UNIAXIAL TENSION

LAB 7

UNIAXIAL TENSION

- Stress and Strain
- Stress-Strain Diagram
- Material Ductility
- Ductile Material vs Brittle Material
- Determination of Yield Stress
- Strain Energy
- Goal: To determine the Young's Modulus, yield stress, ultimate tensile strength, ductility and toughness of aluminum and cast iron

NORMAL STRESS

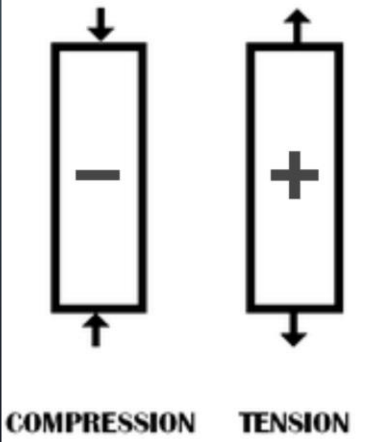
- Stress = intensity of the internal force

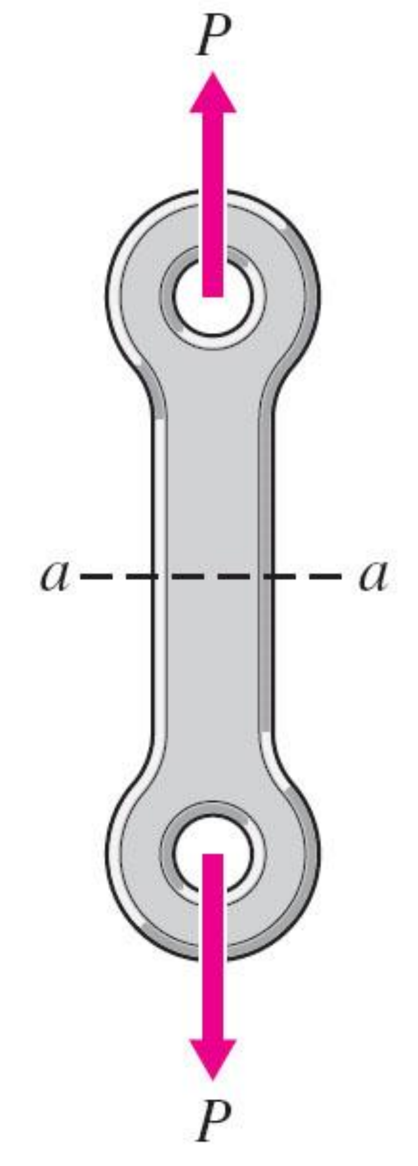
$$Stress = \frac{Force}{Area}$$

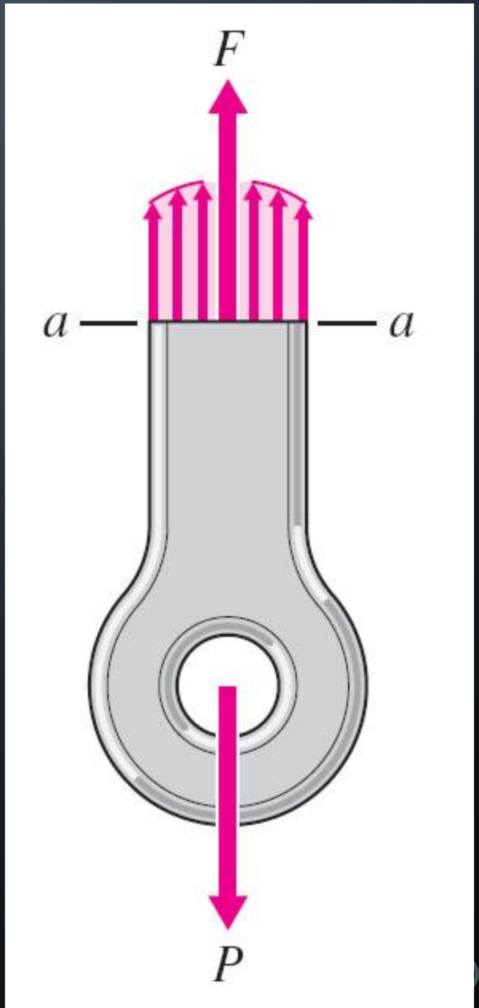
- Normal stress: Greek letter sigma (σ)

$$\sigma_{\text{avg}} = \frac{F}{A}$$

- Units: psi, ksi, pa, kpa, mpa







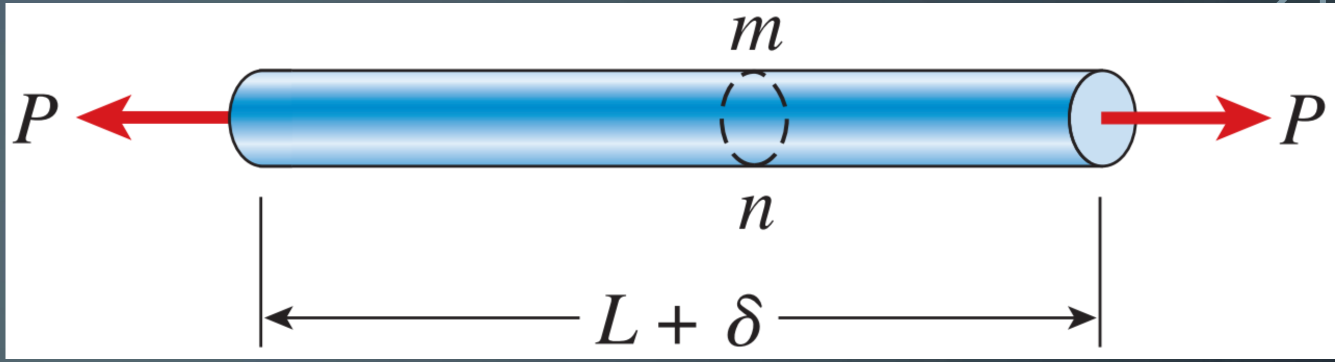
NORMAL STRAIN

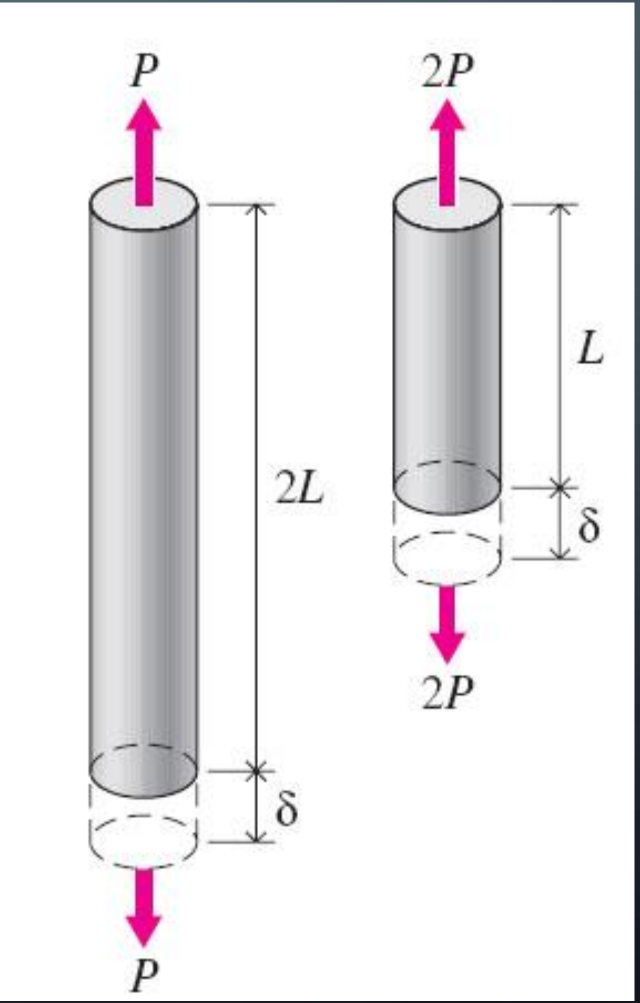
- Deformation: Greek letter δ
- Normal strain: Greek letter ε (epsilon)

