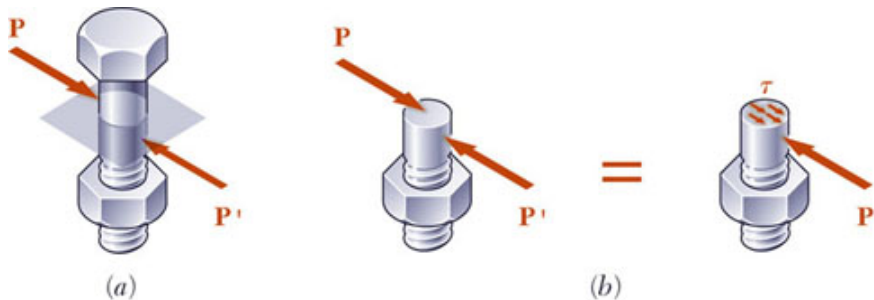
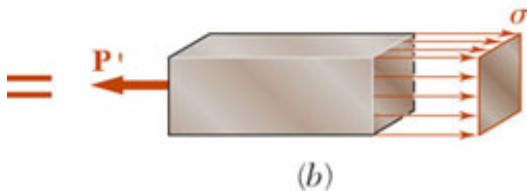
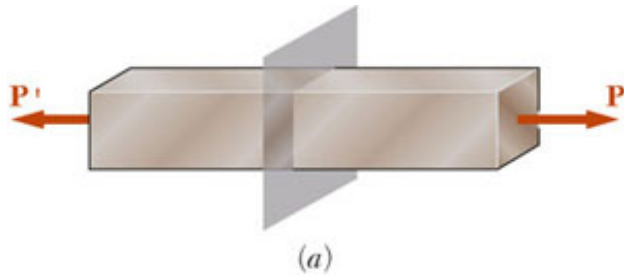


- Homework #1 has been posted on the website

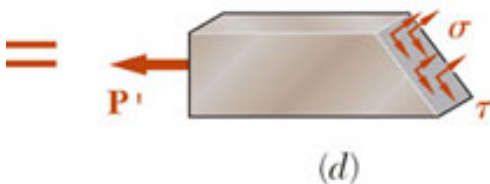
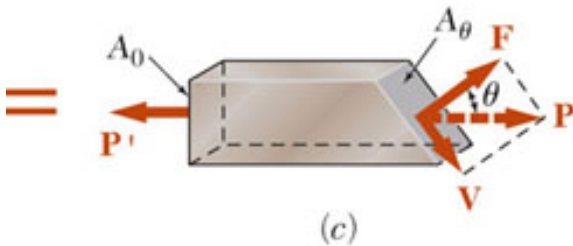
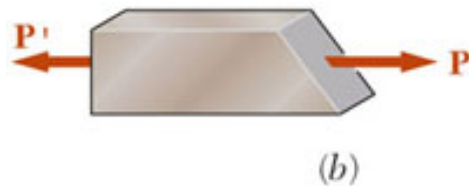
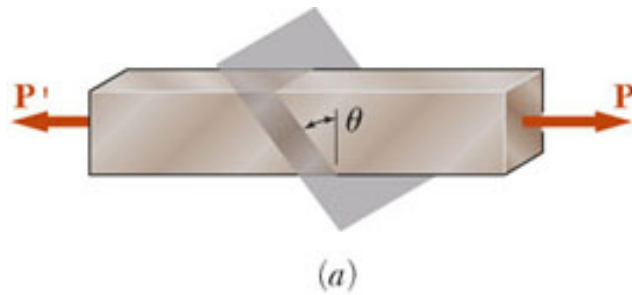


## Stress in Two Force Members



- Axial forces on a two force member result in only normal stresses on a plane cut perpendicular to the member axis.
- Transverse forces on bolts and pins result in only shear stresses on the plane perpendicular to bolt or pin axis.
- Will show that either axial or transverse forces may produce both normal and shear stresses with respect to a plane other than one cut perpendicular to the member axis.

