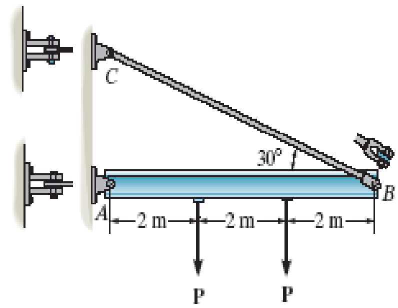
# HW#2 Key Solutions




•**1–61.** Determine the maximum magnitude $P$ of the load the beam will support if the average shear stress in each pin is not to allowed to exceed 60 MPa. All pins are subjected to double shear as shown, and each has a diameter of 18 mm.

Referring to the FBD of member $AB$, Fig. $a$,

$\circlearrowleft + \Sigma M_A = 0; \quad F_{BC} \sin 30°(6) - P(2) - P(4) = 0 \quad F_{BC} = 2P$

$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad A_x - 2P \cos 30° = 0 \quad A_x = 1.732P$

$+\uparrow \Sigma F_y = 0; \quad A_y - P - P + 2P \sin 30° = 0 \quad A_y = P$

Thus, the force acting on pin $A$ is

$F_A = 2\ \overline{A_x^{\,2} + A_y^{\,2}} = 2\ \overline{(1.732P)^2 + P^2} = 2P$

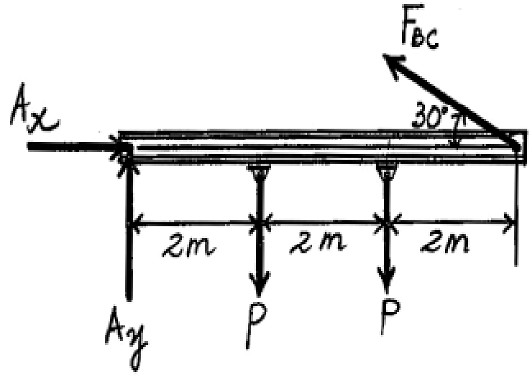
All pins are subjected to same force and double shear. Referring to the FBD of the pin, Fig. $b$,

$V = \frac{F}{2} = \frac{2P}{2} = P$

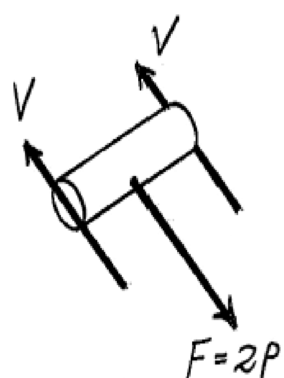
The cross-sectional area of the pin is $A = \frac{\pi}{4}(0.018^2) = 81.0(10^{-6})\pi\ \text{m}^2$. Thus,

$\tau_{\text{allow}} = \frac{V}{A}; \quad 60(10^6) = \frac{P}{81.0(10^{-6})\pi}$

$P = 15\,268\ \text{N} = 15.3\ \text{kN}$ **Ans.**

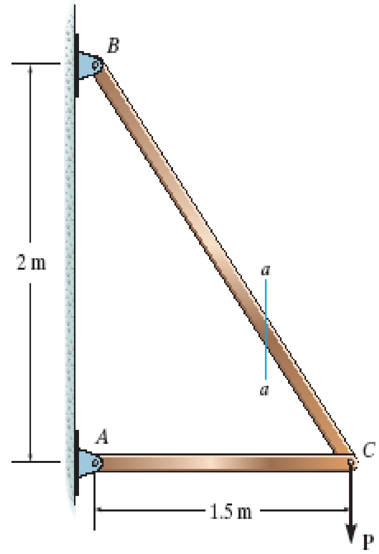



(a)




(b)

**1–66.** Determine the largest load **P** that can be a applied to the frame without causing either the average normal stress or the average shear stress at section *a–a* to exceed $\sigma = 150$ MPa and $\tau = 60$ MPa, respectively. Member *CB* has a square cross section of 25 mm on each side.




