Lecture 3: Shear stress and strain

Lecture Book: Chapter 3

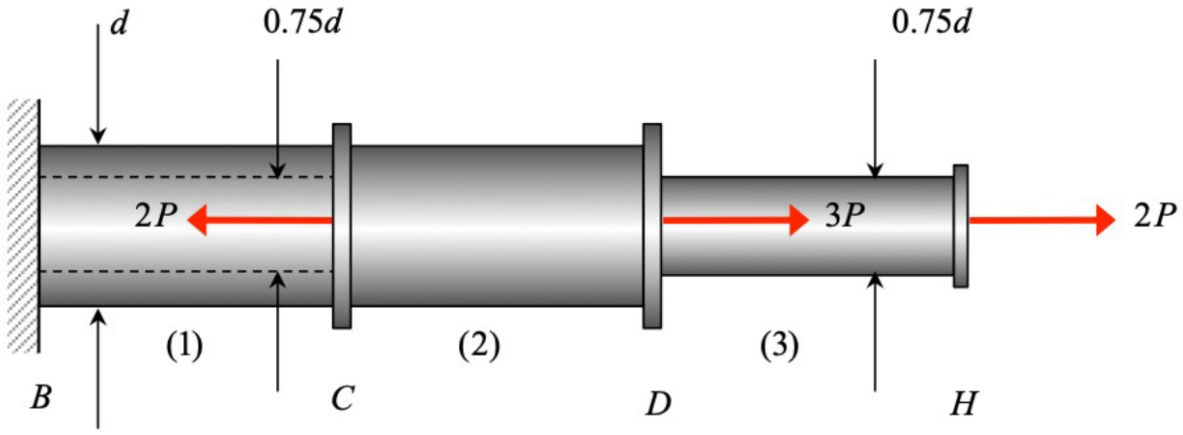
Joshua Pribe

Fall 2019

PURDUE
ENGINEERING

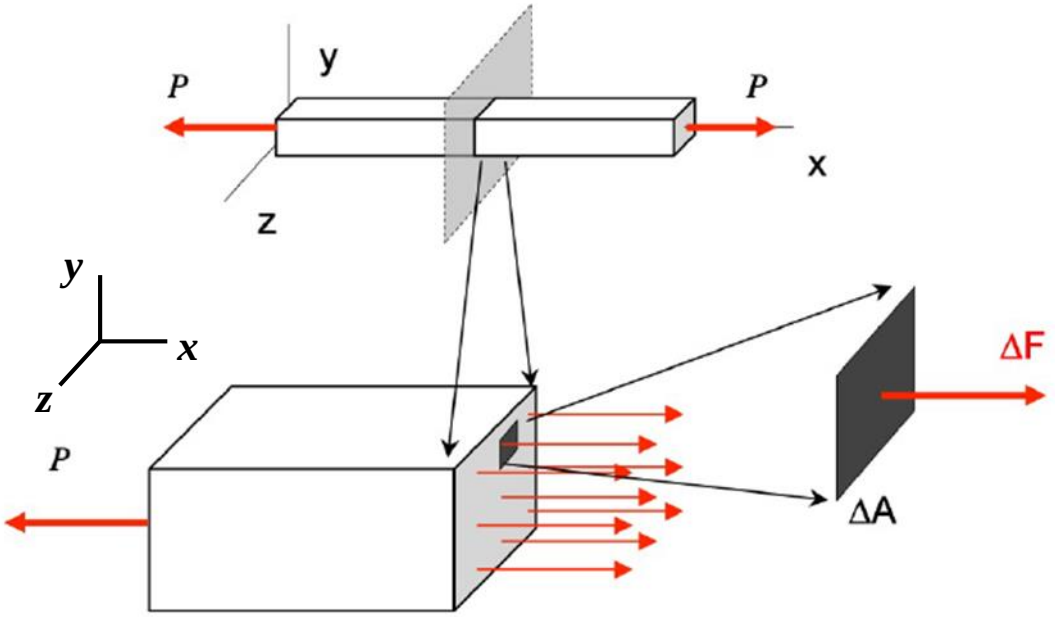
Review of last class

- Average normal stress: $\sigma_{ave} = P/A$
- Extensional strain: $\varepsilon = \Delta L/L_0$
- Mechanical properties (for linear elastic materials under uniaxial loading)
  - Young's modulus E: relates axial stress and strain, $\sigma_x = E\varepsilon_x$
  - Poisson's ratio ν: relates axial strain to transverse strain, $\varepsilon_y = \varepsilon_z = -\nu\varepsilon_x$
- Follow-up on Example 2.7:

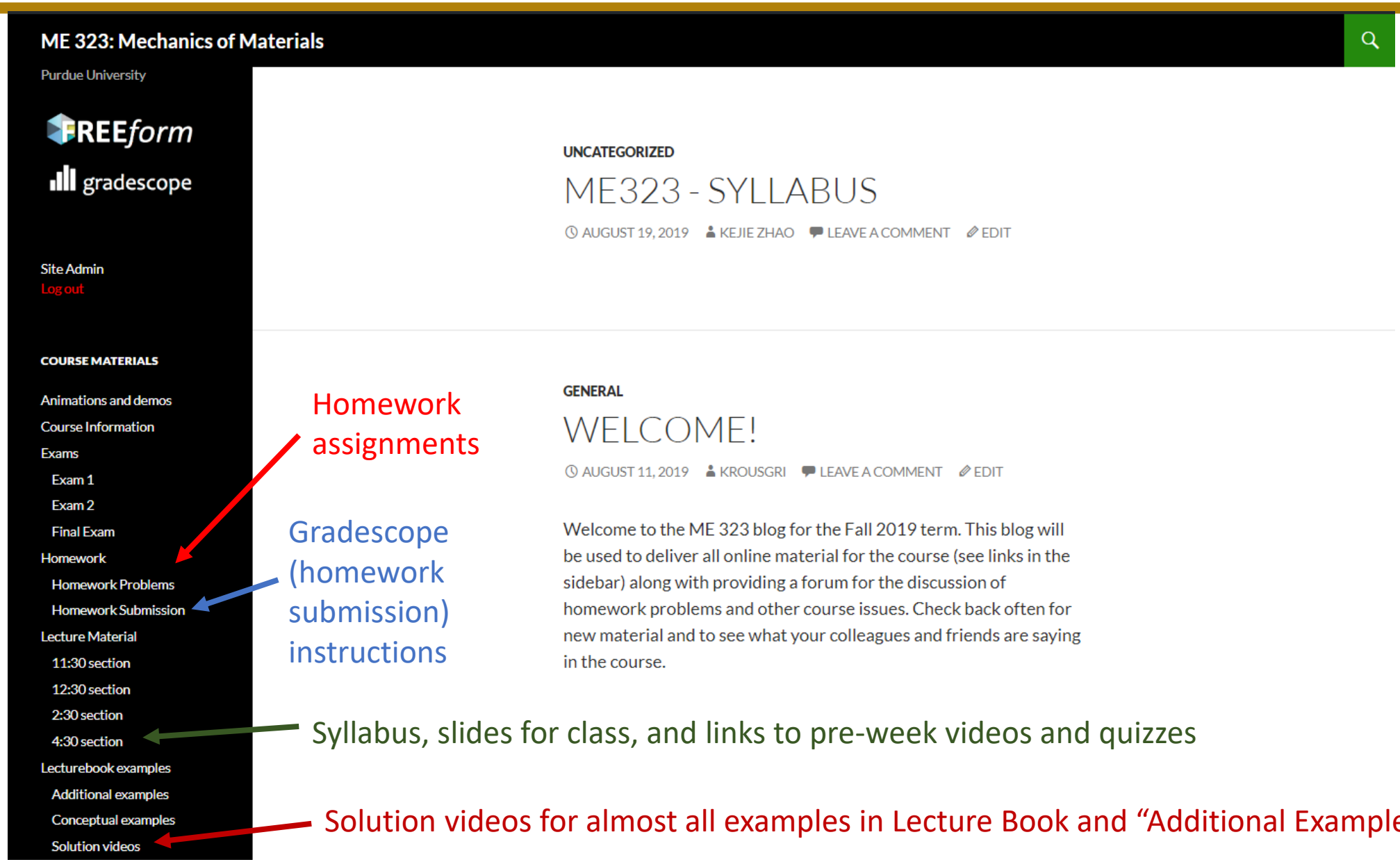


Extension of last class: State of stress

Use a “stress element” to represent the state of stress at a point on the cross section



