MECE 3321 MECHANICS OF SOLIDS CHAPTER 3

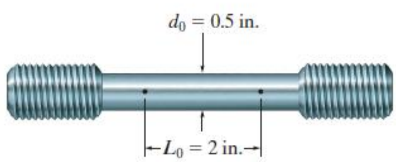
Samantha Ramirez

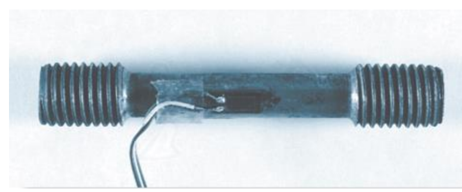
TENSION AND COMPRESSION TESTS

- Tension and compression tests are used primarily to determine the relationship between σ_{avg} and ε_{avg} in any material.
- A specimen of the material is made into a standard shape and size

TENSILE TEST

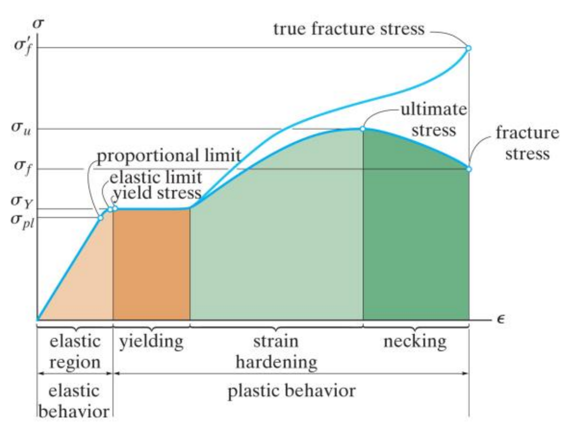
- P is measured using a load cell
  - $\sigma_{avg} = \frac{P}{A}$
- δ is elongation measured using an extensometer (optical or mechanical)
  - $\varepsilon_{avg} = \frac{\delta}{L_o}$
- A strain gauge can be used to measure strain directly





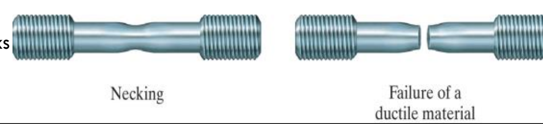
STRESS-STRAIN DIAGRAM

- The most important result from the tension test is the stress-strain diagram (σ-ε diagram).
- Nominal or engineering stress and strain are used to create a σ-ε diagram.
  - $\sigma = \frac{F}{A}$
  - $\varepsilon = \frac{\Delta L}{L_o}$



STRESS-STRAIN DIAGRAM

- Proportional Limit
  - The upper stress limit in the linear elastic region of a σ-ε diagram
- Elastic Limit
  - If the load is removed before reaching the elastic limit, the specimen will return to its original shape
  - If the load passes the elastic limit, the specimen will permanently deform
- Yield Strength
  - The stress that causes a material to breakdown and deform permanently
  - When yield strengths is not well defined, the offset yield strength can be calculated
    - A line parallel to the initial straight-line portion of the stress-strain curve at 0.2% strain (0.002 in/in).
- Ultimate Tensile Strength
  - The maximum stress the material will reach through testing
  - Necking occurs (visibly see permanent deformation)
- Fracture Stress
  - The stress when the material breaks



