Lecture 2: Normal stress, extensional strain, and mechanical properties

Lecture Book: Chapter 2

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PURDUE ENGINEERING

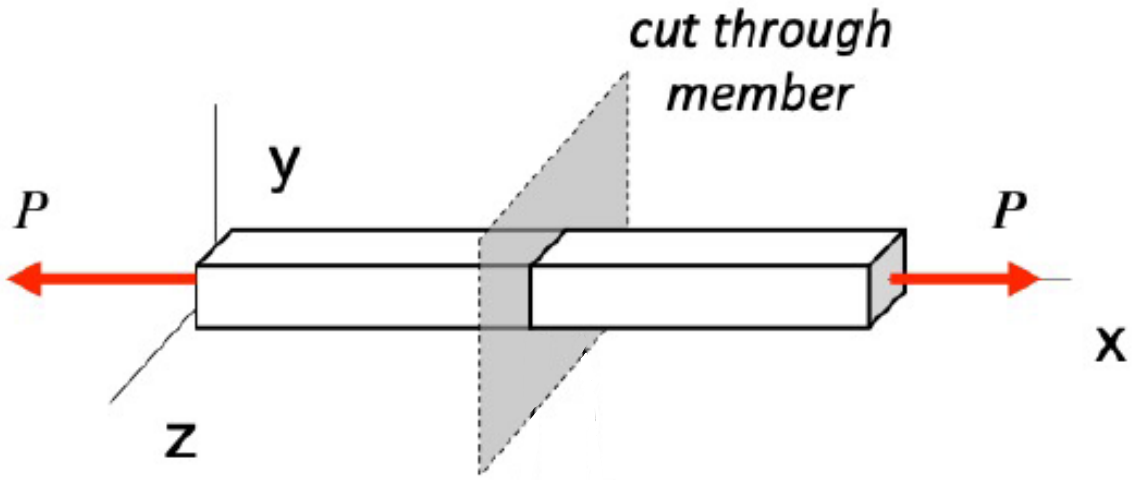
Review of last class

- ME 323 overview: interested in *deformable* materials
- Statics review: steps for FBDs and equilibrium
  - Isolate a body from its connections
  - Sketch a coordinate system
  - Sketch external loads, reactions, and internal resultants
  - Apply equilibrium equations and solve for unknowns

Objectives

- Define normal stress and extensional strain
  - What assumptions can simplify how we calculate these quantities?
- Introduce mechanical properties of materials
  - How are strains in different directions related?
  - How are stress and strain related?
- Examples from the lecture book

Normal stress



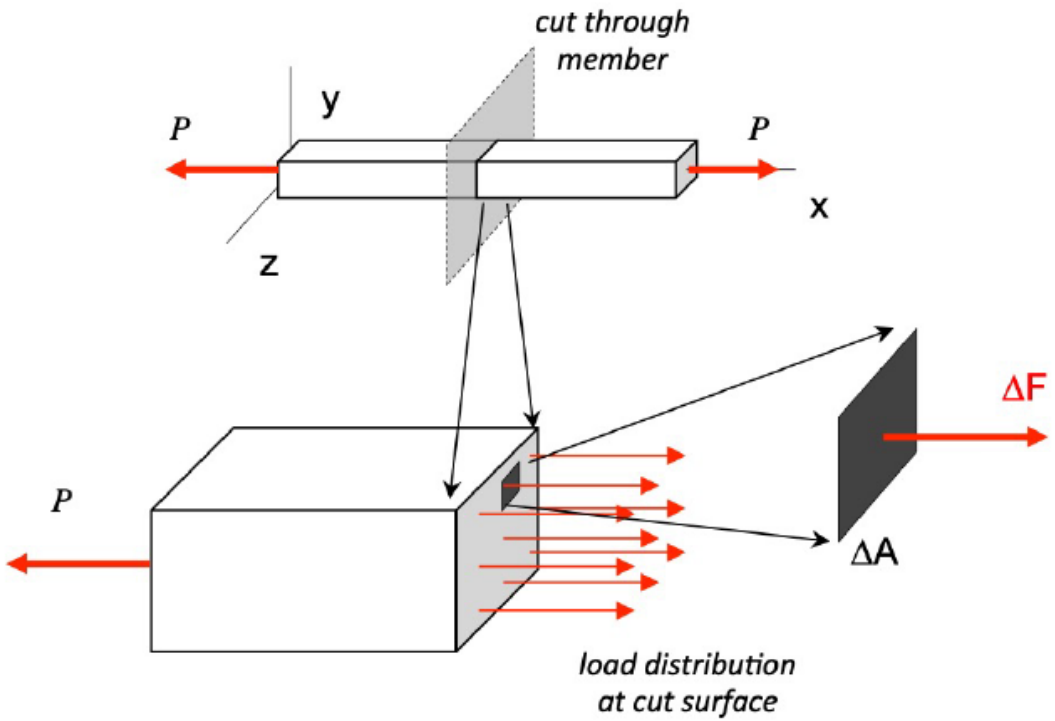
Internal resultants:

Force on a small area, ΔA:

Define normal stress:

Normal stress

How can we determine the *average* stress on a cross section?



Normal stress

Assumptions:

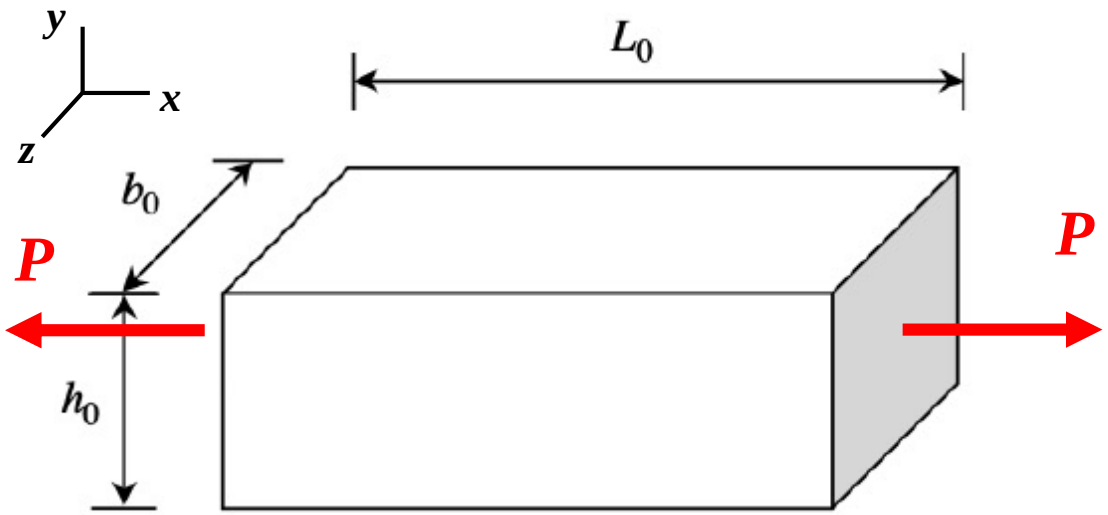
- Applied axial force acts at the centroid of the cross section
- Material is homogeneous and isotropic
- Deformation is uniform

Questions:

- How do these assumptions simplify the problem?
- What is the sign convention for normal stress?
- What are the units of stress?

Extensional strain

Apply an axial load to a rectangular block. How can we describe the deformation?