Course website reminder



Homework assignments

Gradescope (homework submission) instructions

Syllabus, slides for class, and links to pre-week videos and quizzes

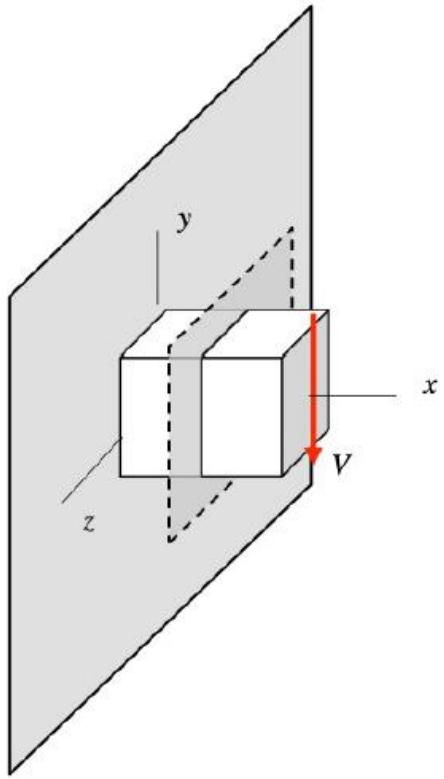
Solution videos for almost all examples in Lecture Book and “Additional Examples”

Objectives

- Define shear stress and shear strain
  - When does a state of direct shear exist in a material?
  - Single shear vs. double shear for pinned/bolted connections
- Relate shear stress and shear strain
- Calculate normal and shear components of stress

Shear stress

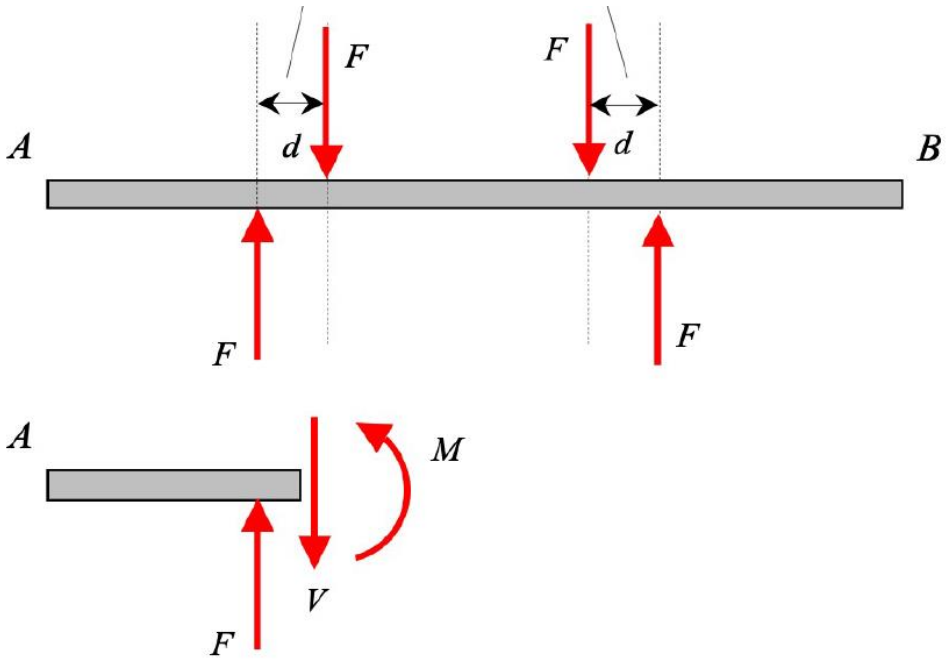
Apply a shear force *V* to a short, stubby member