$$\varepsilon = \frac{\delta}{L} \qquad \varepsilon(P) = \frac{d\delta_n}{dL}$$

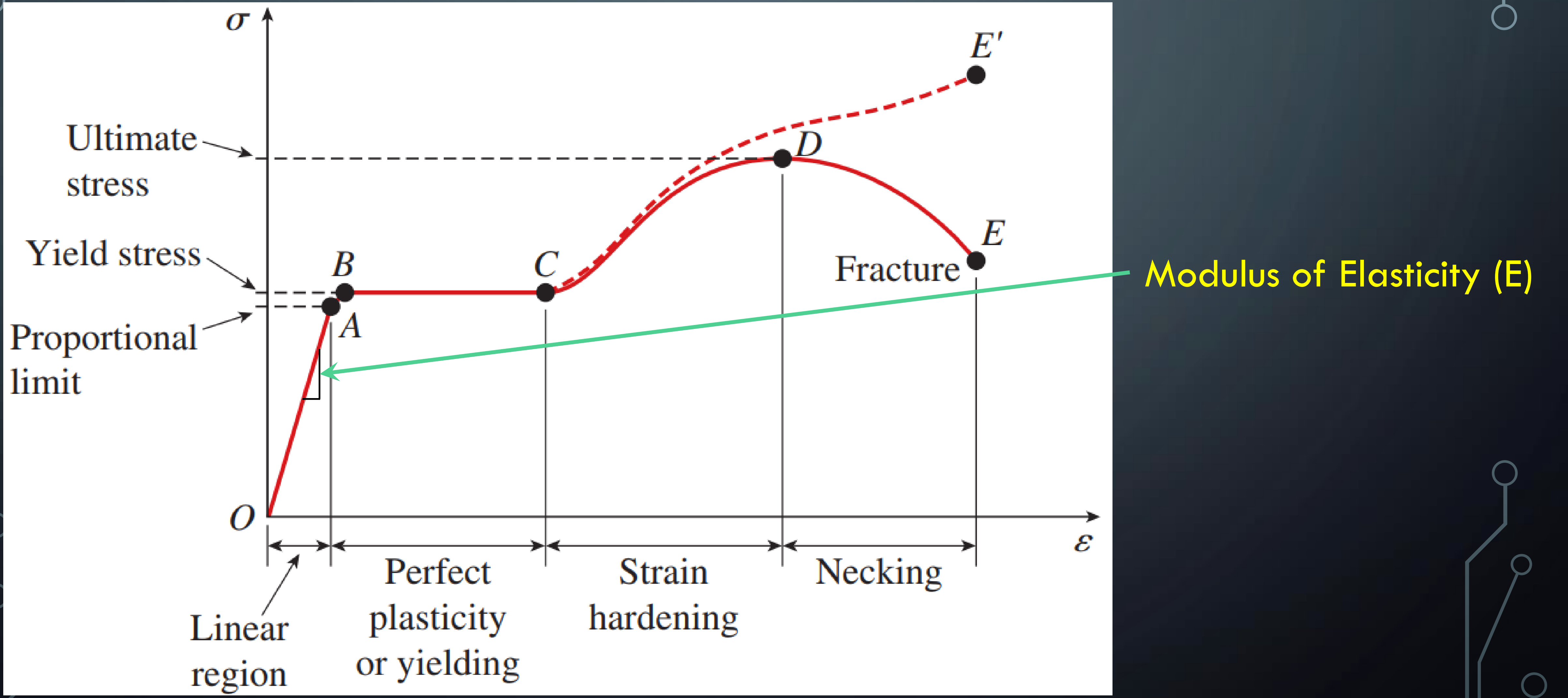
- Units: none (dimensionless)
- Sign: same with the stress
  - Tensile strain: +
  - Compressive strain: −
- Hooke's law

