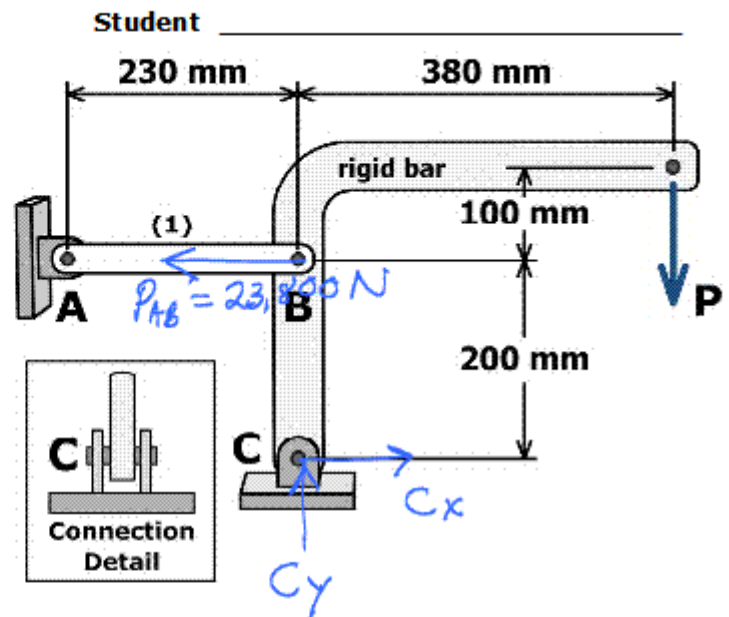


1. A simple pin-connected structure carries a concentrated load P as shown. The rigid bar is supported by an aluminum strut (1) and by a pin support at C. Aluminum strut (1) has a cross-sectional area of 400 mm^2 , a yield strength of 415 MPa , and an elastic modulus of 70 GPa . The steel pin at C has a diameter of 12 mm and an ultimate shear strength of 375 MPa . When load P is applied to the rigid bar, the normal strain in strut (1) is measured as $850 \text{ } \mu\text{r}$. Determine:

- (a) the magnitude of load P (in kN).
(b) the factor of safety of pin C with respect to its ultimate shear strength.



$$850 \times 10^{-6} = \frac{\Delta_{AB}}{230 \text{ mm}}$$

$$\Delta_{AB} = 0.1955 \text{ mm} = 0.0001955 \text{ m} = \frac{P_{AB} (.23)}{(400 \times 10^{-6})(70 \times 10^9)}$$

$$P_{AB} = 23,800 \text{ N}$$

$$\sum M_C^{\uparrow} = 0 = (23,800)(.2) - P(.38)$$

$$(a) \quad P = 12,526 \text{ N}$$

$$\sum F_x = 0 = C_x - 23,800 \text{ N} \Rightarrow C_x = 23,800 \text{ N}$$

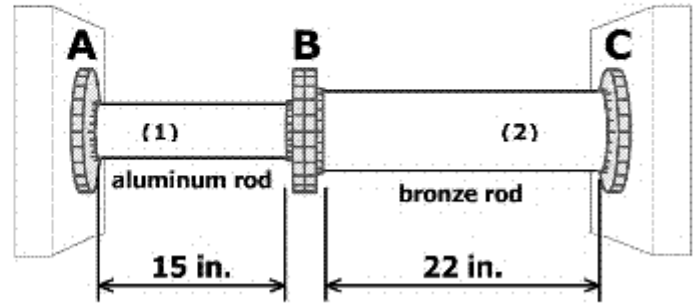
$$\sum F_y = 0 = C_y - 12,526 \text{ N} \Rightarrow C_y = 12,526 \text{ N}$$

$$|C| = 26,895 \text{ N}$$

$$\tau_c = \frac{26,895}{\left(\frac{2\pi}{4}\right) (.012)^2} = 118.9 \text{ MPa}$$

$$(b) \quad f_s = \frac{375}{118.9} = 3.16$$

2. The axial assembly shown consists of a solid 1-in. diameter aluminum alloy rod (1) [$E = 10,000$ ksi, $\nu = 0.32$, $\alpha = 12.5 \times 10^{-6}/^\circ\text{F}$] and a solid 1.5-in. diameter bronze rod (2) [$E = 15,000$ ksi, $\nu = 0.15$, $\alpha = 9.4 \times 10^{-6}/^\circ\text{F}$]. If the supports at A and C are rigid and the assembly is stress free at 0°F , determine:



- (a) The normal stress in both rods at 160°F .
(b) The displacement of flange B (measured from flange A).

$$P_1 = P_2$$

$$\delta_1 = \frac{P_1 (15)}{\frac{\pi}{4} (1)^2 (10 \times 10^6)}$$

$$\delta_2 = \frac{P_2 (22)}{\frac{\pi}{4} (1.5)^2 (15 \times 10^6)}$$

$$\delta_{1T} = (15)(12.5 \times 10^{-6})(160)$$

$$\delta_{2T} = (22)(9.4 \times 10^{-6})(160)$$

$$\delta_1 + \delta_2 = \delta_{1T} + \delta_{2T}$$

$$P_1 = P_2 = 23,026 \text{ lb}$$

$$\delta_1 = 0.043977 \text{ in}$$

$$\delta_2 = 0.01911 \text{ in}$$

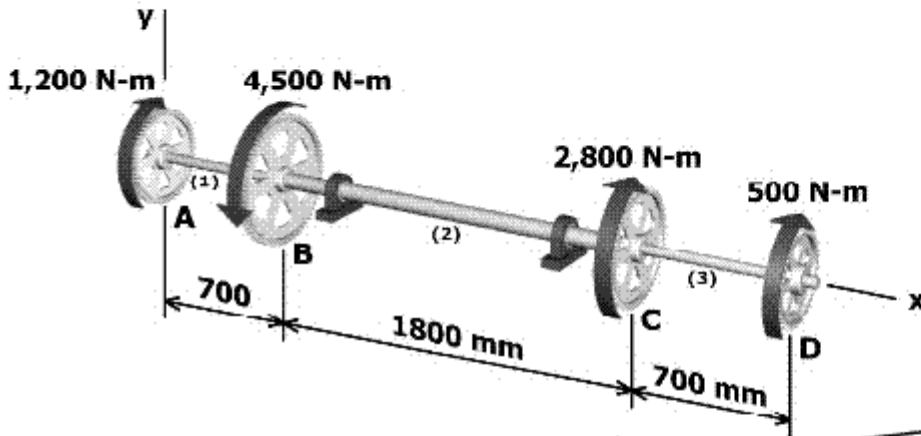
$$\delta_{1T} = 0.03 \text{ in}$$

$$\delta_{2T} = 0.033088 \text{ in}$$

$$\sigma_1 = \frac{23,026}{\frac{\pi}{4} (1)^2} = 29.32 \text{ Ksi}$$

$$\sigma_2 = \frac{23,026}{\frac{\pi}{4} (1.5)^2} = 13.06 \text{ Ksi}$$

$$\text{Flange B} = \delta_{1T} - \delta_1 = -0.01398 \text{ in (to Left)}$$

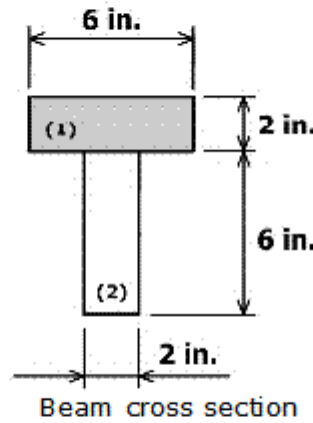
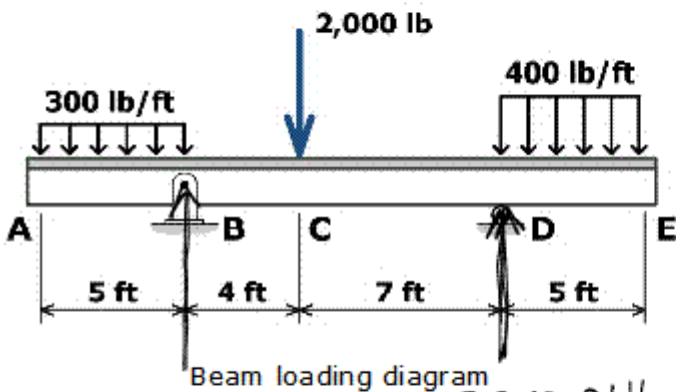