## Stress on an Oblique Plane



- Pass a section through the member forming an angle  $\theta$  with the normal plane.
- From equilibrium conditions, the distributed forces (stresses) on the plane must be equivalent to the force  $P$ .
- Resolve  $P$  into components normal and tangential to the oblique section,
 
$$F = P \cos \theta \quad V = P \sin \theta$$
- The average normal and shear stresses on the oblique plane are

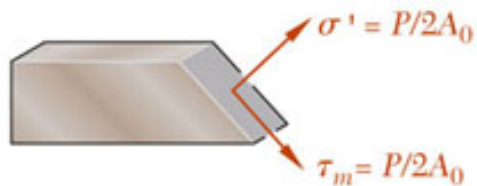
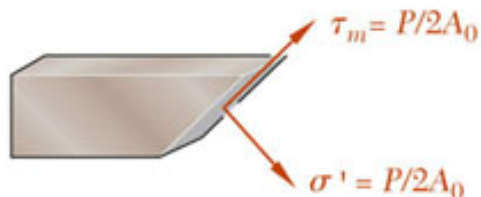
$$\sigma = \frac{F}{A_\theta} = \frac{P \cos \theta}{A_0 / \cos \theta} = \frac{P}{A_0} \cos^2 \theta$$

$$\tau = \frac{V}{A_\theta} = \frac{P \sin \theta}{A_0 / \cos \theta} = \frac{P}{A_0} \sin \theta \cos \theta$$

## Maximum Stresses



(a) Axial loading

(b) Stresses for  $\theta = 0$ (c) Stresses for  $\theta = 45^\circ$ (d) Stresses for  $\theta = -45^\circ$ 

- Normal and shearing stresses on an oblique plane

$$\sigma = \frac{P}{A_0} \cos^2 \theta \quad \tau = \frac{P}{A_0} \sin \theta \cos \theta$$

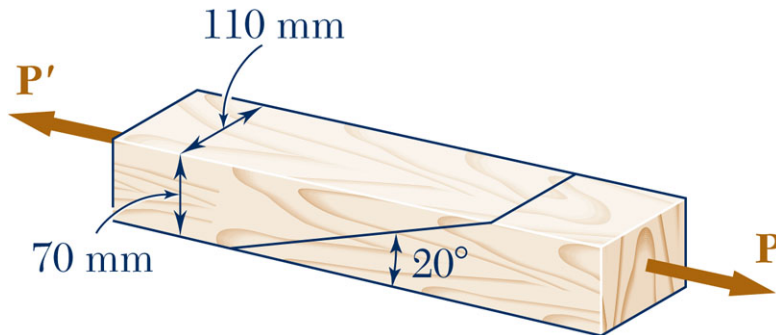
- The maximum normal stress occurs when the reference plane is perpendicular to the member axis,

$$\sigma_m = \frac{P}{A_0} \quad \tau' = 0$$

- The maximum shear stress occurs for a plane at  $\pm 45^\circ$  with respect to the axis,

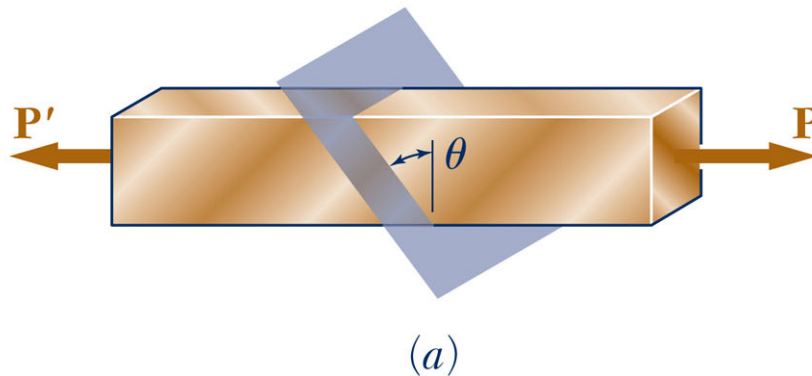
$$\tau_m = \frac{P}{A_0} \sin 45 \cos 45 = \frac{P}{2A_0} = \sigma'$$