$$\sigma = E\varepsilon$$

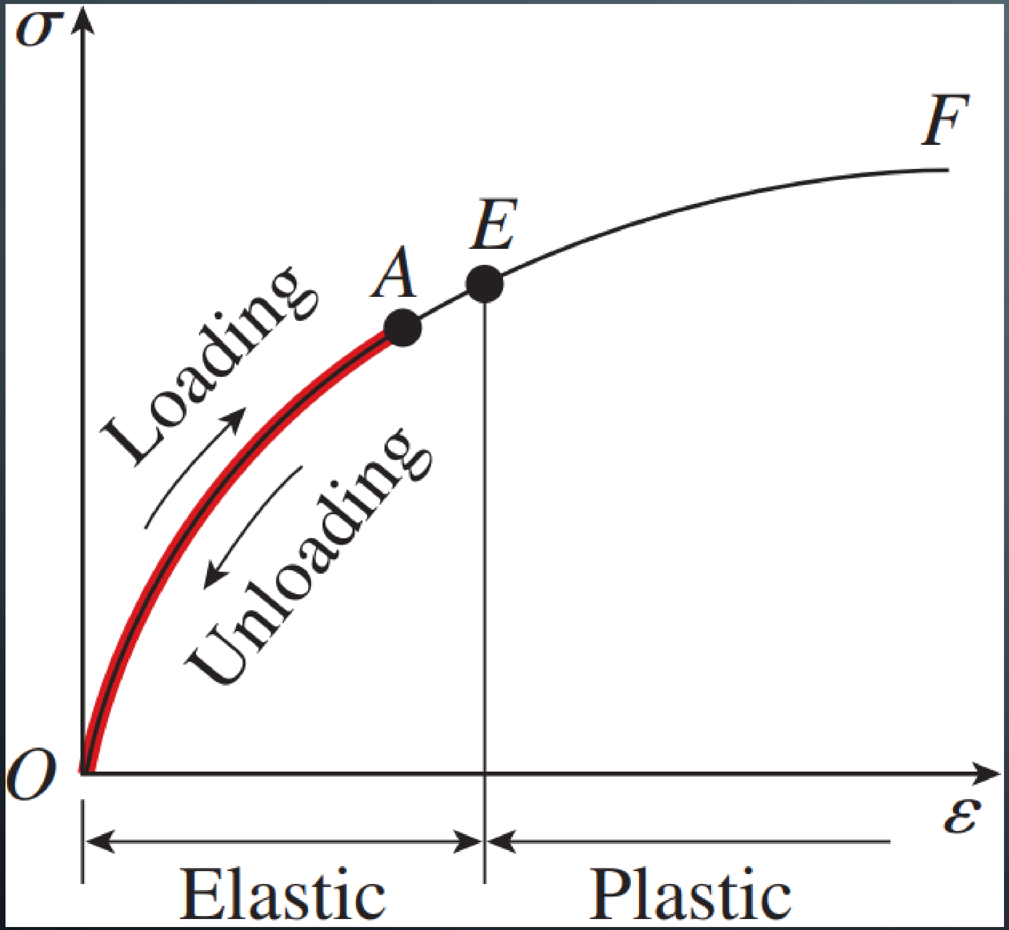


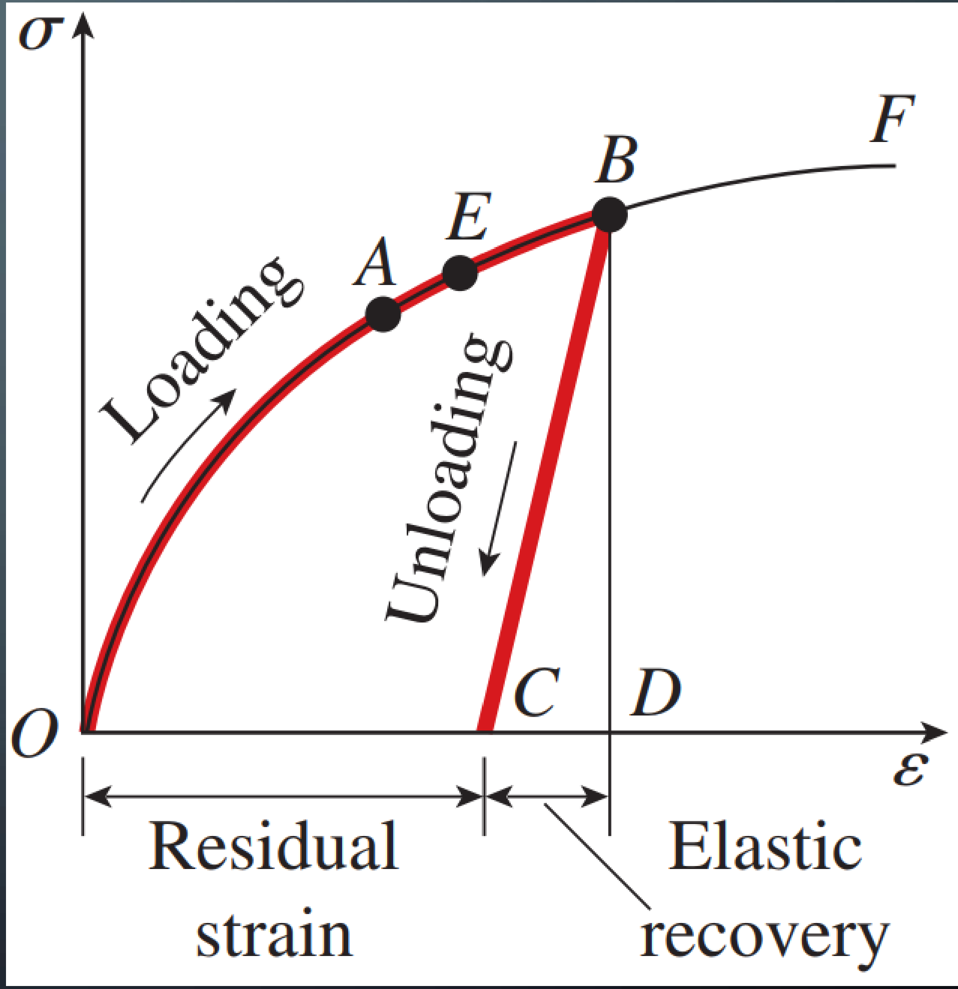


STRESS-STRAIN DIAGRAM



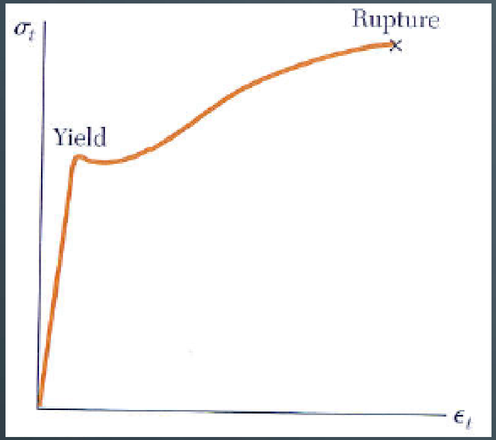
ELASTICITY AND PLASTICITY

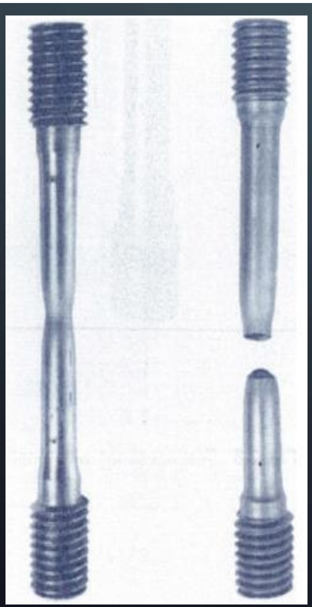


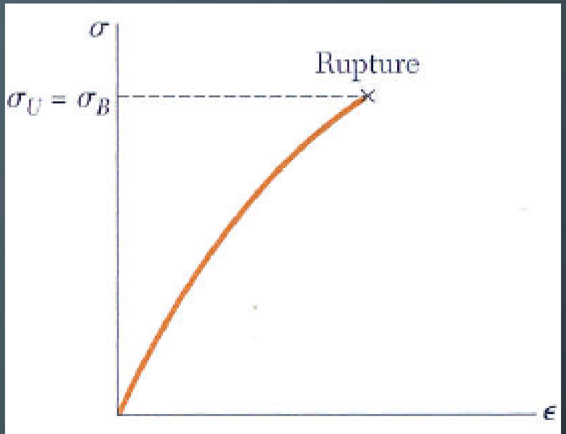


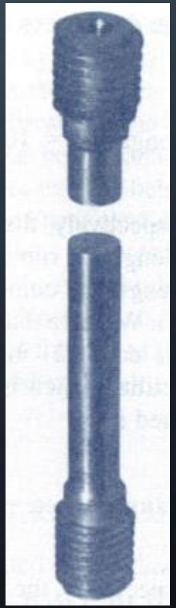
STRAIN HARDENING

NECKING AND FRACTURE



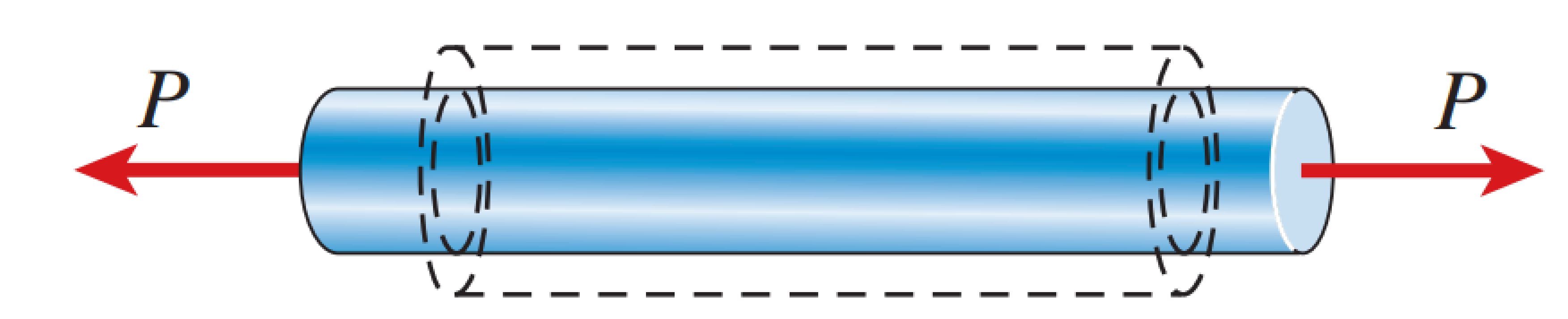






POISSON'S RATIO

- Lateral contraction accompanies axial elongation



- Poisson's Ratio relates these two strains to one another

$$\nu = -\frac{\text{lateral strain}}{\text{axial strain}} = -\frac{\varepsilon'}{\varepsilon}$$

