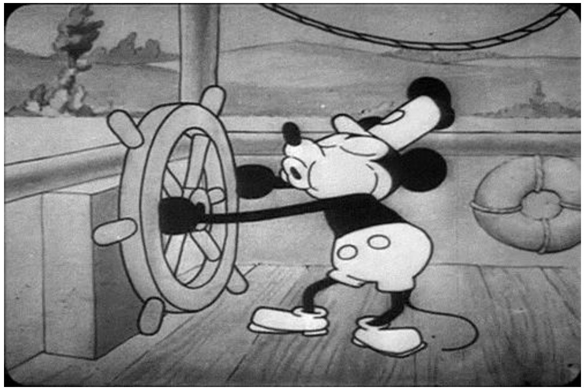
WORCESTER POLYTECHNIC INSTITUTE
MECHANICAL ENGINEERING DEPARTMENT

STRESS ANALYSIS
ES-2502, B'2025

We will get started soon...



27 October 2025

WORCESTER POLYTECHNIC INSTITUTE
MECHANICAL ENGINEERING DEPARTMENT

STRESS ANALYSIS
ES-2502, B'2025

Lecture 05:
Unit 4: designing a connector based on stress criteria

27 October 2025

General information

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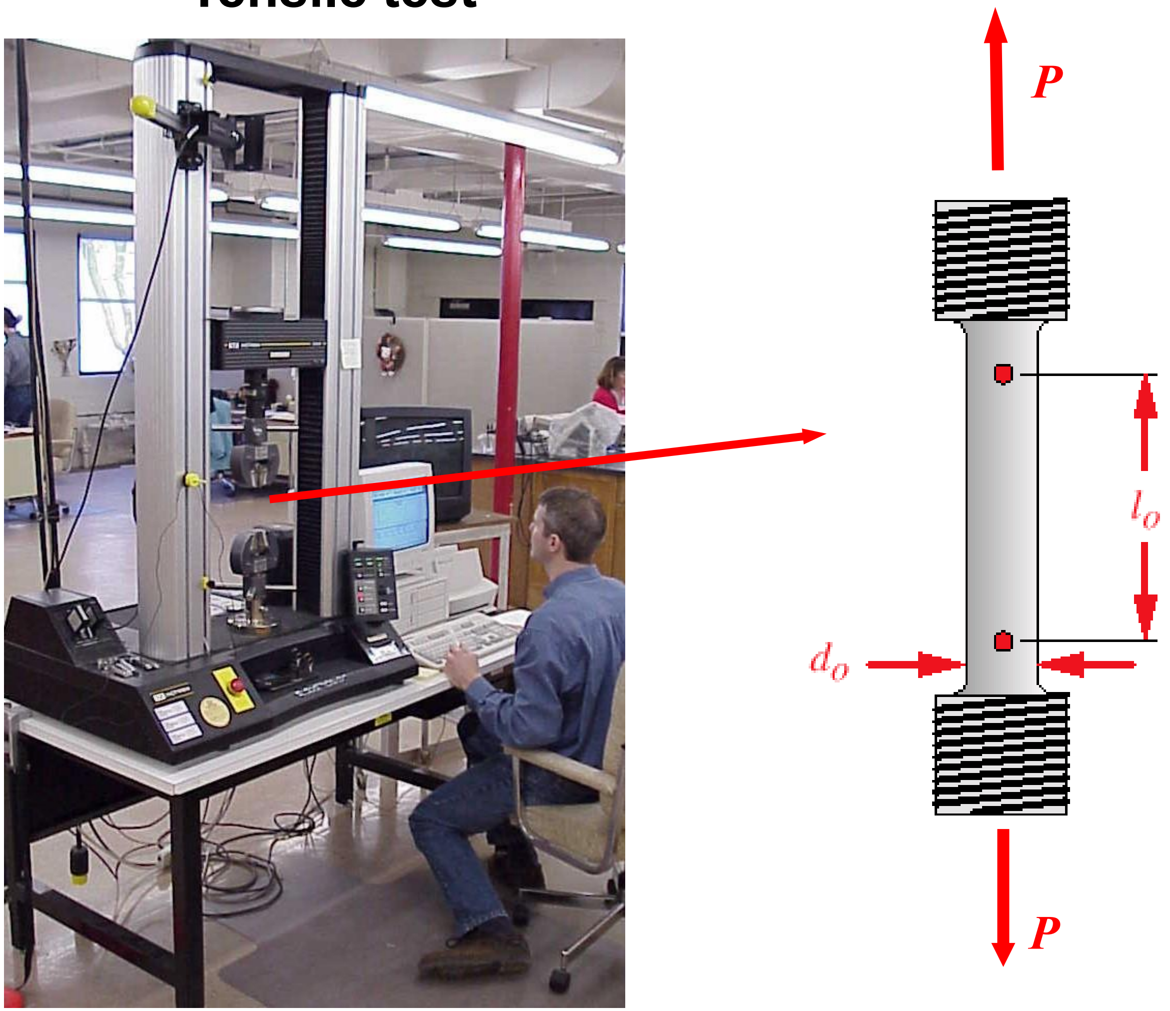
<u>Average</u> normal stress in an axially loaded bar

Tensile test



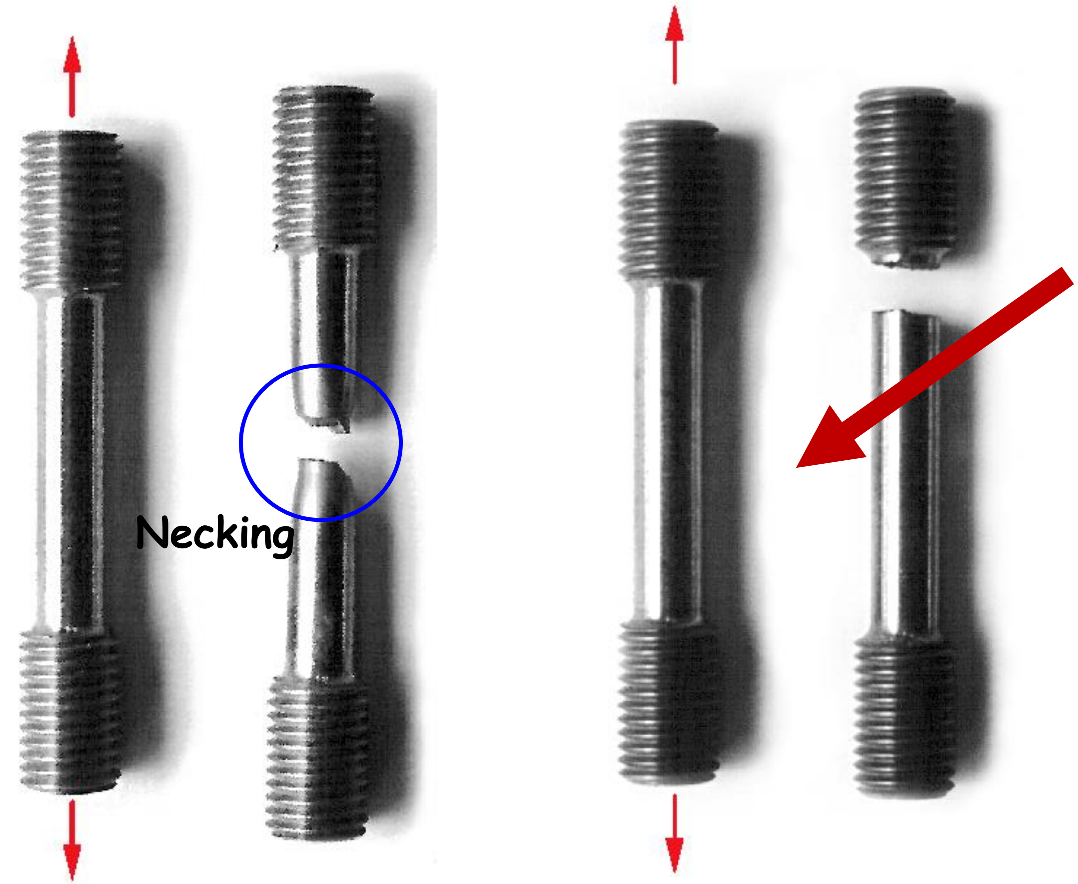
Average normal stress in an axially loaded bar

