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CEE 220 **Mid-term exam 1** **Autumn 2003**

Allowed: 1 page of notes. *Attempt all questions. Points per question are as shown.*

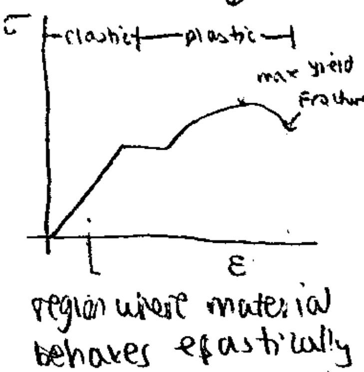
1. a) What does Hooke's law state?

6 Hooke's law states → That stress and strain are proportional by a constant, Yungs modulus, E. ~~E~~ Stress and strain are linearly related by this constant which varies with each material.

2

$$\sigma = E\varepsilon, \text{ where } \sigma = \text{stress}, \varepsilon = \text{strain}, E = \text{Young's Modulus}$$

1 b) What is meant by elastic behavior? not necessarily



Elastic behavior occurs ~~where~~ the stain and stress are increasing linearly on the stress/strain graph. [see figure left] The relationship is proportioned by E, Young's modulus. If a material is said to have elastic behavior, it is streching and the amount the body deforms is related to the force distribution within it by Yungs modulus.

c) What is the Modulus of Toughness of a material? Give an example of a material with a high Modulus of Toughness.

The modulus of Toughness of a material is the ability it has to streach or bend. If a material has a high modulus of toughness, it does not bend easily.

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A material with a high modulus of toughness is steel.

What sort?

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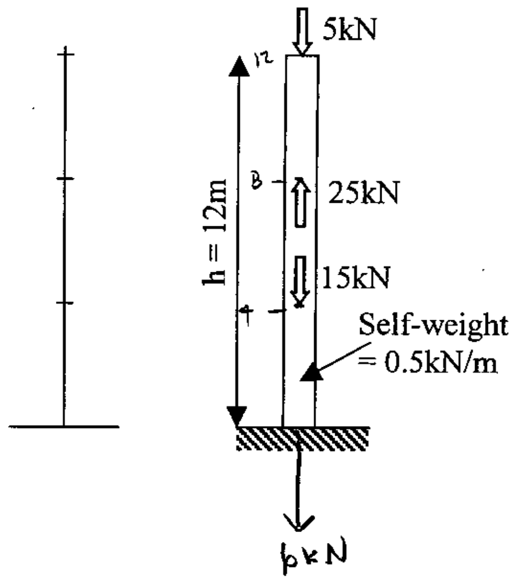
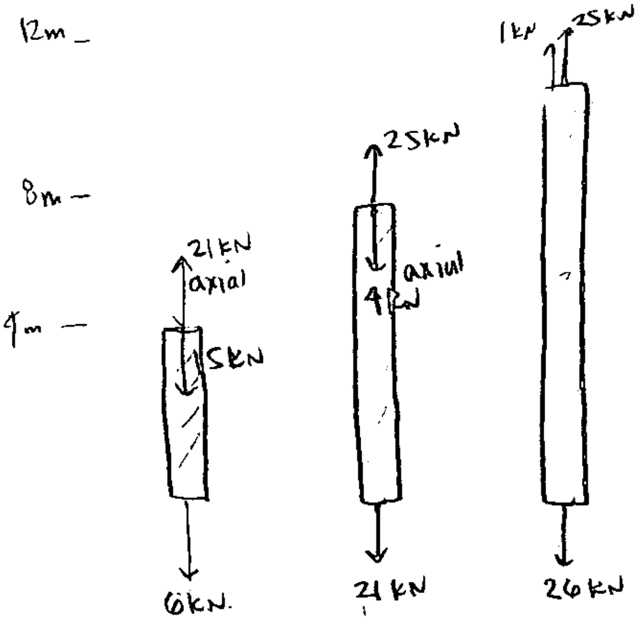
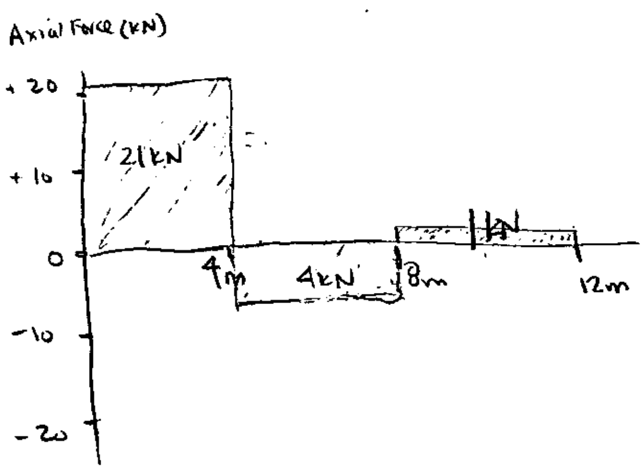
2. Draw the Axial Force Diagram.

(10)



Each member must be in equilibrium.





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3. The drawing shows the connection detail between the link-bars in an old suspension bridge in Pittsburg. Find the maximum shear stress in the pin, which has a diameter of 6 inches.

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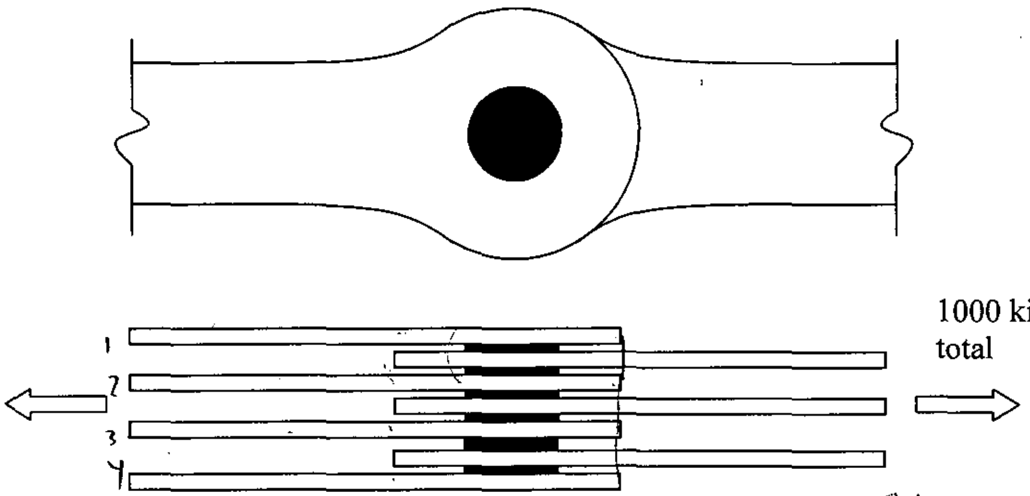

3 double shear supports

$V = \frac{F}{4}$

shear stress $= \tau = \frac{V}{A}$, where V is the internal resultant shear force, and A is the area of the section.

$$\tau = \frac{\frac{F}{4}}{A} = \frac{\left(\frac{1000}{3}\text{ kips}\right)}{(\pi(3\text{ in})^2)} \rightarrow \frac{333.3\text{ kip}}{9\pi\text{ in}^2} = 11.78\text{ kips/in}^2$$

× 5

Consider the resultant force acting on the shear plane.

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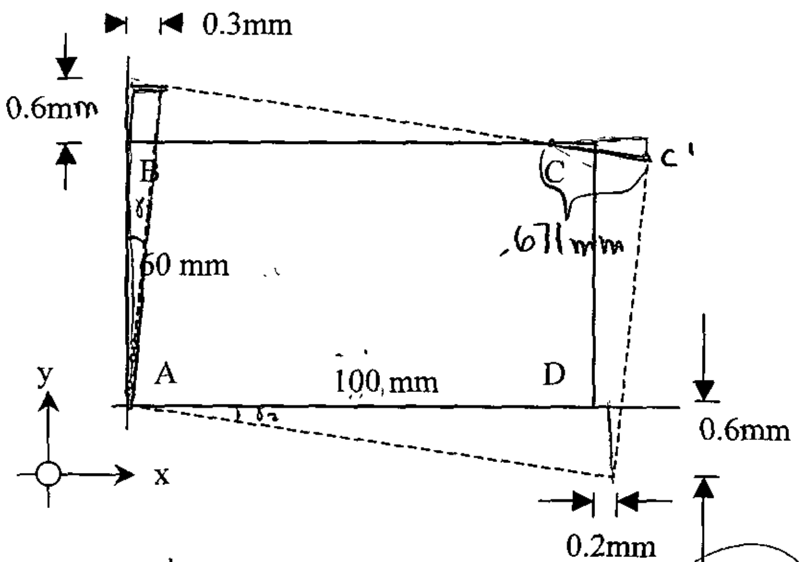
4. The figure shows a piece of material that has undergone deformation. Find the strains ε_{xx}, ε_{yy} and γ_{xy}. If the strains throughout the element are constant, what is the displacement of point C?

(24)



$$\varepsilon_{xx} = \frac{\Delta S' - \Delta S}{\Delta S} \qquad \varepsilon_{yy} = \frac{\Delta S' - \Delta S}{\Delta S}$$

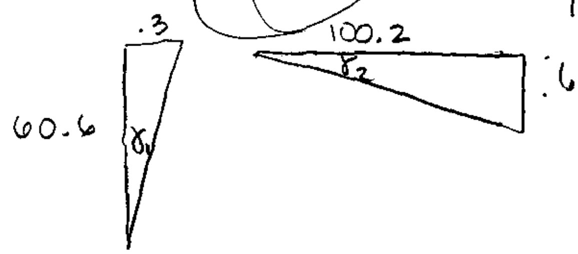
$\Delta S_x = 100\,mm$ $\quad$ $\Delta S_y = 60\,mm$

$\Delta S_x' = .3\,mm$ $\quad$ $\Delta S_y' = .6\,mm$

$$\varepsilon_{xx} = \frac{.3\,mm}{100\,mm} \qquad \varepsilon_{yy} = \frac{.6\,mm}{60\,mm}$$

$\boxed{\varepsilon_{xx} = 0.003}$ X (1) $\quad$ $\boxed{\varepsilon_{yy} = 0.01}$ ✓ (4)

$\gamma_{xy} = \gamma_1 + \gamma_2$



$\tan\gamma_1 = \left(\frac{.3}{60.6}\right) \Rightarrow \gamma_1 = .2836\left(\frac{\pi}{180}\right) = 0.00495$

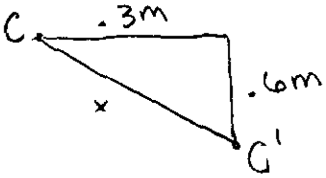
$\tan\gamma_2 = \left(\frac{.6}{100.2}\right) \Rightarrow \gamma_2 = .3431\left(\frac{\pi}{180}\right) = 0.00599$

(3)

$\gamma_{xy} = \gamma_1 + \gamma_2$

$\gamma_{xy} = 0.00495 + 0.00599 = 0.01094$

$\boxed{\text{@ Point C}}$



$.3^2 + .6^2 = x^2$

$\sqrt{.09 + .36} = x$

$\boxed{x = .671\,mm}$ is the amount that point C displaces

X

(2)

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5. Find the deflection at the tip of the rod. E = 10,000 ksi.

25

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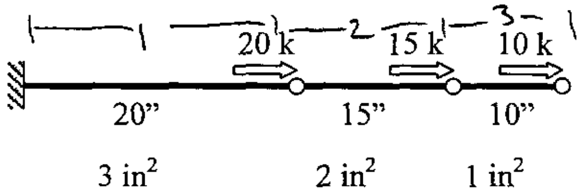

$$\sigma_{total} = \sigma_1 + \sigma_2 + \sigma_3$$

$$\sigma_{total} = \frac{F_1}{A_1} + \frac{F_2}{A_2} + \frac{F_3}{A_3}$$ ✓

$$\sigma_{total} = \frac{20k}{3in^2} + \frac{15k}{2in^2} + \frac{10k}{1in^2} = \frac{14.5k}{6in^2} = 24.167\ k/in^2$$

$E\varepsilon = \sigma$ ✓ $\qquad \varepsilon = \dfrac{\Delta s' - \Delta s}{\Delta s}$