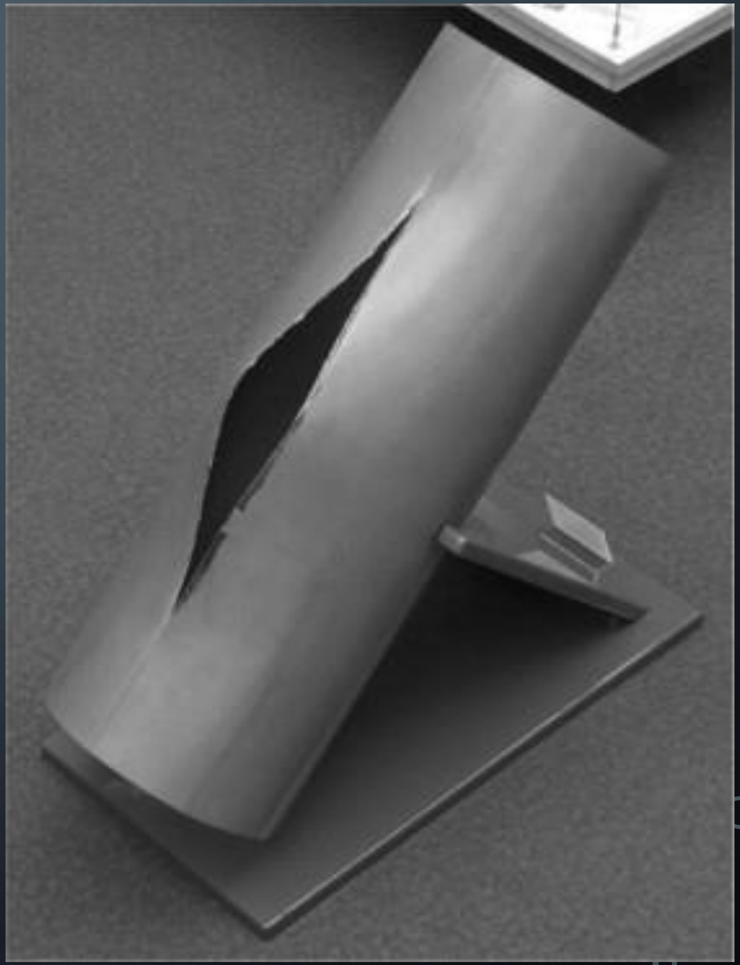
- Units: none (dimensionless)
- Limitations:
  - The material must be homogeneous
  - Elastic properties must be the same in all directions perpendicular to the longitudinal axis ==> isotropic material
  - Theoretical maximum is 0.5 (Rubber~0.5)

MATERIAL DUCTILITY

Ductility is defined by the degree to which a material can sustain plastic deformation before failure from a tensile stress greater than the material's yield stress.

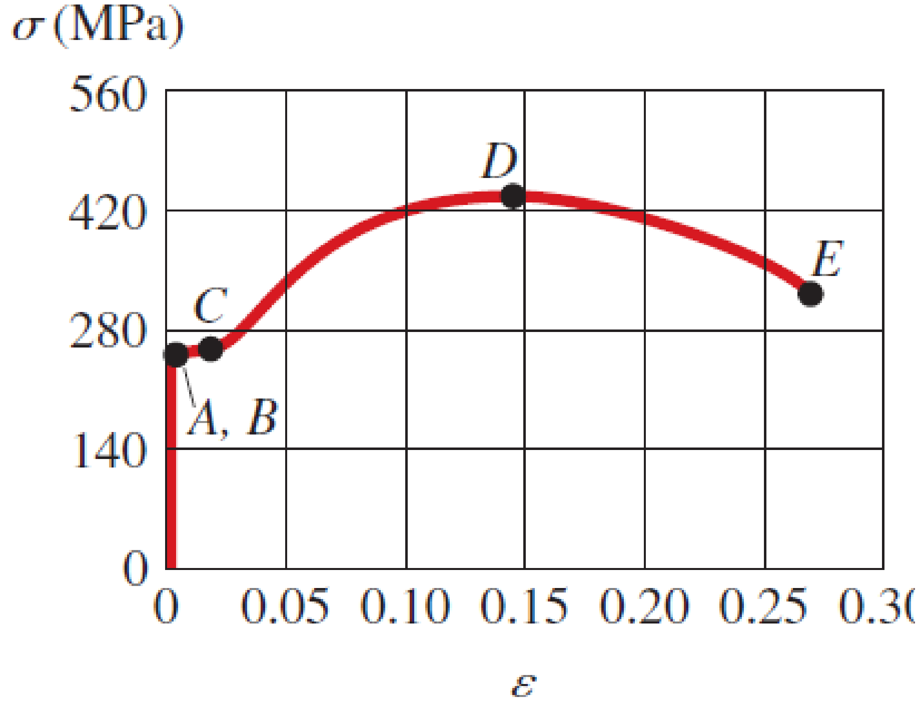
$$\%Elongation = \frac{L_B - L_0}{L_0} \times 100$$

