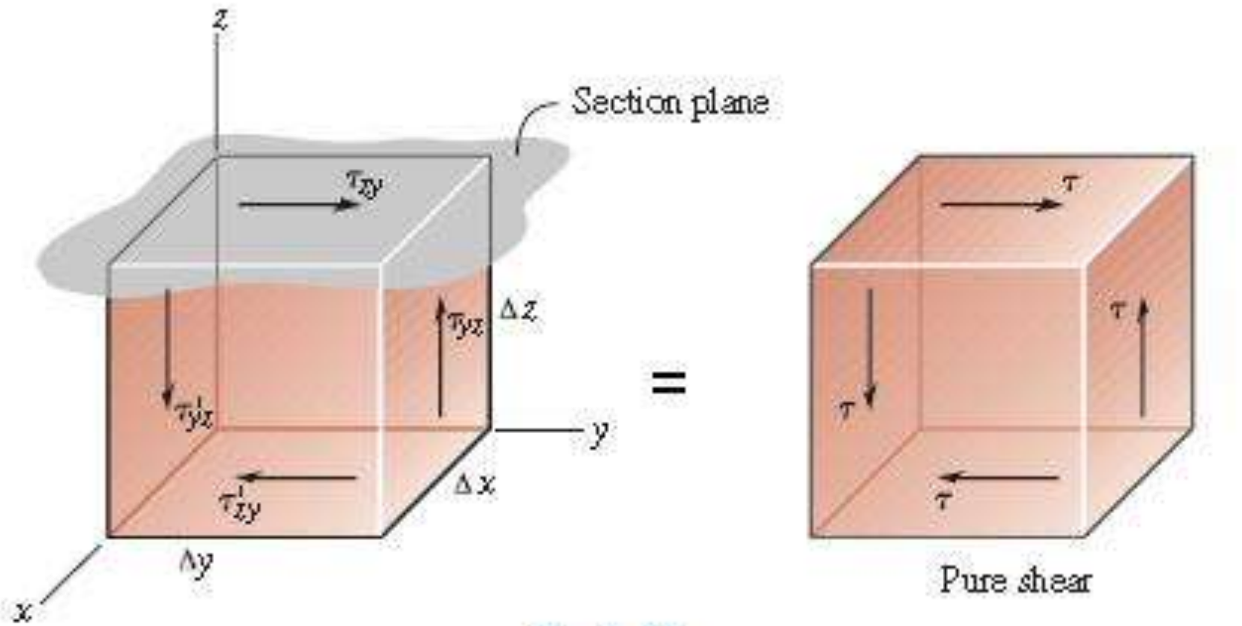


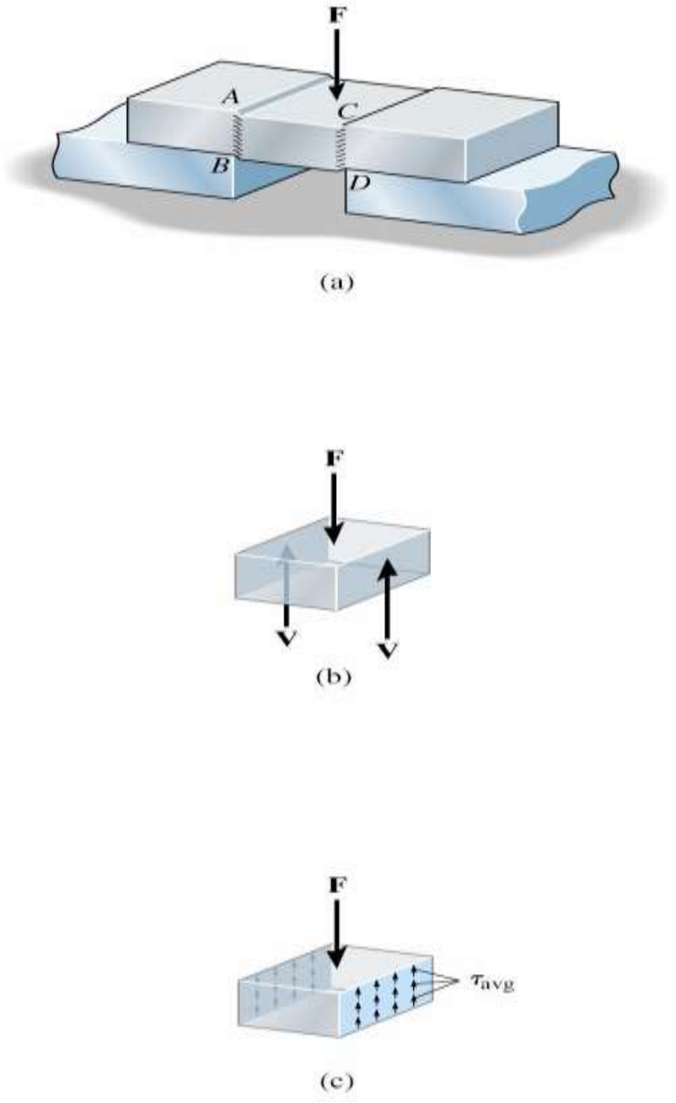
Average Shear Stress

Average shear stress at the section, which is assumed to be the same at each point located on the section $\tau = V/A$

V = internal resultant shear force at the section determined from the equations of equilibrium