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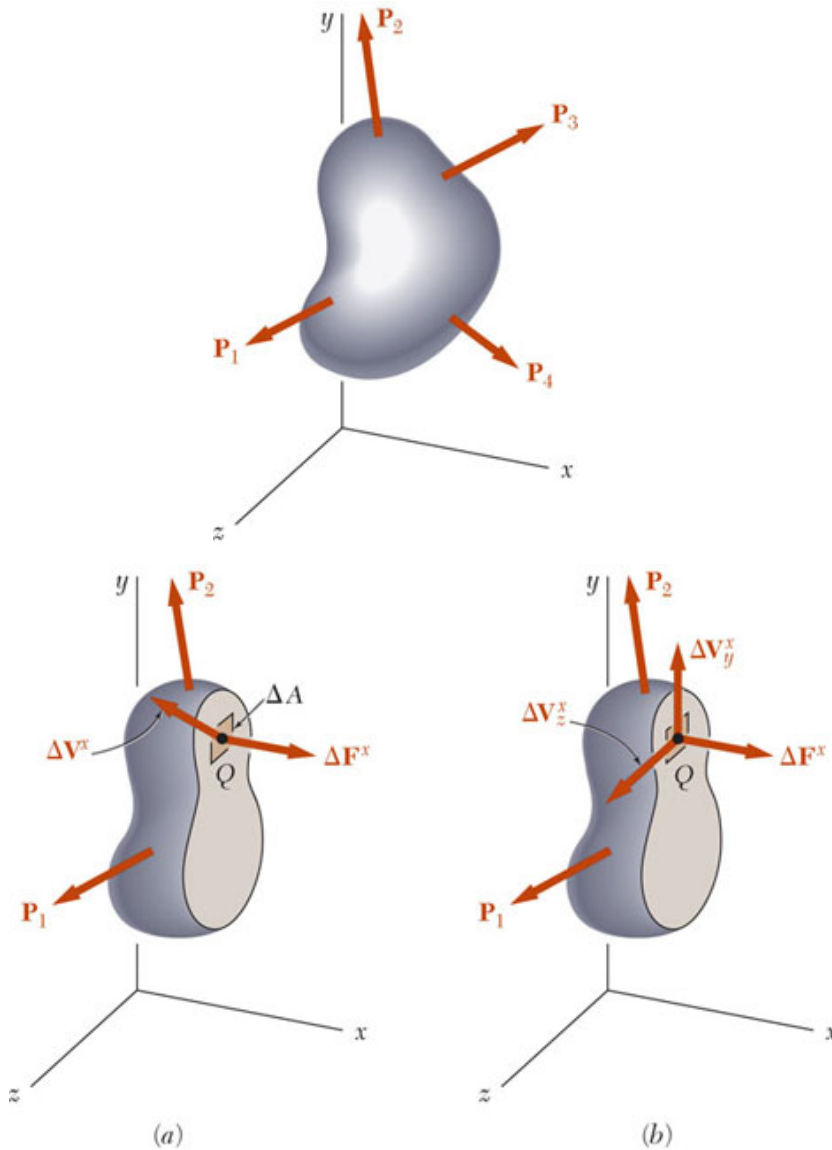
- Maximum shear stress = 500 kPa.
- $P_{max} = ?$

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$$\theta = (90 - 20) = 70 \text{ degrees}$$

## Stress Under General Loadings



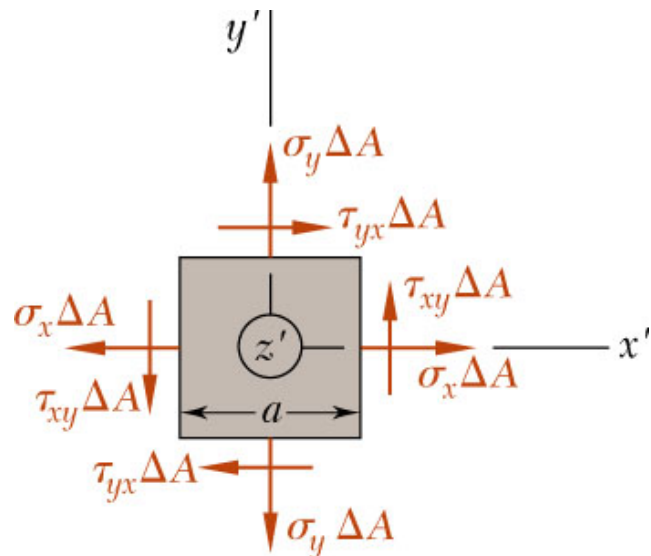
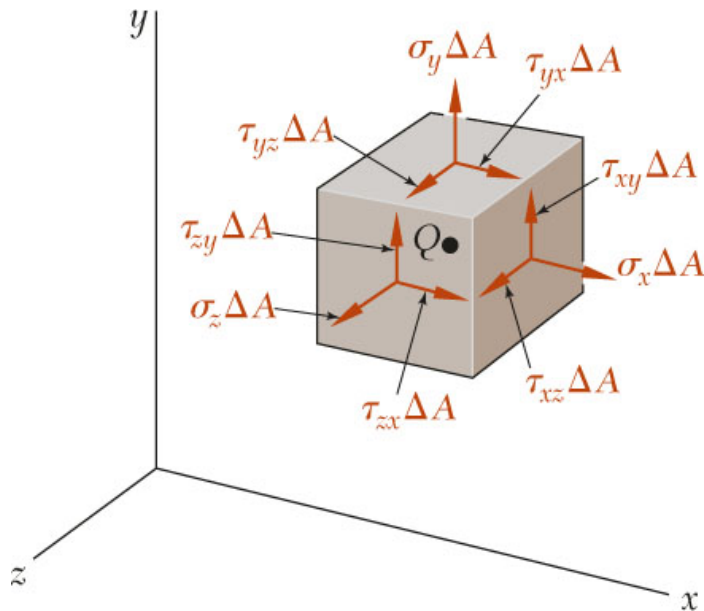
- A member subjected to a general combination of loads is cut into two segments by a plane passing through  $Q$
- The distribution of internal stress components may be defined as,