$$\%Reduction\ in\ Area = \frac{A_0 - A_B}{A_0} \times 100$$

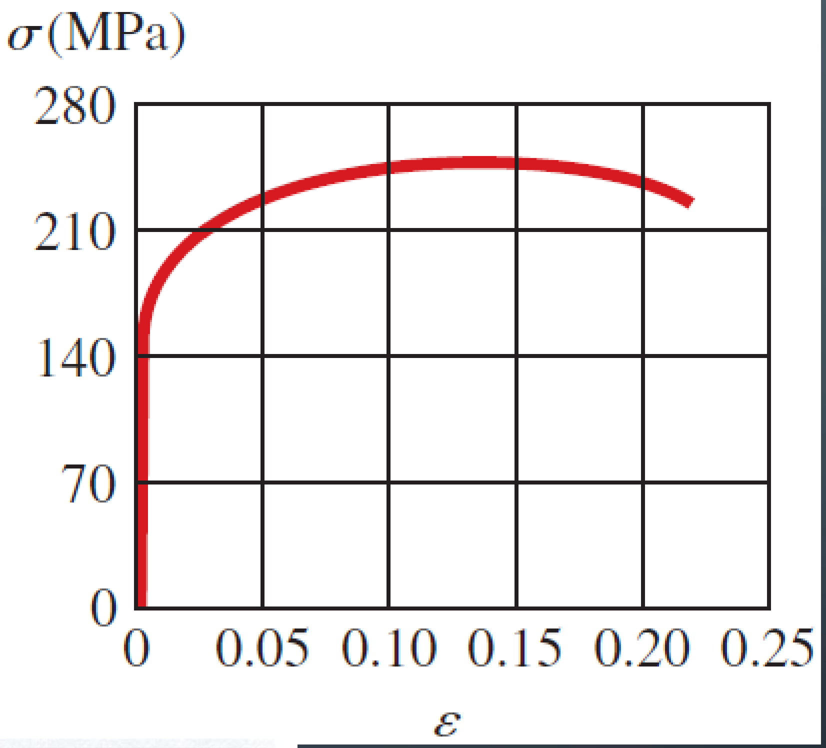


DUCTILE MATERIAL VS BRITTLE MATERIAL

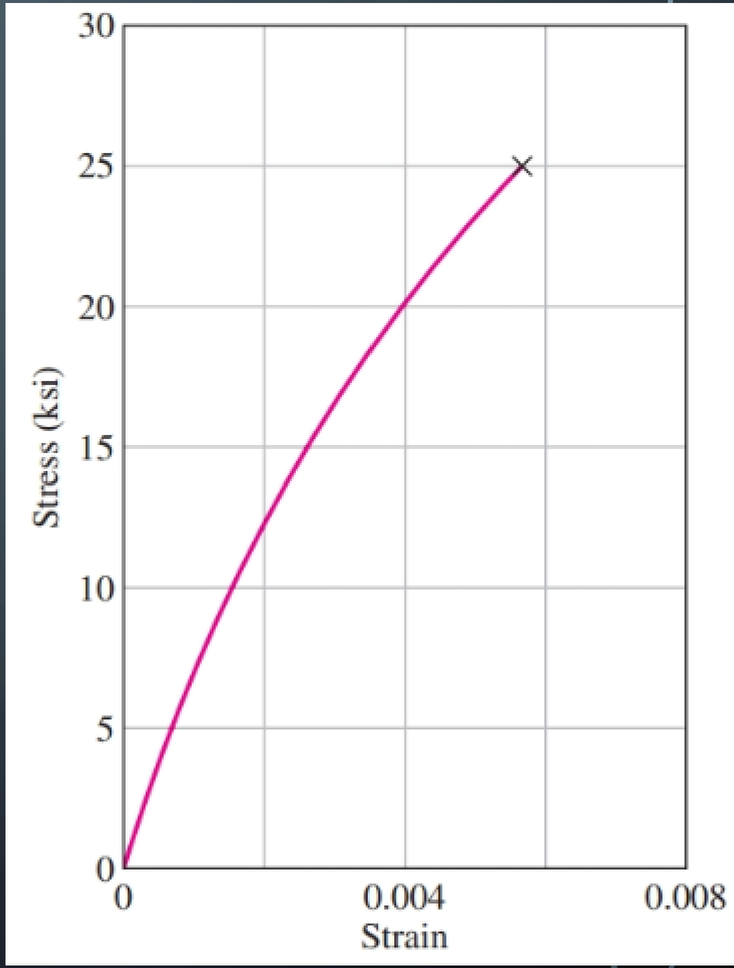
Structural Steel

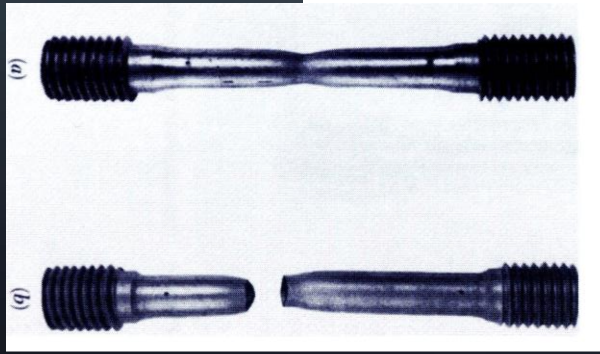


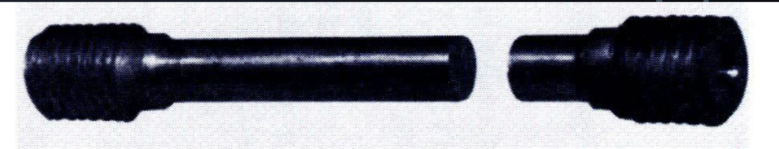
Aluminum Alloy



Cast Iron

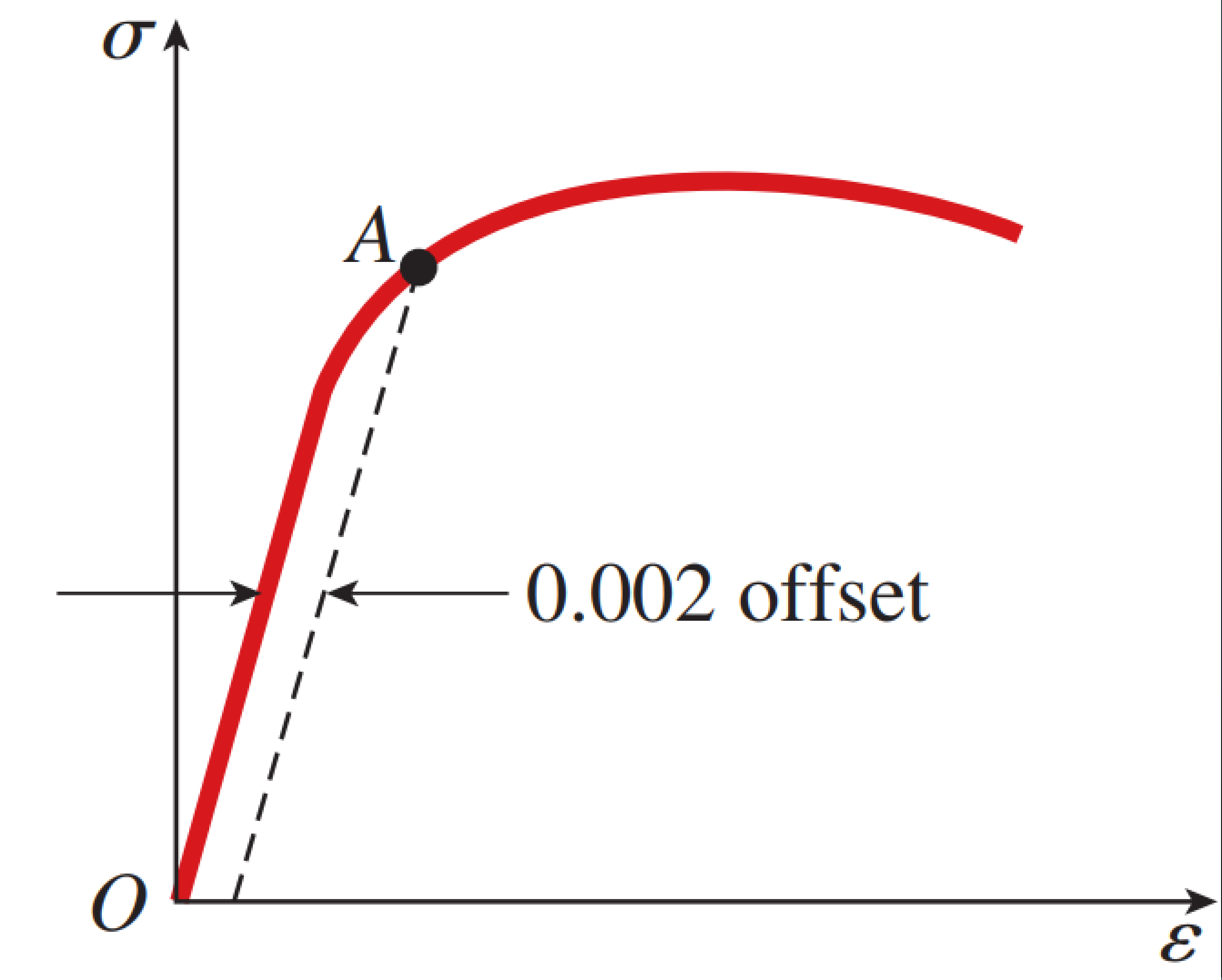




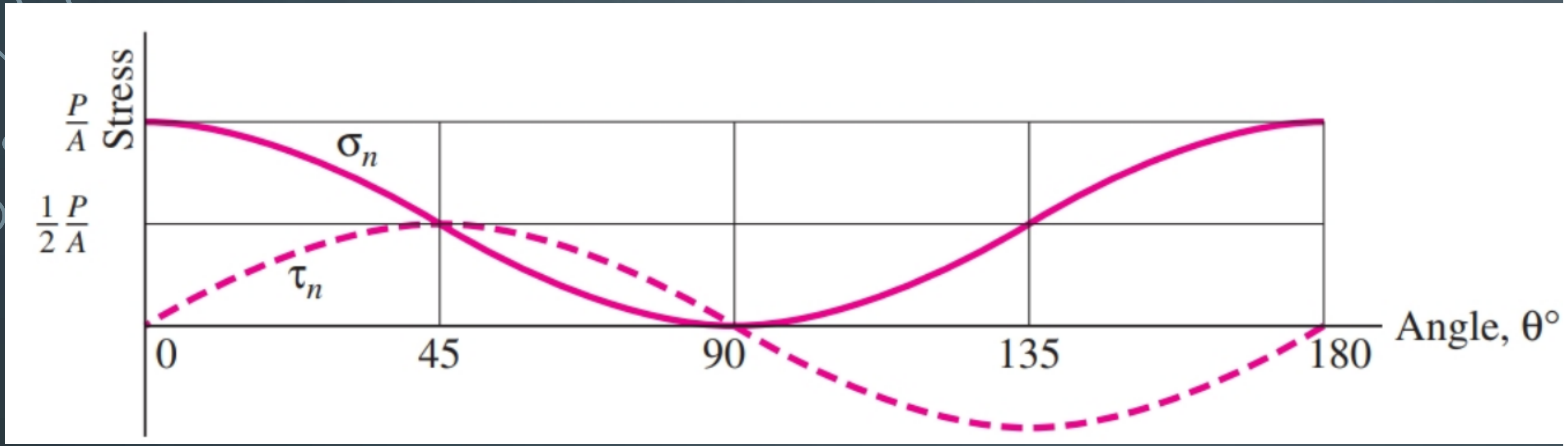


