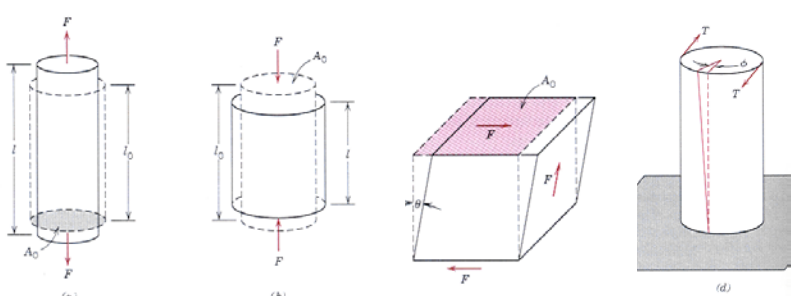
Chapter 6: Mechanical properties of metals

Outline

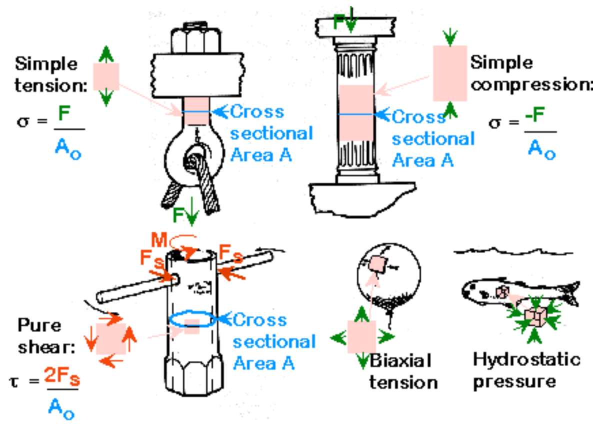
- Introduction
- Concepts of stress and strain
- Elastic deformation
  - Stress-strain behavior
  - Elastic properties of materials
- Plastic deformation
  - Yield and yield strength
  - Ductility
  - Resilience
  - Toughness

Concepts of stress and strain

- Tension, compression, shear, and torsion

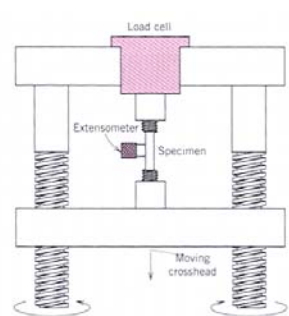


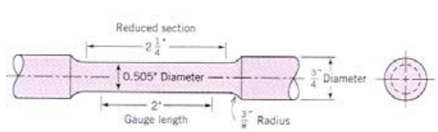
Common states of stress



Concepts of stress and strain (continue)

- Tension tests
  - engineering stress
  - engineering strain

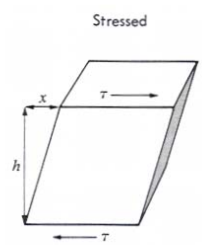


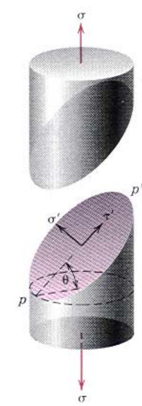


- Compression tests

Concepts of stress and strain(*continue*)

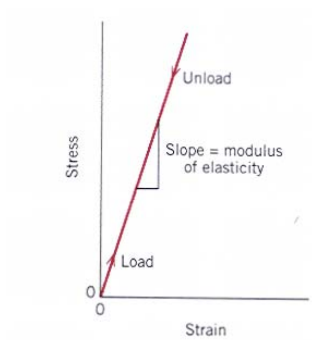
- Shear and torsional tests
  - Shear stress
  - Shear strain
- Geometric considerations of the stress state