$$\sigma_x = \lim_{\Delta A \rightarrow 0} \frac{\Delta F^x}{\Delta A}$$

$$\tau_{xy} = \lim_{\Delta A \rightarrow 0} \frac{\Delta V_y^x}{\Delta A} \quad \tau_{xz} = \lim_{\Delta A \rightarrow 0} \frac{\Delta V_z^x}{\Delta A}$$

- For equilibrium, an equal and opposite internal force and stress distribution must be exerted on the other segment of the member.

## State of Stress



- Stress components are defined for the planes cut parallel to the  $x$ ,  $y$  and  $z$  axes. For equilibrium, equal and opposite stresses are exerted on the hidden planes.
- The combination of forces generated by the stresses must satisfy the conditions for equilibrium:

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

$$\sum M_x = \sum M_y = \sum M_z = 0$$

- Consider the moments about the  $z$  axis:

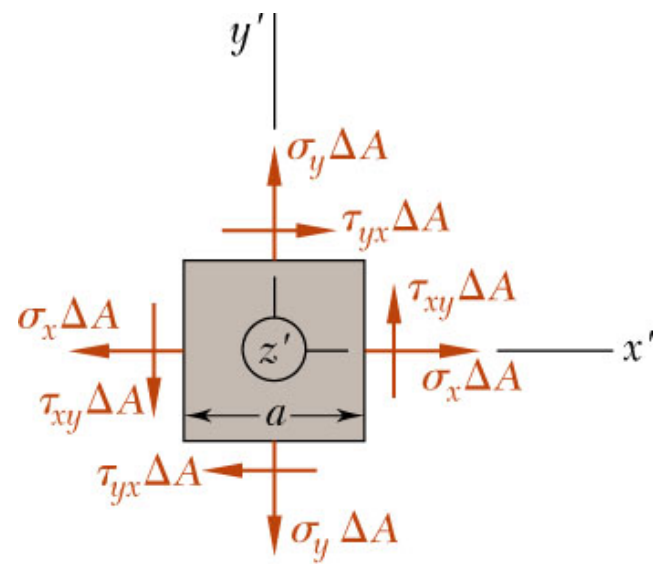
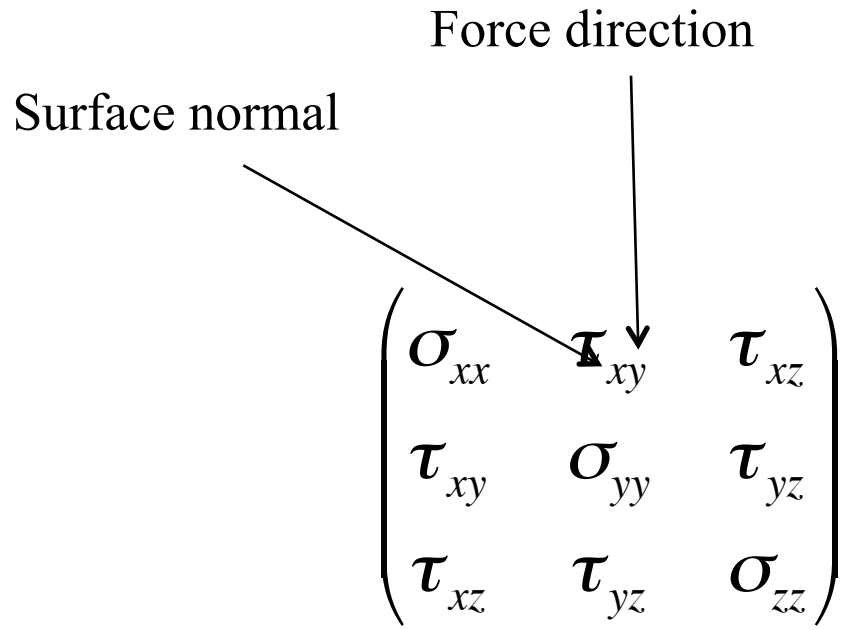
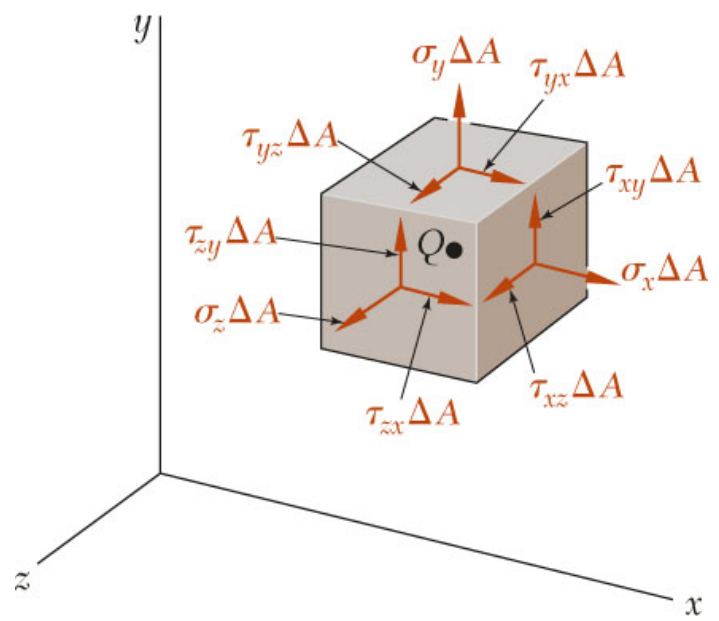
$$\sum M_z = 0 = (\tau_{xy}\Delta A)a - (\tau_{yx}\Delta A)a$$