TRUE STRESS-TRUE STRAIN DIAGRAM

- Engineering Stress

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

- True Stress

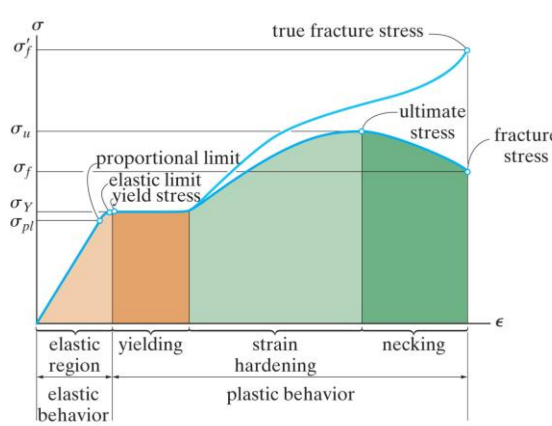
$$\sigma = \frac{F}{A}$$

- Engineering Strain

$$\varepsilon = \frac{\Delta L}{L_o}$$

- True Strain

$$\varepsilon = \frac{\Delta L}{L}$$



DUCTILITY

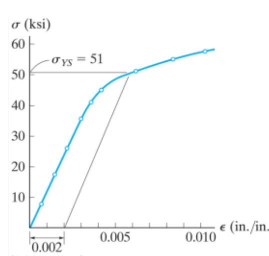
- The characterization of the strain experienced by a material before it fractures

$$\% \, Elongation = \frac{L_f - L_o}{L_o} \times 100\%$$

$$\% \, Reduction \; of \; Area = \frac{A_o - A_f}{A_o} \times 100\%$$

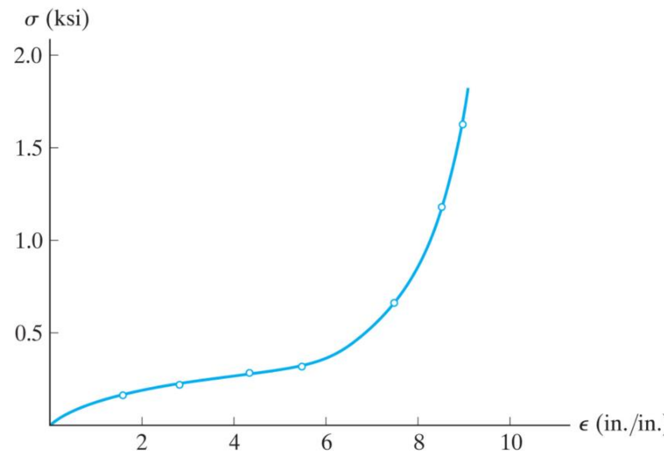
BRITTLE MATERIALS

- Brittle materials do not undergo significant yield beyond the elastic range; for example aluminum, concrete mix, and gray cast iron.
  - Brittle materials can take much larger loads in compression than in tension.
- The yield point of brittle materials is found using the offset method of 0.2% strain.