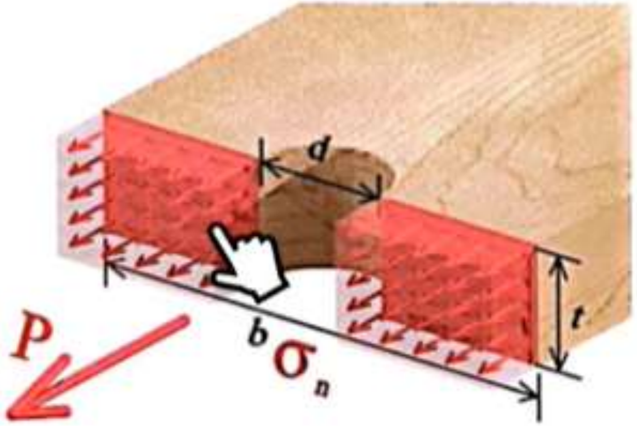
A= area at the section (parallel to the shear force.)

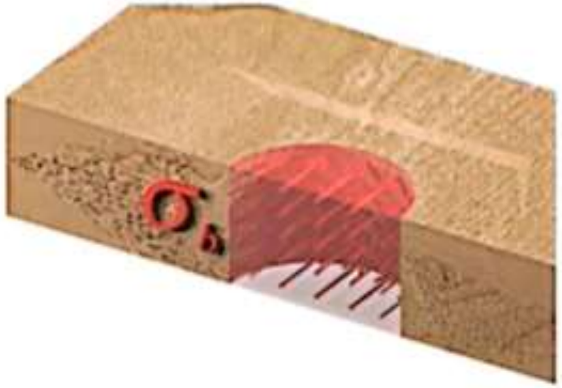


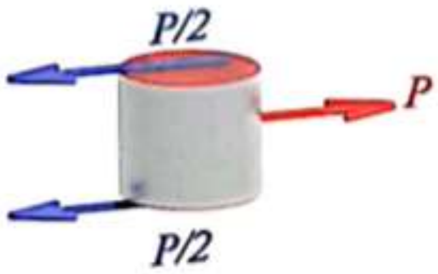


Types of Stress

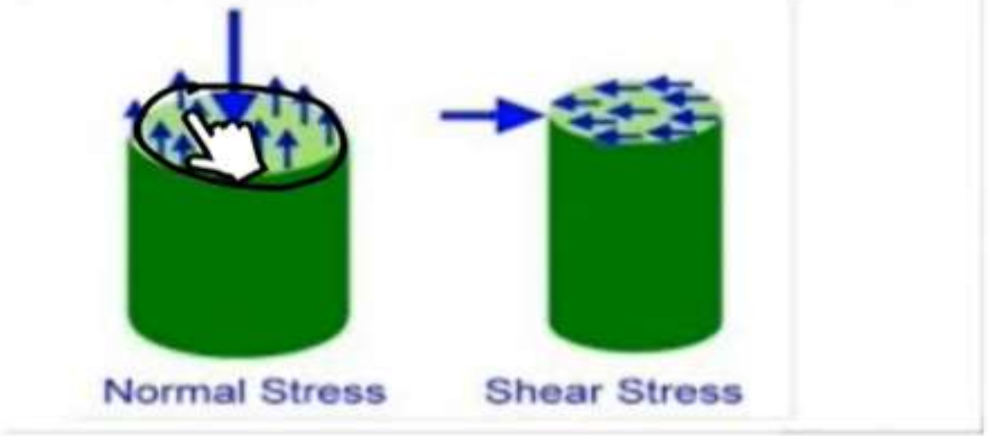
Normal stress
Shear stress
Bearing stress

