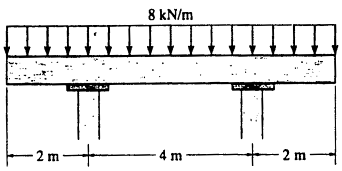
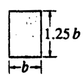
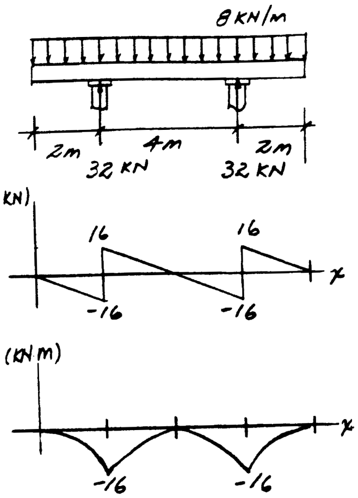
11–1 The simply supported beam is made of timber that has an allowable bending stress of $\sigma_{allow} = 6.5$ MPa and an allowable shear stress of $\tau_{allow} = 500$ kPa. Determine its dimensions if it is to be rectangular and have a height-to-width ratio of 1.25.







$$I_x = \frac{1}{12}(b)(1.25b)^3 = 0.16276b^4$$

$$Q_{max} = \bar{y}'A' = (0.3125b)(0.625b)(b) = 0.1953125b^3$$

Assume bending moment controls :

$$M_{max} = 16\ \text{kN}\cdot\text{m}$$

$$\sigma_{allow} = \frac{M_{max}c}{I}$$

$$6.5(10^6) = \frac{16(10^3)(0.625b)}{0.16276b^4}$$

$b = 0.21143\text{m} = 211$ mm **Ans**

h = 1.25b = 264mm Ans

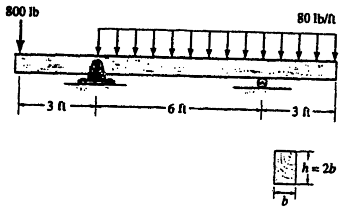
Check shear :

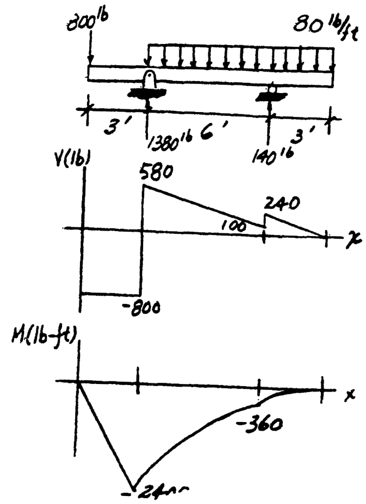
$$Q_{max} = 1.846159(10^{-3})\ \text{m}^3$$

$$I = 0.325248(10^{-3})\text{m}^4$$

$$\tau_{max} = \frac{VQ_{max}}{It} = \frac{16(10^3)(1.846159)(10^{-3})}{0.325248(10^{-3})(0.21143)} = 429\ \text{kPa} < 500\ \text{kPa} \qquad \text{OK}$$

11-2. The beam is made of Douglas fir having an allowable bending stress of $\sigma_{allow} = 1.1$ ksi and an allowable shear stress of $\tau_{allow} = 0.70$ ksi. Determine the width b of the beam if the height $h = 2b$.





$$I_x = \frac{1}{12}(b)(2b)^3 = 0.6667\ b^4$$

$$Q_{max} = \bar{y}'A' = (0.5b)(b)(b) = 0.5b^3$$

Assume bending moment controls :

$$M_{max} = 2400\ \text{lb} \cdot \text{ft}$$

$$\sigma_{allow} = \frac{M_{max}\,c}{I}$$

$$1100 = \frac{2400(12)(b)}{0.6667b^4}$$

$b = 3.40$ in. **Ans**

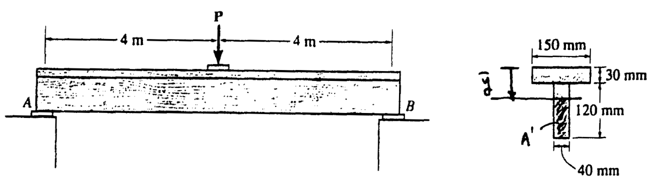
Check shear :

$$Q_{max} = 19.65\ \text{in}^3$$

$$I = 89.09\ \text{in}^4$$

$$\tau_{max} = \frac{VQ_{max}}{It} = \frac{800(19.65)}{89.09(3.40)} = 51.9\ \text{psi} < 700\ \text{psi} \quad \text{OK}$$