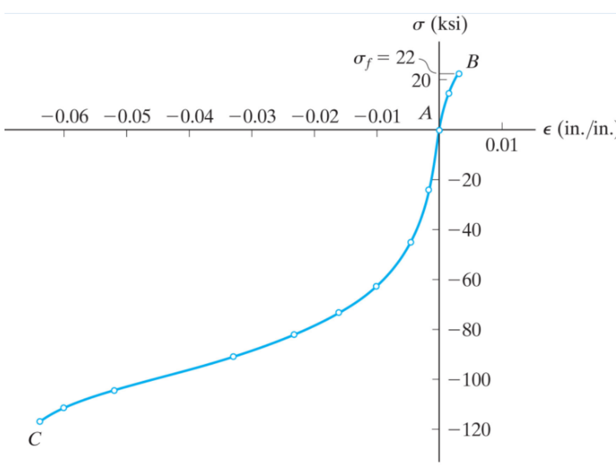
Yield strength for an aluminum alloy

σ-ε Diagram for Other Materials



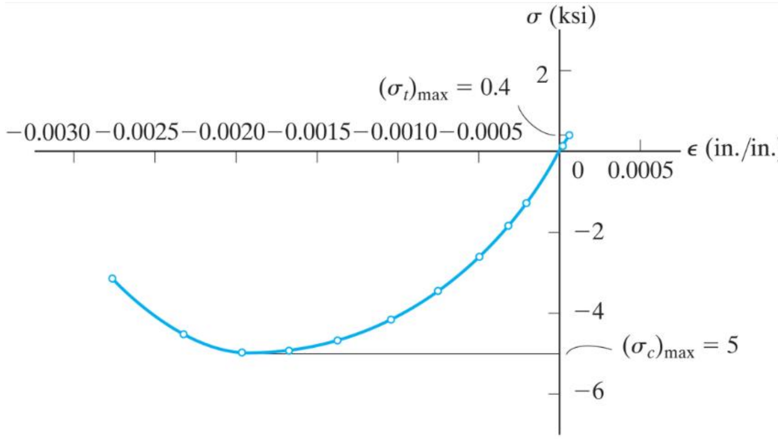
σ–ϵ diagram for natural rubber

σ-ε Diagram for Other Materials



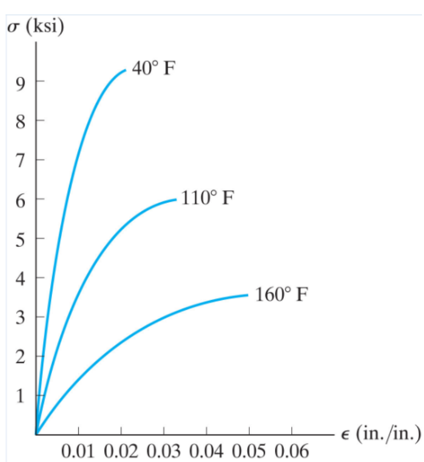
σ–ϵ diagram for gray cast iron

σ-ε Diagram for Other Materials



σ − ϵ diagram for typical concrete mix

σ-ε Diagram for Other Materials



σ − ϵ diagrams for a methacrylate plastic

HOOKE'S LAW

- The proportional limit was observed by Robert Hooke in 1676

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

  - E: Young's Modulus, the constant of proportionality
    - Young's Modulus or the modulus of elasticity is a mechanical property of a material that indicates stiffness.
  - $\frac{\sigma}{\varepsilon}$: Slope of the straight-line portion of the stress-strain curve

- Theoretical Moduli
  - Steel: E=29 Msi or 200 GPa
  - Aluminum: E=10 Msi or 69 Gpa

- The modulus of elasticity can only be used if a materials has linear elastic behavior and is being subjected to stresses below the proportional limit.
  - If a material has yielded, the modulus of elasticity cannot be used.

PROBLEM F3-9

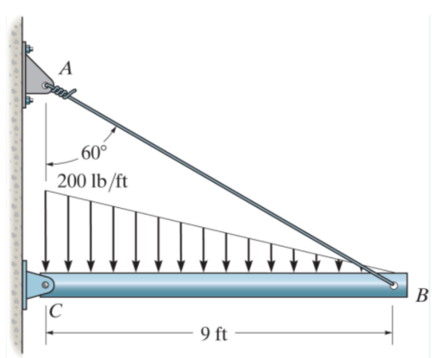
A 10 mm diameter rod has a modulus of elasticity of E=100 GPa. If it is 4 m long and subjected to an axial tensile load of 6 kN, determine its elongation. Assume linear-elastic behavior.

PROBLEM 3.6

A specimen is originally 1 ft long, has a diameter of 0.5 in, and is subjected to a force of 500 lb. When the force is increased from 500 lb to 1800 lb, the specimen elongates 0.009 in. Determine the modulus of elasticity for the material if it remains linear elastic.

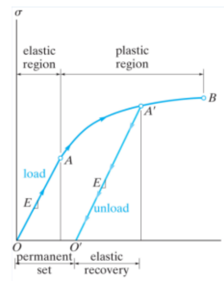
PROBLEM 3.8

The strut is supported by a pin at C and an A-36 steel guy wire AB. If the wire has a diameter of 0.2 in, determine how much it stretches when the distributed load acts on the strut.