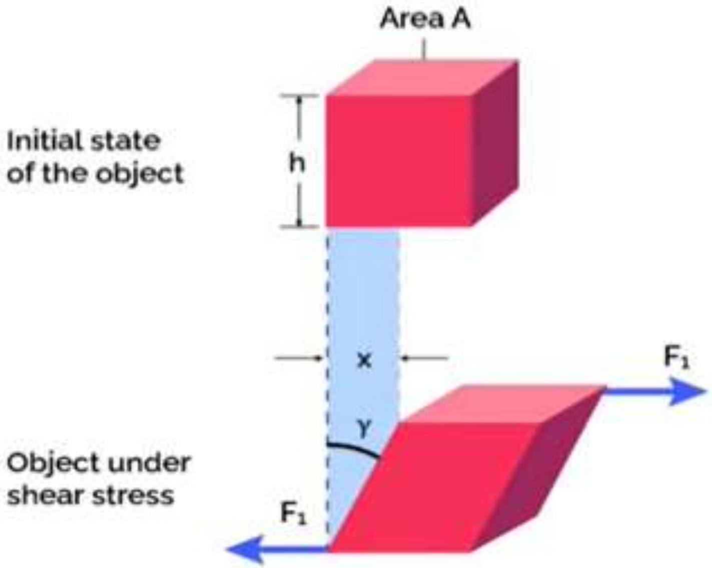




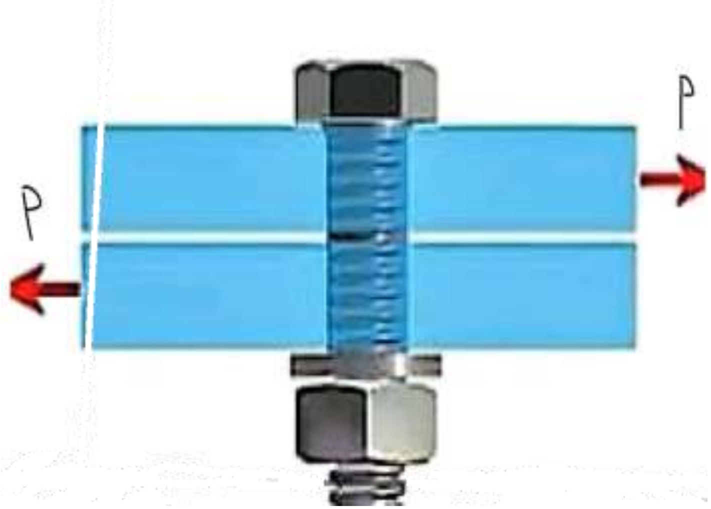


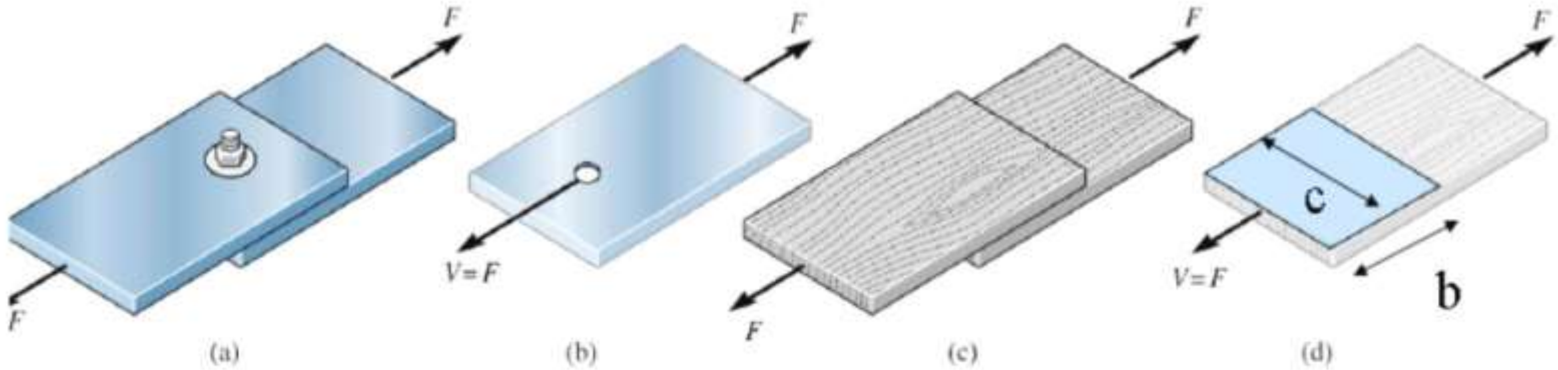
Difference between Normal Stress & Shear Stress