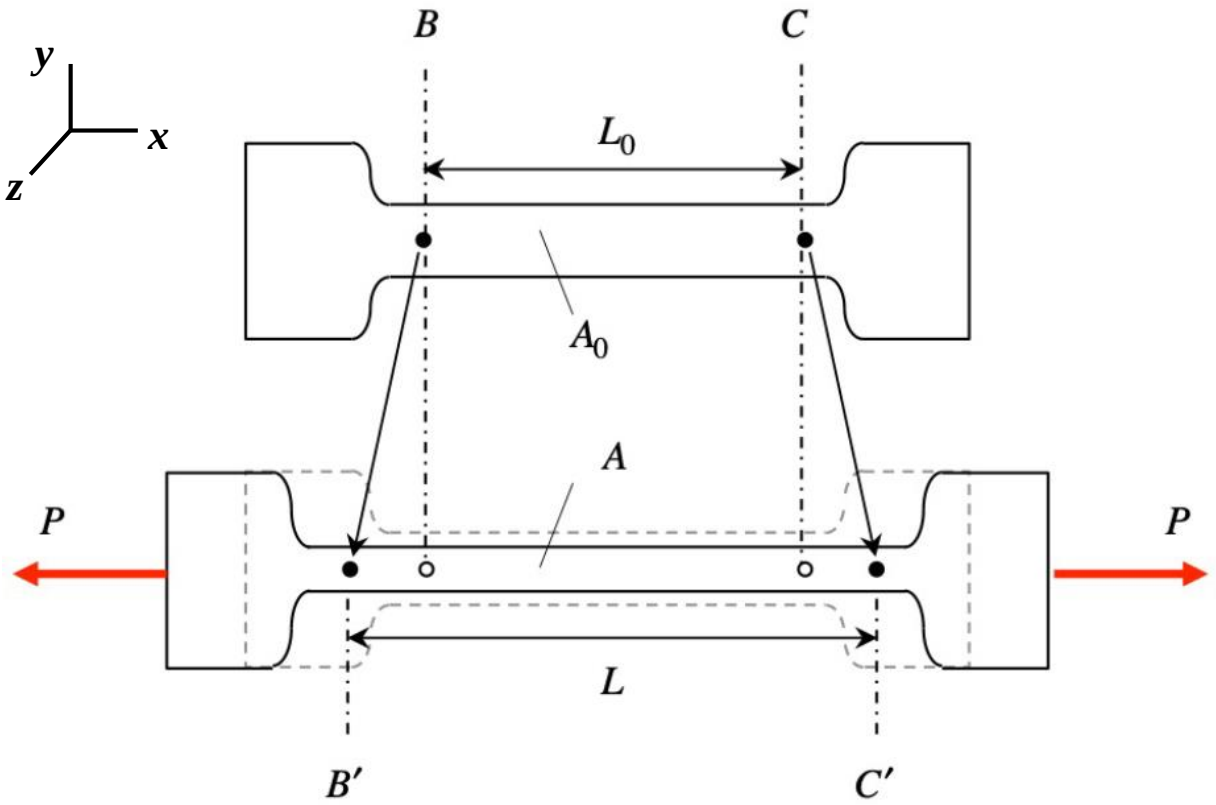
Extensional strain

Questions:

- Are the axial and transverse strains related?
- What is the sign convention for extensional strain?
- What are the units of strain?