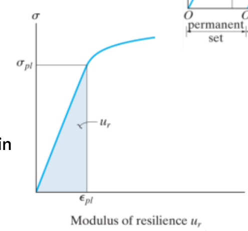


PLASTIC ELONGATION

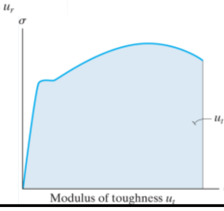
- If a ductile material is loaded into the plastic region and then unloaded, elastic strain is recovered; but the material suffers a permanent set.



- Modulus of Resilience
  - Area under the elastic region of a stress-strain diagram
  - $u_r = \frac{1}{2}\sigma_{pl}\varepsilon_{pl} = \frac{1}{2}\frac{\sigma_{pl}^2}{E}$

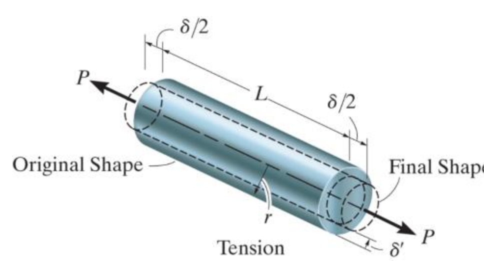


- Modulus of Toughness
  - Area under the entire stress-strain diagram



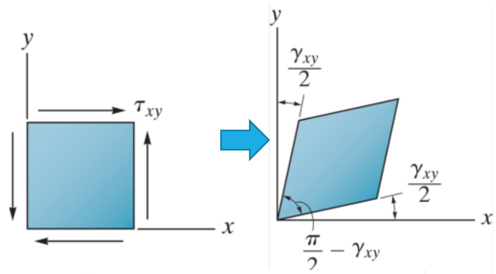
POISSON'S RATIO

- A deformable body subjected to a normal tensile load not only elongates but also contracts laterally.
- $\varepsilon_{long} = \frac{\delta}{L}$
- $\varepsilon_{lat} = \frac{\delta'}{r}$
- $\nu = -\frac{\varepsilon_{lat}}{\varepsilon_{long}}$

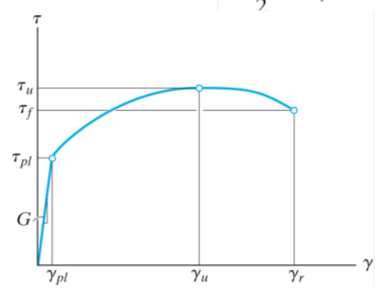


SHEAR-STRAIN DIAGRAM

- Hooke's Law for Shear
  - $G = \frac{\tau}{\gamma}$
    - G: Shear modulus of elasticity or modulus of rigidity
    - τ: Shear stress
    - γ: Shear strain



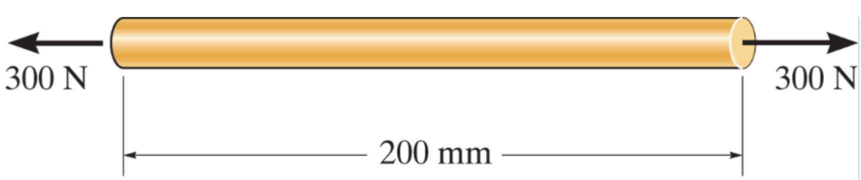
- Relation of modulus of elasticity and rigidity
- $G = \frac{E}{2(1+\nu)}$



- For steel,
  - E=29000 ksi
  - G=11000 ksi
  - ν=0.32

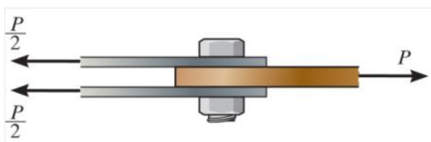
PROBLEM 3.25

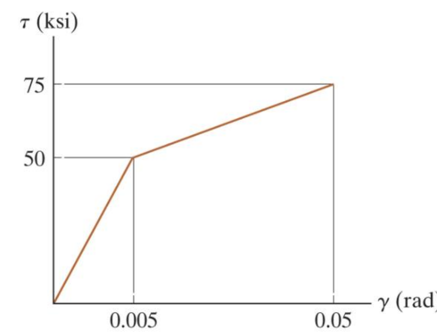
The acrylic plastic rod is 200 mm long and 15 mm in diameter. If an axial load of 300 N is applied to it, determine the change in its length and the change in its diameter. E_p= 2.7 GPa, ν_p= 0.4.