Tensile test

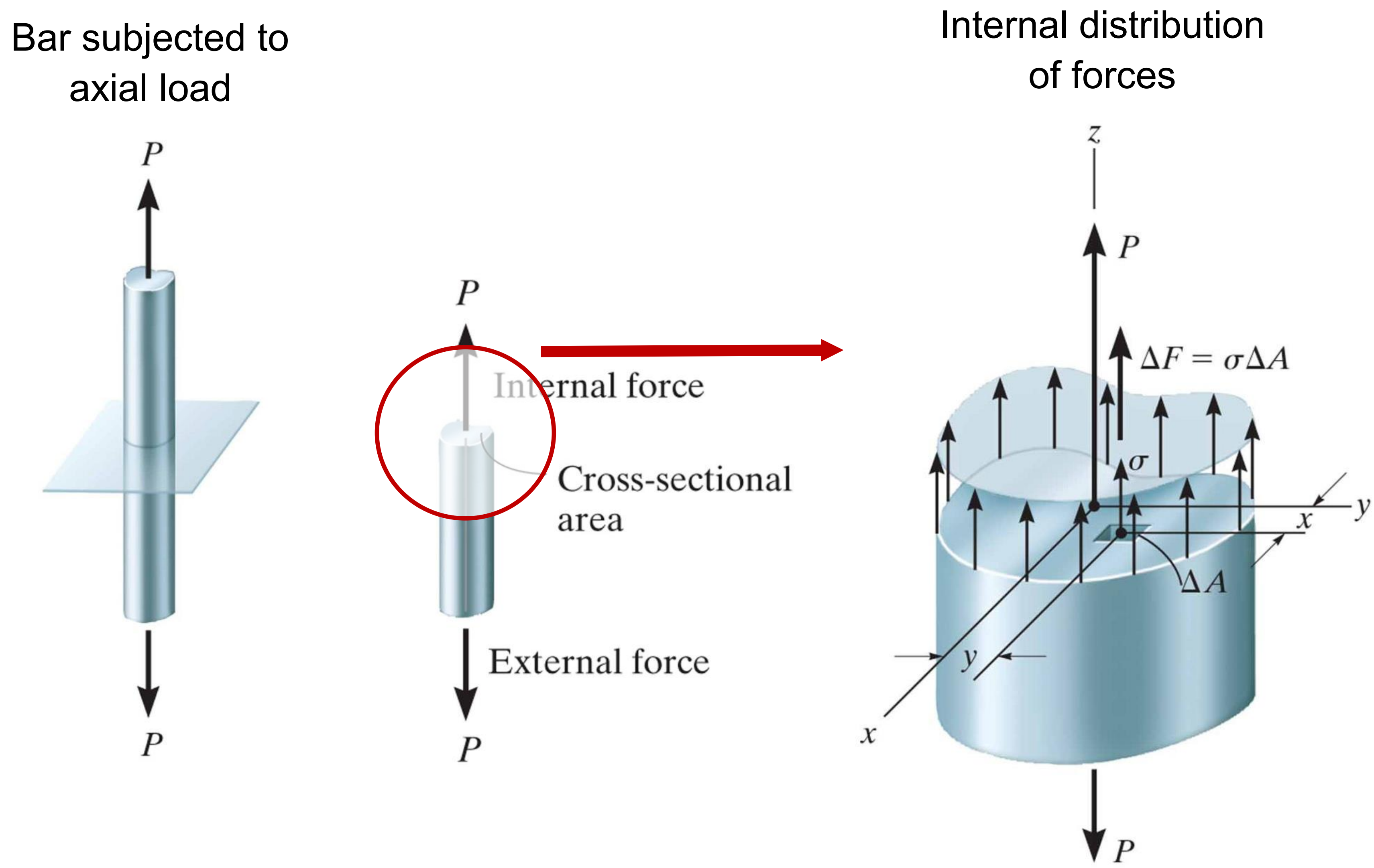
Typical results

Ductile material

Brittle material

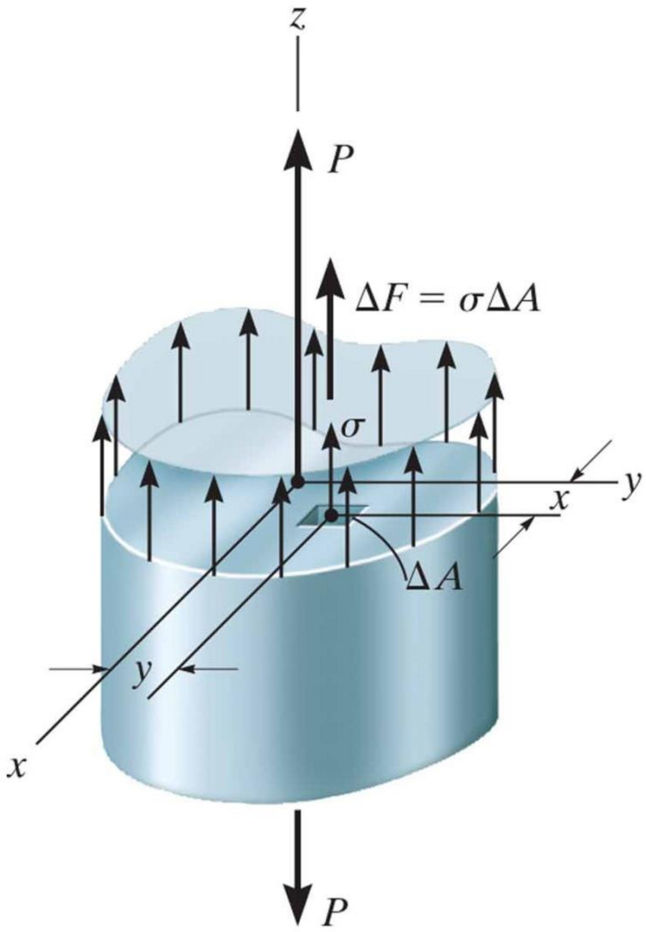


Average normal stress in an axially loaded bar



Average normal stress in an axially loaded bar

Internal distribution of forces



$$+\uparrow F_{Rz} = \sum F_z$$

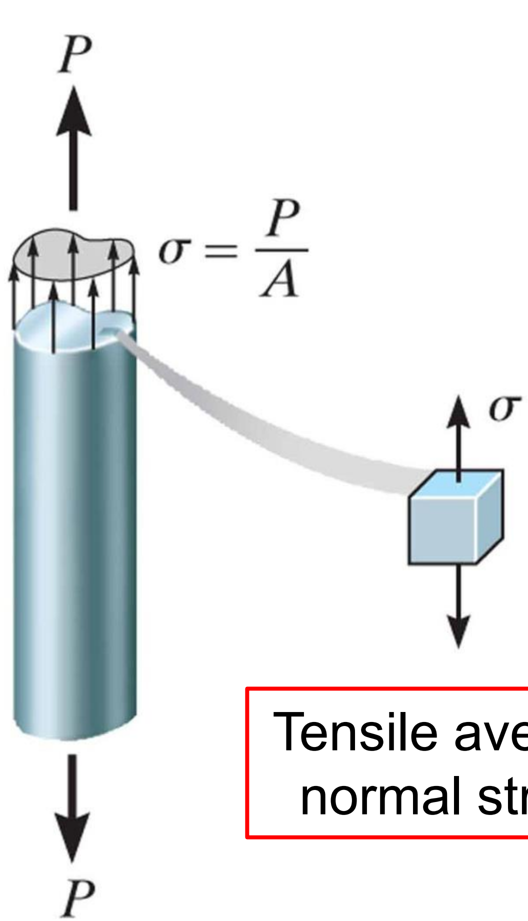
$$\int dF = \int_A \sigma \, dA$$

$$P = \sigma A$$

Average normal stress:

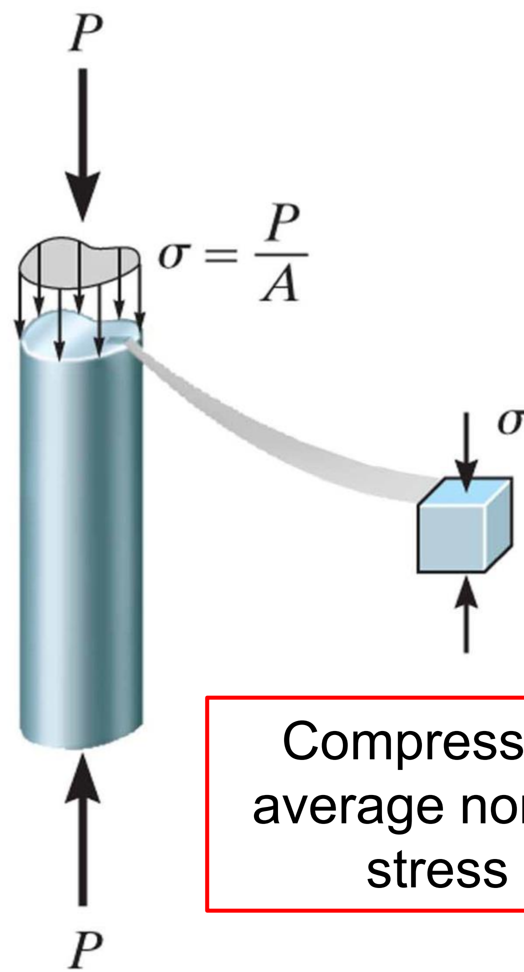
$$\sigma = \frac{P}{A}$$

Average normal stress in an axially loaded bar



Tension

Tensile average normal stress



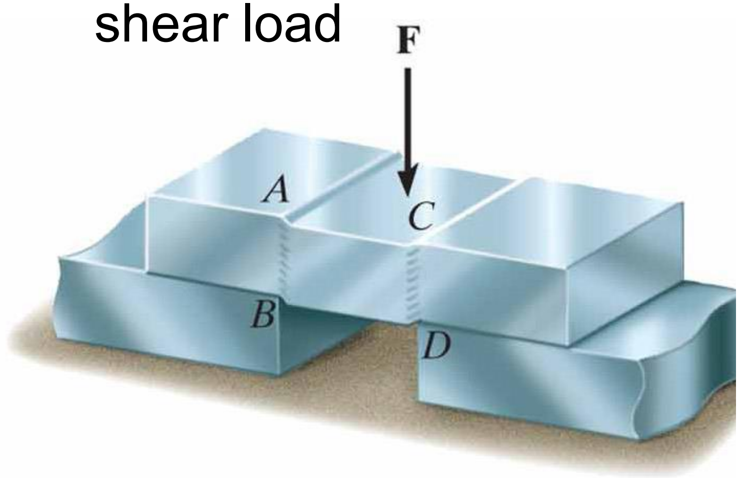
Compression

Compressive average normal stress

Average shear stress

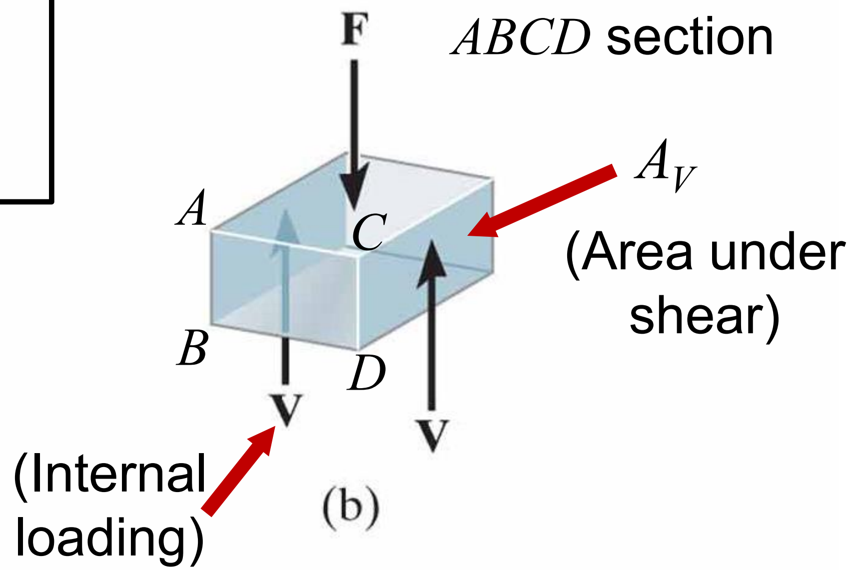
$$\tau_{avg} = \frac{V}{A_V}$$

Bar subjected to shear load

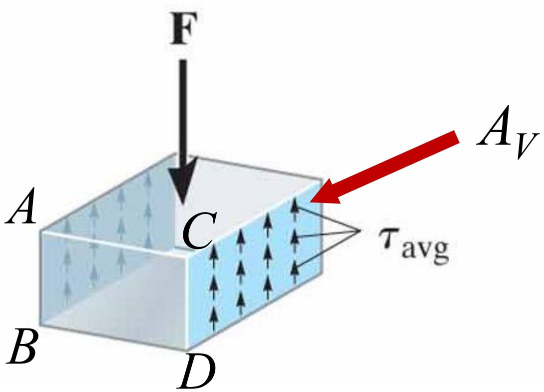


(a)

ABCD section

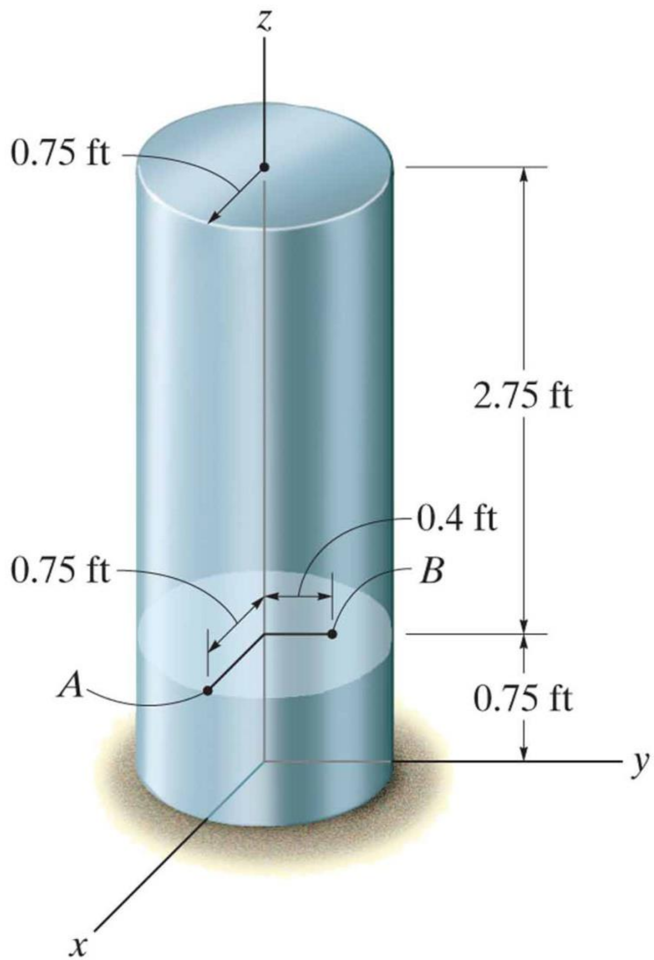


(b)



Average normal stress: example A

The casting shown is made of steel having a specific weight of $\gamma_{st}=490\ lb_f/ft^3$. Determine the average compressive stress acting at points A and B.



