Al-Mustaqbal University

Collage of Engineering

Prosthetics and Orthotics Engineering

First Stage

PHYSICS OF MATERIALS

Asst. Lec. Muntadher Saleh Mahdi

2st term – Lecture 3

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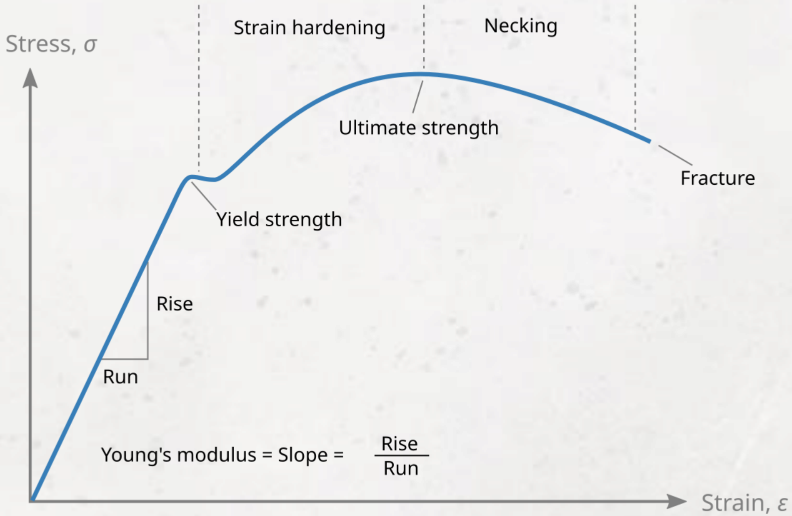
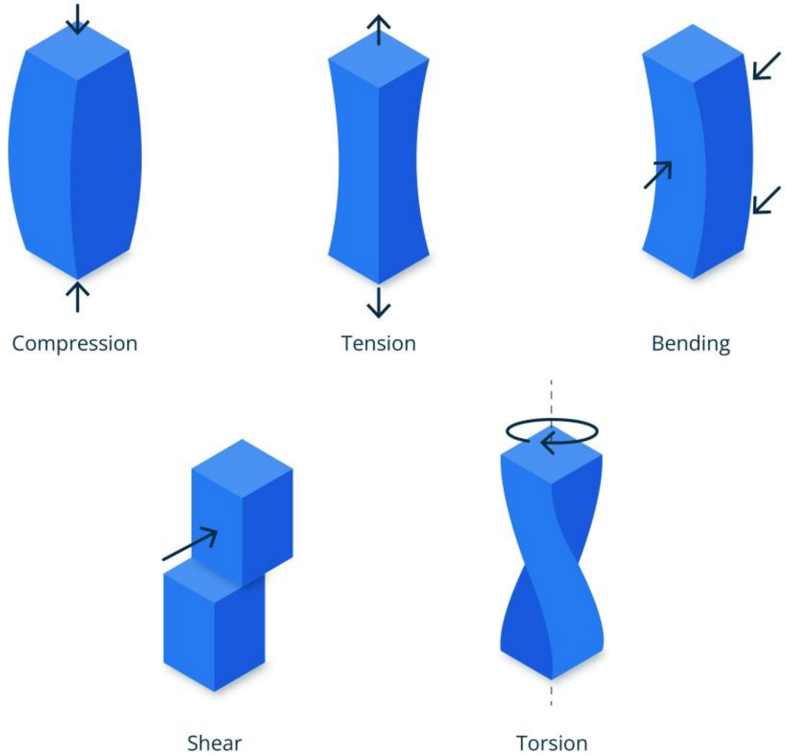
Muntadher.saleh.mahdi@uomus.edu.iq
UOMU013024

