IDE 110 Fall 2007 Final Exam Key

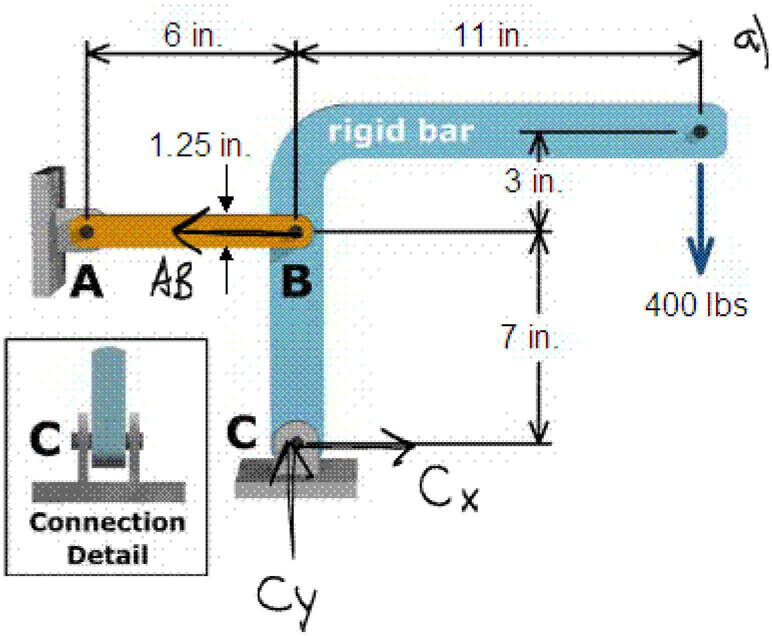
1. In the frame below, member AB is 1.25 inches wide and 0.125 inches thick. The 0.25 inch pins at A and B are in single shear.

a. Find the force in member AB and state whether it is in tension or compression. Also find the reaction on the pin at C.

b. Find the shear stress on the pin at B.

c. Find the bearing stress in member AB at point B.

d. Find the required diameter for the pin at C if the shear stress must be limited to 15 ksi.



a) $\Sigma F_x = 0 = C_x - AB$

$\Sigma F_y = 0 = C_y - 400$

$\Sigma M_C = 0 = AB(7) - 400(11)$

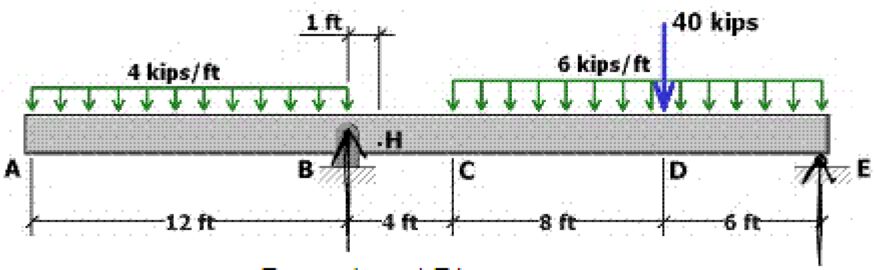
$$\boxed{\begin{array}{l} AB = 628.6 \text{ lb} \\ C_x = 628.6 \text{ lb} \\ C_y = 400 \text{ lb} \\ |C| = 745 \text{ lb} \end{array}}$$

b) $\tau_B = \dfrac{628.6}{\frac{\pi}{4}(.25)^2} = \boxed{12.8 \text{ Ksi}}$

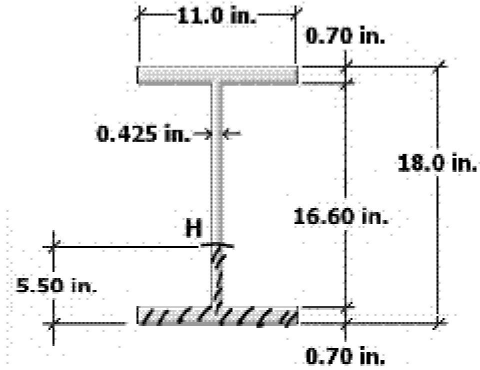
c) $\sigma_b = \dfrac{628.6}{(.25)(.125)} = \boxed{20.1 \text{ Ksi}}$

d) $15{,}000 = \dfrac{745}{\frac{\pi}{4}d^2}$ $\quad \boxed{d = 0.251 \text{ in.}}$

2. For the simply supported beam shown, determine the normal stress and shear stress acting at point H as shown on the figures below. Show these stresses on a stress element.



