Mechanics of Materials

Lecture 2 - Stress

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schedule

- 3 Feb - Stress
- 8 Feb - Strain, Homework 1 Due
- 10 Feb - Mechanical Properties
- 15 Feb - Exam Review, Homework 2 Due

office hours

- No traditional office hours this year, questions should either be asked during recitation on Tuesday/Thursday
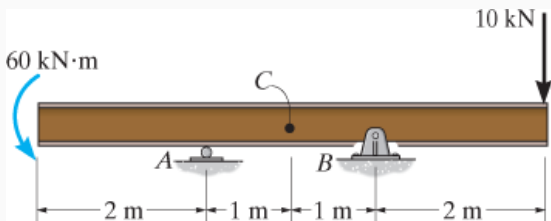- Office appointments can be scheduled via e-mail, although remote meetings are preferred

outline

- review
- stress
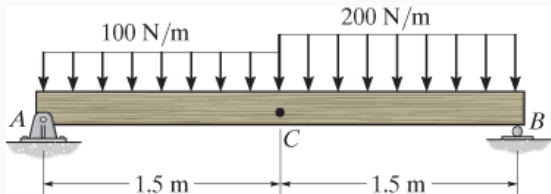- average normal stress
- average shear stress

Find the internal forces at C.

group two

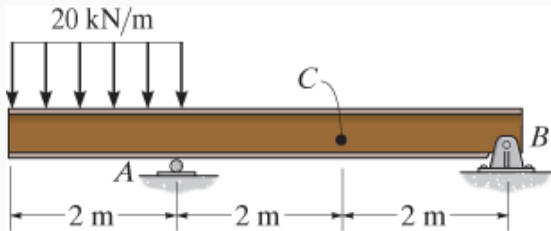

100 N/m

200 N/m

A

B

C

1.5 m

1.5 m

Find the internal forces at C.

group three

20 kN/m

C

A

B

2 m

2 m

2 m

Find the internal forces at C.

10 kN/m

A

C

B

3 m

3 m
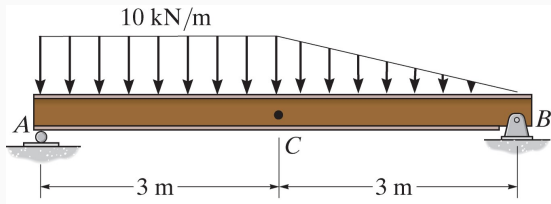
Find the internal forces at C.

stress

stress

- For a continuous and cohesive material, consider an infinitely small cube of material
- A finite force, ΔF will act on this material, and we can consider its three components, ΔF_x, ΔF_y, and ΔF_z
- The limit of the force divided by the area of the cube is defined as stress

normal stress

- The stress acting normal to a face of the cube is referred to as the normal stress

$$\sigma_x = \lim_{\Delta A_x \to 0} \frac{\Delta F_x}{\Delta A_x}$$

$$\sigma_y = \lim_{\Delta A_y \to 0} \frac{\Delta F_y}{\Delta A_y}$$

$$\sigma_z = \lim_{\Delta A_z \to 0} \frac{\Delta F_z}{\Delta A_z}$$

shear stress

- Similarly, forces acting tangent to the face of the cube create shear stresses
- Often (but not always), τ is used instead of σ for shear stresses

$$\tau_{xy} = \lim_{\Delta A_y \to 0} \frac{\Delta F_x}{\Delta A_y}$$

$$\tau_{yz} = \lim_{\Delta A_z \to 0} \frac{\Delta F_y}{\Delta A_z}$$

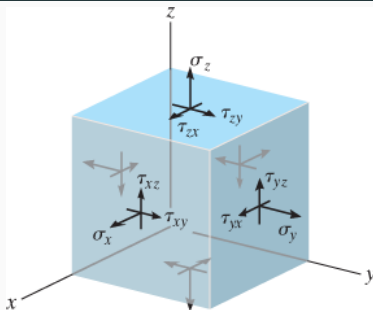$$\tau_{xz} = \lim_{\Delta A_x \to 0} \frac{\Delta F_z}{\Delta A_x}$$

general stress

Figure 1: A cube with stresses illustrated on each of the faces, following the notation described previously.