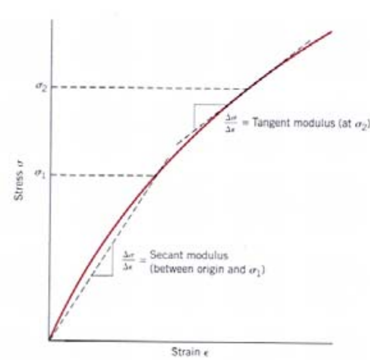




Stress-strain behavior

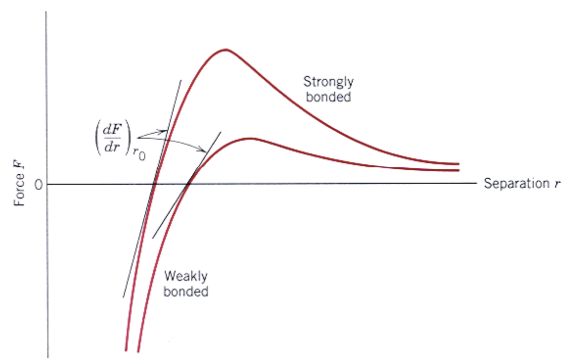
- Hooke's law
- Stress-strain for linear elastic deformation
- Stress-strain for non-linear elastic deformation





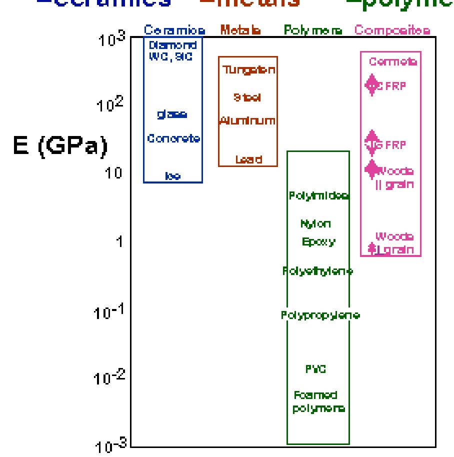
Stress-strain behavior(*continue*)

- Modulus of elasticity E is proportional to $(dF/dr)_r$



Comparison of Young's Moduli

$E_{ceramics} > E_{metals} >> E_{polymers}$

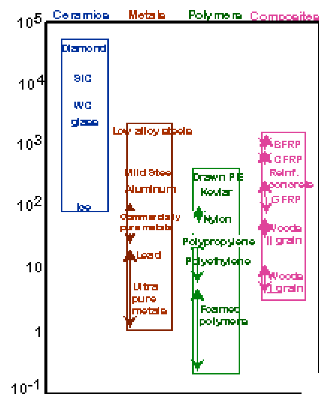


Comparison of yield strength

σ_y(ceramics) >> σ_y(metals) >> σ_y(polymers)

σ_y (MPa)

Room T values



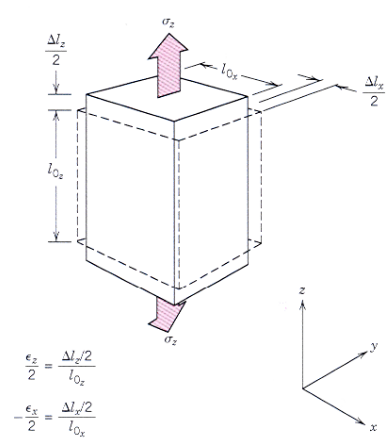
Elastic properties of materials

- Poisson's ratio

$$\nu = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\varepsilon_y}{\varepsilon_z}$$

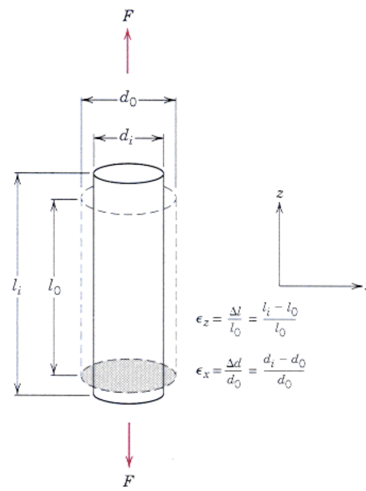
- Relation of elastic properties for isotropic materials