Beam Load Diagram



Beam Cross-Section

$$\Sigma M_B = 0 = 4(12)(6) - 40(12) - 6(14)(11) + R_E(18)$$

$$R_E = 62 \text{ Kips}$$

$$\Sigma M_E = 0 = 6(14)(7) + 40(6) + 4(12)(24) - R_B(18)$$

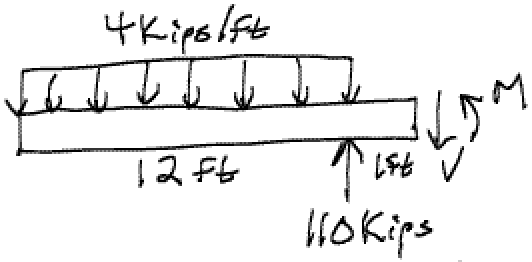
$$R_B = 110 \text{ Kips}$$

$$\Sigma F_y = 0 = R_B + R_E - 4(12) - 40 - 6(14)$$

checks

$$I = 2\left[\frac{11(.7)^3}{12} + (11)(.7)(8.65)^2\right] + \frac{(.425)(16.6)^3}{12} = 1314.9 \text{ in}^4$$

$$Q_H = (11)(.7)(8.65) + (4.8)(.425)(5.9) = 78.641 \text{ in}^3$$



$$\tau = \frac{(62{,}000)(78.641)}{(1314.9)(.425)} = 8725 \text{ psi}$$

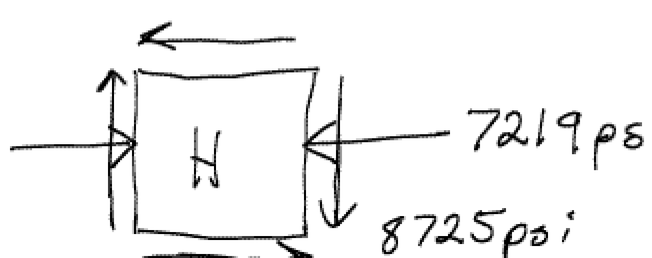
$$\sigma = \frac{(226{,}000 * 12)(3.5)}{1314.9} = 7219 \text{ psi C}$$

$$\Sigma F_y = 0 = 110 - 4(12) - V$$

$$V = +62 \text{ Kips}$$

$$\Sigma M_{cut} = 0 = M - 110(1) + 4(12)(7)$$

$$M = -226 \text{ Kip ft}$$

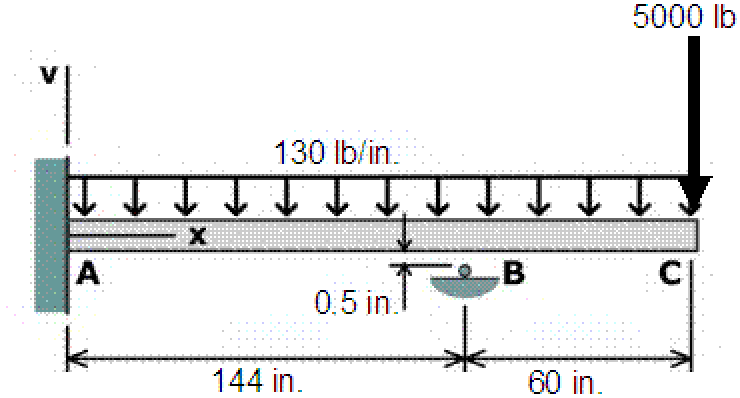


Answer.