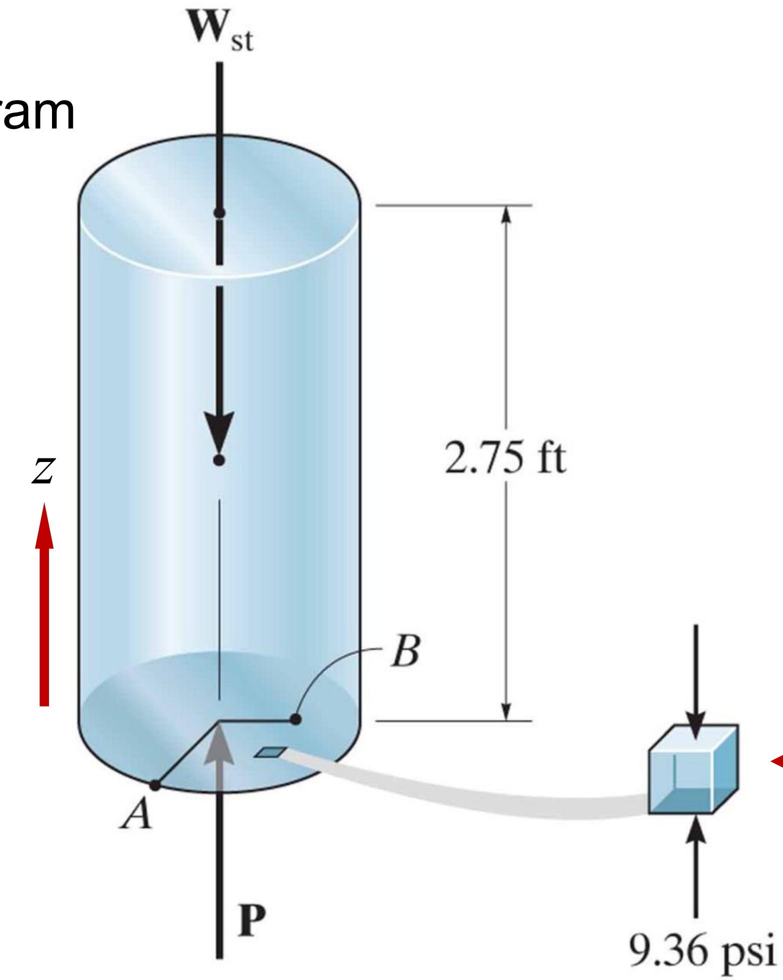
Approach:

1) Define free-body diagrams
2) Determine internal loadings
3) Compute average stresses

Average normal stress: example A

The casting shown is made of steel having a specific weight of $\gamma_{st}=490\ lb_f/ft^3$. Determine the average compressive stress acting at points A and B.

Free-body diagram (FBD)



Compute internal loading

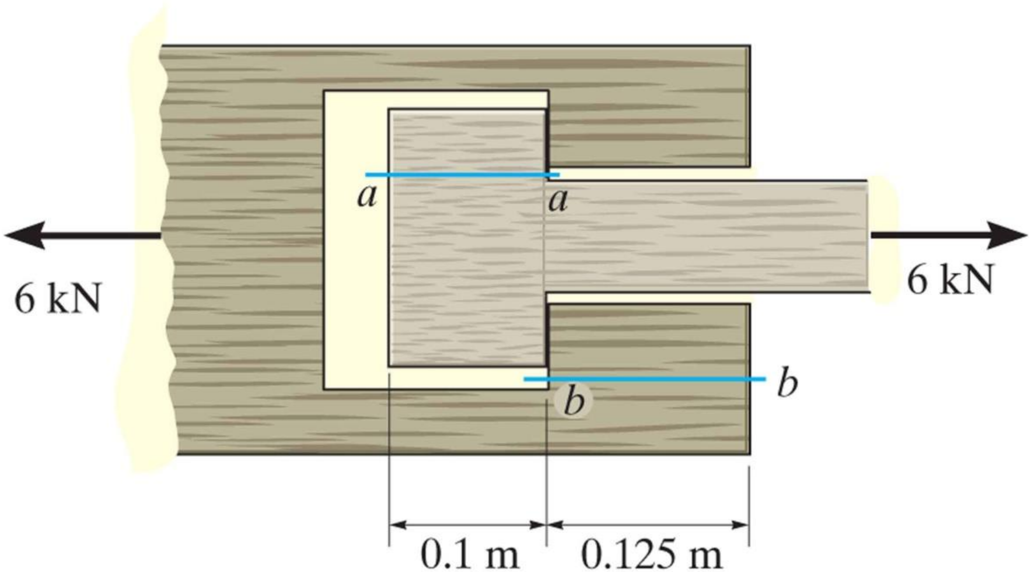
&

Average compressive stresses

(Stress cube)

Average shear stress: example B

Wood joints 150 mm deep (perpendicular to the plane) are loaded as shown. Determine the average shear stress developed along planes a-a and b-b.

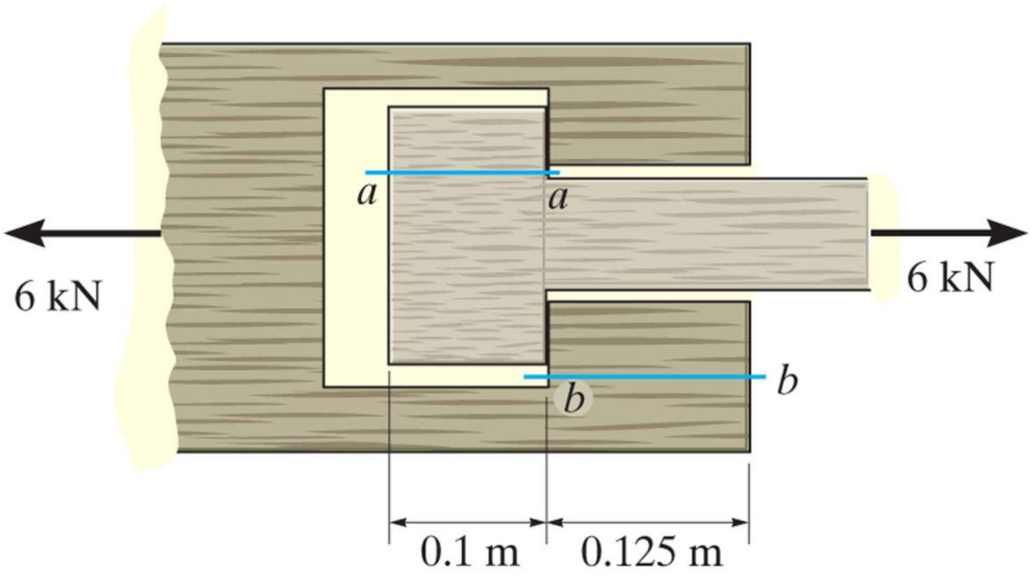


Approach:

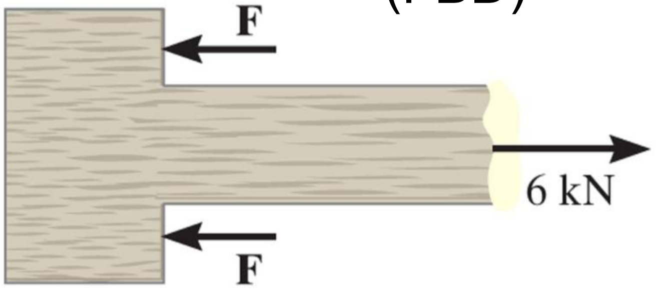
1) Define free-body diagrams
2) Determine internal loadings
3) Compute average stresses

Average shear stress: example B

Wood joints 150 mm deep (perpendicular to the plane) are loaded as shown. Determine the average shear stress developed along planes *a*-*a* and *b*-*b*.

