Fall, 2022

ME 323 – Mechanics of Materials

Lecture 4 – Mechanical properties

Reading assignment: Ch.4 lecturebook

PURDUE UNIVERSITY | Mechanical Engineering

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The smell of oil and steel and the sound of machinery

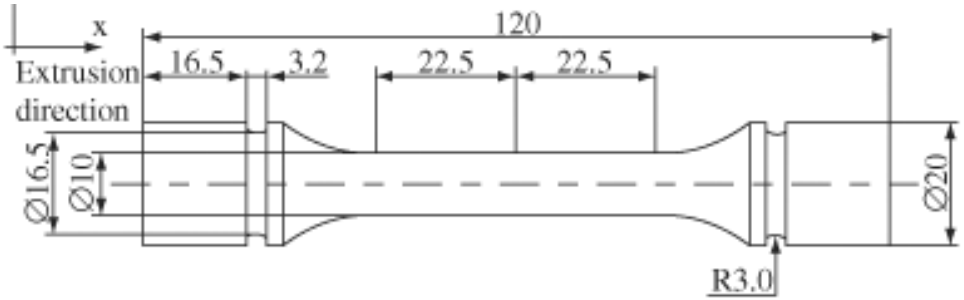
Shinya Kimura: *"In 1962 I was born in old town Tokyo. I was brought up surrounded by the smell of oil and steel and the sound of machinery. I think this is why this life suits me well. I have images but I am not inspired by any particular thing. I don't draw either. I cut steel or bend aluminum, listening to how I feel at that moment. I use my own hands and break my back making bikes. I believe that speaks to people's emotions and makes them want one."*

Video

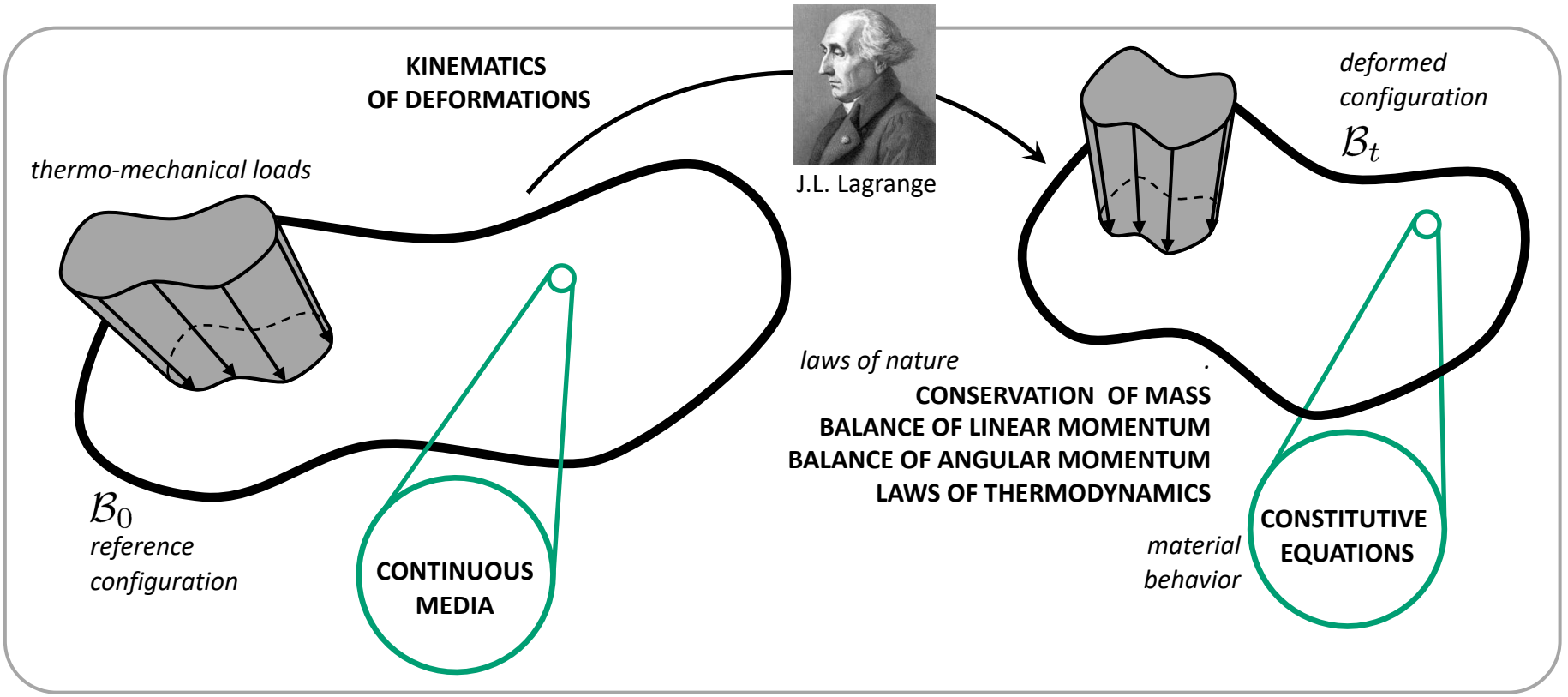
Mechanical properties

Learning by experimenting:

- Universal testing machines
  Uniaxial (tension and compression)
  Multiaxial (torsional, biaxial)
- Static loading (?)
  … also rate and thermal effects, etc.
- What do we measure? Force + Displacement
  Stress-strain diagrams $\sigma = \sigma(\epsilon)$
- ASTM standards
  American Society for Testing and Materials



Stress and strain

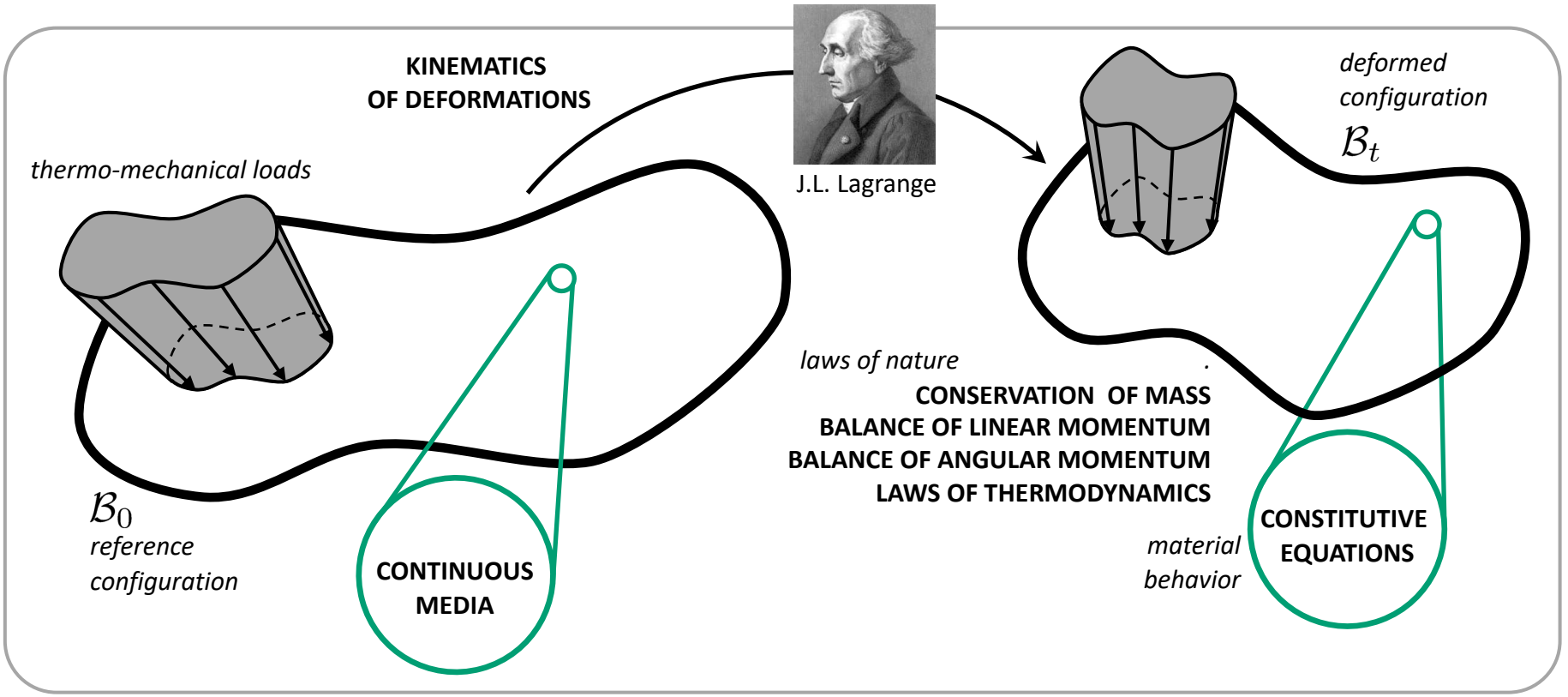


Strain-displacement relationship

$$\epsilon = \frac{L_t - L_0}{L_0} = \frac{\Delta L}{L_0}$$

- It is a strictly geometric relationship
- If we know the displacement, then we know the strain
- If we know the strain, then we know the displacement

Stress and strain



Small displacements / Small strains (small deformations)

- We will restrict attention to small displacement and deformations

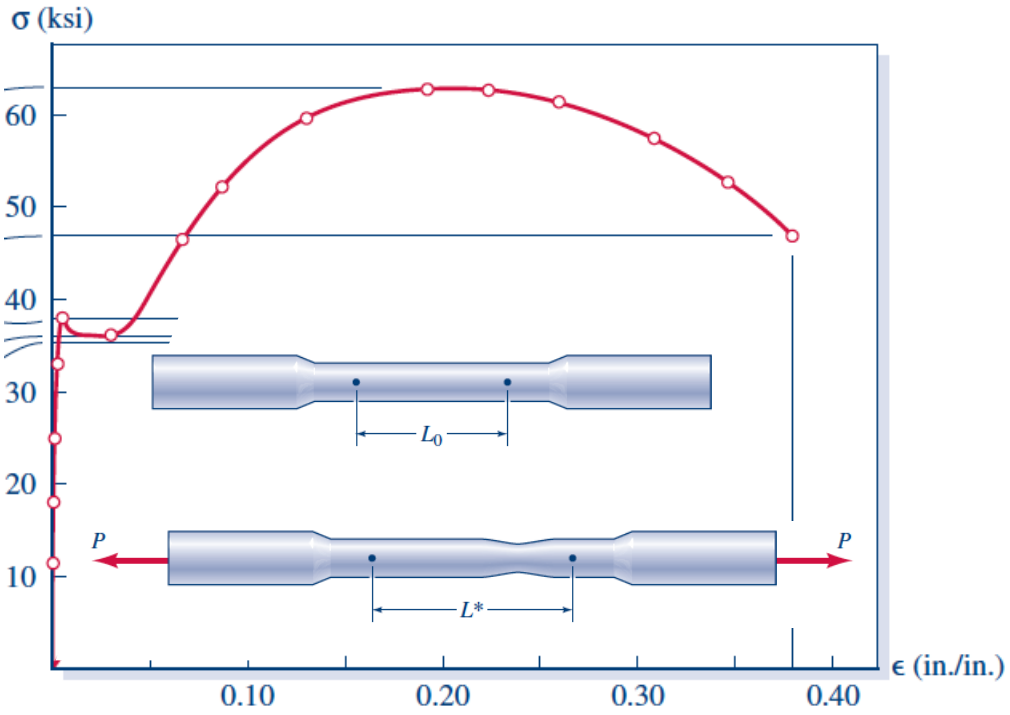
$$\epsilon = \frac{\Delta L}{L_0} << 1$$

$$\Delta L << L_0$$

Mechanical properties

Material properties from stress-strain diagrams:

- Tensile uniaxial test

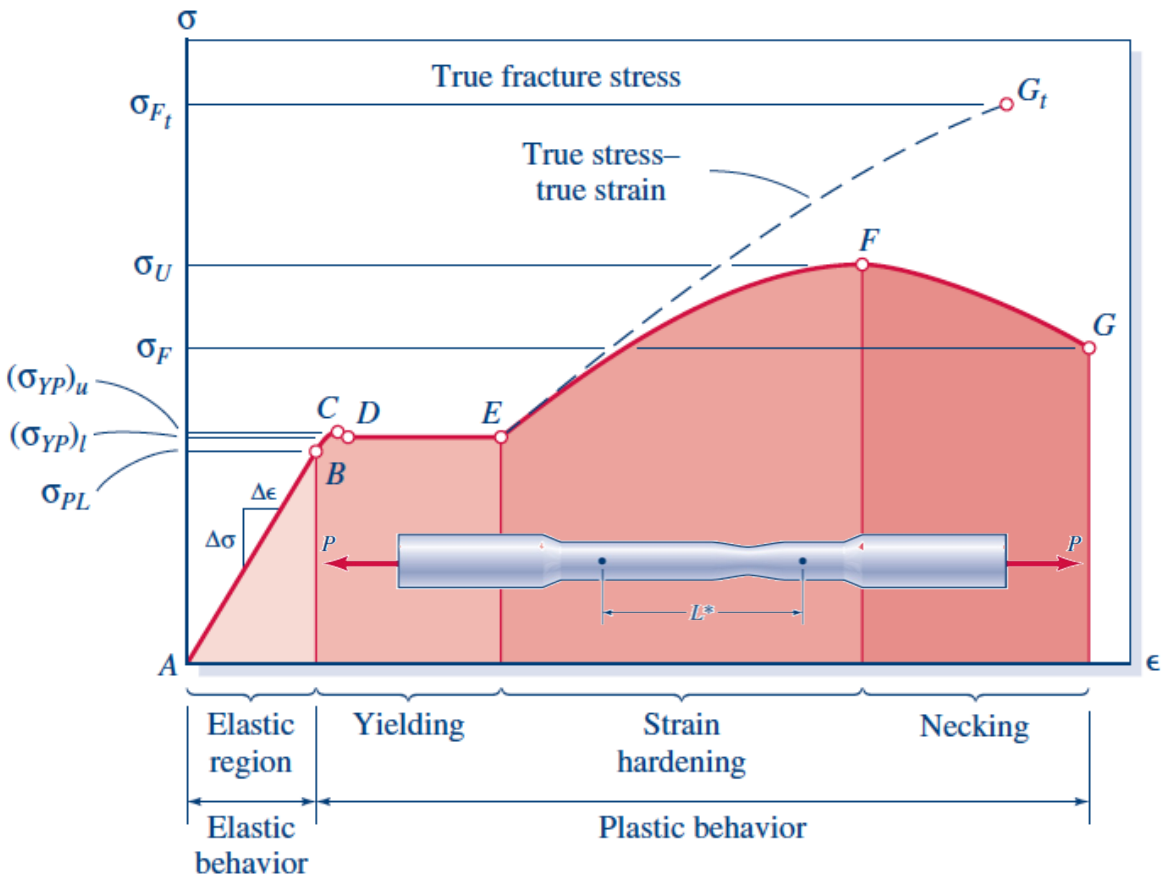


Engineering stress and strain: $\sigma = \dfrac{P}{A_0} \quad \epsilon = \dfrac{\Delta L}{L_0}$

Mechanical properties

Material properties from stress-strain diagrams:

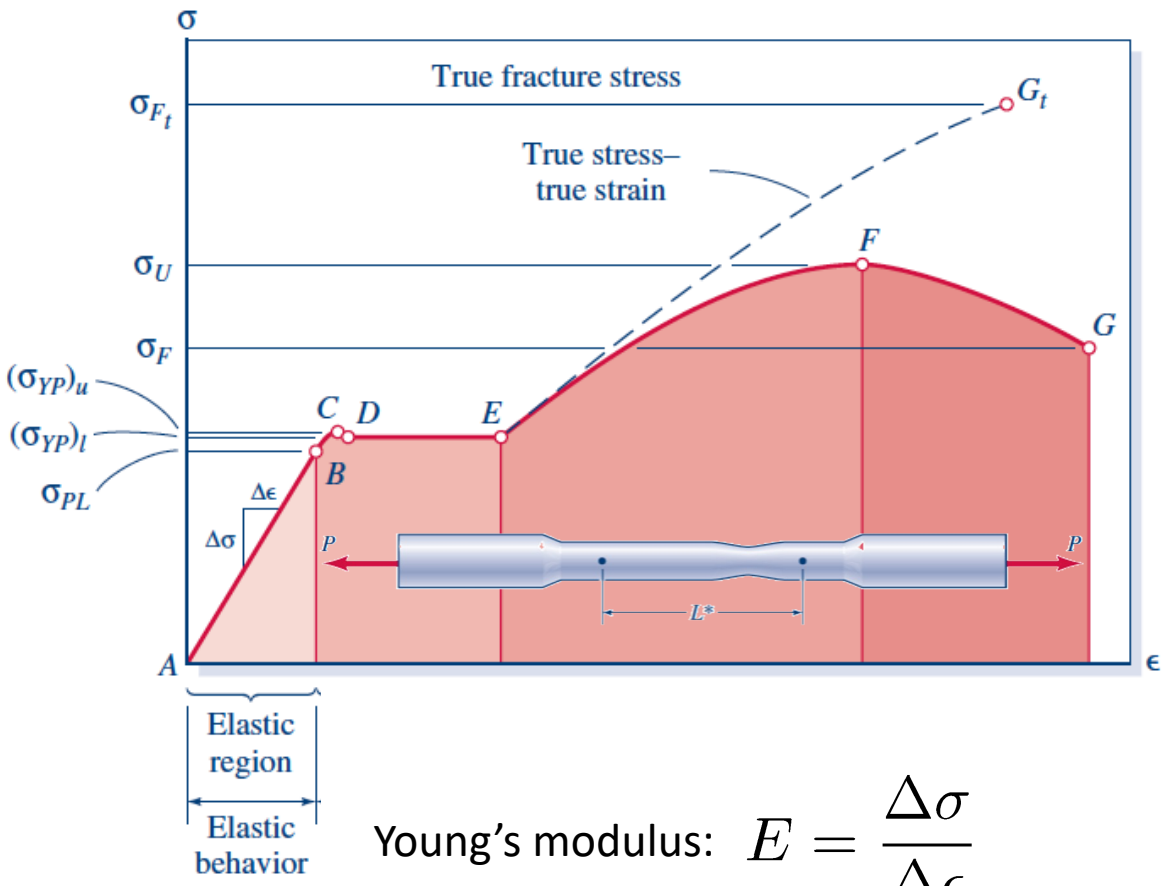
- Tensile uniaxial test



Mechanical properties

Material properties from stress-strain diagrams:

- Tensile uniaxial test

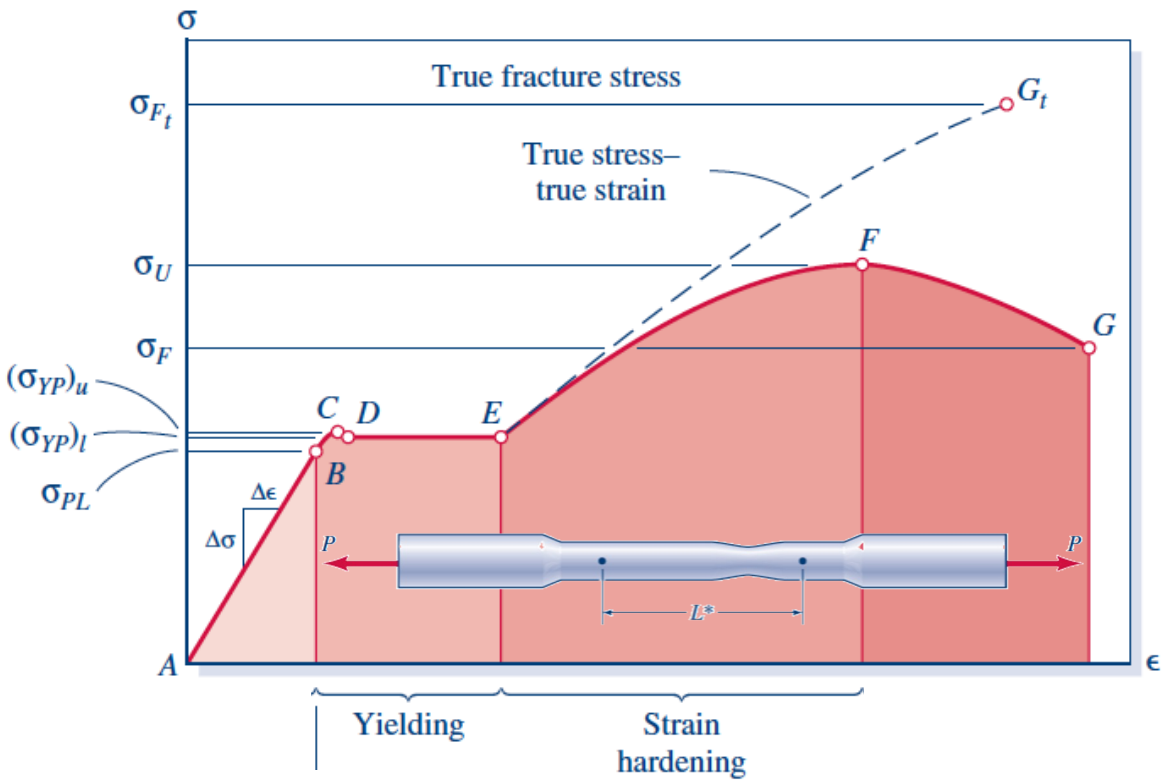


Young's modulus: $E = \dfrac{\Delta\sigma}{\Delta\epsilon}$

Mechanical properties

Material properties from stress-strain diagrams:

- Tensile uniaxial test



Proportional limit σ_{PL}

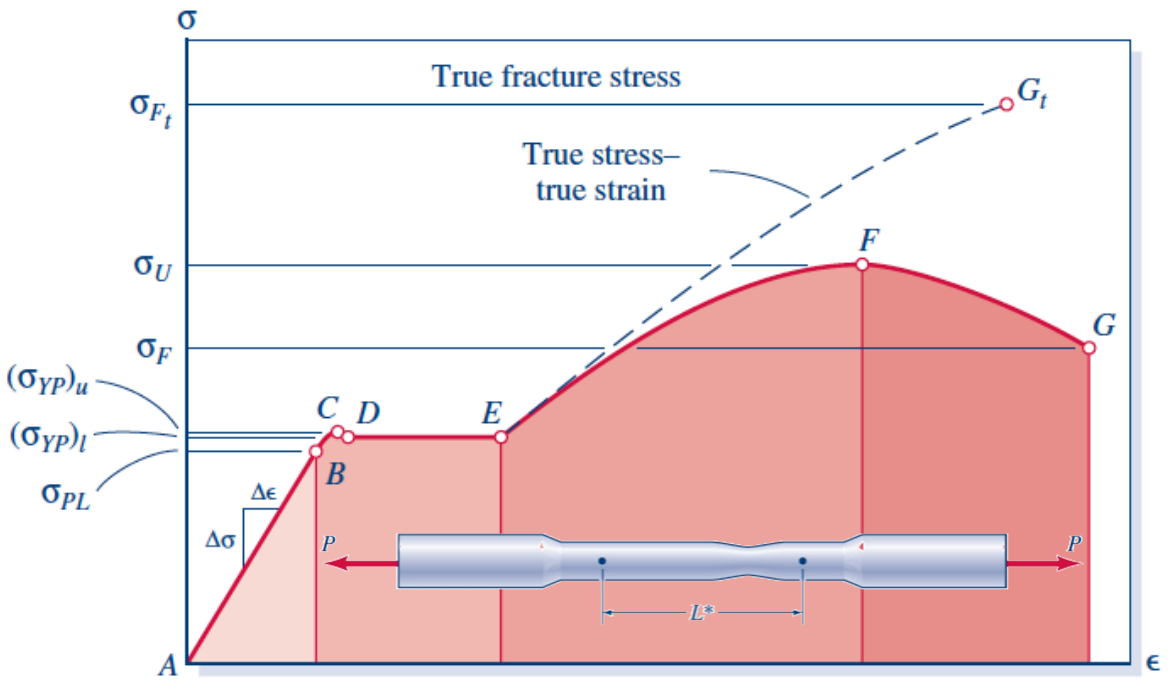
Yield point $\sigma_{YP} \equiv \sigma_Y$

Ultimate strength σ_U

Mechanical properties

Material properties from stress-strain diagrams:

- Tensile uniaxial test



True stress and strain:

$$\sigma_{\text{true}} = \frac{P}{A_t}$$

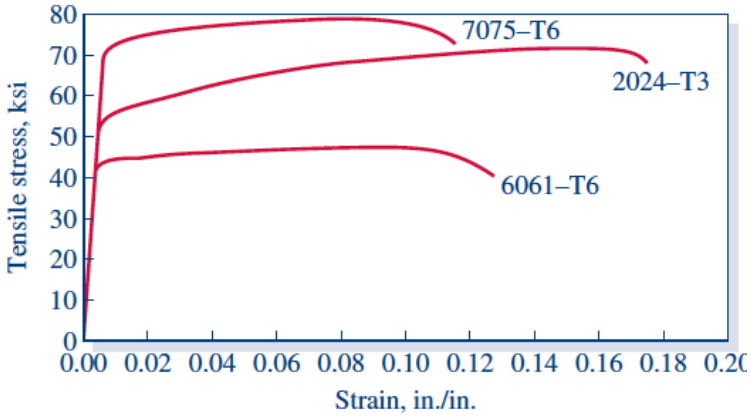
$$\epsilon_{\text{true}} = \ln(1+\epsilon) = \ln\left(\frac{A_0}{A_t}\right)$$

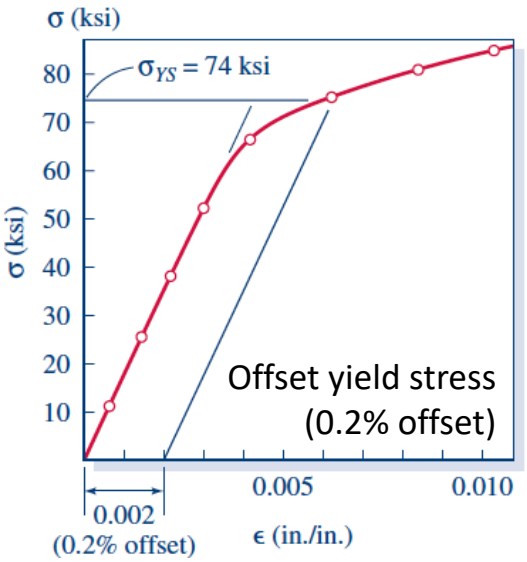
Mechanical properties

Material properties from stress-strain diagrams:

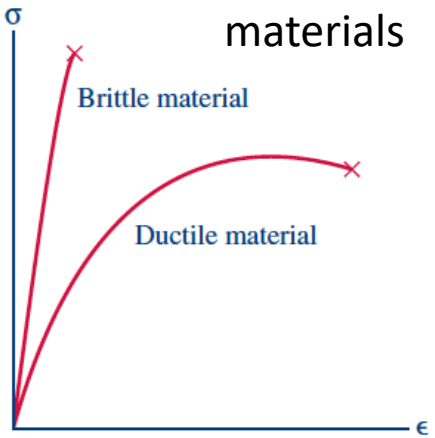
- Tensile uniaxial test – Is it always this easy?
  No!

Aluminum alloys have no significant yield at constant stress





Brittle vs. ductile materials



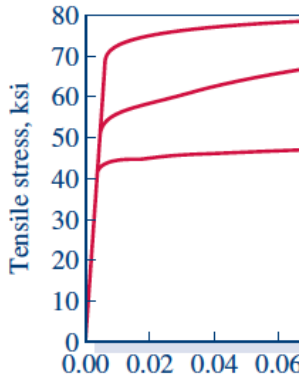
- Tension and compression tests are typically different!
- Composite materials (recall the definition of a continuum solid)

Mechanical properties

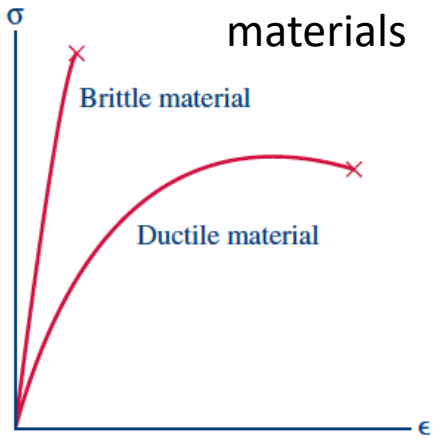
Material properties from stress-strain diagrams:

- Tensile uniaxial test – Is it always this easy?
  No!

Aluminum alloy
yield at constan



Brittle vs. ductile materials



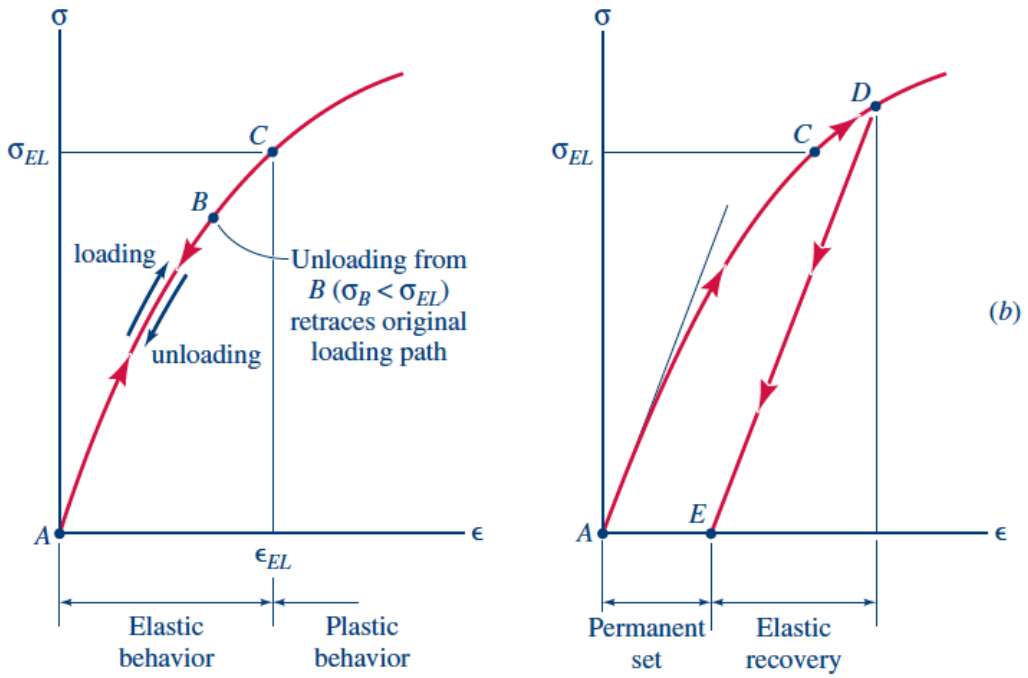
Brittle Ductile

- Tension and compression tests are typically different!
- Composite materials (recall the definition of a continuum solid)

Mechanical properties

Material properties from stress-strain diagrams:

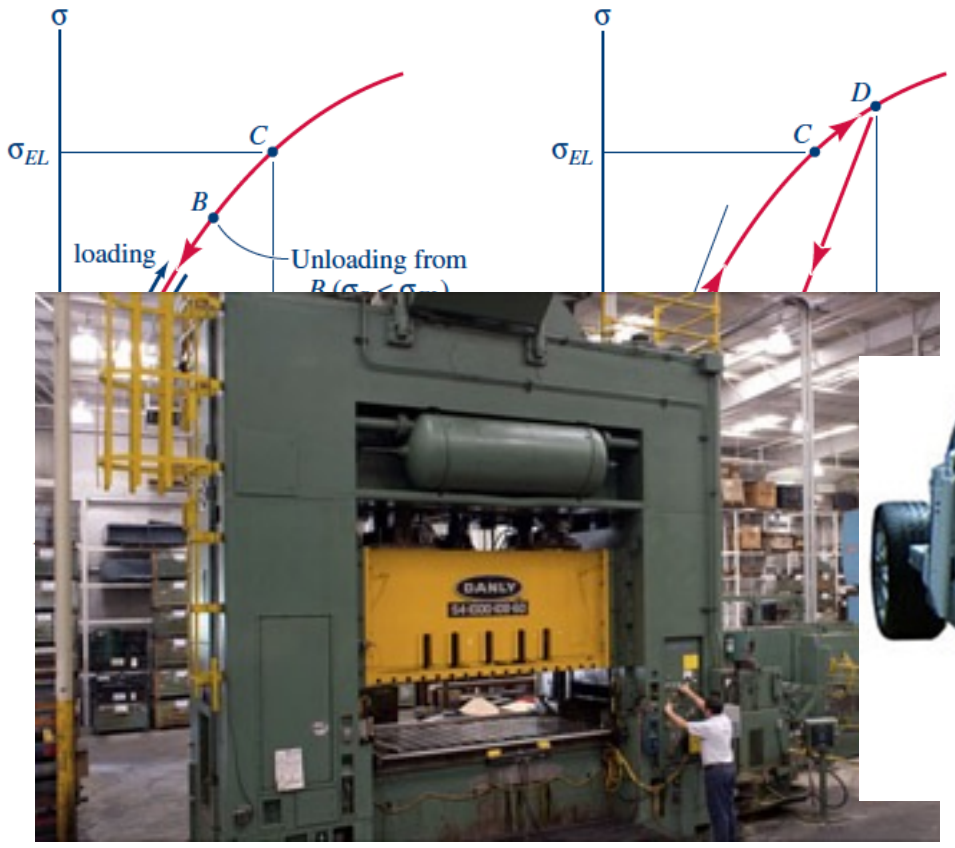
- Plastic deformations



Mechanical properties

Material properties from stress-strain diagrams:

- Plastic deformations



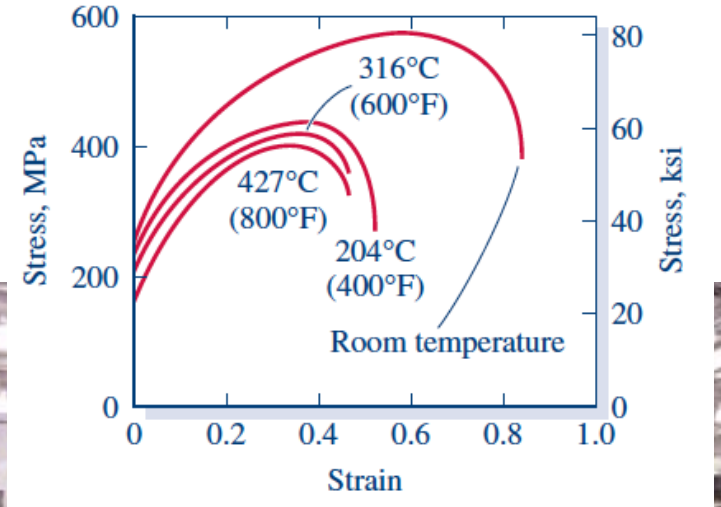
(b)

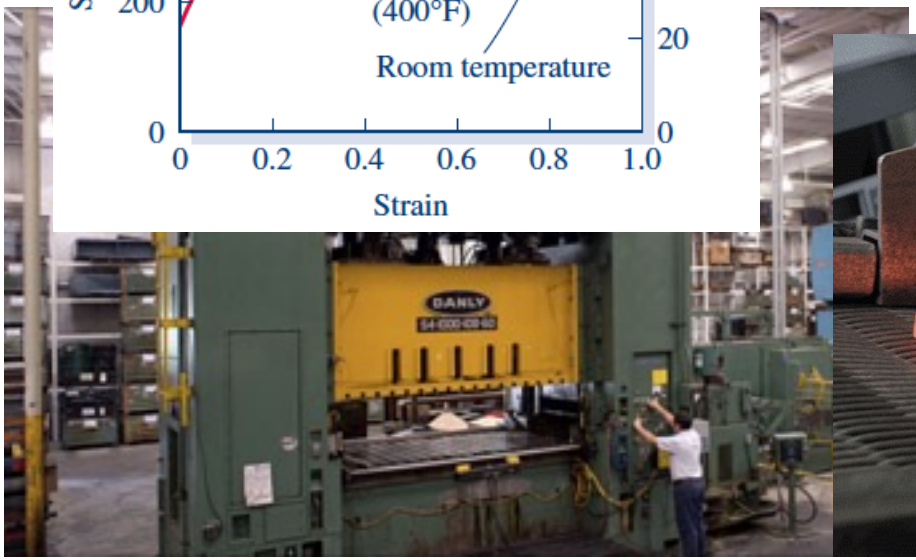
Automotive metal stamping

Mechanical properties

Material properties from stress-strain diagrams:

- Influence of temperature



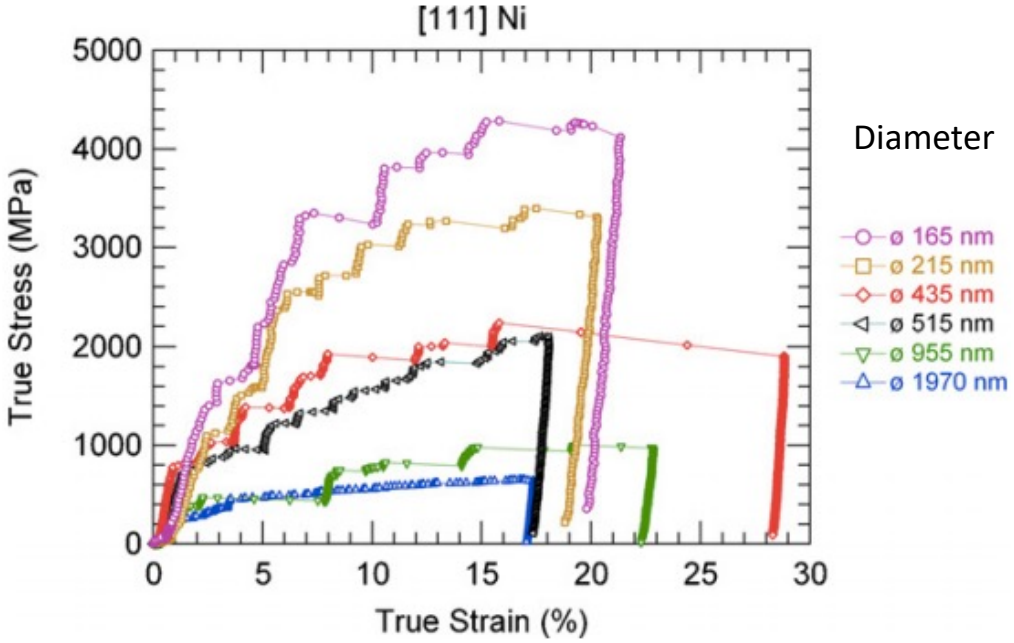


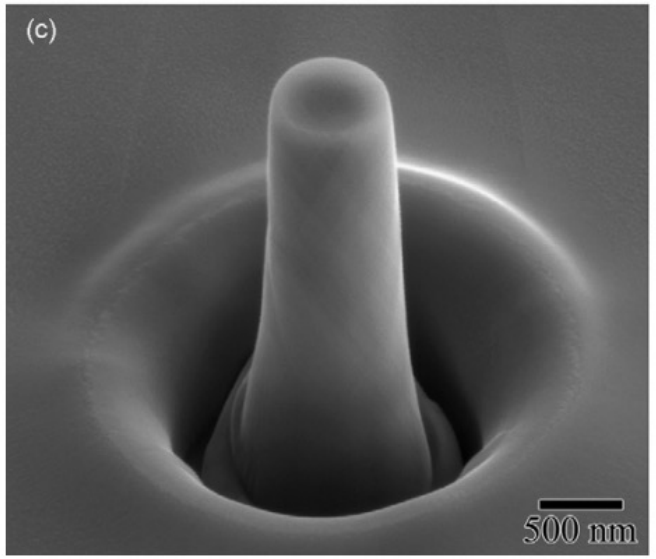
Forging of automotive parts
Automotive metal stamping

Mechanical properties

Material properties from stress-strain diagrams:

- Size effects?
  These are material properties and therefore do not depend on the size of the specimen. However, we may break down the hypothesis of continuum solids if the size is ‘too small’.
  This opens the door to nanoscience and nanotechnology.

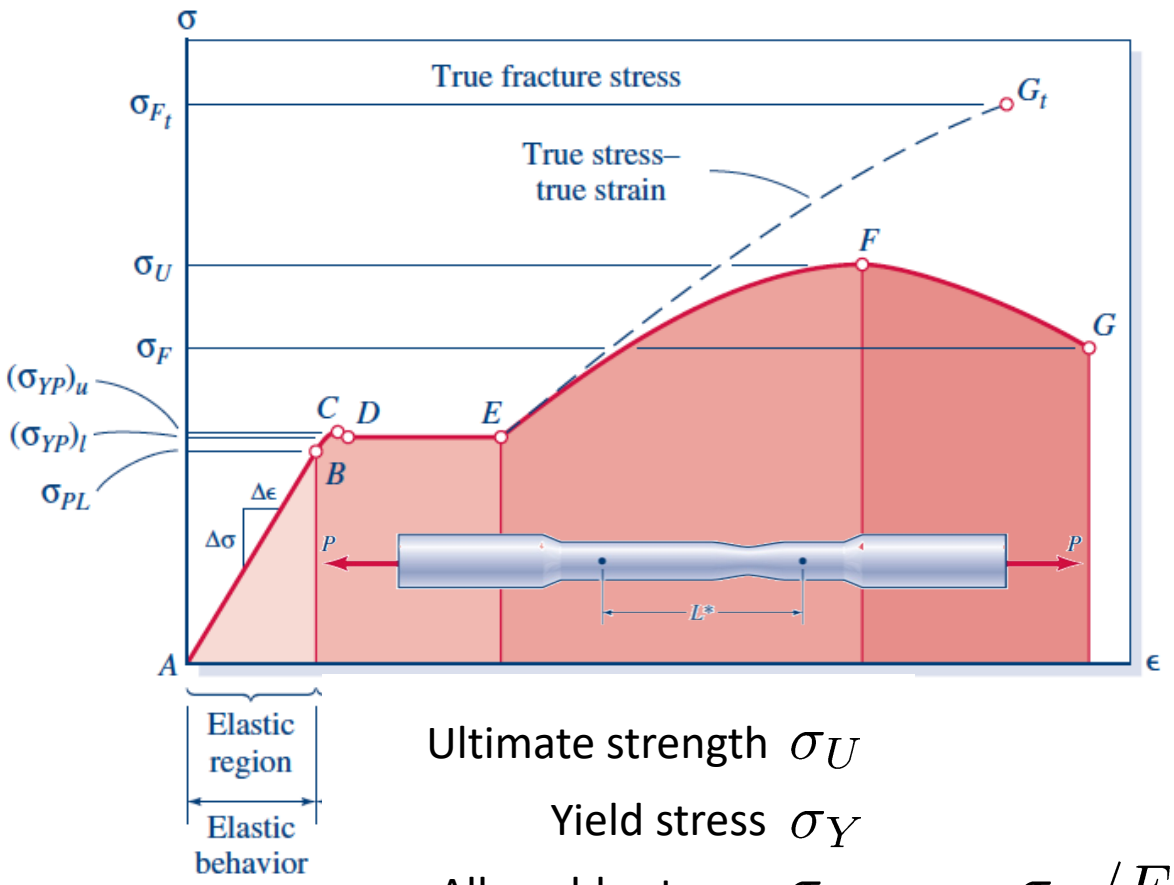




Design of deformable bodies – Factor of safety (FS)

Material properties from stress-strain diagrams:

- Tensile axial loads



Ultimate strength σ_U

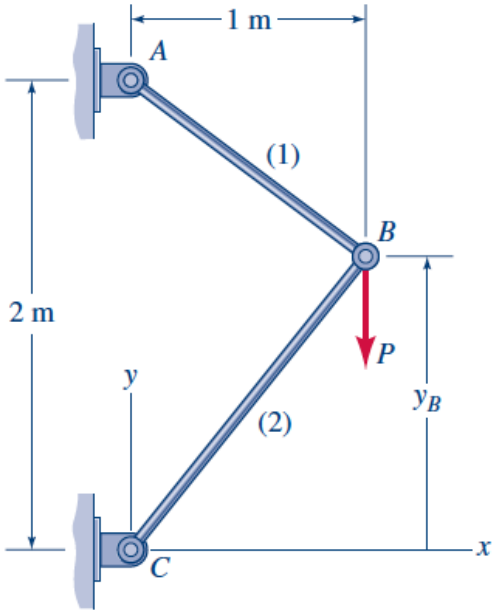
Yield stress σ_Y

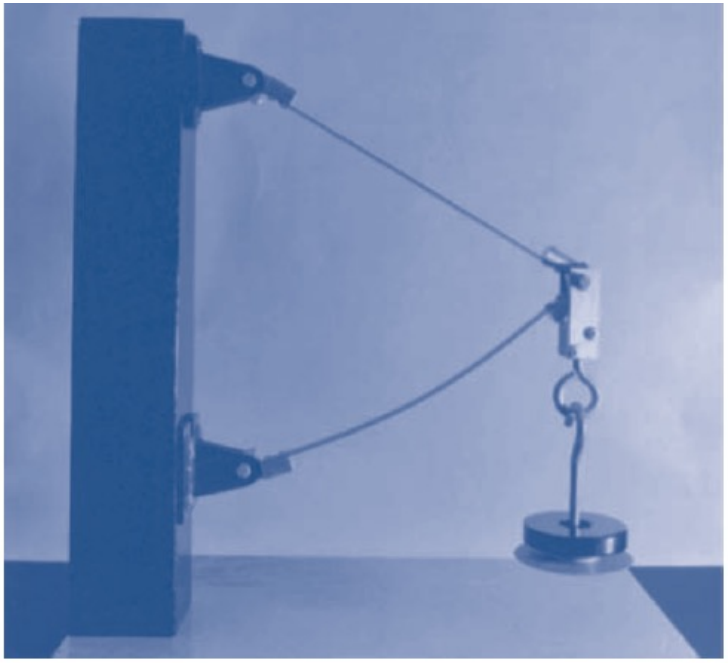
Allowable stress $\sigma_{\text{allow}} = \sigma_Y / FS$

Design of deformable bodies – Factor of safety (FS)

Material properties from stress-strain diagrams:

- Buckling under compression





$$\sigma_{\text{buckling}} = \frac{P_{\text{buckling}}}{A}$$

$$\sigma_{\text{allow}} = \sigma_{\text{buckling}}/FS$$

Q: Does the buckling load $P_{buckling}$ depend on the geometry of the bar?

Q: Does yield stress depend on the geometry of the bar?

Mechanical properties

Any questions?