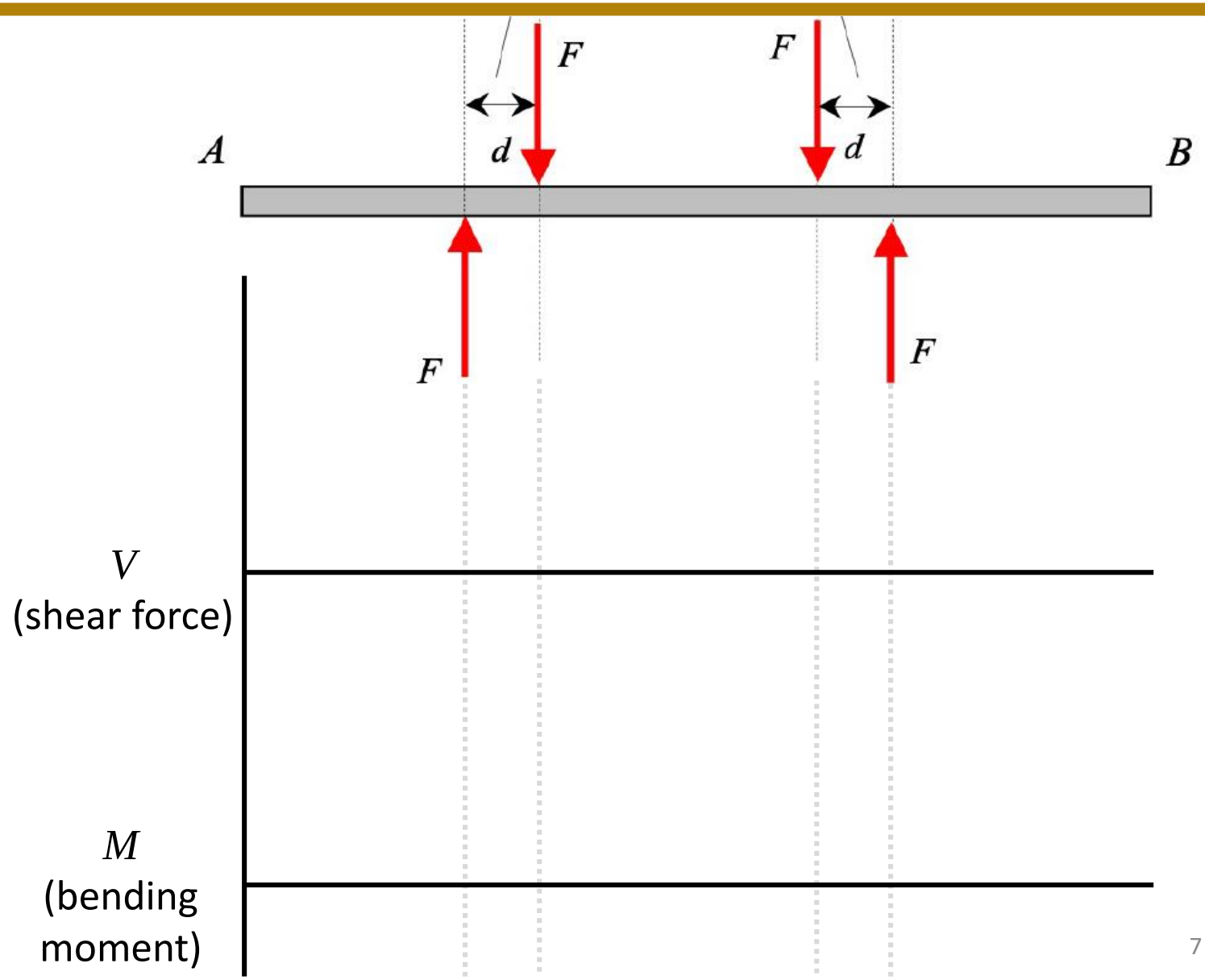


Internal resultants and shear stress:

Direct shear

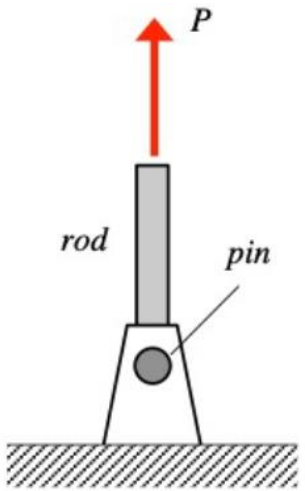
What happens to the shear force and bending moment between the pairs of applied forces as $d \rightarrow 0$?



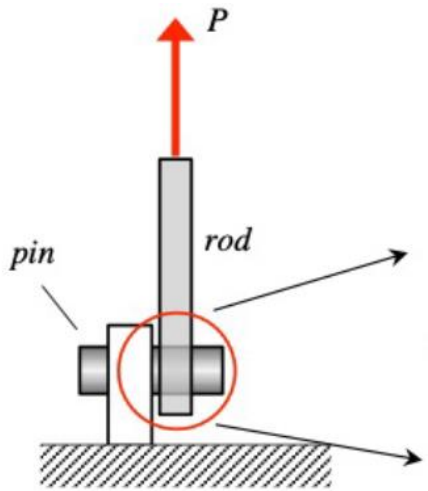


Single and double shear connections

Single shear:



side view

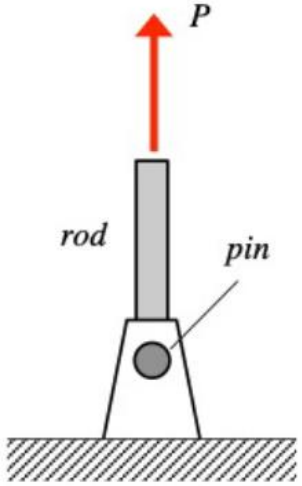


edge view

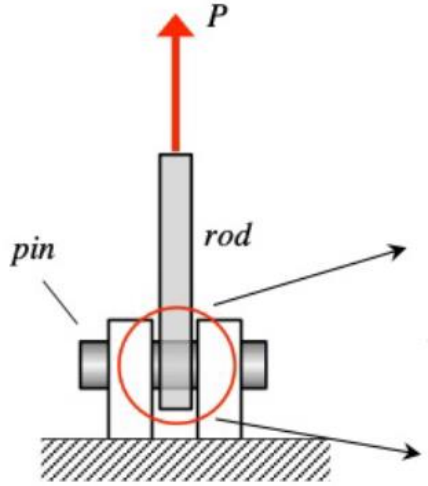
FBD of pin

shear stress

Double shear:



side view



edge view

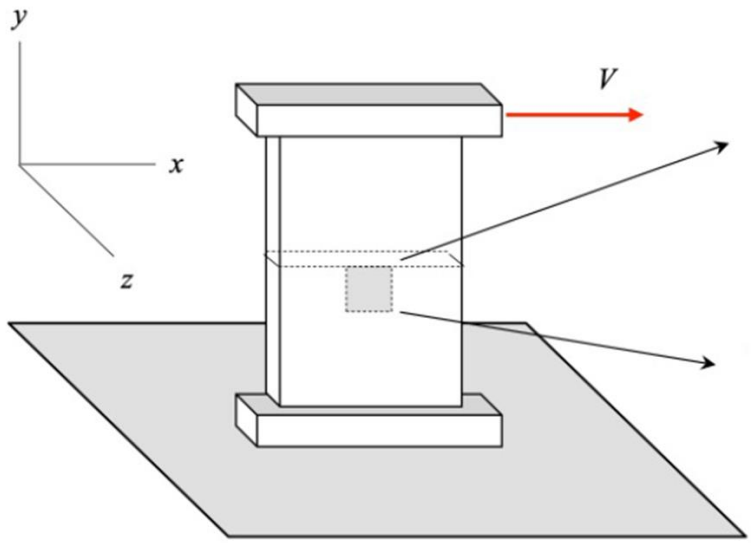
FBD of pin

shear stress

Shear stress and strain; shear modulus

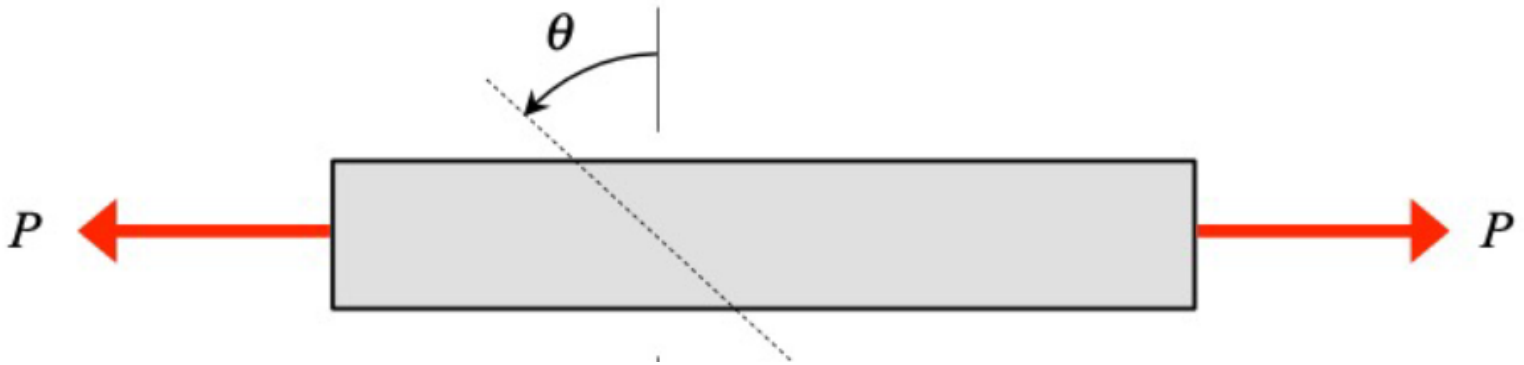
For the applied shear force *V*:

- How do we represent the shear stress on a stress element?
- What is the shear strain?
- How are shear stress and strain related?