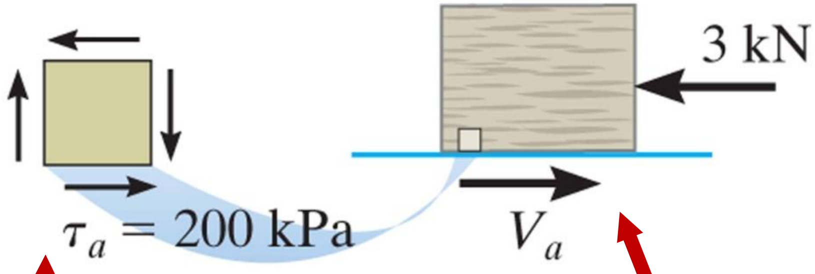


Free-body diagram (FBD)

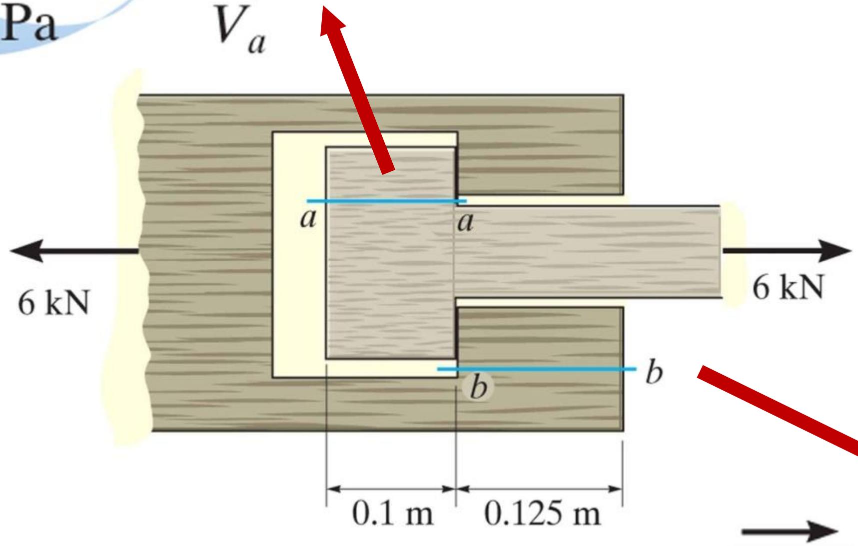


Average **shear** stress: example B

Wood joints 150 mm deep (perpendicular to the plane) are loaded as shown. Determine the average shear stress developed along planes *a-a* and *b-b*.



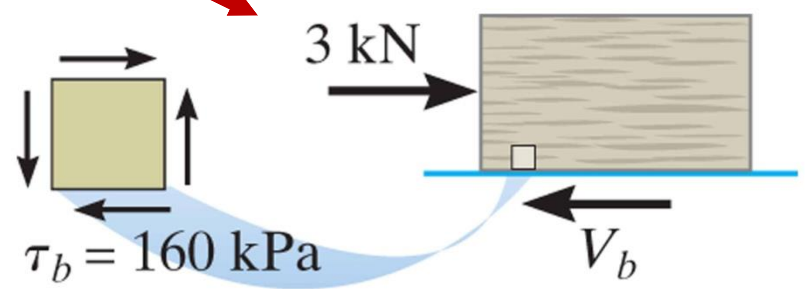
(Stress cube)



Compute internal loading

&

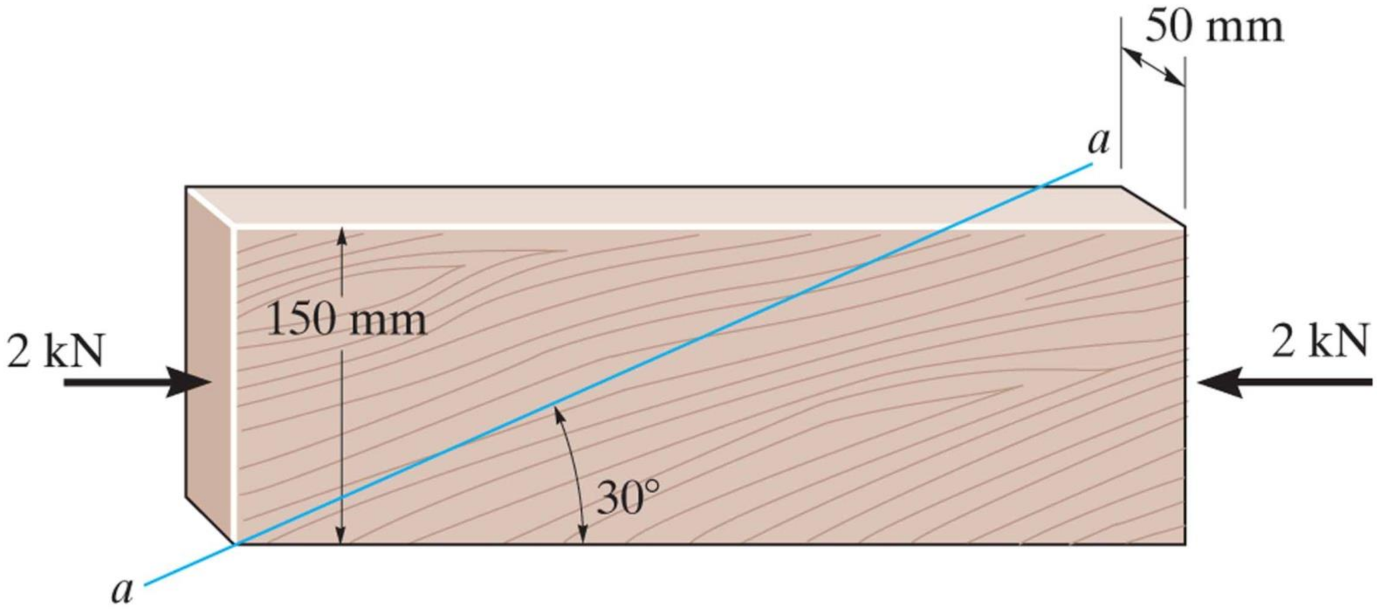
Average shear stresses



(Stress cube)