$$E = 2G(1+\nu)$$



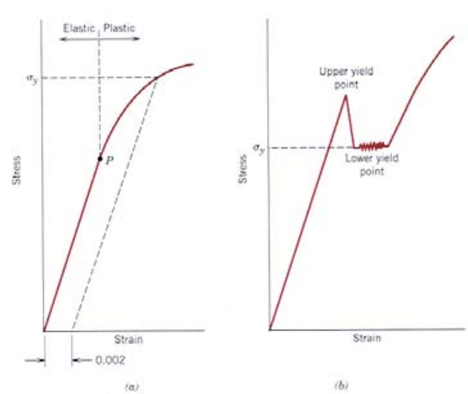
Examples

- Determine the load required to produce a 2.5×10^{-3} change in diameter



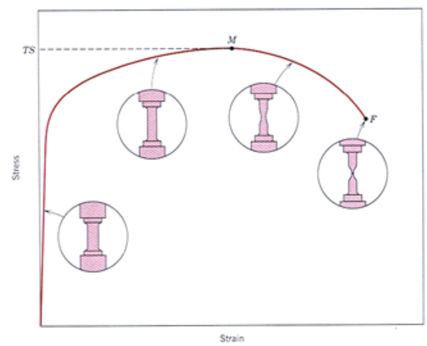
Plastic deformation: yield and yield strength

- Yielding
- Proportional limit
- Yield strength



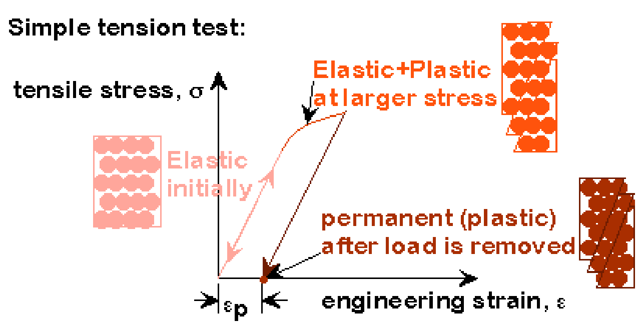
Tensile strength

- Tensile strength:
- Metals:
- Ceramics:
- Polymers:



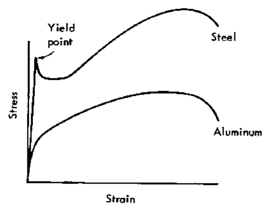
Plastic (permanent) deformation

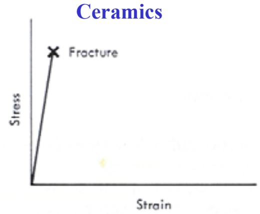
At lower temperature: T< Tmelt/3

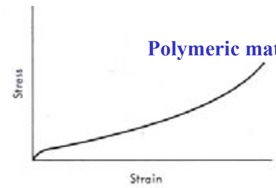


Elastic and plastic deformations

- Stress-strain relations under uniaxial loading





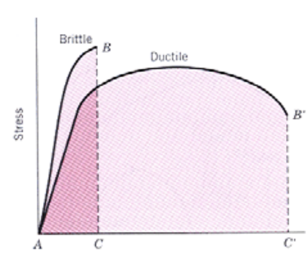


Ductility

- Ductility:

$$\%EL = \left(\frac{l_f - l_0}{l_0}\right) \times 100$$

$$\%RA = \left(\frac{A_0 - A_f}{A_0}\right) \times 100$$



Mechanic properties of typical metals

Table 6.2 Typical Mechanical Properties of Several Metals and Alloys in an Annealed State

Metal Alloy	*Yield Strength MPa (ksi)*	*Tensile Strength MPa (ksi)*	*Ductility, %EL [in 50 mm (2 in.)]*
Aluminum	35 (5)	90 (13)	40
Copper	69 (10)	200 (29)	45
Brass (70Cu–30Zn)	75 (11)	300 (44)	68
Iron	130 (19)	262 (38)	45
Nickel	138 (20)	480 (70)	40
Steel (1020)	180 (26)	380 (55)	25
Titanium	450 (65)	520 (75)	25
Molybdenum	565 (82)	655 (95)	35

Resilience

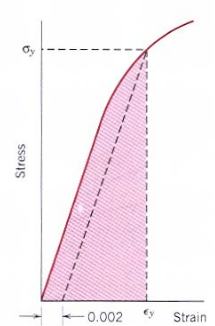
- Resilience:

Resilience

$$U_r = \int_0^{\epsilon_y} \sigma \, d\epsilon$$

$$U_r = \tfrac{1}{2}\sigma_y \epsilon_y$$

$$U_r = \tfrac{1}{2}\sigma_y \epsilon_y = \tfrac{1}{2}\sigma_y \left(\frac{\sigma_y}{E}\right) = \frac{\sigma_y^2}{2E}$$



Toughness

- Toughness: