

## Lecture 2 - Stress

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## schedule

- 20 Aug - Stress
- 25 Aug - Strain, Homework 1 Due
- 27 Aug - Mechanical Properties, Project 1 Due
- 1 Sep - Exam Review

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## office hours

- TBD
- As always, if you can't make it to office hours, just send me an e-mail and we'll try to work something out

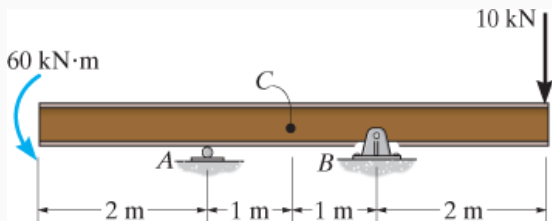
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## outline

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

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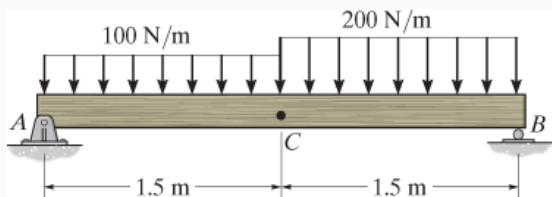
## group one



Find the internal forces at C.

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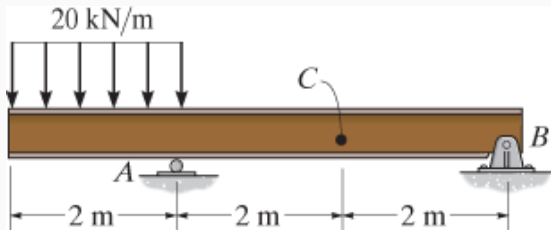
## group two



Find the internal forces at C.

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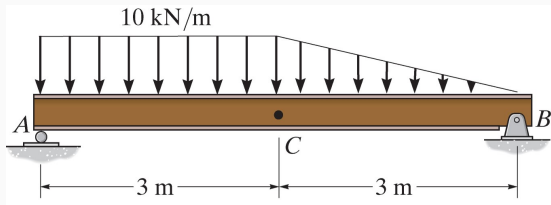
### group three



Find the internal forces at C.

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### group four



Find the internal forces at C.

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- For a continuous and cohesive material, consider an infinitely small cube of material
- A finite force,  $\Delta F$  will act on this material, and we can consider its three components,  $\Delta F_x$ ,  $\Delta F_y$ , and  $\Delta F_z$
- The limit of the force divided by the area of the cube is defined as stress

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## normal stress

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

$$\sigma_x = \lim_{\Delta A_x \rightarrow 0} \frac{\Delta F_x}{\Delta A_x} \sigma_y = \lim_{\Delta A_y \rightarrow 0} \frac{\Delta F_y}{\Delta A_y} \sigma_z = \lim_{\Delta A_z \rightarrow 0} \frac{\Delta F_z}{\Delta A_z}$$

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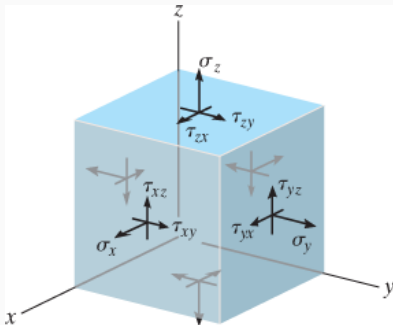
## shear stress

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

$$\tau_{xy} = \lim_{\Delta A_y \rightarrow 0} \frac{\Delta F_x}{\Delta A_y} \tau_{yz} = \lim_{\Delta A_z \rightarrow 0} \frac{\Delta F_y}{\Delta A_z} \tau_{xz} = \lim_{\Delta A_x \rightarrow 0} \frac{\Delta F_z}{\Delta A_x}$$

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## general stress



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

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- 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)

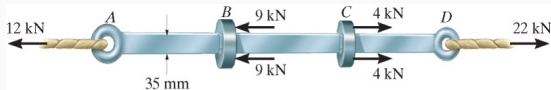
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## average normal stress

- 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

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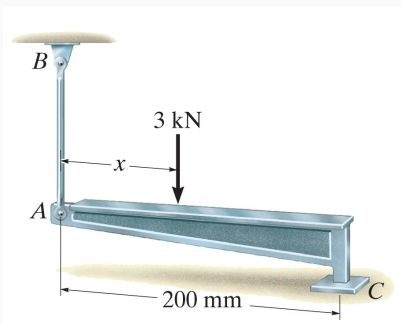
## example 1.5



**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.

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## example 1.8



**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

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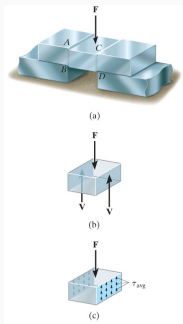


## shear stress

- 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

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## shear stress



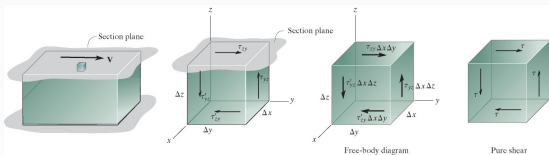
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## shear stress equilibrium

- 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  $F = \sigma A$

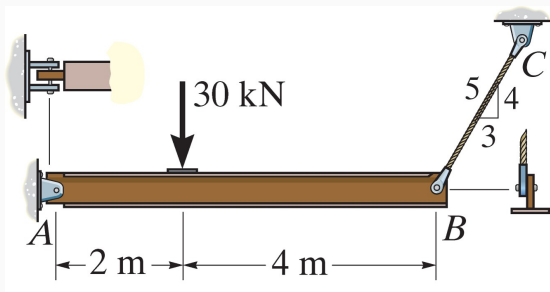
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## shear stress equilibrium



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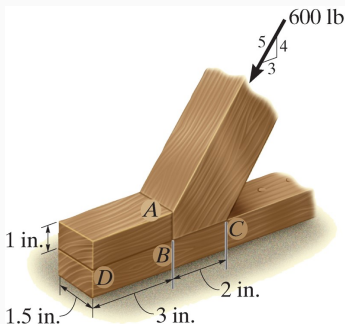
## example 1-9



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

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## example 1-11



**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 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