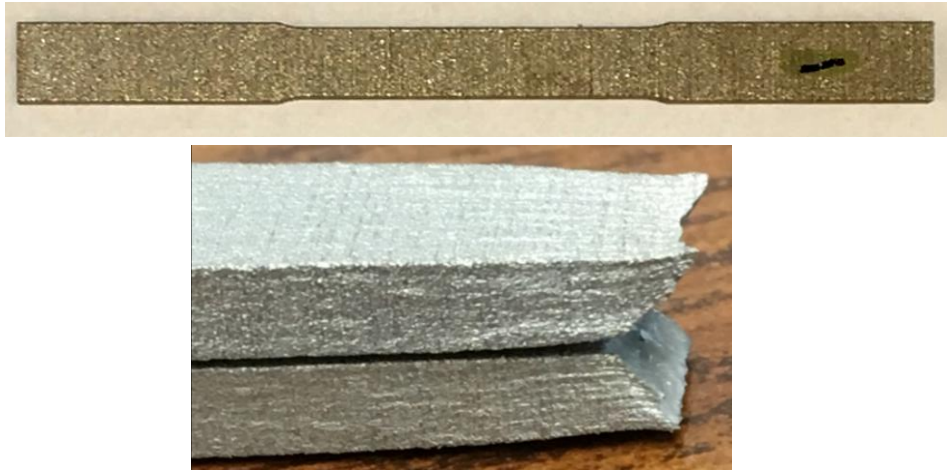


Example: Stress on an inclined plane

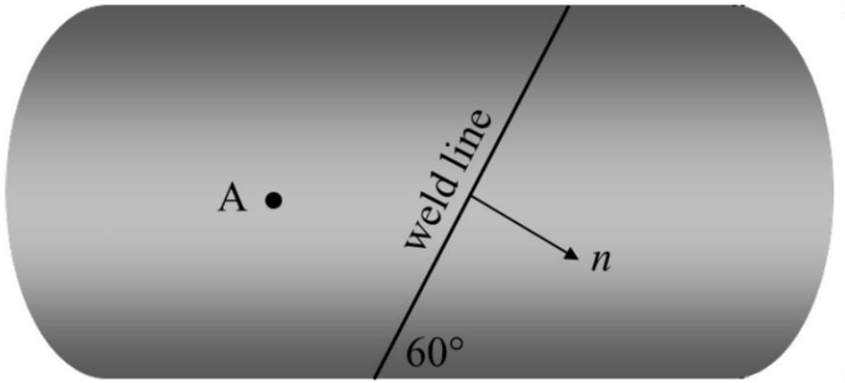
For the axially loaded rectangular bar, what are the normal and tangential components of the stress acting on the plane given by the angle θ?



Motivation: Metals typically fail due to *shear* stress



Motivation: Axial member with a weld line



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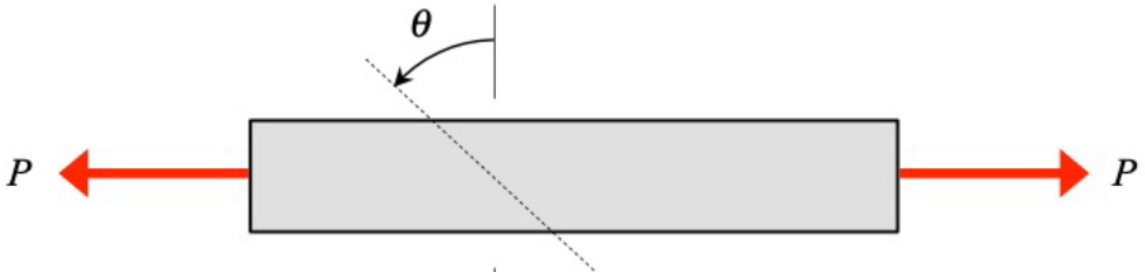

Summary

- Average shear stress: $\tau_{ave} = V/A$
- Shear strain: $\gamma = \pi/2 - \theta^* \approx \delta_s / L_s$
- Shear modulus relates shear stress and strain: $\tau = G\gamma$
  - Calculate shear modulus from E and v: $G = \dfrac{E}{2(1-v)}$
- Direct shear: shear forces without bending moments or normal forces
- Single vs. double shear

- Pre-week videos: design of deformable materials, general states of stress, and axial deformation