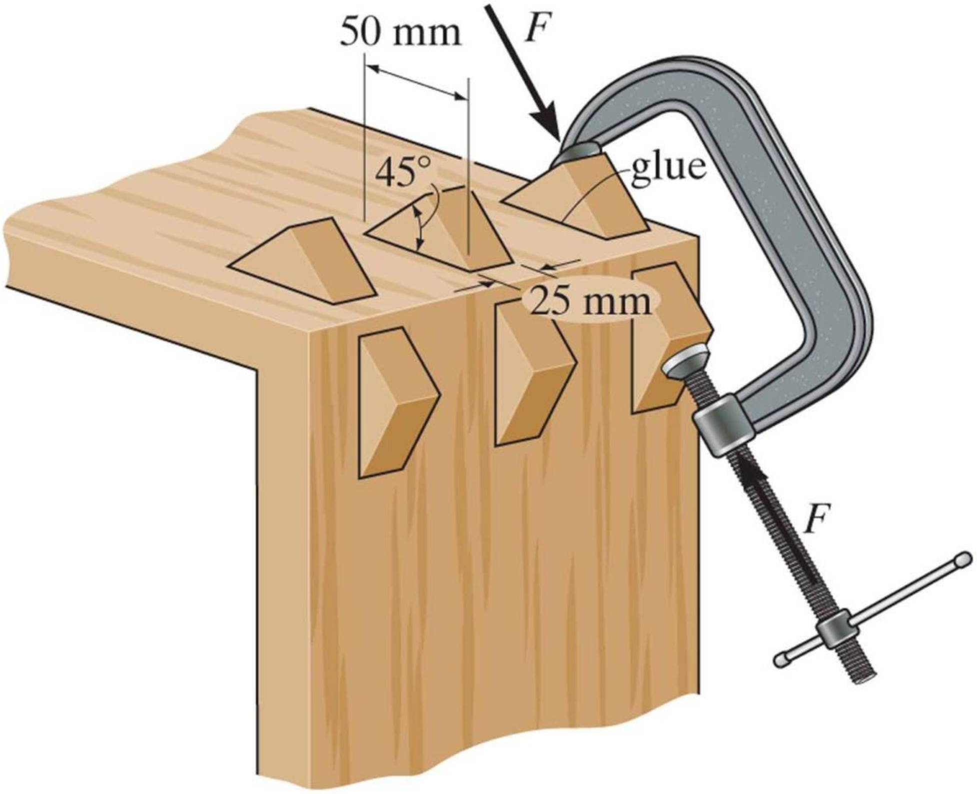
Average normal + shear stress: example C

The block is subjected to a compressive force of $2\ \mathrm{kN}$. Determine the average normal and average shear stress developed in the wood fibers that are oriented along section $a–a$ at $30°$ with the axis of the block



Average normal + shear stress: example D

The triangular blocks are glued along each side of the joint. A C-clamp placed between two of the blocks is used to draw the joint tight. If the clamping force is $F = 900$ N, determine the average normal and shear stresses developed in the glued shear plane.



Design of simple connections

Allowable stress: safety factor (SF)

$$SF = \frac{F_{fail}}{F_{allow}}$$

In terms of forces

or

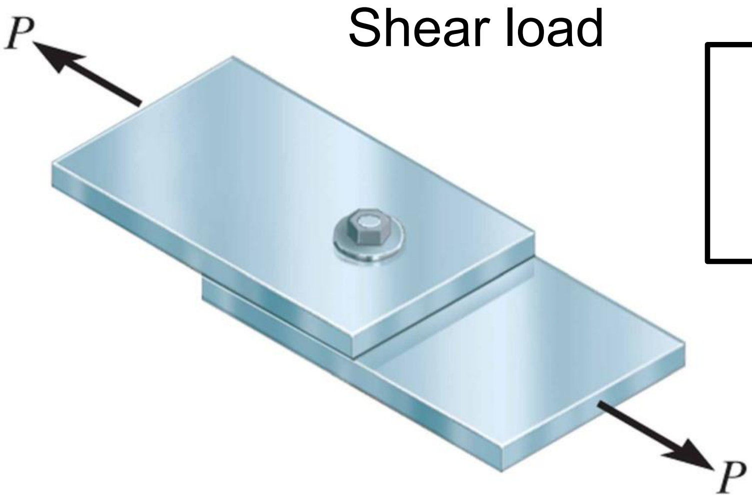
$$SF = \frac{\sigma_{fail}}{\sigma_{allow}}$$

In terms of normal stresses

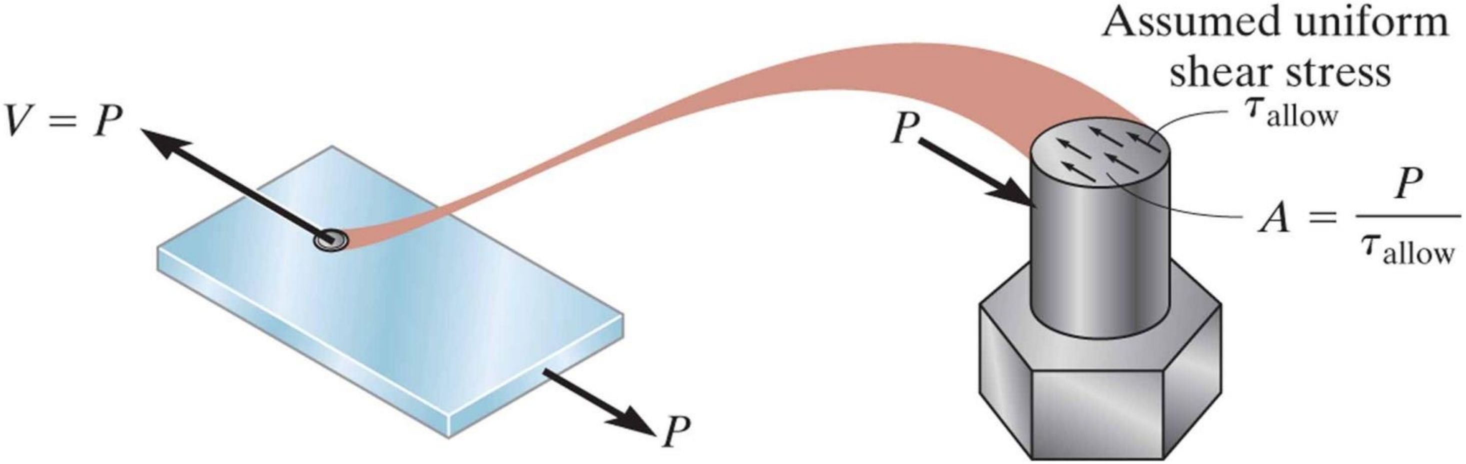
$$SF = \frac{\tau_{fail}}{\tau_{allow}}$$