Use $\delta = \dfrac{PL}{AE}$

APPLY TO EACH SECTION...

$$\frac{(10)(10")}{(1 in^2)E} + \frac{(25)(15")}{(1 in^2)E} + \cdots$$

$$\varepsilon = \frac{\sigma_{tot}}{E}$$

$$\varepsilon = \frac{24.167\ k/in^2}{10{,}000\ ksi} = 0.00242$$

$\Delta s = 45"$

$$0.00242 = \frac{\Delta s' - \Delta s}{\Delta s}$$

$$0.00242 = \frac{\Delta s' - 45}{45}$$

$$\Delta s' = 45.1089$$ X

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Therefore, deflection at the tip of the rod is $\boxed{0.1089\ in}$ [45.1089 − 45 = 0.1089]

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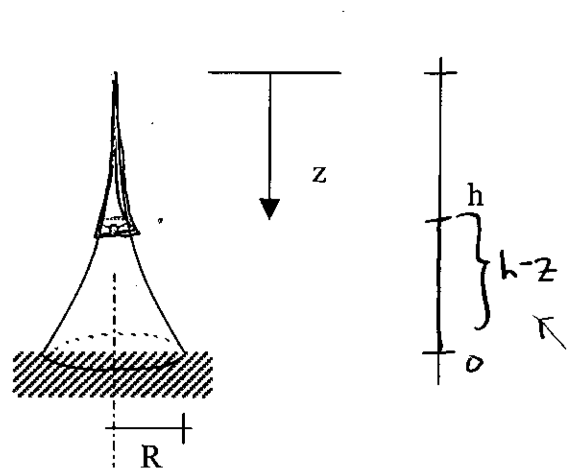
6. The figure shows an electrical contact in a sensitive switch. It is circular in cross-section, has weight density ρ, height h, Young's modulus E, and a radius given by

25

$$r(z) = R\left(\frac{z}{h}\right)^{1.5}$$

a) Find the stress due to self weight at a location z.

b) By how much would the length change if the system were turned upside down, so the contact was in tension, rather than compression, due to self-weight?



(a) $\sigma_z = \frac{F}{A}$ $F = \rho V$. $V = \pi r^2 z = \pi\left[\int_z^h r(z)\right]^2$ z = height ✓

$F = z\rho\pi\left[\int_z^h r(z)\right]^2$ ✓

$\sigma_z = \frac{z\rho\pi\left[\int_z^h r(z)\right]^2}{\text{Area}}$ $\text{Area} = \cancel{\pi\left[\int_z^h r(z)\right]^2} = \pi r^2$ ✗

5

$\sigma_z = \frac{z\rho\pi\left[\int_z^h r(z)\right]^2}{\pi\left[\int_z^h r(z)\right]^2} = \boxed{z\rho = \sigma_z}$ they do not cancel.

The new height

(b) The stress due to self weight would still be $\sigma = \rho z'$, where z' now equals $[h-z]$. So stress after turning it upside down is now $\sigma' = \rho(h-z)$ because the π and integrals will still cancel eachother out from the formula $\sigma = \frac{F}{A}$. We relate stress and change in length through strain and Young's Modulus E. Therefore:

$\sigma = z\rho = \varepsilon E \Rightarrow \varepsilon = \frac{z\rho}{E} = \frac{L'}{L_o}$; $L_o = z$ strain 1 : $\frac{z\rho}{E} = \frac{L'}{L_o}$; $\frac{z\rho}{E} = \frac{L'}{z} \rightarrow L' = \frac{\rho}{E}$

$\sigma' = \rho(h-z) = \varepsilon E \Rightarrow \varepsilon = \frac{\rho(h-z)}{E} = \frac{L'}{L_o}$; $L_o = h-z$ upside down strain 2 : $\frac{(h-z)\rho}{E} = \frac{L'}{L_o}$; $\frac{(h-z)\rho}{E} = \frac{L'}{(h-z)} \rightarrow L' = \frac{\rho}{E}$

L' is the elongation. In both cases the elongation is $\frac{\rho}{E}$, therefore the length changes proportionally to the self-weight. ✓ 3