3. The propped cantilever beam shown below is made from a W14 X 48 I-Beam which has a moment of inertia of I = 484 in.^{4} and a modulus of elasticity of E = 29,000 ksi. Before the loads are applied, the support at point B is located 0.5 inches below the beam as shown in the figure.

a. Find the support reaction on the beam at B.

b. Find the deflection at point C.



$$EI = 14.036\times10^9 \text{ lb in}^2$$

$$V_B = -0.5 = \frac{-(130)(144)}{24(14.036\times10^9)}\left(144^2 - 4(204)(144) + 6(204)^2\right) - \frac{5000(144)^2}{6(14.036\times10^9)}\left(3(204) - 144\right) + \frac{R_B(144)^3}{3(14.036\times10^9)}$$

-0.008498

-0.57616

$$\boxed{R_B = 1193.9 \text{ lb}}$$

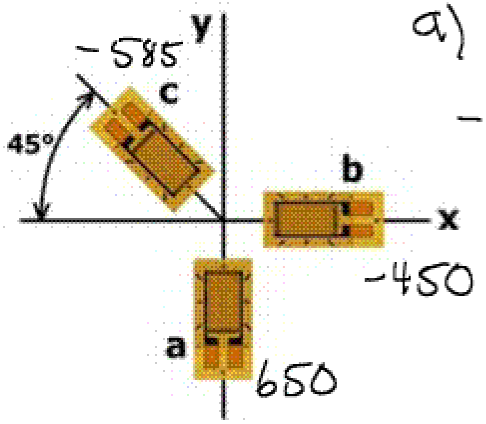
$$V_C = \frac{-130(204)^4}{8(14.036\times10^9)} - \frac{5000(204)^3}{3(14.036\times10^9)} + \frac{(1193.9)(144)^3}{3(14.036\times10^9)} + \frac{(1193.9)(144)^2}{2(14.036\times10^9)}(60) = \boxed{-2.876 \text{ in}}$$

4. The strain rosette shown was used to obtain normal strain data at a point on the free surface of a machine part. $\varepsilon_a = 650\mu$, $\varepsilon_b = -450\mu$, and $\varepsilon_c = -585\mu$. E = 96 GPa and Poisson's ratio for the material is $\nu = 0.33$.

a. Determine the strain components ε_x, ε_y and γ_{xy} at the point.

b. Determine the stress components σ_x, σ_y and τ_{xy} at the point.

c. Determine the principal stresses and the maximum in-plane shear stress at the point. Show these stresses on an appropriate sketch that indicates the orientation of the principal plans and the planes of maximum in-plane shear stress.



a) $\boxed{\epsilon_x = -450\mu}$ $\boxed{\epsilon_y = 650\mu}$

$$-585 = -450\cos^2 135 + 650\sin^2 135 + \gamma_{xy}\sin 135\cos 135$$

$$\boxed{\gamma_{xy} = 1370\,\mu}$$

b) $$\sigma_x = \frac{96\times10^9}{1-(.33)^2}\left(-450+(.33)(650)\right)\times10^{-6} = -25.37\text{ MPa}$$

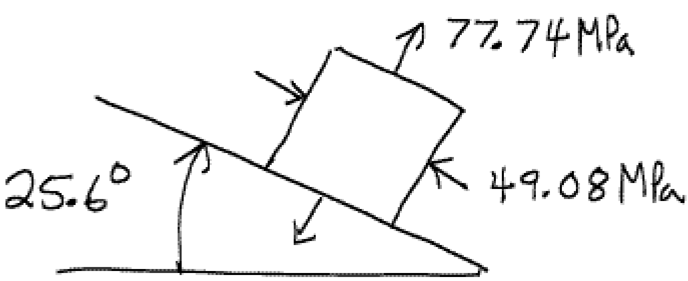
$$\sigma_y = \frac{96\times10^9}{1-(.33)^2}\left(650+(.33)(-450)\right)\times10^{-6} = 54.03\text{ MPa}$$

$$\tau_{xy} = \frac{96\times10^9}{2(1.33)}\left(1370\times10^{-6}\right) = 49.44\text{ MPa}$$

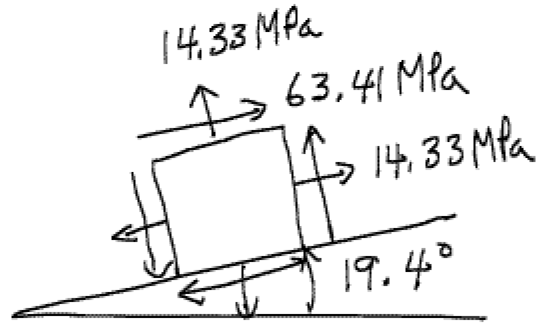
c) $$\sigma_{p1,p2} = \frac{-25.37+54.03}{2} \pm \sqrt{\left(\frac{-25.37-54.03}{2}\right)^2 + (49.44)^2} = \begin{cases} 77.74 \\ -49.08 \end{cases}$$

$$14.33 \pm 63.41$$

$$\tan 2\theta_p = \frac{49.44}{\left(\frac{-25.37-54.03}{2}\right)} \qquad \theta_p = -25.6^\circ$$