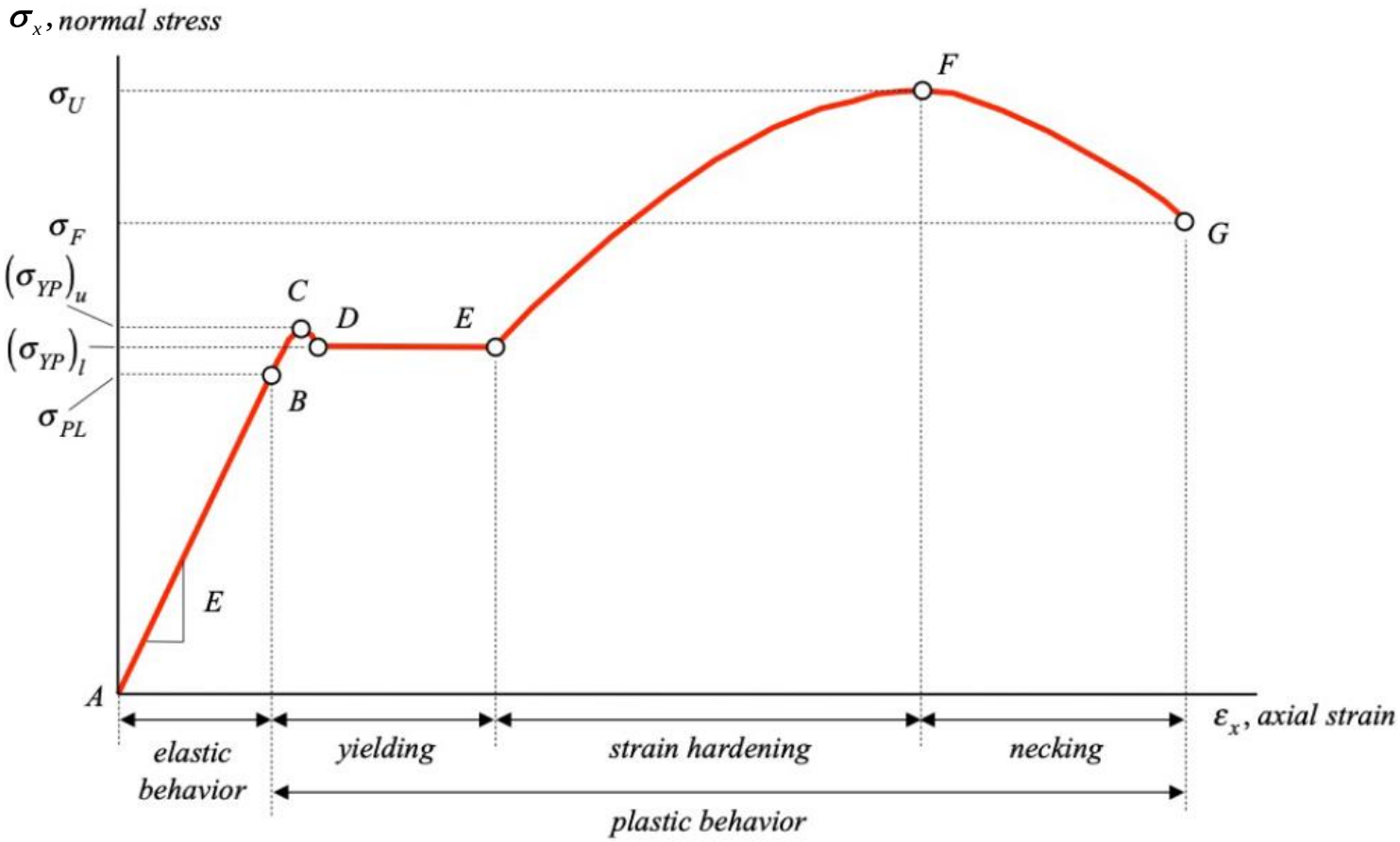
Tensile test

- Apply a uniaxial load
- What are the stress and strain measures we want to relate?



Tensile test

Typical stress strain curve for steel – what quantities from this plot are useful?



Mechanical properties

We've identified two mechanical properties relating normal stress and extensional strains

Young's modulus E: $\sigma_x = E\epsilon_x$

Poisson's ratio v: $\varepsilon_y = \varepsilon_z = -v\varepsilon_x$

For what assumptions are these equations valid?

Summary

- Normal stress: $\sigma \equiv \lim_{\Delta A \to 0} \frac{\Delta F}{\Delta A} = \frac{dF}{dA}$
  - Load at centroid; isotropic & homogeneous material; uniform deformation: $\sigma = \sigma_{ave} = \frac{P}{A}$
- Extensional strain: $\varepsilon \equiv \frac{\Delta L}{L_0}$
- Mechanical properties
  - Young's modulus E: relates uniaxial stress and strain, $\sigma_x = E\varepsilon_x$
  - Poisson's ratio ν: relates axial strain to transverse strain, $\varepsilon_y = \varepsilon_z = -\nu\varepsilon_x$
  - Remember our assumptions for these equations!
- Next time: shear stress and strain