Analyse the equilibrium of joint *C* using the FBD Shown in Fig. *a*,

$$+\uparrow \Sigma F_y = 0; \qquad F_{BC}\left(\frac{4}{5}\right) - P = 0 \qquad F_{BC} = 1.25P$$

Referring to the FBD of the cut segment of member *BC* Fig. *b*.

$$\xrightarrow{+} \Sigma F_x = 0; \qquad N_{a-a} - 1.25P\left(\frac{3}{5}\right) = 0 \qquad N_{a-a} = 0.75P$$

$$+\uparrow \Sigma F_y = 0; \qquad 1.25P\left(\frac{4}{5}\right) - V_{a-a} = 0 \qquad V_{a-a} = P$$

The cross-sectional area of section *a–a* is $A_{a-a} = (0.025)\left(\frac{0.025}{3/5}\right) = 1.0417(10^{-3})\text{m}^2$. For Normal stress,

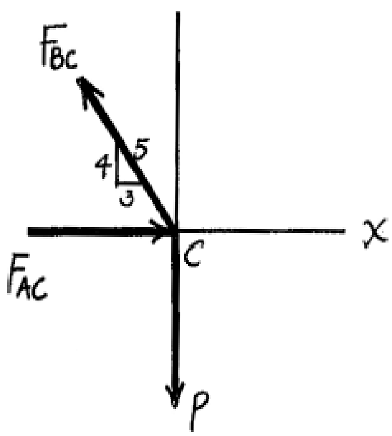
$$\sigma_{\text{allow}} = \frac{N_{a-a}}{A_{a-a}}; \qquad 150(10^6) = \frac{0.75P}{1.0417(10^{-3})}$$

$$P = 208.33(10^3)\text{ N} = 208.33\text{ kN}$$

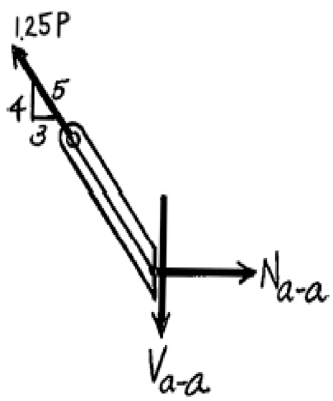
For Shear Stress

$$\tau_{\text{allow}} = \frac{V_{a-a}}{A_{a-a}}; \qquad 60(10^6) = \frac{P}{1.0417(10^{-3})}$$

$P = 62.5(10^3)$ N $= 62.5$ kN (Controls!) **Ans.**

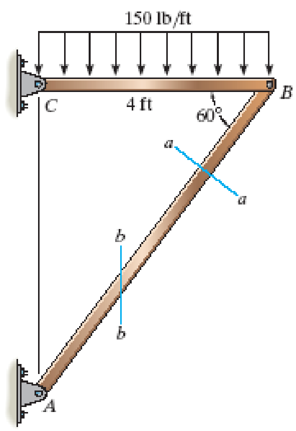



(a)




(b)

**1–71.** Determine the average normal stress at section $a$–$a$ and the average shear stress at section $b$–$b$ in member $AB$. The cross section is square, 0.5 in. on each side.




Consider the FBD of member $BC$, Fig. $a$,

$\circlearrowleft + \Sigma M_C = 0; \quad F_{AB} \sin 60°(4) - 150(4)(2) = 0 \quad F_{AB} = 346.41 \text{ lb}$

Referring to the FBD in Fig. $b$,

$\overset{+}{\swarrow} \Sigma F_{x'} = 0; \quad N_{a-a} + 346.41 = 0 \quad N_{a-a} = -346.41 \text{ lb}$

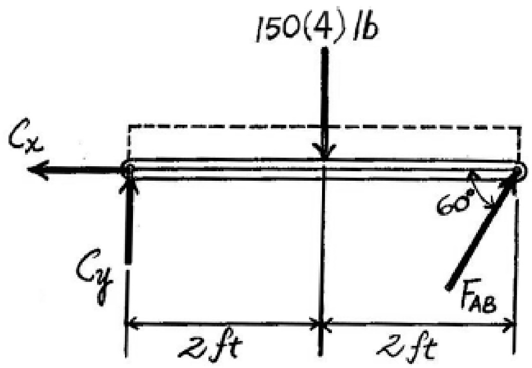
Referring to the FBD in Fig. $c$.

$+\uparrow \Sigma F_y = 0; \quad V_{b-b} - 346.41 \sin 60° = 0 \quad V_{b-b} = 300 \text{ lb}$

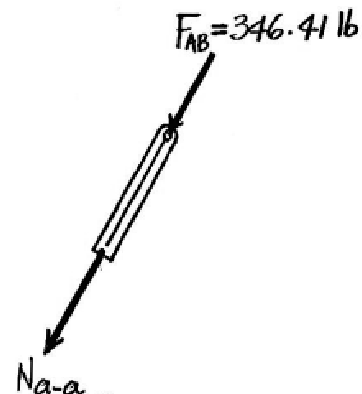
The cross-sectional areas of section $a$–$a$ and $b$–$b$ are $A_{a-a} = 0.5(0.5) = 0.25 \text{ in}^2$ and $A_{b-b} = 0.5\left(\frac{0.5}{\cos 60°}\right) = 0.5 \text{ in}^2$. Thus

$$\sigma_{a-a} = \frac{N_{a-a}}{A_{a-a}} = \frac{346.41}{0.25} = 1385.64 \text{ psi} = 1.39 \text{ ksi} \qquad \textbf{Ans.}$$

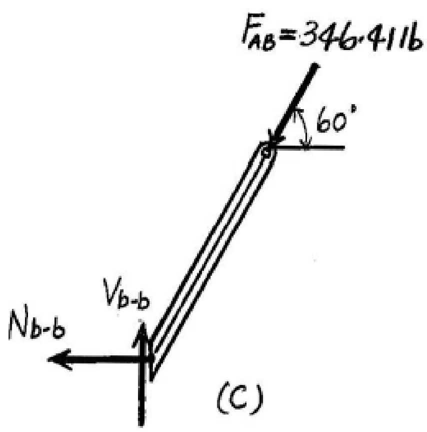
$$\tau_{b-b} = \frac{V_{b-b}}{A_{b-b}} = \frac{300}{0.5} = 600 \text{ psi} \qquad \textbf{Ans.}$$




(a)

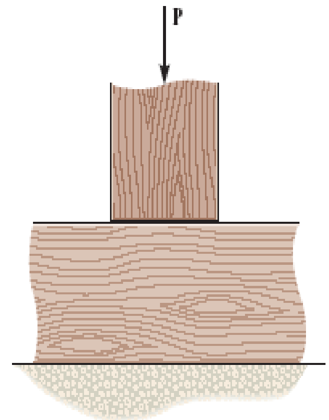



(b)




(c)

**1–87.** The 60 mm × 60 mm oak post is supported on the pine block. If the allowable bearing stresses for these materials are $\sigma_{oak} = 43$ MPa and $\sigma_{pine} = 25$ MPa, determine the greatest load *P* that can be supported. If a rigid bearing plate is used between these materials, determine its required area so that the maximum load *P* can be supported. What is this load?




For failure of pine block:

$$\sigma = \frac{P}{A}; \qquad 25(10^6) = \frac{P}{(0.06)(0.06)}$$

$$P = 90 \text{ kN} \qquad \textbf{Ans.}$$

For failure of oak post:

$$\sigma = \frac{P}{A}; \qquad 43(10^6) = \frac{P}{(0.06)(0.06)}$$

$$P = 154.8 \text{ kN}$$

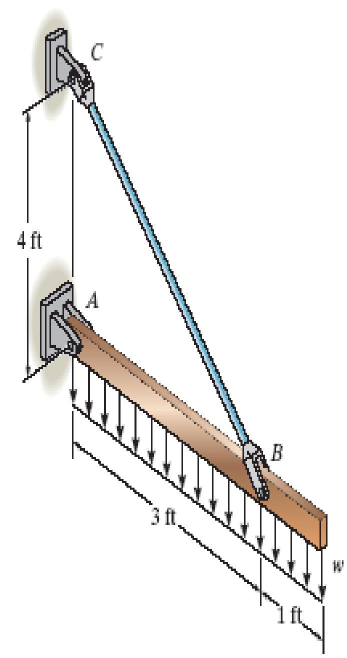
Area of plate based on strength of pine block:

$$\sigma = \frac{P}{A}; \qquad 25(10^6) = \frac{154.8(10)^3}{A}$$

$$A = 6.19(10^{-3})\text{m}^2 \qquad \textbf{Ans.}$$

$$P_{max} = 155 \text{ kN} \qquad \textbf{Ans.}$$

**1–94.** If the allowable shear stress for each of the 0.30-in.-diameter steel pins at $A$, $B$, and $C$ is $\tau_{allow} = 12.5$ ksi, and the allowable normal stress for the 0.40-in.-diameter rod is $\sigma_{allow} = 22$ ksi, determine the largest intensity $w$ of the uniform distributed load that can be suspended from the beam.