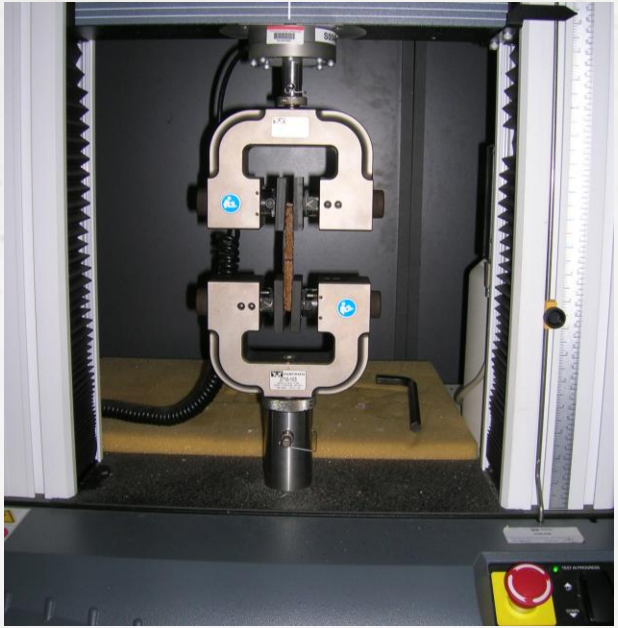


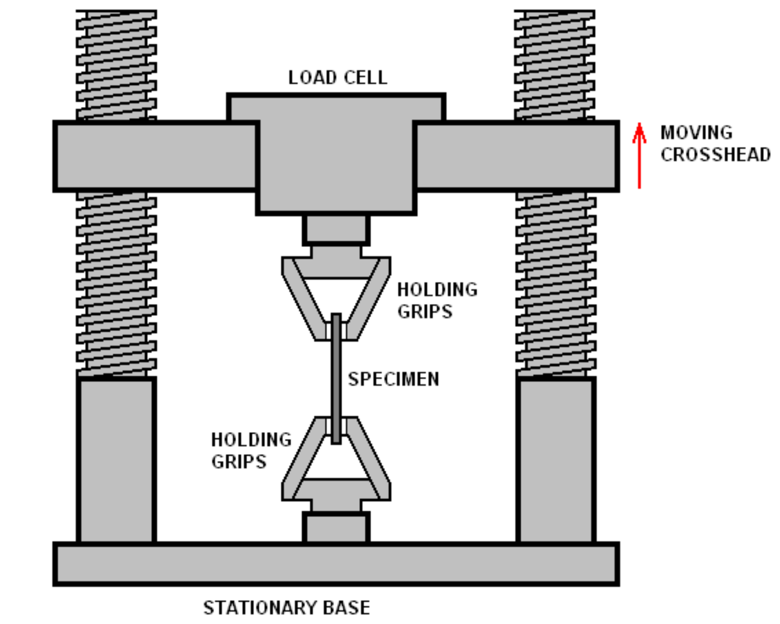
Different Types of Stresses



Mechanical Properties

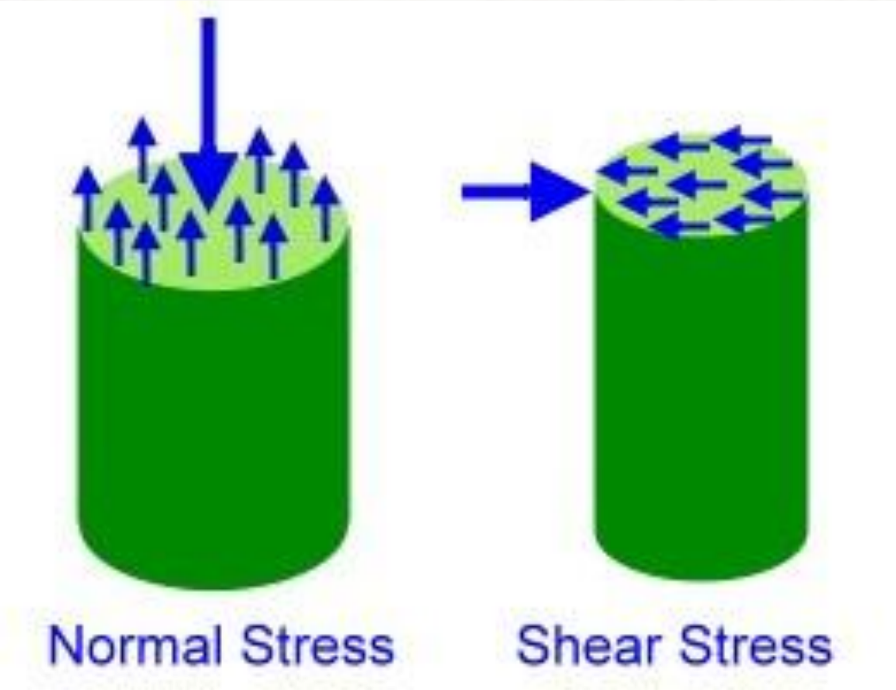
- **Tension Test**: Pulling force that stretches material
- **Compression Test:** Pushing force that shortens material