$$\tau_{xy} = \tau_{yx}$$

$$\text{similarly, } \tau_{yz} = \tau_{zy} \quad \text{and} \quad \tau_{yx} = \tau_{xy}$$

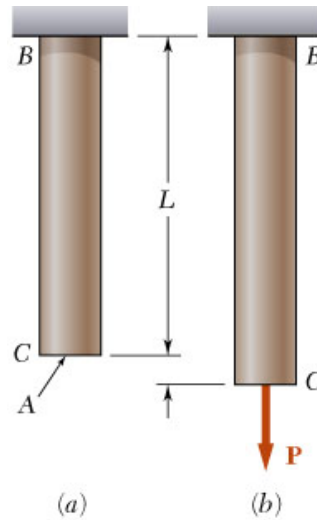
- It follows that only 6 components of stress are required to define the complete state of stress

## State of Stress



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## Normal Strain

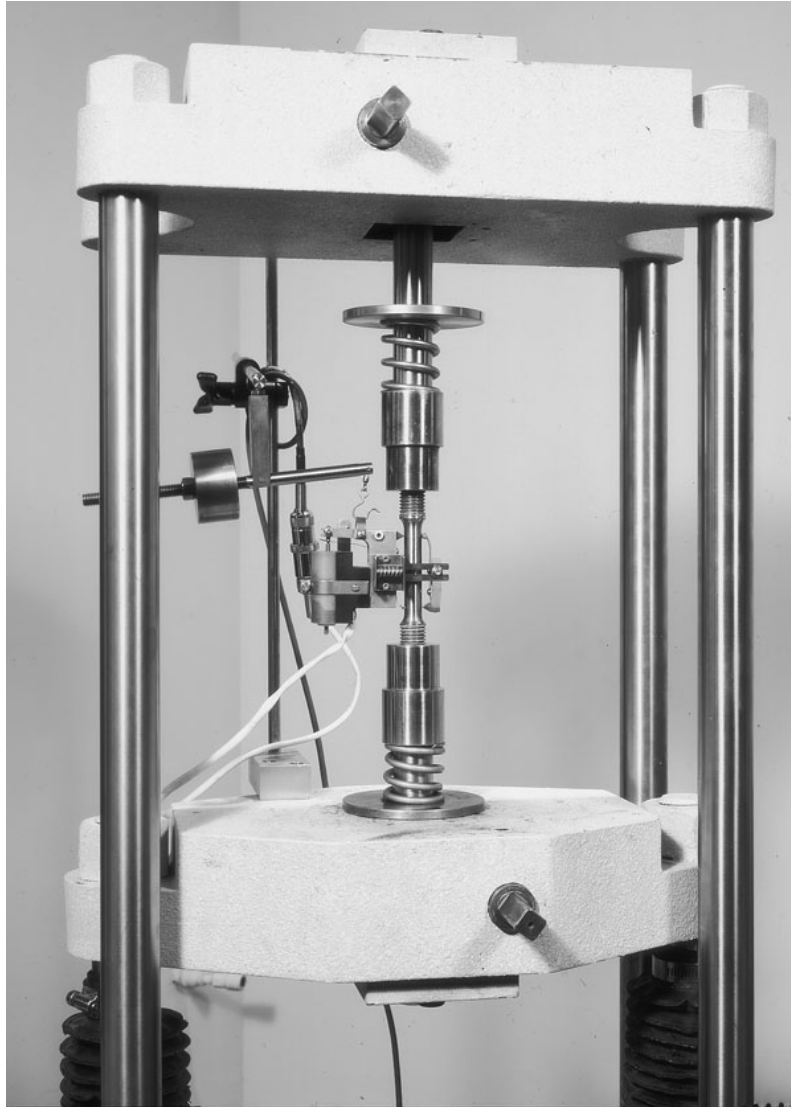
**Fig. 2.1**

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

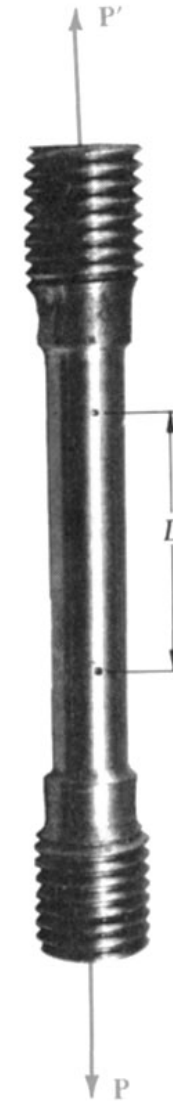
$$\varepsilon = \frac{\delta}{L} = \text{normal strain}$$

- Constitutive law: Relation between stress and strain

## Stress-Strain Test

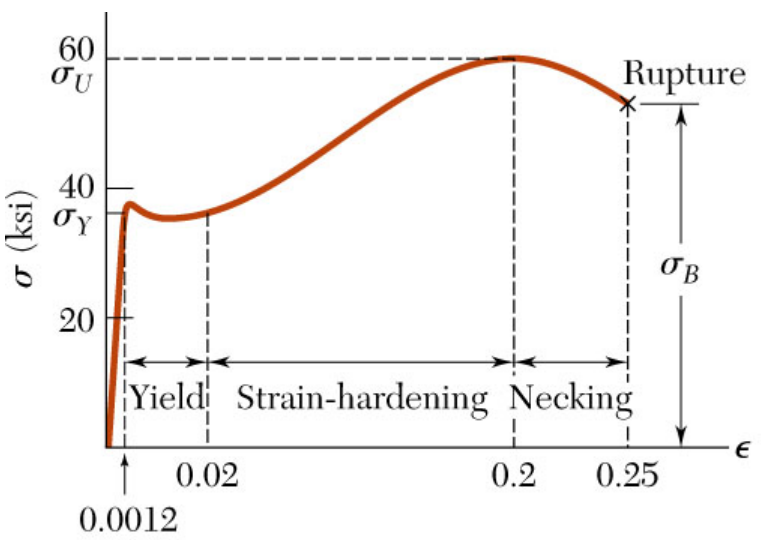
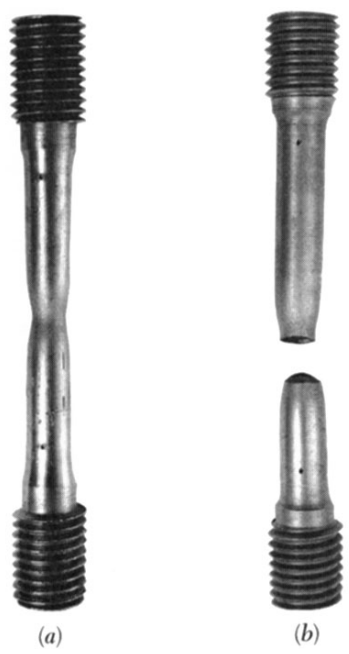