PROBLEM 3.31

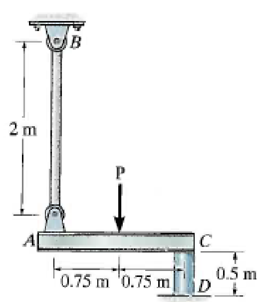
The lap joint is connected together using a 1.25 in diameter bolt. If the bolt is made from a material having a shear stress-strain diagram that is approximated as shown, determine the permanent shear strain in the shear plane of the bolt when the applied force P=150 kip is removed.

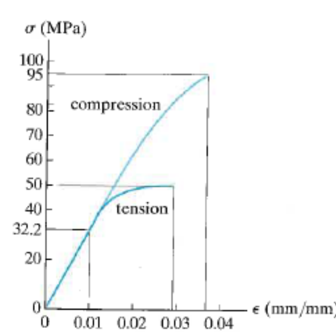




EXAMPLE PROBLEM 1

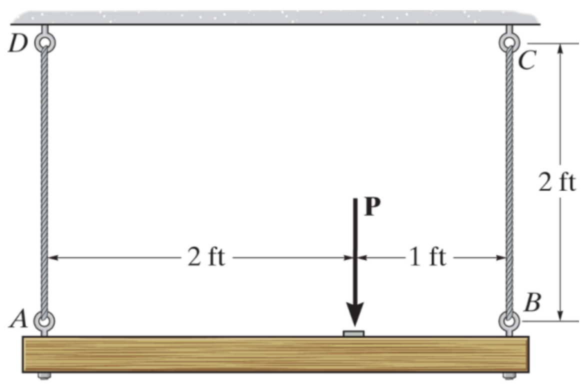
The stress-strain diagram for a polyester resin is given in the figure. If the rigid beam is supported by a strut AB and post CD made from this material, determine the largest load P that can be applied to the beam before it ruptures. Determine the final diameter and length of post CD at rupture if the diameter of the strut is 12 mm and the diameter of the post is 40 mm.





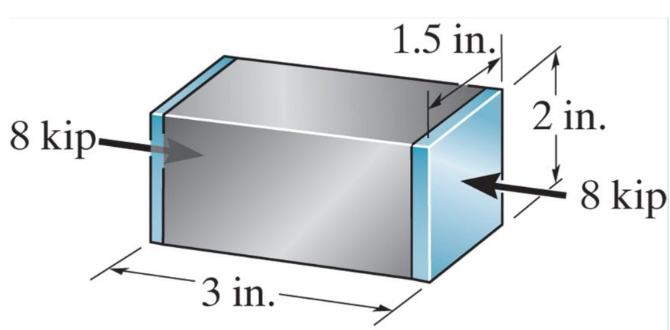
PROBLEM 3.38

The wires each have a diameter of 0.5 in, length of 2 ft, and are made of 304 stainless steel. If P=6 kip, determine the angle of tilt of the rigid beam AB.



PROBLEM 3-33

The aluminum block has a rectangular cross section and is subjected to an axial compressive force of 8 kip. If the 1.5 in side changed its length to 1.500132 in, determine Poisson's ratio and the new length of the 2 in side. $E_{al}=10(10^3)$ ksi.



PROBLEM 3-36

The elastic portion of the tension stress-strain diagram for an aluminum alloy is shown in the figure. The specimen used for the test has a gauge length of 2 in and a diameter of 0.5 in. If the applied load is 10 kip, determine the new diameter of the specimen. The shear modulus is $G_{al} = 3.8 \times 10^3$ ksi.