11–3 The timber beam is to be loaded as shown. If the ends support only vertical forces, determine the greatest magnitude of **P** that can be applied. $\sigma_{allow} = 25$ MPa, $\tau_{allow} = 700$ kPa.



$$\bar{y} = \frac{(0.015)(0.150)(0.03) + (0.09)(0.04)(0.120)}{(0.150)(0.03) + (0.04)(0.120)} = 0.05371 \text{ m}$$

$$I = \frac{1}{12}(0.150)(0.03)^3 + (0.15)(0.03)(0.05371 - 0.015)^2 + \frac{1}{12}(0.04)(0.120)^3 + (0.04)(0.120)(0.09 - 0.05371)^2 = 19.162(10^{-6}) \text{ m}^4$$

Maximum moment at center of beam :

$$M_{max} = \frac{P}{2}(4) = 2P$$

$$\sigma = \frac{Mc}{I}; \qquad 25(10^6) = \frac{(2P)(0.15 - 0.05371)}{19.162(10^{-6})}$$

$$P = 2.49 \text{ kN}$$

Maximum shear at end of beam :

$$V_{max} = \frac{P}{2}$$

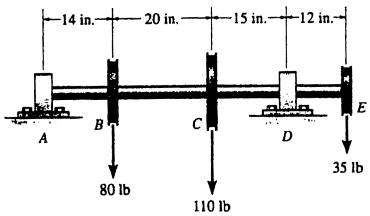
$$\tau = \frac{VQ}{It}; \qquad 700(10^3) = \frac{\left[\frac{1}{2}(0.15 - 0.05371)(0.04)(0.15 - 0.05371)\right]}{19.162(10^{-6})}$$

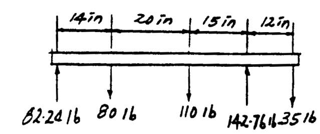
$$P = 145 \text{ kN}$$

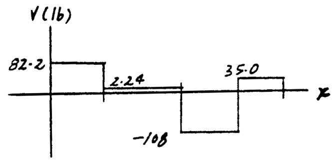
Thus,

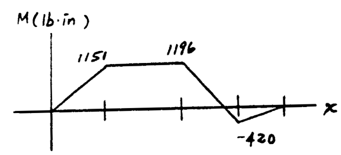
$P = 2.49$ kN **Ans**

•11–4 Draw the shear and moment diagrams for the shaft, and determine its required diameter to the nearest $\frac{1}{4}$ in. if $\sigma_{allow} = 7$ ksi and $\tau_{allow} = 3$ ksi. The bearings at A and D exert only vertical reactions on the shaft. The loading is applied to the pulleys at B, C, and E.









$$\sigma_{allow} = \frac{M_{max}\,c}{I}$$

$$7(10^3) = \frac{1196\,c}{\frac{\pi}{4}c^4}; \qquad c = 0.601 \text{ in.}$$

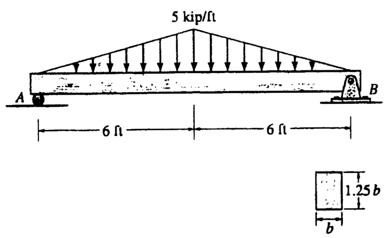
$$d = 2c = 1.20 \text{ in.}$$

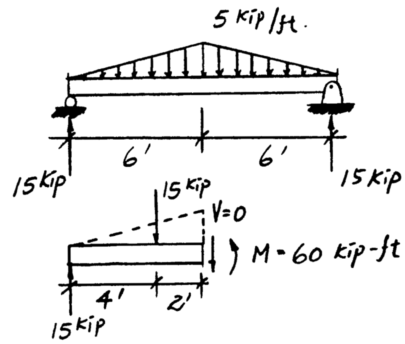
Use $d = 1.25$ in. **Ans**

Check shear :

$$\tau_{max} = \frac{V_{max}\,Q}{I\,t} = \frac{108\left(\frac{4(0.625)}{3\pi}\right)(\pi)\left(\frac{0.625^2}{2}\right)}{\frac{\pi}{4}(0.625)^4(1.25)} = 117 \text{ psi} < 3 \text{ ksi} \qquad \text{OK}$$

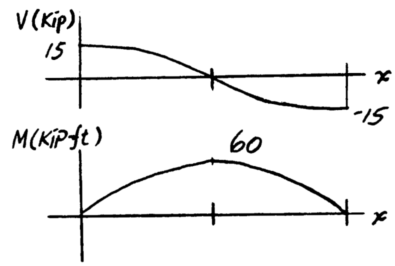
11–5 The simply supported beam is made of timber that has an allowable bending stress of $\sigma_{allow} = 960$ psi and an allowable shear stress of $\tau_{allow} = 75$ psi. Determine its dimensions if it is to be rectangular and have a height-to-width ratio of 1.25.





$$I = \frac{1}{12}(b)(1.25b)^3 = 0.16276b^4$$

$$S_{req'd} = \frac{I}{c} = \frac{0.16276b^4}{0.625b} = 0.26042b^3$$



Assume bending moment controls :

$$M_{max} = 60 \text{ kip} \cdot \text{ft}$$

$$\sigma_{allow} = \frac{M_{max}}{S_{req'd}}$$

$$960 = \frac{60(10^3)(12)}{0.26042\, b^3}$$

$b = 14.2$ in.

Check shear :

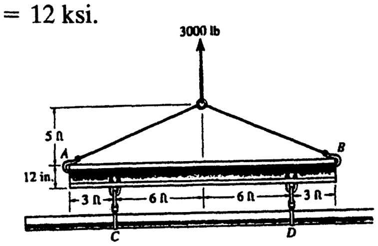
$$\tau_{max} = \frac{1.5V}{A} = \frac{1.5(15)(10^3)}{(14.2)(1.25)(14.2)} = 88.9 \text{ psi} > 75 \text{ psi} \qquad \text{NG}$$

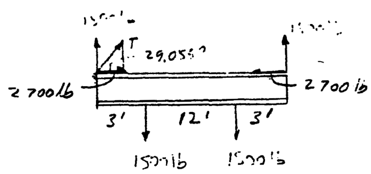
Shear controls :

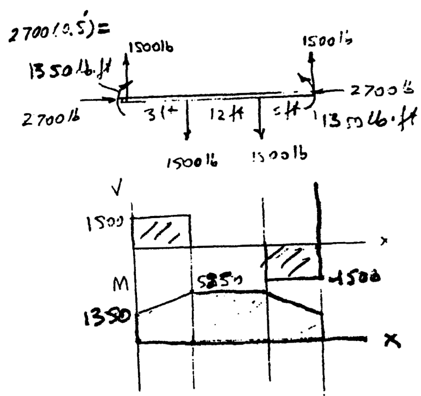
$$\tau_{allow} = \frac{1.5V}{A} = \frac{1.5(15)(10^3)}{(b)(1.25b)}$$

$b = 15.5$ in. **Ans**

11-6. The spreader beam AB is used to lift slowly the 3000-lb pipe that is centrally located on the straps at C and D. If the beam is a $W\,12 \times 45$, determine if it can safely support the load. The allowable bending stress is $\sigma_{\text{allow}} = 22$ ksi and the allowable shear stress is $\tau_{\text{allow}} = 12$ ksi.