**Fig 2.7** This machine is used to test tensile test specimens, such as those shown in this chapter.

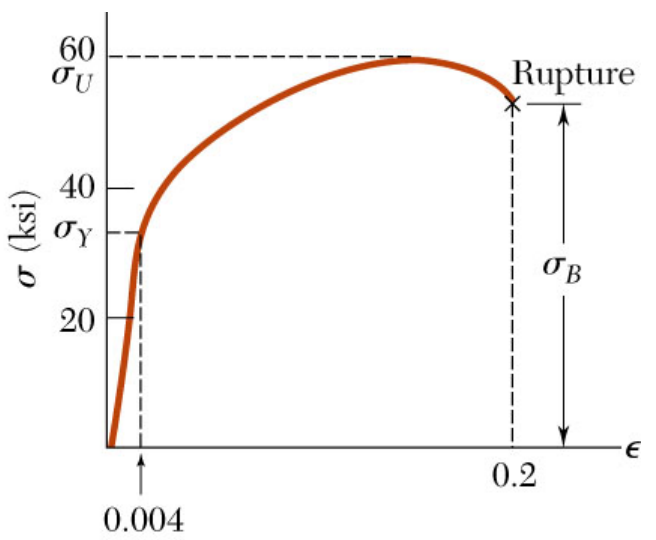


**Fig 2.8** Test specimen with tensile load.

## Stress-Strain Diagram: Ductile Materials



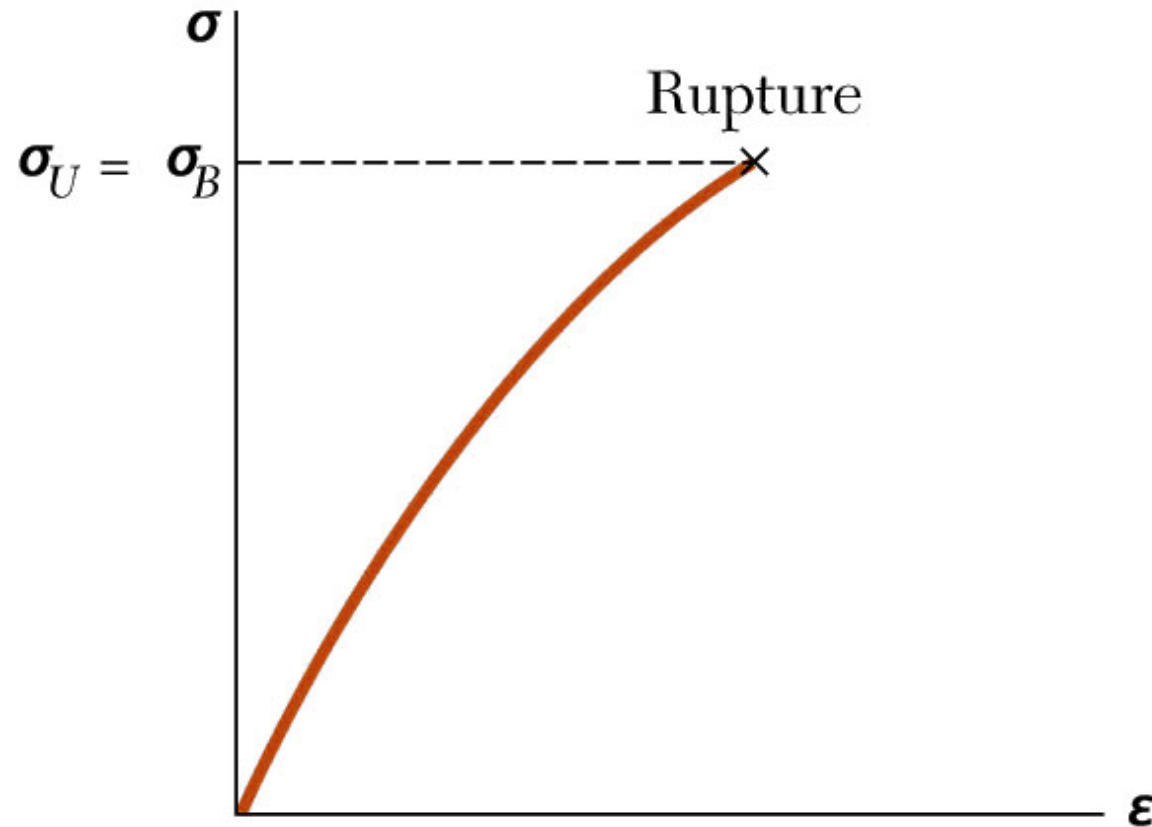
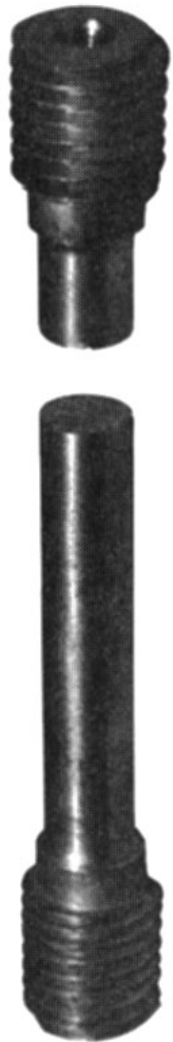
(a) Low-carbon steel