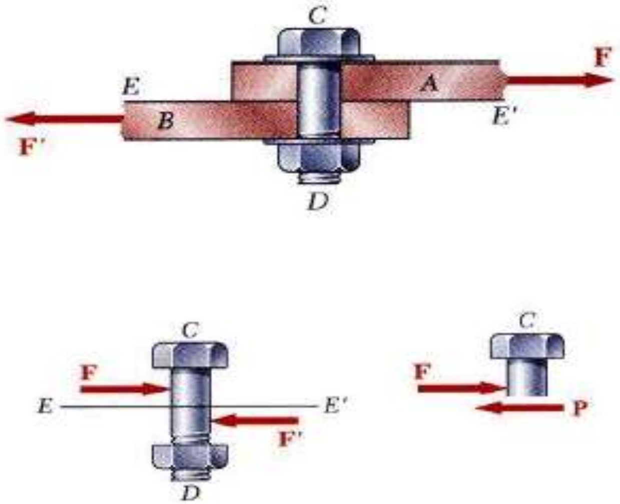
Single Shear





Shear stress on bolt

Shear stress on bonded area



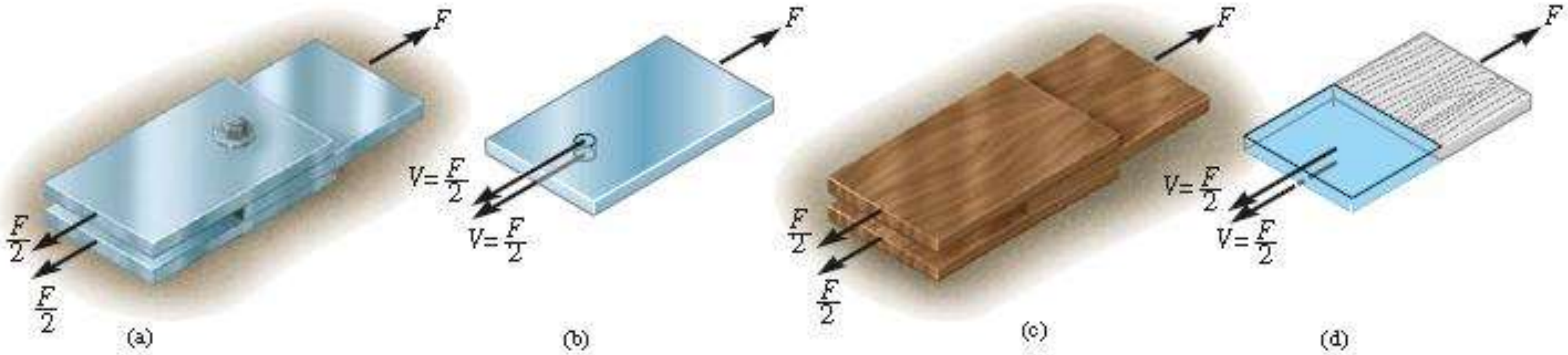
$\tau = F/A = F/\pi r^2$

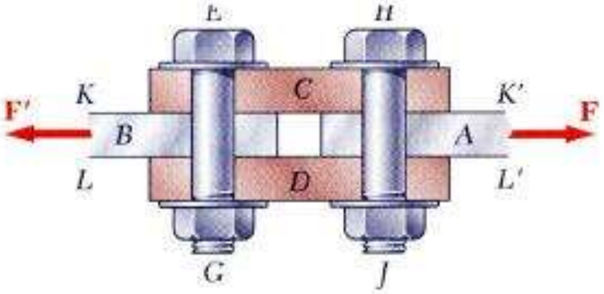
Where r is the radius of the bolt

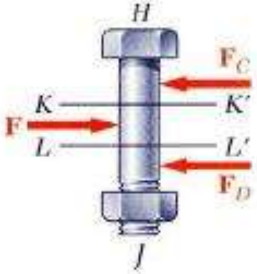
$\tau = F/bc$

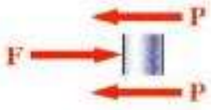
Where (bc) is the area of contact subjected to the shear force