Assume failure of pins $B$ and $C$:

$$\tau_{allow} = 12.5 = \frac{1.667w}{\frac{\pi}{4}(0.3^2)}$$

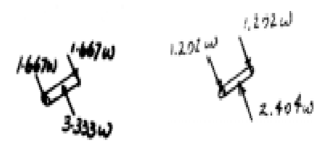
$w = 0.530$ kip/ft (controls) **Ans.**

Assume failure of pins $A$:

$$F_A = 2\ \overline{(2w)^2 + (1.333w)^2} = 2.404\,w$$

$$\tau_{allow} = 12.5 = \frac{1.202w}{\frac{\pi}{4}(0.3^2)}$$

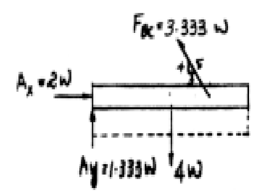
$w = 0.735$ kip/ft



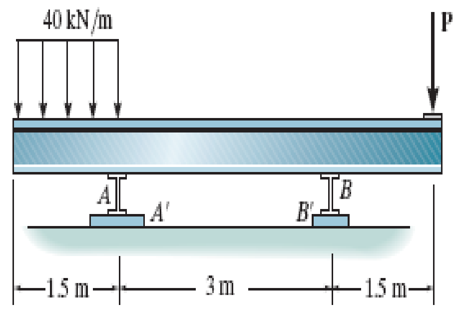

Assume failure of rod $BC$:

$$\sigma_{allow} = 22 = \frac{3.333w}{\frac{\pi}{4}(0.4^2)}$$

$w = 0.829$ kip/ft



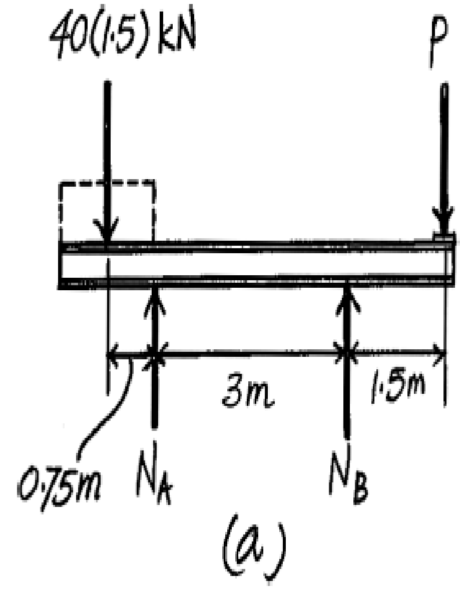
***1–96.** If the allowable bearing stress for the material under the supports at $A$ and $B$ is $(\sigma_b)_{allow} = 1.5$ MPa, determine the maximum load $P$ that can be applied to the beam. The bearing plates $A'$ and $B'$ have square cross sections of 150 mm × 150 mm and 250 mm × 250 mm, respectively.




Referring to the FBD of the beam, Fig. *a*,

$$\circlearrowleft + \Sigma M_A = 0; \quad N_B(3) + 40(1.5)(0.75) - P(4.5) = 0 \quad N_B = 1.5P - 15$$

$$\circlearrowleft + \Sigma M_B = 0; \quad 40(1.5)(3.75) - P(1.5) - N_A(3) = 0 \quad N_A = 75 - 0.5P$$




For plate $A'$,

$$(\sigma_b)_{allow} = \frac{N_A}{A_{A'}}; \qquad 1.5(10^6) = \frac{(75 - 0.5P)(10^3)}{0.15(0.15)}$$