In terms of shear stresses

Design of simple connections

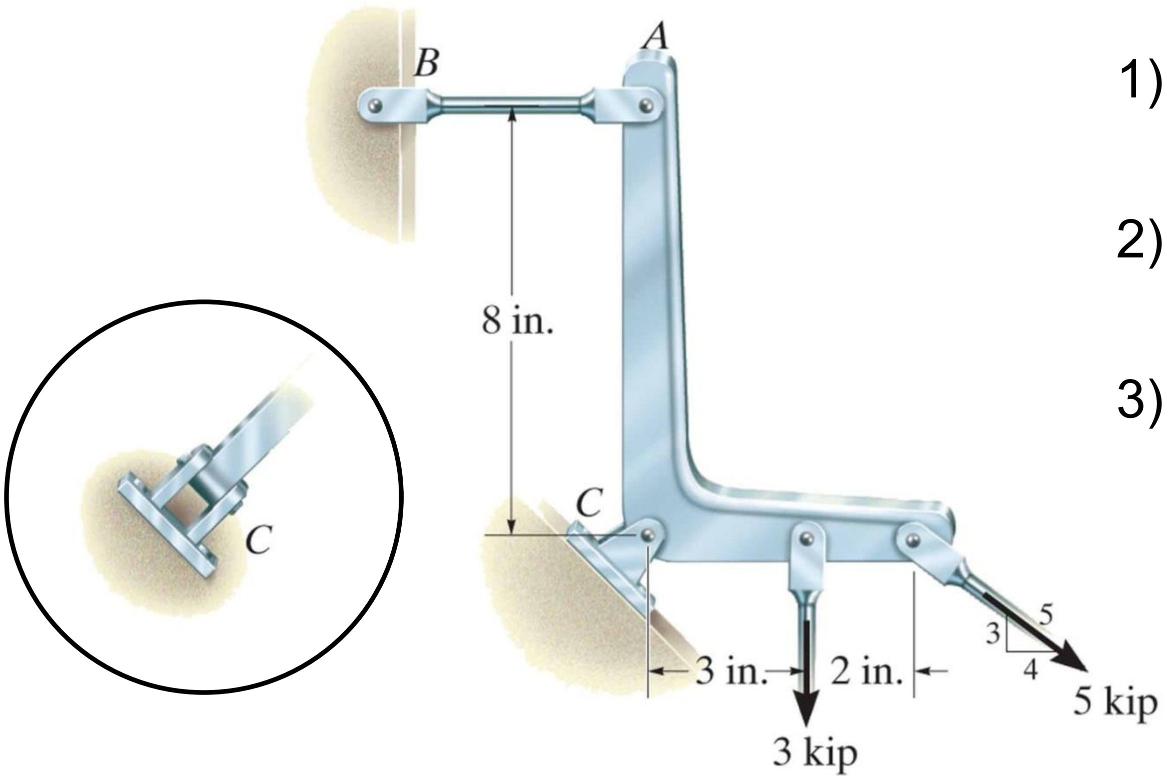


$$A_{bolt} = \frac{V_{applied}}{\tau_{allow}} \Rightarrow \quad bolt\ diameter$$



Design of simple connections: example A

The control arm is subjected to the loading shown. Determine to the nearest ¼" the required diameter of the steel pin at C if the allowable stress for the steel is $\tau_{allow} = 8\ ksi$.

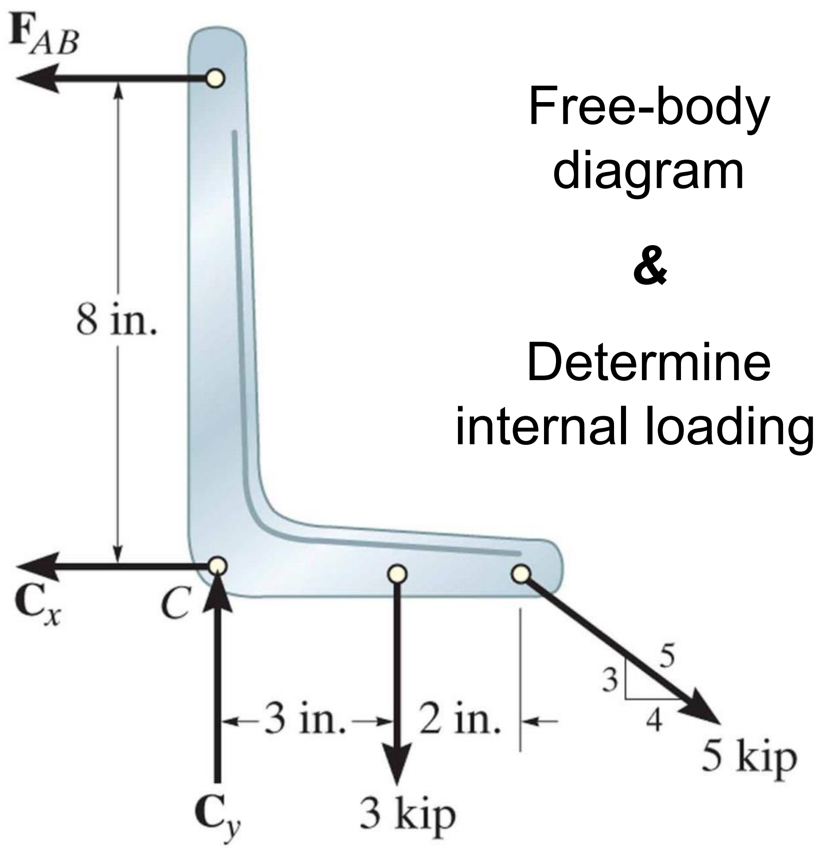


Approach:

1) Define free-body diagrams
2) Determine internal loadings
3) Compute required area and diameter

Design of simple connections: example A

The control arm is subjected to the loading shown. Determine to the nearest ¼” the required diameter of the steel pin at C if the allowable stress for the steel is $\tau_{allow} = 8\ ksi$.



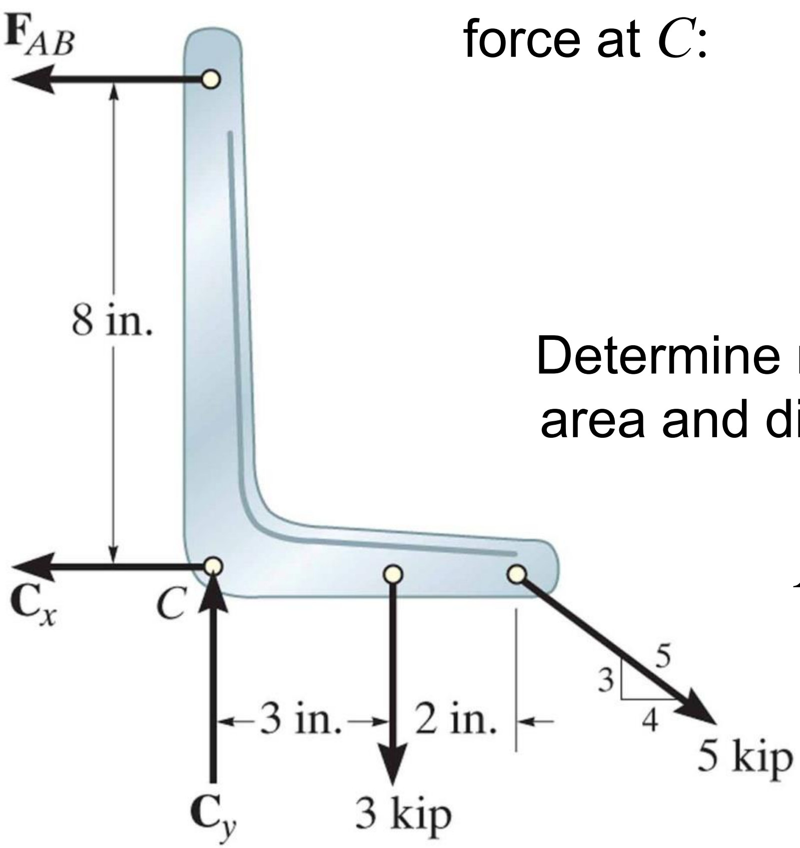
Free-body diagram

&

Determine internal loadings

Design of simple connections: example A

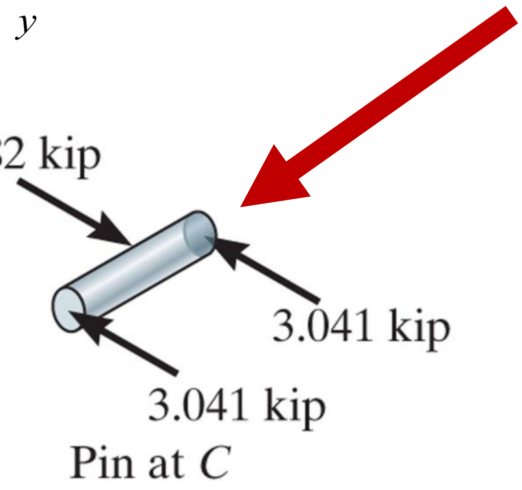
The control arm is subjected to the loading shown. Determine to the nearest ¼” the required diameter of the steel pin at C if the allowable stress for the steel is $\tau_{allow} = 8\ ksi$.