Principal Stresses



In-Plane Max Shear Stress

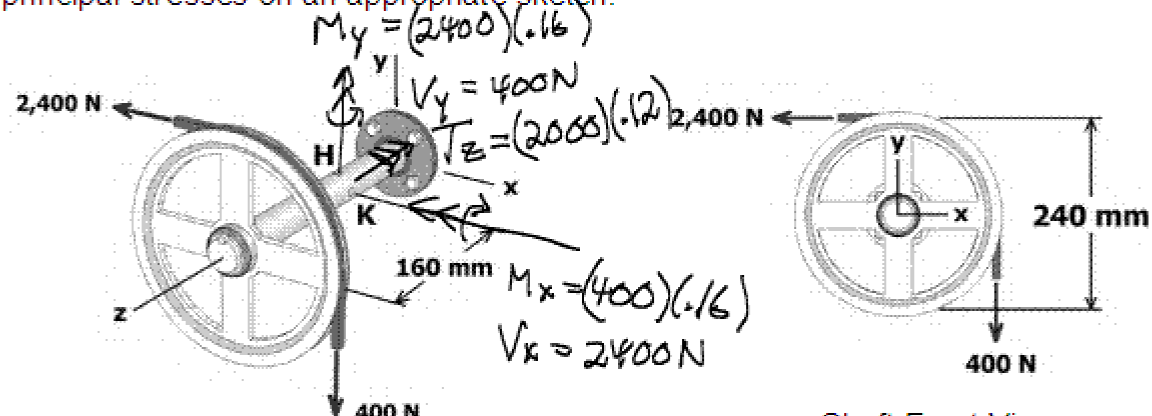
5. A solid steel shaft with an outside diameter of 36 mm supports a 240-mm-diameter pulley. Belt tensions of 2,400 N and 400 N act as shown.

(a) Determine the normal and shear stresses on the top surface of the shaft at point *H* and show them on a stress element.

(b) Determine the principal stresses at point *H*. **Note:** You do not need to show the orientation of the principal stresses on an appropriate sketch.

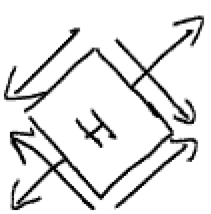
(c) Determine the normal and shear stresses on the side of the shaft at point *K* and show them on a stress element.

(d) Determine the principal stresses at point *K*. **Note:** You do not need to show the orientation of the principal stresses on an appropriate sketch.



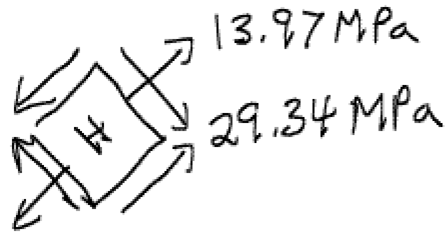
Shaft Front View

Shaft Perspective



$$\frac{M_x y}{I} = \frac{(400)(.16)(.018)}{\frac{\pi}{64}(.036^4)} = 13.97\text{ MPa}$$

$$\frac{Tr}{J} + \frac{V_x Q}{It} = \frac{(2000)(.12)(.018)}{\frac{\pi}{32}(.036^4)} + \frac{(2400)\frac{2}{3}(.018^3)}{\frac{\pi}{64}(.036^4)(.036)} = 29.34\text{ MPa}$$



$$\frac{M_y y}{I} = \frac{(2400)(.16)(.018)}{\frac{\pi}{64}(.036^4)} = 83.83\text{ MPa}$$

$$\frac{Tr}{J} - \frac{V_y Q}{It} = \frac{(2000)(.12)(.018)}{\frac{\pi}{32}(.036^4)} - \frac{(400)\frac{2}{3}(.018)^3}{\frac{\pi}{64}(.036^4)(.036)} = 25.67\text{ MPa}$$