3. A solid circular steel ($G = 76 \text{ GPa}$) shaft of variable diameter is subjected to the torques shown. The diameter of the shaft in segments (1) and (3) is 50 mm, and the diameter of the shaft in segment (2) is 80 mm. Determine:
- the shear stress in each segment of the shaft.
 - the rotation angle of gear D relative to gear A.
 - ~~the maximum tension normal stress in segment (2) of the shaft.~~

$$\begin{aligned}
 a) \tau_{AB} &= \frac{1200(0.025)}{\frac{\pi}{32}(0.05)^4} = 48.9 \text{ MPa} \\
 \tau_{BC} &= \frac{3300(0.04)}{\frac{\pi}{32}(0.08)^4} = 32.8 \text{ MPa} \\
 \tau_{CD} &= \frac{500(0.025)}{\frac{\pi}{32}(0.05)^4} = 20.4 \text{ MPa}
 \end{aligned}$$

$$\begin{aligned}
 b) \theta_{AD} &= \frac{1200(0.7)}{(76 \times 10^9) \frac{\pi}{32}(0.05)^4} - \frac{3300(1.8)}{(76 \times 10^9) \frac{\pi}{32}(0.08)^4} - \frac{500(0.7)}{(76 \times 10^9) \frac{\pi}{32}(0.05)^4} \\
 &= \boxed{-0.008929 \text{ rad}}
 \end{aligned}$$

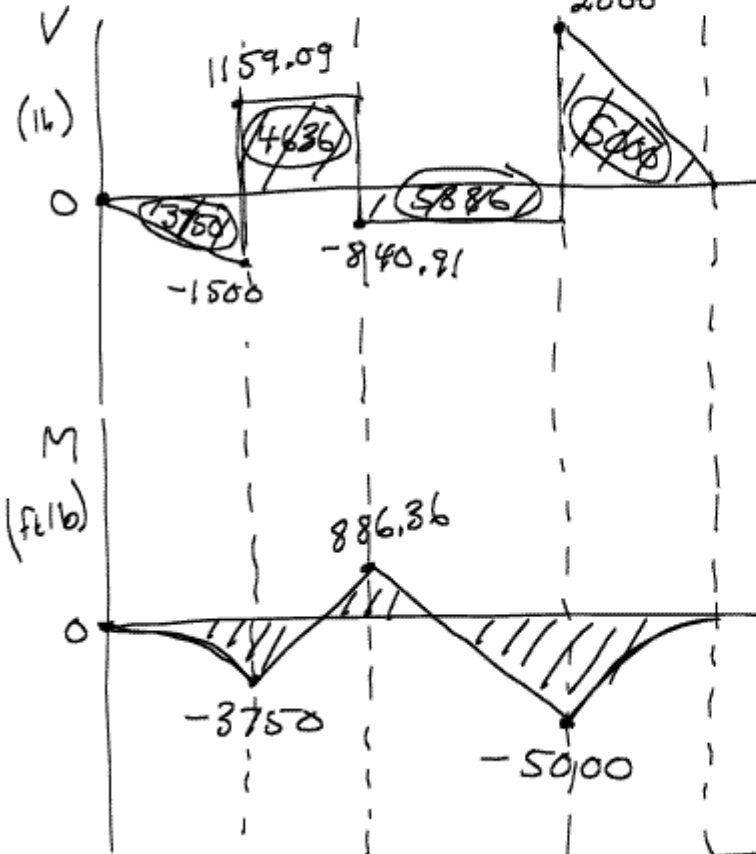
4. The top flange (1) of the composite beam has a modulus of elasticity of 1×10^6 psi while the tee stem (2) has an elastic modulus of 3×10^6 psi. Determine the maximum tensile and compressive bending stresses in the beam.



Transform to material (1)