Compute resultant force at C:

$$F_C = \sqrt{C_x^2 + C_y^2}$$

$$F_C = 6.082 \text{ kip}$$

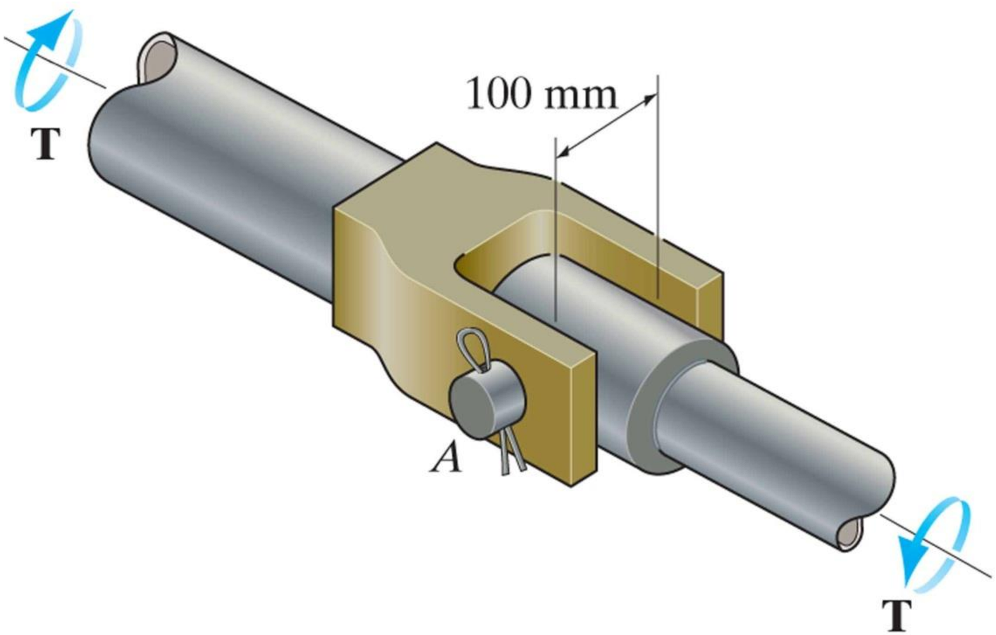


Determine required area and diameter:

$$A_{pin} = \frac{V_{applied}}{\tau_{allow}}$$

Design of simple connections: example B

Determine the maximum allowable torque **T** that can be transmitted by the joint shown. Pin A has a diameter of 25 mm and it is made from a material with a failure shear stress of $\tau_{fail} = 150\ MPa$. Apply a safety factor of 3.

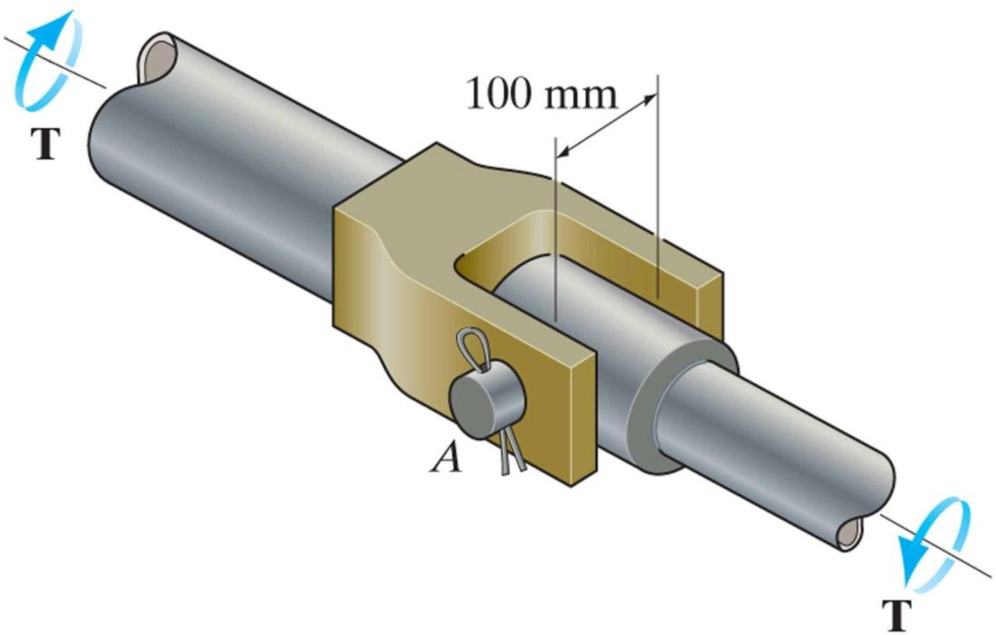


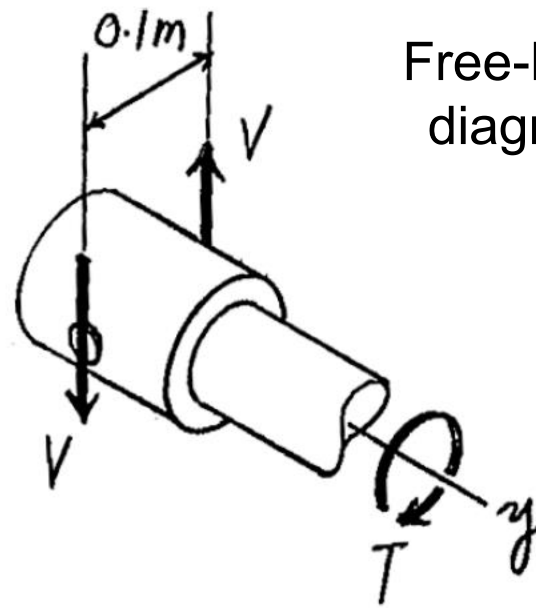
Approach:

1) Define free-body diagrams
2) Determine internal loadings
3) Use safety factor
4) Compute torque

Design of simple connections: example B

Determine the maximum allowable torque **T** that can be transmitted by the joint shown. Pin *A* has a diameter of 25 mm and it is made from a material with a failure shear stress of $\tau_{fail} = 150\ MPa$. Apply a safety factor of 3.

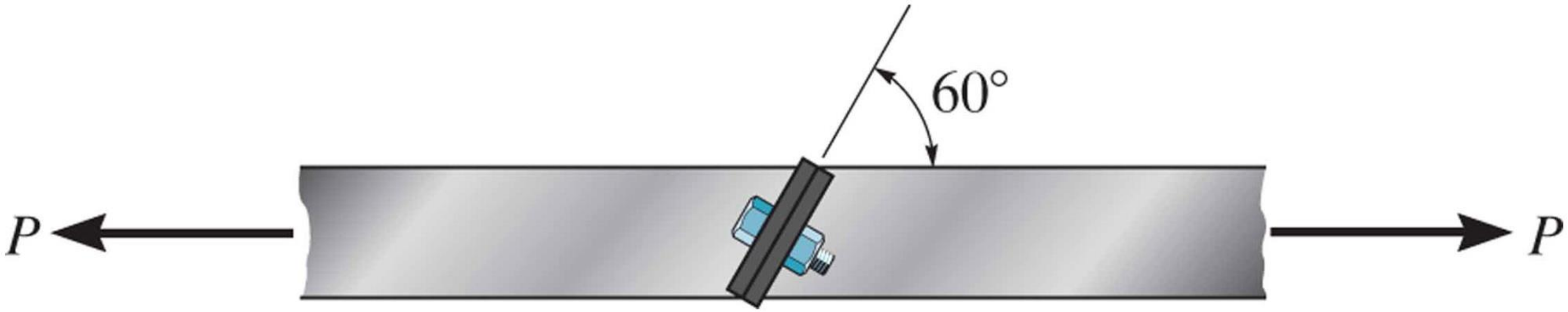




Free-body diagram

Design of simple connections: example C

The tension member is fastened together using *two* bolts, one on each side of the member as shown. Each bolt has a diameter of 0.3 in. Determine the maximum load P that can be applied to the member if the allowable shear stress for the bolts is $\tau_{allow} = 12$ ksi and the allowable average normal stress is $\sigma_{allow} = 20$ ksi.



Reading assignment

- Chapter 1 of textbook
- Review notes and text: ES2001, ES2501

Homework assignment

- As indicated on webpage of our course