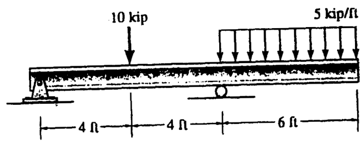
$$h = \frac{1500}{\tan 29.055^\circ} = 2700 \text{ lb}$$

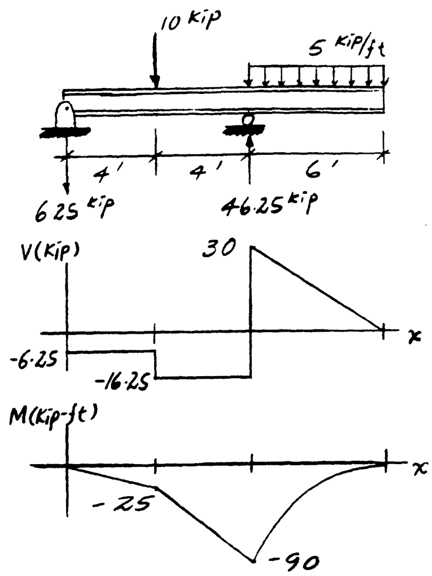
$$\sigma = \frac{M}{S}; \qquad \sigma = \frac{5850(12)}{58.1} = 1.21 \text{ ksi} < 22 \text{ ksi} \qquad \textbf{OK}$$

$$\tau = \frac{V}{A_{web}}; \qquad \tau = \frac{1500}{(12.06)(0.335)} = 371 \text{ psi} < 12 \text{ ksi} \qquad \textbf{OK}$$

Yes. **Ans**

11–7 Select the lightest-weight steel wide-flange beam from Appendix *B* that will safely support the loading shown. The allowable bending stress is $\sigma_{allow} = 24$ ksi and the allowable shear stress is $\tau_{allow} = 14$ ksi.





Assume bending moment controls.

$M_{max} = 90 \text{ kip} \cdot \text{ft}$

$$S_{req'd} = \frac{M_{max}}{\sigma_{allow}} = \frac{90(12)}{24} = 45 \text{ in}^3$$

Select a W 16 x 31

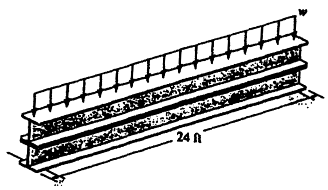
$S_x = 47.5 \text{ in}^3$ $\quad d = 15.88$ in. $\quad t_w = 0.275$ in.

Check shear :

$$\tau_{max} = \frac{V_{max}}{A_w} = \frac{30}{(15.88)(0.275)} = 6.87 \text{ ksi} < 14 \text{ ksi} \qquad \text{OK}$$

Use W 16 x 31 **Ans**

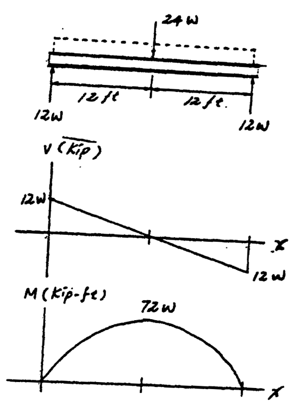
***11-8.** The simply supported beam is composed of two $W\ 12 \times 22$ sections built up as shown. Determine the maximum uniform loading w the beam will support if the allowable bending stress is $\sigma_{allow} = 22$ ksi and the allowable shear stress is $\tau_{allow} = 14$ ksi.



Section properties : For $W\ 12 \times 22$ ($d = 12.31$ in. $I_x = 156\ \text{in}^4$ $t_w = 0.260$ in. $A = 6.48\ \text{in}^2$)

$$I = 2[156 + 6.48(\frac{12.31}{2})^2] = 802.98\ \text{in}^4$$

$$S = \frac{I}{c} = \frac{802.98}{12.31} = 65.23\ \text{in}^3$$



Maximum Loading : Assume moment controls.

$$M = \sigma_{allow} S$$

$$(72\,w)(12) = 22(65.23)$$

$$w = 1.66\ \text{kip / ft} \qquad \textbf{Ans}$$

Check Shear : (Neglect area of flanges.)

$$\tau_{max} = \frac{V_{max}}{A_w} = \frac{12(1.66)}{2(12.31)(0.26)} = 3.11\ \text{ksi} < \tau_{allow} = 14\ \text{ksi} \quad \textbf{OK}$$