(b) Aluminum alloy

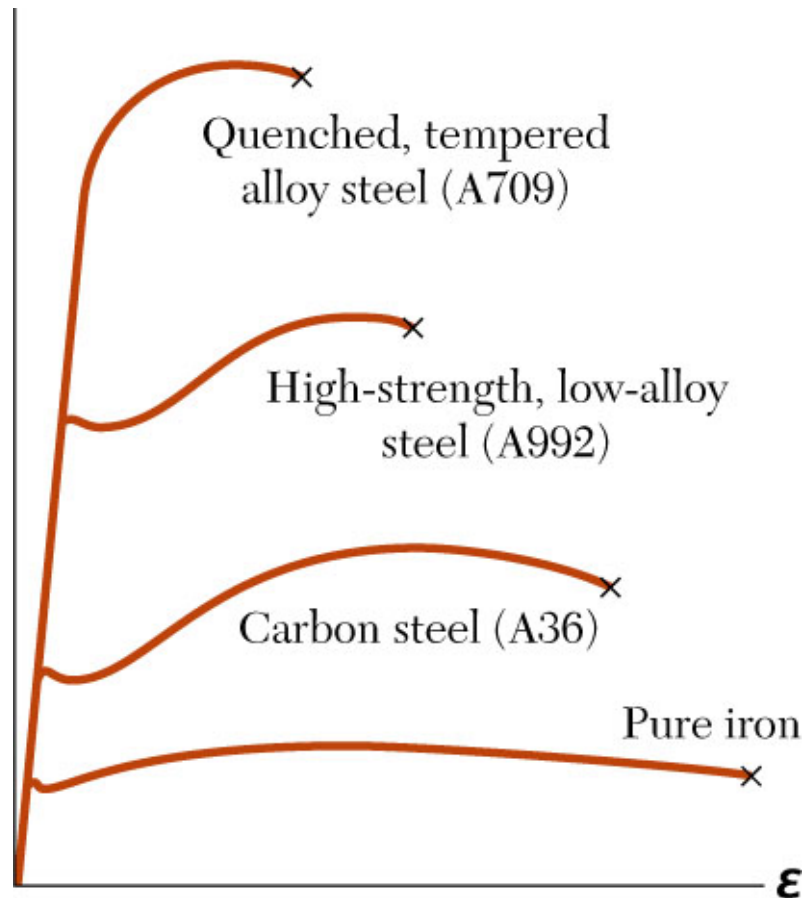
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## Stress-Strain Diagram: Brittle Materials



**Fig 2.1** Stress-strain diagram for a typical brittle material.

## Hooke's Law: Modulus of Elasticity



**Fig 2.16** Stress-strain diagrams for iron and different grades of steel.

- Below the yield stress

$$\sigma = E\epsilon$$

$E$  = Young's Modulus or  
Modulus of Elasticity

- Strength is affected by alloying, heat treating, and manufacturing process but stiffness (Modulus of Elasticity) is not.