Materials behave differently under these forces

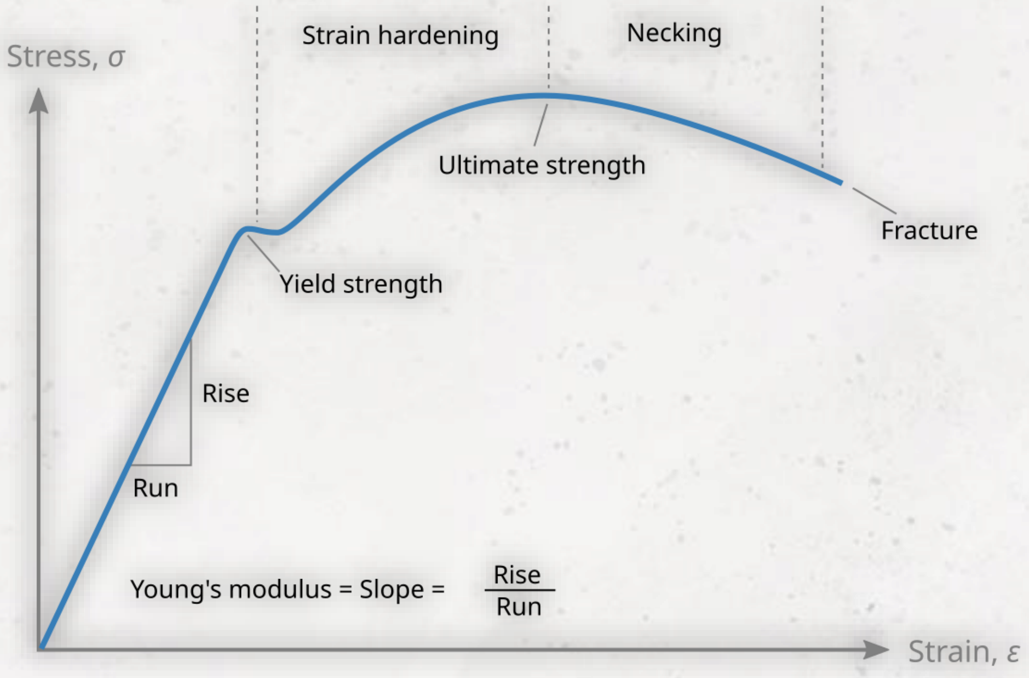
Shear Stress (τ): Causes material layers to slide past one another



Young's Modulus (Elastic Modulus)