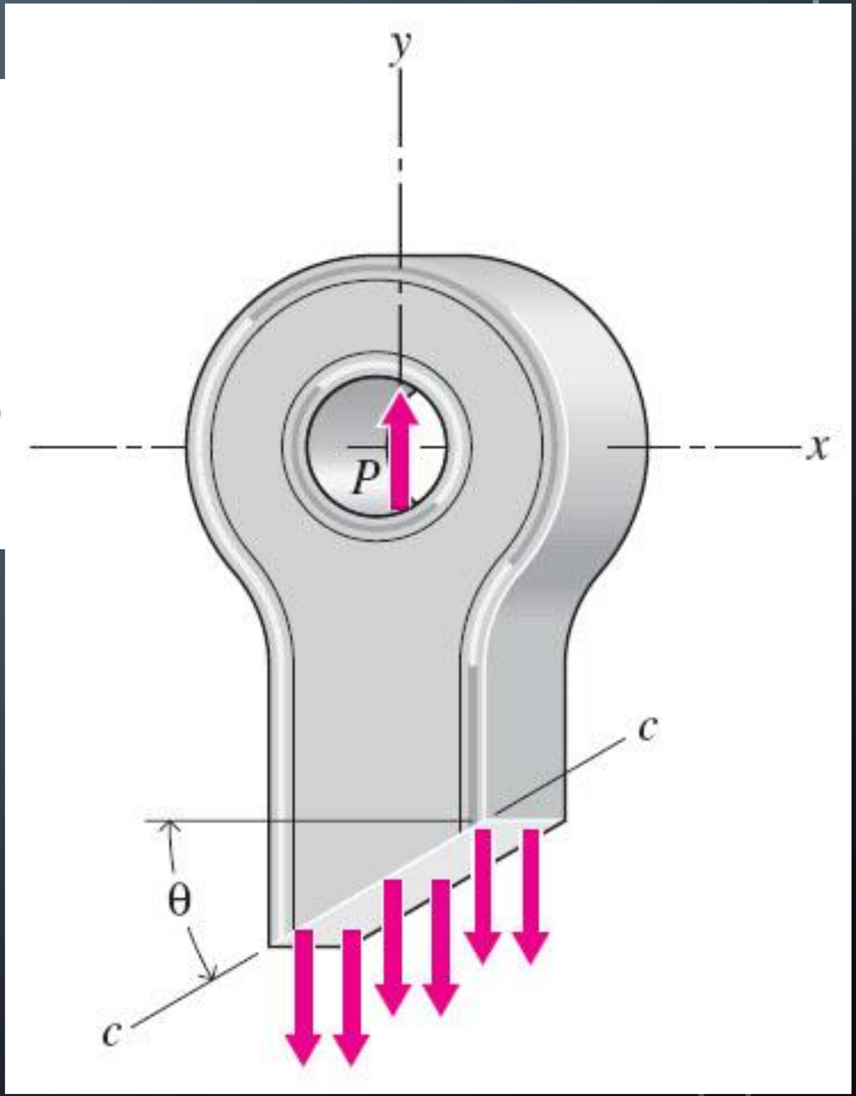
DETERMINATION OF YIELD STRESS

- Used to determine an arbitrary yield stress
- A straight line is drawn on the stress-strain diagram parallel to the initial linear part of the curve at an offset of 0.002 (or 0.2%) strain
- The intersection of the offset line and the stress-strain curve (point A) defines the "offset yield stress".