Double Shear









$$\tau=(F/2)/A=F/2A$$

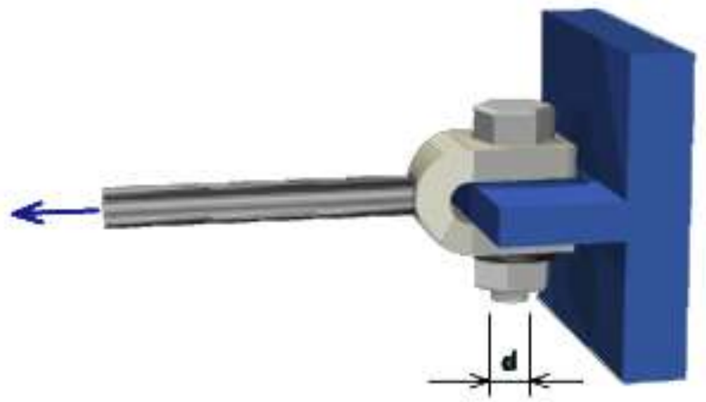
Where A is the parallel area of the bolt subjected to shear force

The bolted connection is subjected to a tensile force of P= 91kN. The diameter of the bolt d= 22mm.

Determine the average shear stress in the bolt in (MPa) P

Cross section area of bolt = 380.13 mm^2

Shear stress (τ) = 91x 1000 N /(2*380.13) = 119.7 MPa

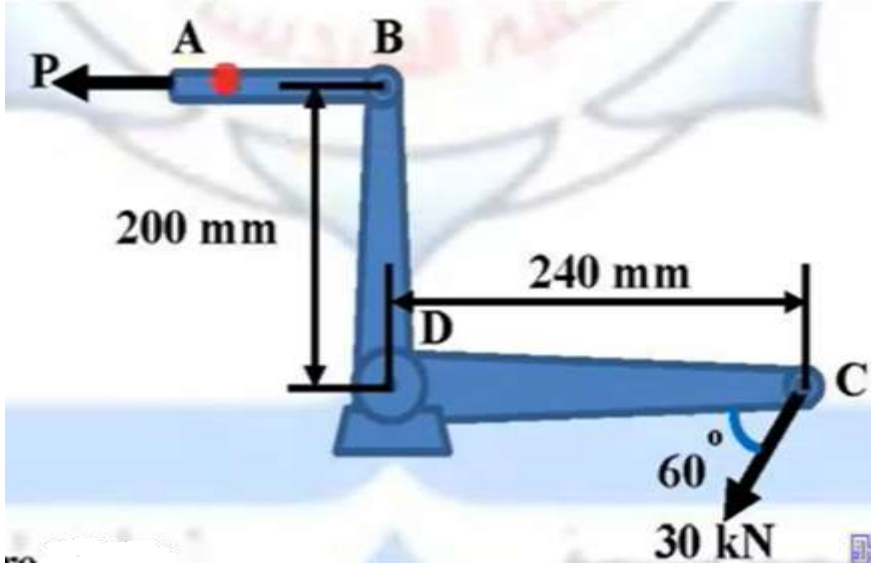


Example 1

The bell crank shown in figure is in equilibrium ,

Determine the required diameter of the connecting rod AB if its axial stress is limited to 100 MPa .