Measures stiffness of a material

Stress-Strain Curve



stress σ is defined by the relationship

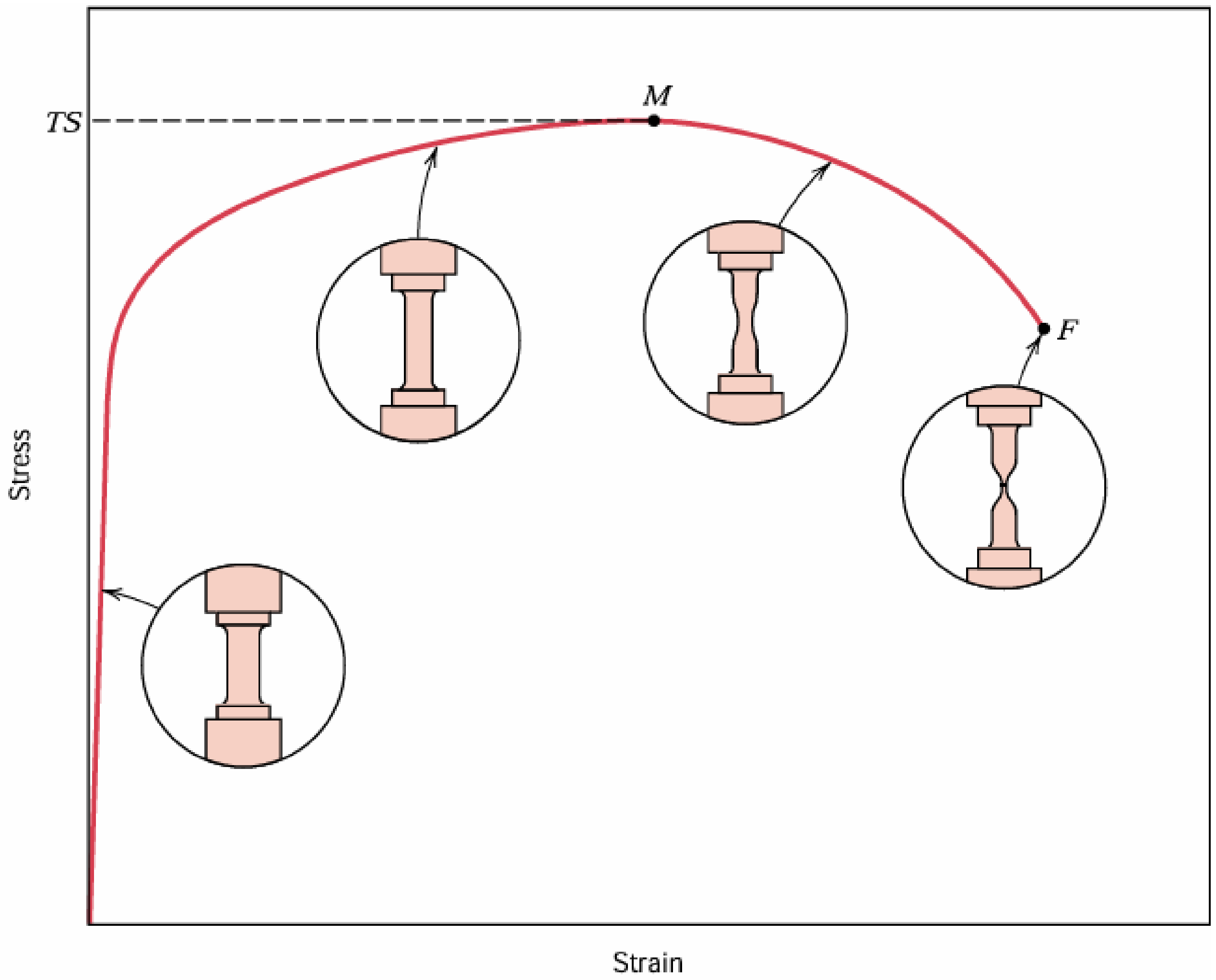
$$\sigma = \frac{F}{A_0}$$

Engineering strain ϵ is defined according to

$$\epsilon = \frac{l_i - l_0}{l_0} = \frac{\Delta l}{l_0}$$

Young's modulus of elasticity

$$E = \frac{\sigma}{\varepsilon}$$



TS
M
F
Stress
Strain

Example Problem 7.1

A piece of copper originally 305 mm (12 in.) long is pulled in tension with a stress of 276 MPa (40,000 psi). If the deformation is entirely elastic, what will be the resultant elongation?

Solution

Since the deformation is elastic, strain is dependent on stress according to Equation 7.5. Furthermore, the elongation Δl is related to the original length l_0 through Equation 7.2. Combining these two expressions and solving for Δl yields

$$\sigma = \epsilon E = \left(\frac{\Delta l}{l_0}\right) E$$

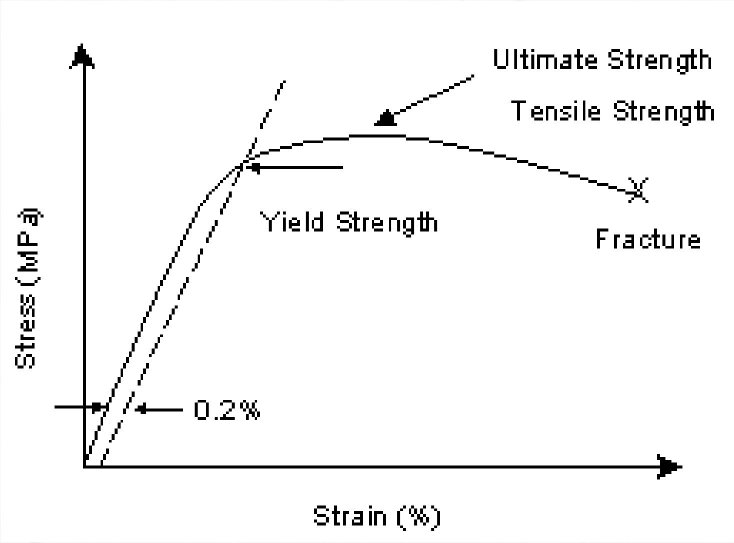
$$\Delta l = \frac{\sigma l_0}{E}$$

The values of σ and l_0 are given as 276 MPa and 305 mm, respectively, and the magnitude of E for copper from Table 7.1 is 110 GPa (16×10^6 psi). Elongation is obtained by substitution into the expression above as

$$\Delta l = \frac{(276 \text{ MPa})(305 \text{ mm})}{110 \times 10^3 \text{ MPa}} = 0.77 \text{ mm } (0.03 \text{ in.})$$