MAXIMUM STRESSES





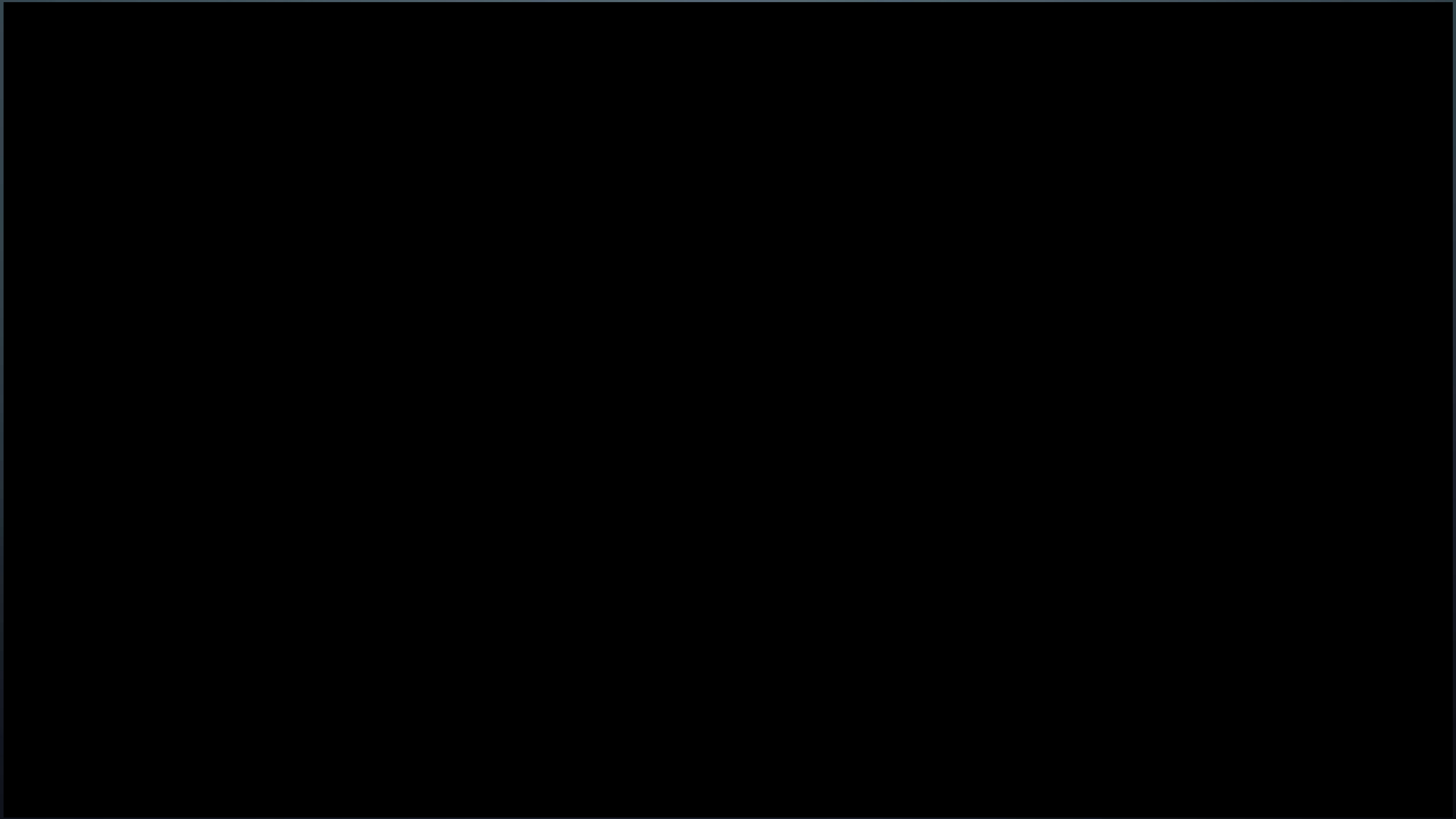
- The maximum normal stress occurs when the reference plane is perpendicular to the member axis

$$\sigma_{max} = \frac{P}{A_0}, \qquad \tau' = 0$$

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

$$\tau_{max} = \frac{P}{2A_0}, \qquad \sigma' = \frac{P}{2A_0}$$

TENSILE TEST



STRAIN ENERGY

- Average force magnitude

$$\frac{\Delta F}{2} = \frac{1}{2}(\sigma \Delta x \Delta y)$$

- Strain energy

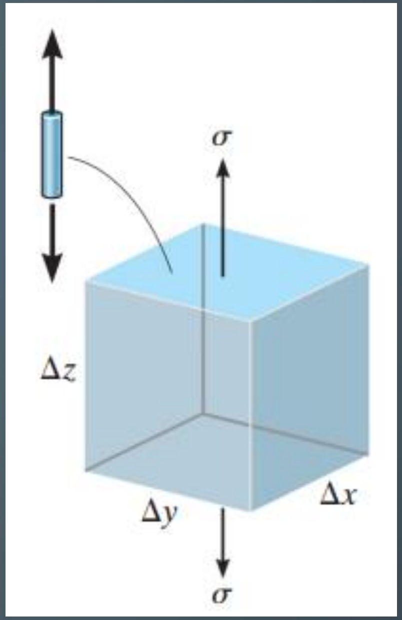
$$\Delta U = \frac{1}{2}(\sigma \Delta x \Delta y)\epsilon \Delta z$$

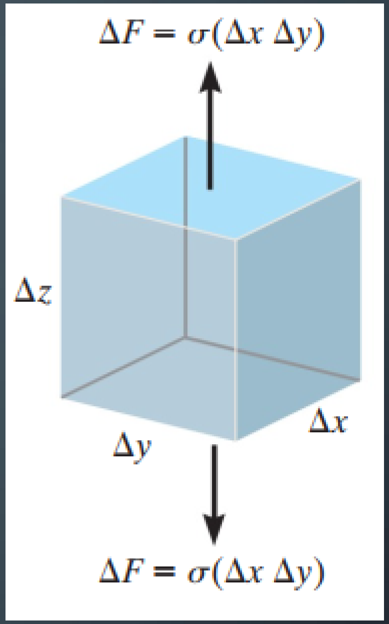
- Strain energy density

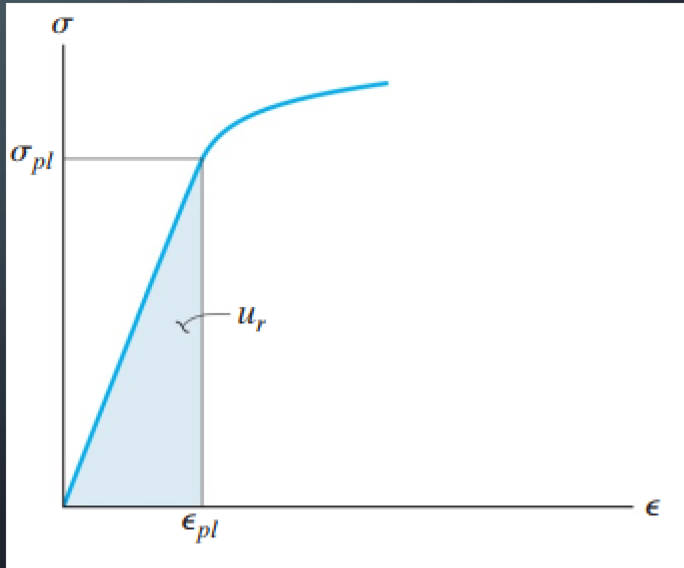
$$\Delta V = \Delta x \Delta y \Delta z;\ u = \frac{\Delta U}{\Delta V} = \frac{1}{2}\sigma\epsilon$$