$$I = \frac{6(8)^3}{12} = 256 \text{ in}^4$$



$$\sum M_B = 0 = (300)(5)(2.5) - 2000(4) - 400(5)(13.5) + R_D(11)$$

$$R_D = 2840.91 \text{ lb}$$

$$\sum M_D = 0 = -400(5)(2.5) + 2000(7) + 300(5)(13.5) - R_B(11)$$

$$R_B = 2659.09 \text{ lb}$$

$$\sum F_y = 0 = R_B + R_D - 300(5) - 2000 - 400(5)$$

Checks

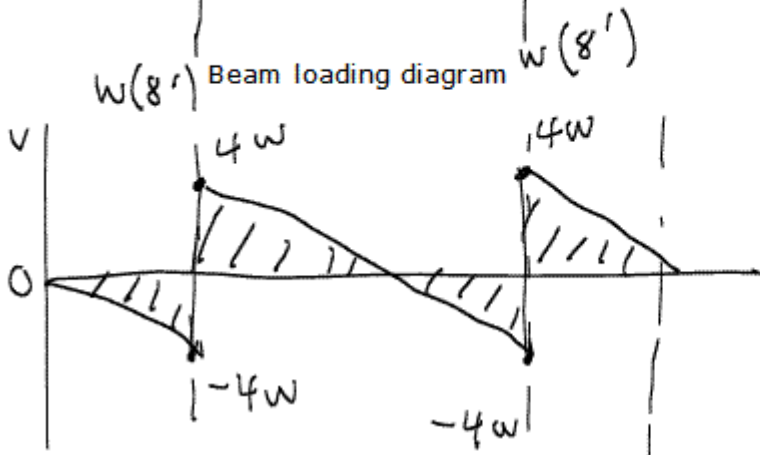
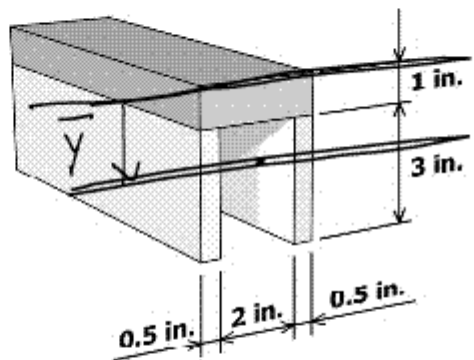
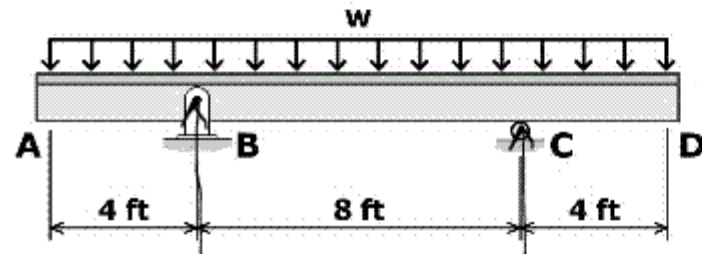
$$M_{max} = 5000 \text{ Ft/lb}$$

$$\text{Tension Max} = \frac{(5000 \times 12)(4)}{256} = 937.5 \text{ psi}$$

$$\text{Compression Max} = \frac{(5000 \times 12)(4)(3)}{256} = 2812.5 \text{ psi}$$

500 psi

5. The beam is constructed from 3 pieces of plastic glued together as shown. The allowable shearing stress in the plastic is 800 psi and each glued joint can withstand ~~500 lb/ft~~ (along the beam span). Determine the maximum value of uniformly distributed load w that can be applied to the beam.



$$V_{max} = 4w$$

$$800 \text{ psi} = \frac{(4w)(.5)(2.5)(1.25)}{(8.5)(.5)}$$

$$500 \text{ psi} = \frac{(4w)(.5)(3)(1)}{(8.5)(.5)}$$

Beam cross section

$$\bar{y} = \frac{(1)(3)(.5) + 2(.5)(3)(2.5)}{(1)(3) + 2(.5)(3)}$$

$$= 1.5''$$

$$I = \frac{3(1)^3}{12} + (3)(1)(1)^2 + \left[\frac{(.5)(3)^3}{12} + (.5)(3)(1)^2 \right] (2)$$

$$= 8.5 \text{ in}^4$$

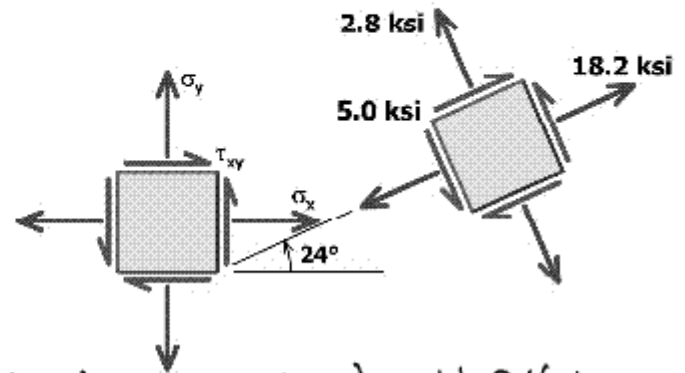
$$w = 544 \text{ lb/ft}$$

$$w = 354.2 \text{ lb/ft}$$

glue limits

6. The stress components are given for a stress state rotated 24° as illustrated in the figure.

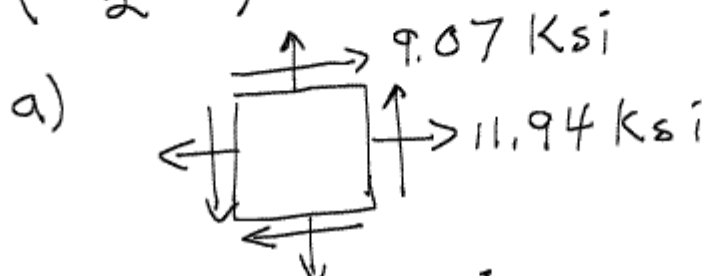
- (a) Find the stress components (σ_x , σ_y and τ_{xy}) for the x-y coordinate system and illustrate your answer on a properly oriented element.
- (b) If the material properties are $E = 10.4 \times 10^6$ psi and $\nu = 0.32$, find the strain components in the x-y coordinate system, and illustrate the state of strain on a properly oriented element.



$$\sigma_x = \frac{18.2 + 2.8}{2} + \left(\frac{18.2 - 2.8}{2} \right) \cos(-48) + 5 \sin(-48) = 11.94 \text{ Ksi}$$

$$\sigma_y = \frac{18.2 + 2.8}{2} - \left(\frac{18.2 - 2.8}{2} \right) \cos(-48) - 5 \sin(-48) = 9.06 \text{ Ksi}$$

$$\tau_{xy} = - \left(\frac{18.2 - 2.8}{2} \right) \sin(-48) + 5 \cos(-48) = 9.07 \text{ Ksi}$$



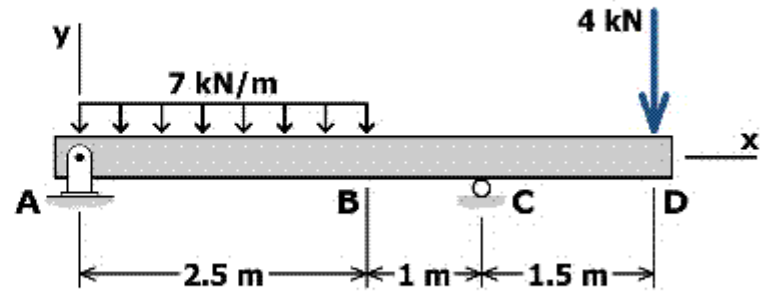
b)

$$\epsilon_x = \frac{1}{10.4 \times 10^6} [11.94 - (0.32)(9.06)] = 869 \mu$$

$$\epsilon_y = \frac{1}{10.4 \times 10^6} [9.06 - (0.32)(11.94)] = 504 \mu$$

$$\gamma_{xy} = \frac{2(0.32)}{10.4 \times 10^6} (9.07) = 2302 \mu$$

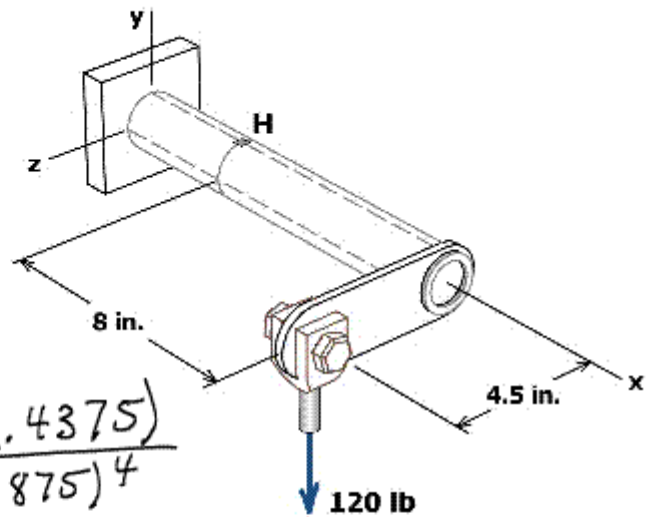
7. The beam shown below is made of steel ($E = 200 \text{ GPa}$) and has a moment of inertia of $I = 4.3 \times 10^6 \text{ mm}^4$. Compute the deflection at point B for the loading shown.