Ultimate Tensile Strength:

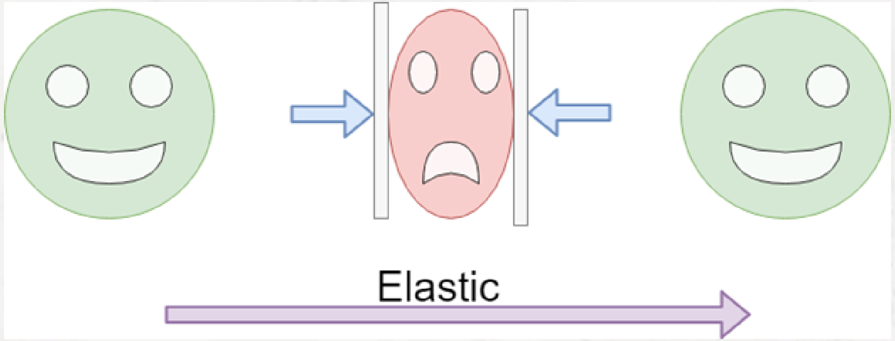
- Maximum stress a material can withstand while being stretched
- Found at the peak of the stress-strain curve
- Important for structural integrity

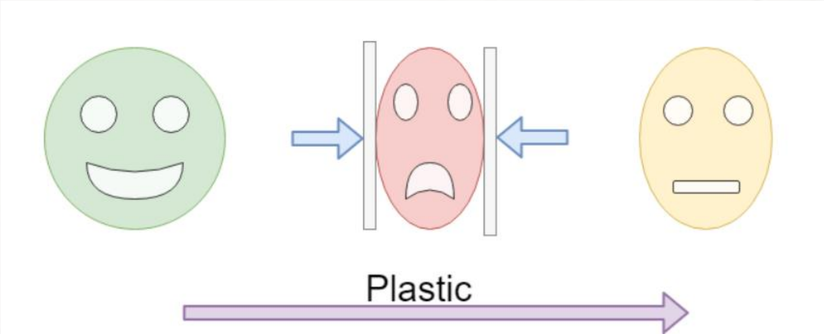


- **Elastic Deformation:** Temporary, material returns to original shape

- **Plastic Deformation:** Permanent deformation

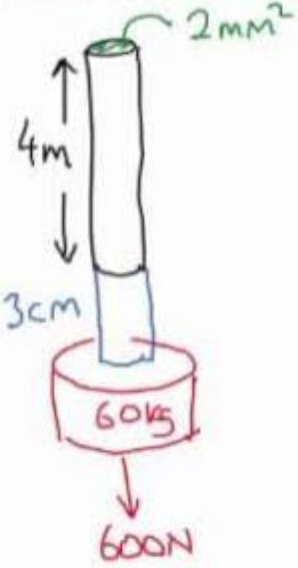
- **Yield point:** Start of plastic deformation

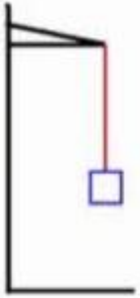




In-Class Check

A 60kg block hangs from a wire that has a cross-sectional area of $2mm^2$. The wire was originally 4m long but stretches by 3cm under the load. What is the Younge's Modulus of the wire?





$$Y = \frac{STRESS}{STRAIN} = \frac{F/A}{\Delta L / L_o} = \frac{F}{A}\frac{L_o}{\Delta L}$$

$$Y = \frac{(600)(4)}{(2\times 10^{-6})(3\times 10^{-2})}$$

$$Y = \frac{2400}{6\times 10^{-8}} = 40\text{ GPa}$$

Problems

A carbon fiber rod in a prosthetic leg has a cross-sectional area of $1.2\ \mathrm{cm}^2$, length $45\ \mathrm{cm}$, and stretches by $2\ \mathrm{mm}$ under a walking load of $800\ \mathrm{N}$.

Find the Young's Modulus of the rod.

A femur experiences a compressive force of $1500\ \mathrm{N}$ while walking.

Its cross-sectional area is $4.5\ \mathrm{cm}^2$, and the bone shortens by $0.1\ \mathrm{mm}$ over a length of $40\ \mathrm{cm}$.

Calculate the stress, strain, and approximate Young's Modulus.


Thank you