- stress has units of force per area
- In metric units, this is Pa (or often MPa and GPa)
- In english units, this is psi (or often ksi)

average normal stress

average normal stress

- We can use statics to find the statically equivalent normal force acting on some cross-section
- The average normal stress will be the normal force divided by the area of the cross-section
- If a bar is loaded at different points, or if it changes cross-sectional area, the average normal stress can vary, we can find the stress at different cross-sections to find the maximum average normal stress
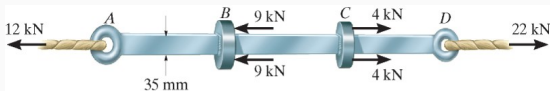
example 1.5

Figure 2: The bar with a width of 35 mm and a thickness of 10 mm is loaded at multiple locations. From the left end, at point A, there is a 12 kilonewton load (in the left direction) to the right of this at point B load another left-pointing load of 9 kilonewtons is applied. To the right of that, point C, another load of 4 kilonewtons is applied in the right direction, and finally at the right end, point D, a 22 kilonewton load is applied pointing to the right. Find the maximum average normal stress in the bar.

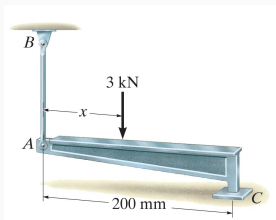The bar shown as a width of 35 mm and a thickness of 10 mm.

example 1.8

Determine the position, x, of the load so that the average compressive stress at C is equal to the average tensile stress in the rod AB. The rod has an area of 400 mm² and the contact at C has an area of 650 mm².

Figure 3: A block 200 mm long has a leg resting against the floor at its right end, point C, and is supported by a vertical hanging rod at its left end (points A and B). A 3 kilonewton force pointing

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Calculate the stresses for elements in last week's lecture: - Stress in the workpiece - Stress in the vise screw - Stress in the pinboard - Stress in St. Peter's Cross
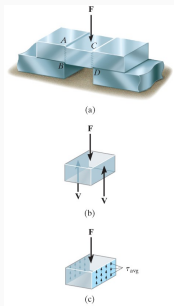
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average shear stress

shear stress

- If we consider a section from a bridge-like structure we can demonstrate one way shear stress can be formed in a material
- As a reminder, shear stress is formed by forces acting in the plane of a section cut
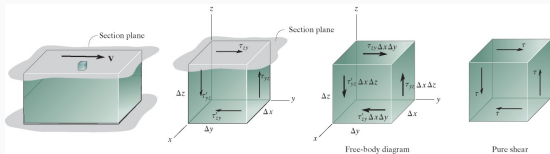
shear stress

(a)

(b)

(c)

shear stress equilibrium

- If we consider equilibrium of an element subjected to shear on one face, we will find that there must be shear forces on other faces to remain in equilibrium
- In the following example, we will consider the sum of forces in the y-direction and the sum of moments about the x-axis
- We can convert between stresses and forces by recalling that $\sigma = F/A$, or $F = \sigma A$
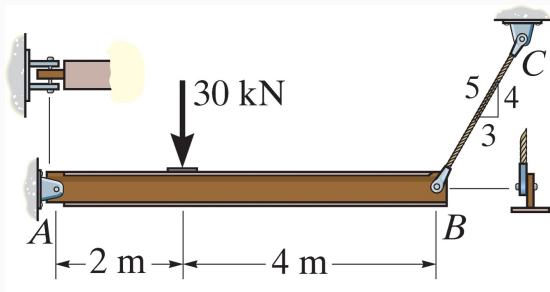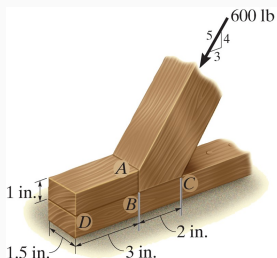
shear stress equilibrium

Section plane

Free-body diagram

Pure shear

example 1-9

30 kN

5 4 3

C

A

B

← 2 m → ← 4 m →

Determine the average shear stress in the 20-mm diameter pin at *A* and the 30-mm diameter pin at *B*.

example 1-11

Determine the average compressive stress along the smooth contact of AB and BC and the average shear stress along the horizontal plane DB.

Figure 4: A wooden block is shown with one leg at a 3-4-5 angle and a 600 pound compressive load acting in the direction of that leg.

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Calculate the average shear stress in the pin connecting the two legs in "St. Peter's Cross" from the leg vise example.

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