$$\begin{aligned} \delta_B &= \frac{-wa^3}{24LEI} (4L^2 - 7aL + 3a^2) + \frac{Mx}{6LEI} (x^2 - 3Lx + 2L^2) \\ &= \frac{-(7000)(2.5)^3}{24(3.5)(4.3 \times 10^6)(200 \times 10^9)} (4(3.5)^2 - 7(2.5)(3.5) + 3(2.5)^2) \\ &\quad + \frac{(6000)(1)}{6(3.5)(4.3 \times 10^6)(200 \times 10^9)} (1^2 - 3(3.5)(1) + 2(3.5)^2) \\ &= -0.009841 + 0.004983 \end{aligned}$$

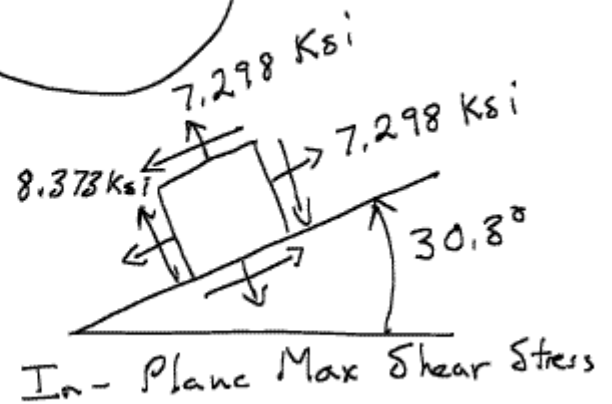
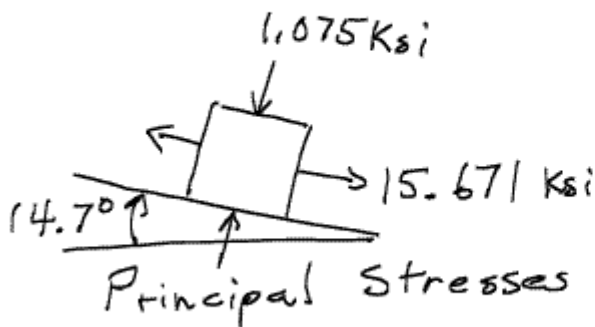
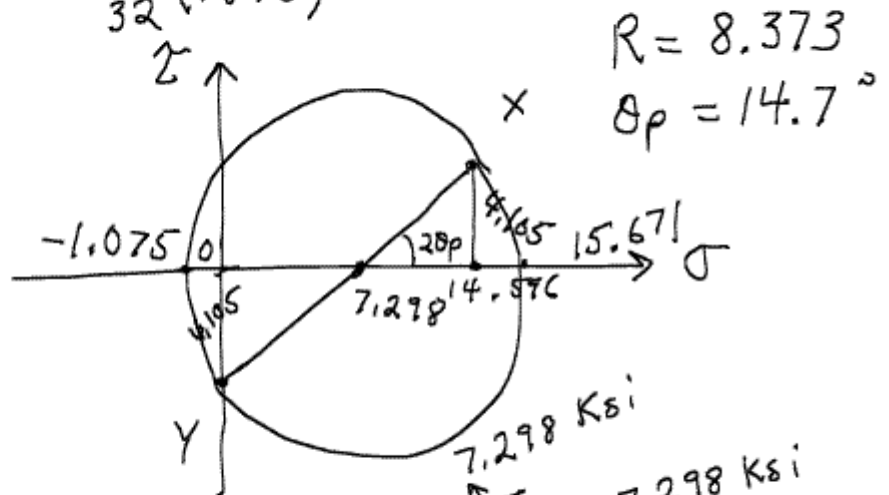
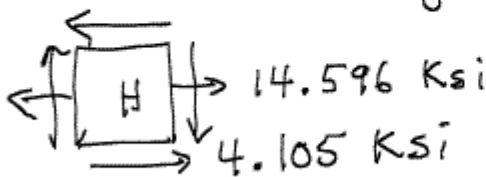
$$\delta_B = 4.86 \text{ mm } \downarrow$$

8. The crank mechanism shown has a solid 0.875-in.-diameter that is connected to a crank handle of length 4.5 inches. A vertical load of 120 pounds is applied at the crank handle as illustrated. Determine the principal stresses and the maximum shear stress in the shaft at point H, which is located on top of the shaft.



$$\frac{M_y}{I} = \frac{(120)(8)(.4375)}{\frac{\pi}{64} (.875)^4}$$

$$\frac{T_r}{J} = \frac{(120)(4.5)(.4375)}{\frac{\pi}{32} (.875)^4}$$



$$\tau_{max} = \tau_p = 8.373 \text{ Ksi}$$