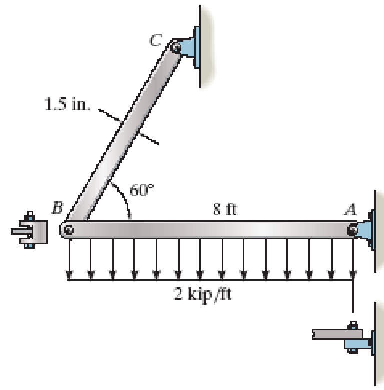
$$P = 82.5 \text{ kN}$$

For plate $B'$,

$$(\sigma_b)_{allow} = \frac{N_B}{A_{B'}}; \qquad 1.5(10^6) = \frac{(1.5P - 15)(10^3)}{0.25(0.25)}$$

$$P = 72.5 \text{ kN} \quad \text{(Controls!)}$$ **Ans.**

**1–103.** Determine the required thickness of member $BC$ and the diameter of the pins at $A$ and $B$ if the allowable normal stress for member $BC$ is $\sigma_{allow} = 29$ ksi and the allowable shear stress for the pins is $\tau_{allow} = 10$ ksi.




Referring to the FBD of member $AB$, Fig. $a$,

$$\zeta + \Sigma M_A = 0; \quad 2(8)(4) - F_{BC} \sin 60° \, (8) = 0 \quad F_{BC} = 9.238 \text{ kip}$$

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \quad 9.238 \cos 60° - A_x = 0 \quad A_x = 4.619 \text{ kip}$$

$$+\uparrow \Sigma F_y = 0; \quad 9.238 \sin 60° - 2(8) + A_y = 0 \quad A_y = 8.00 \text{ kip}$$

Thus, the force acting on pin $A$ is

$$F_A = \sqrt{A_x^2 + A_y^2} = \sqrt{4.619^2 + 8.00^2} = 9.238 \text{ kip}$$

Pin $A$ is subjected to single shear, Fig. $c$, while pin $B$ is subjected to double shear, Fig. $b$.

$$V_A = F_A = 9.238 \text{ kip} \qquad V_B = \frac{F_{BC}}{2} = \frac{9.238}{2} = 4.619 \text{ kip}$$

For member $BC$

$$\sigma_{allow} = \frac{F_{BC}}{A_{BC}}; \quad 29 = \frac{9.238}{1.5(t)} \quad t = 0.2124 \text{ in.}$$

$$\text{Use } t = \frac{1}{4} \text{ in.}$$ **Ans.**

For pin $A$,

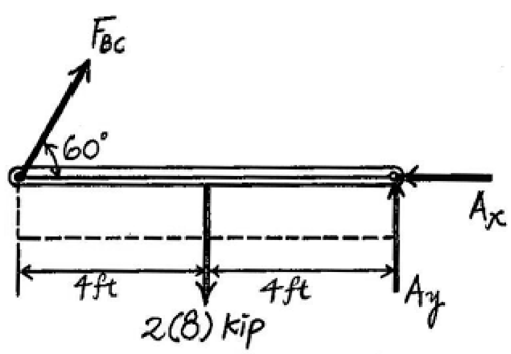
$$\tau_{allow} = \frac{V_A}{A_A}; \quad 10 = \frac{9.238}{\frac{\pi}{4} d_A^2} \quad d_A = 1.085 \text{ in.}$$

$$\text{Use } d_A = 1\frac{1}{8} \text{ in}$$ **Ans.**

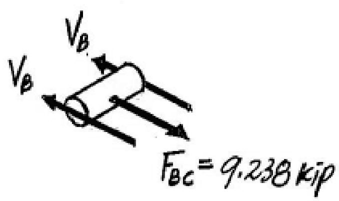
For pin $B$,

$$\tau_{allow} = \frac{V_B}{A_B}; \quad 10 = \frac{4.619}{\frac{\pi}{4} d_B^2} \quad d_B = 0.7669 \text{ in}$$

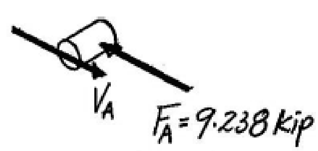
$$\text{Use } d_B = \frac{13}{16} \text{ in}$$ **Ans.**




(a)




(b)




(c)