Determine the shearing stress in the pin at point D if its radius the 20 mm,



Solution

$$\sum M_D = 0 \rightarrow P(200) = 30 sin60(240)$$

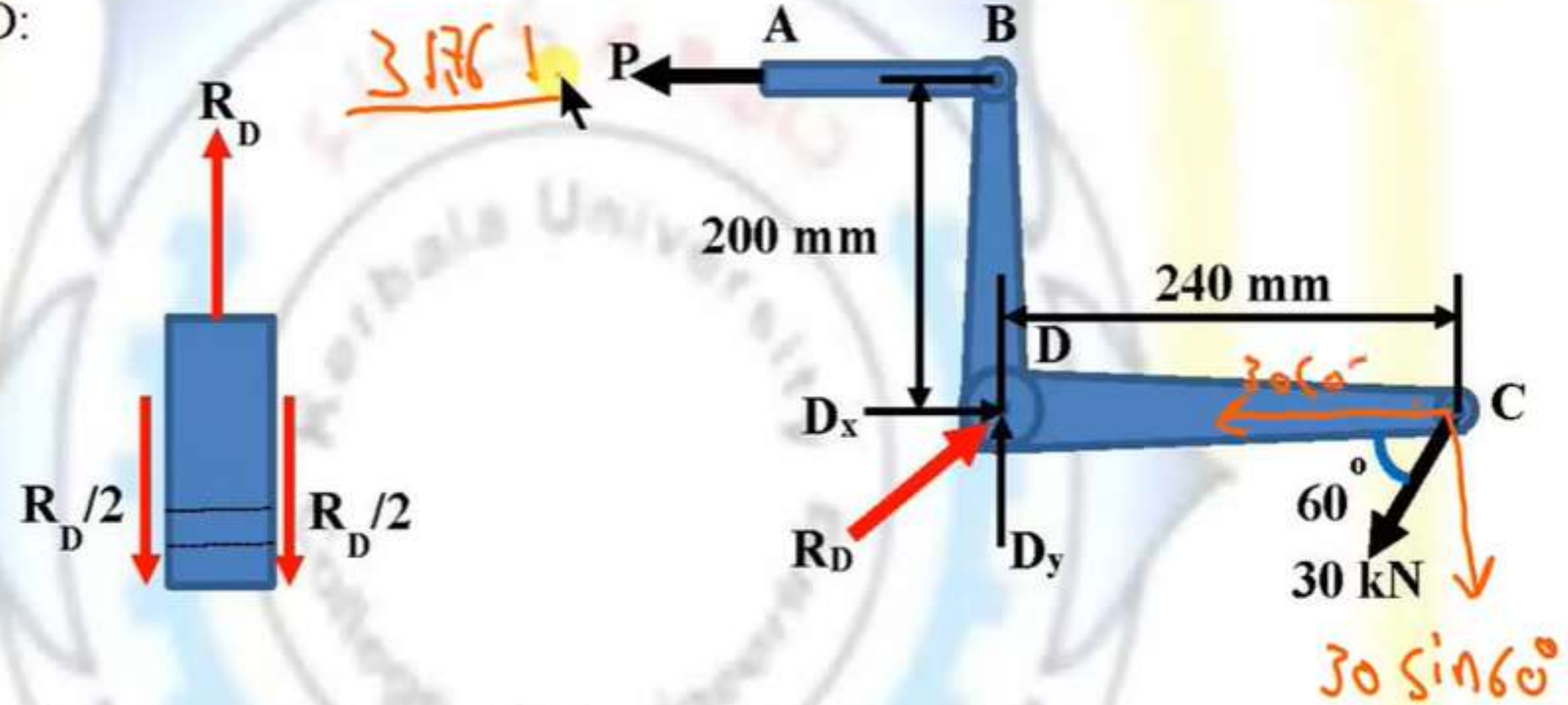
$$\rightarrow P = 31.176\ kN$$

$$\sigma = \frac{P}{A} = \frac{31.176 \times 10^3}{A} = 100\ MPa$$

$$\rightarrow A = \frac{31.176 \times 10^3}{100} = 311.77\ mm^2$$

$$A = \pi(r^2) = 311.77 \rightarrow r \cong 10\ mm$$

b) Frame as F.B.D:



$$\sum F_x = 0 \rightarrow D_x = P + 30cos60 \rightarrow D_x = 48.5\ kN$$

$$\sum F_y = 0 \rightarrow D_y = 30sin60 \rightarrow D_y = 25.98\ kN$$

$$R_D = \sqrt{(D_x)^2 + (D_y)^2} = \sqrt{(48.5)^2 + (25.98)^2} = 55\ kN$$