- Modulus of Resilience

$$u_r = \frac{1}{2}\sigma_{pl}\epsilon_{pl}$$





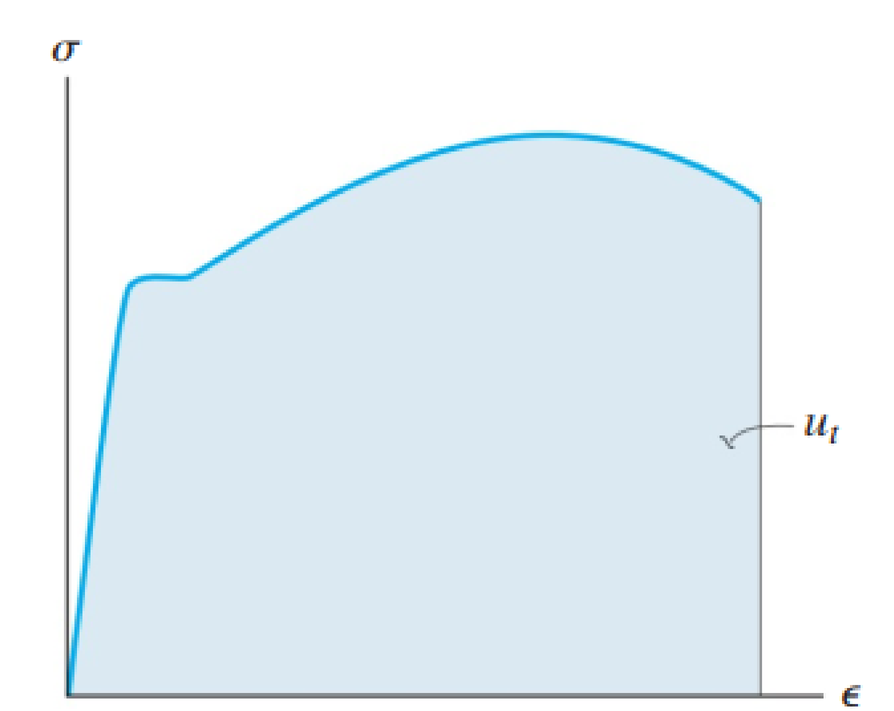


Modulus of resilience u_r

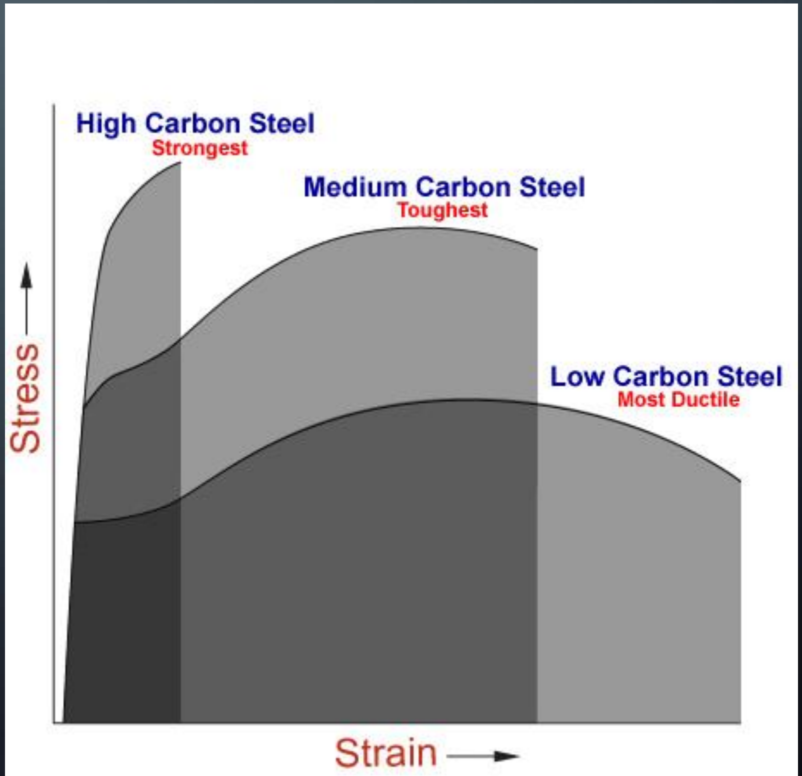
STRAIN ENERGY

Toughness is the ability of a material to absorb energy and plastically deform without fracturing. Energy volume

$$Toughness = \int_0^{\epsilon} \sigma \, d\epsilon$$



Modulus of toughness u_t



Segment 1:

Selected crashworthiness tests

Insurance Institute for Highway Safety

FOR THE REPORT

- 3 Aluminum Samples
- 3 Cast Iron Samples
- Plots:
  - A complete stress-strain curve for each material.
  - A plot of the linear elastic region with offset curve intersection.
  - A curve fit of the elastic deformation region
- 95% confidence t-test
- Compare your calculated and observed values to known published values

MATERIAL PROPERTIES

Properties of Selected Materials (SI Units)

Exact values may vary widely with changes in composition, heat treatment, and mechanical working. More precise information can be obtained from manufacturers.

Materials	Density (Mg/m^3)	Elastic Strength[a] Tension (MPa)	Elastic Strength[a] Comp. (MPa)	Elastic Strength[a] Shear (MPa)	Ultimate Strength Tension (MPa)	Ultimate Strength Comp. (MPa)	Ultimate Strength Shear (MPa)	Endurance Limit[c] (MPa)	Modulus of Elasticity (GPa)	Modulus of Rigidity (GPa)	Coefficient of Thermal Expansion ($10^{-6}/°C$)
Ferrous metals											
Wrought iron	7.70	210	[b]		330	[b]	170	160	190		12.1
Structural steel	7.87	250	[b]		450	[b]		190	200	76	11.9
Steel, 0.2% C hardened	7.87	430	[b]		620	[b]			210	80	11.9
Steel, 0.4% C hot-rolled	7.87	360	[b]		580	[b]		260	210	80	
Steel, 0.8% C hot-rolled	7.87	520	[b]		840	[b]			210	80	
Cast iron—gray	7.20				170	690		80	100		12.1
Cast iron—malleable	7.37	220	[b]		340	[b]			170		11.9
Cast iron—nodular	7.37	480			690				170		11.9
Stainless steel (18–8) annealed	7.92	250	[b]		590	[b]		270	190	86	17.3
Stainless steel (18–8) cold-rolled	7.92	1140	[b]		1310	[b]		620	190	86	17.3
Steel, SAE 4340, heat-treated	7.84	910	1000		1030	[b]	650	520	200	76	
Nonferrous metal alloys											
Aluminum, cast, 195-T6	2.77	160	170		250		210	50	71	26	
Aluminum, wrought, 2014-T4	2.80	280	280	160	430	[b]	260	120	73	28	22.5
Aluminum, wrought, 2024-T4	2.77	330	330	190	470	[b]	280	120	73	28	22.5
Aluminum, wrought, 6061-T6	2.71	270	270	180	310	[b]	210	93	70	26	22.5

STUDIO

- The following data was obtained for a 0.2% C plain-carbon steel
  - Plot the stress-strain curve.
  - Determine the Young's Modulus of the material.
  - Determine the yield stress of the material.
  - Determine the ultimate stress of the material.
  - Determine the percent elongation at fracture

Carbon-Steel (0.2% C)	
Stress (MPa)	Strain (%)
0	0
207	0.1
379	0.2
414	0.5
469	1
496	2
510	4
517	6
524	8
517	10
503	12
476	14
448	16
386	18
352	19