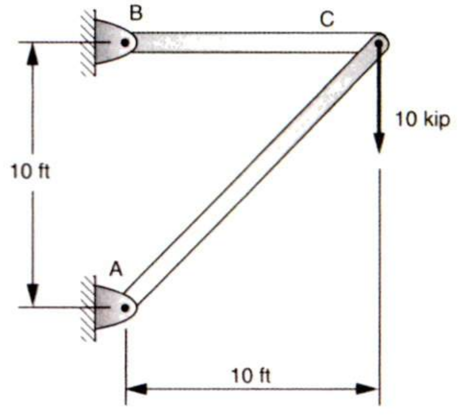
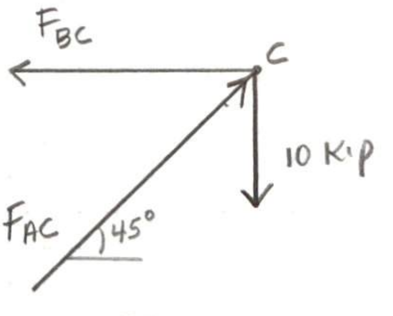
Solution.

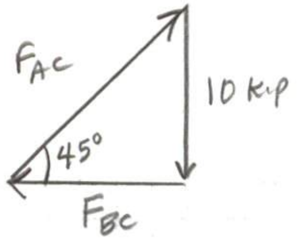
1. The bracket shown is supported by pins at each support and both members are two-force members. Calculate the stress in both members if the cross-sectional area in both is 3 in^2. Also determine the change of length in each member if E = 30 x 10^6 psi.



Solution.



FBD



Force- Triangle

$$\tan 45° = \frac{10 \text{ kip}}{F_{BC}}$$

$$F_{BC} = \frac{10 \text{ kip}}{\tan 45°} = 10 \text{ kip (T)}$$

$$F_{AC} = \sqrt{10 \text{ kip}^2 + 10 \text{ kip}^2} = 14.1 \text{ kip(c)}$$

MEMBER AC

$$\sigma = \frac{F_{AC}}{A} = \frac{14.1 \text{ kip}}{3 \text{ in}^2} = 4.7 \text{ ksi}$$

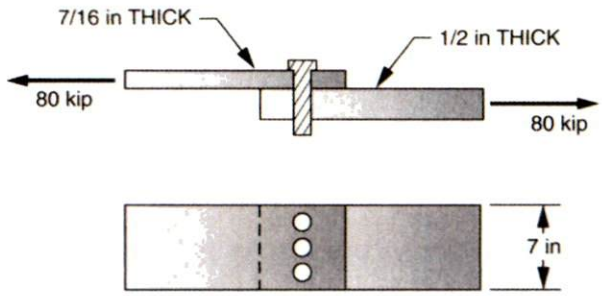
$$\delta = \sigma\left(\frac{L}{E}\right) = 4.7 \text{ ksi}\left(\frac{\sqrt{10 \text{ ft}^2 + 10 \text{ ft}^2}\ \left(\frac{12 \text{ in}}{\text{ft}}\right)}{30{,}000 \text{ ksi}}\right) = 0.0266 \text{ in}$$

Member BC

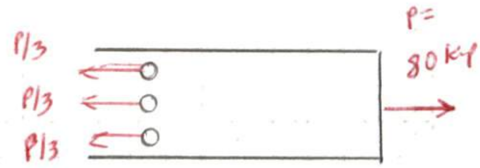
$$\sigma = \frac{F_{BC}}{A} = \frac{10 \text{ kip}}{3 \text{ in}^2} = 3.33 \text{ ksi}$$

$$\delta = \sigma\left(\frac{L}{E}\right) = 3.33 \text{ ksi}\left(\frac{10 \text{ ft} \times \frac{12 \text{ in}}{\text{ft}}}{30{,}000 \text{ ksi}}\right) = 0.0133 \text{ in.}$$

2. The connection shown is pulled on with 80 kip of force. Calculate the shear stresses that will need to be developed in the ¾ in. diameter bolts.



Solution.

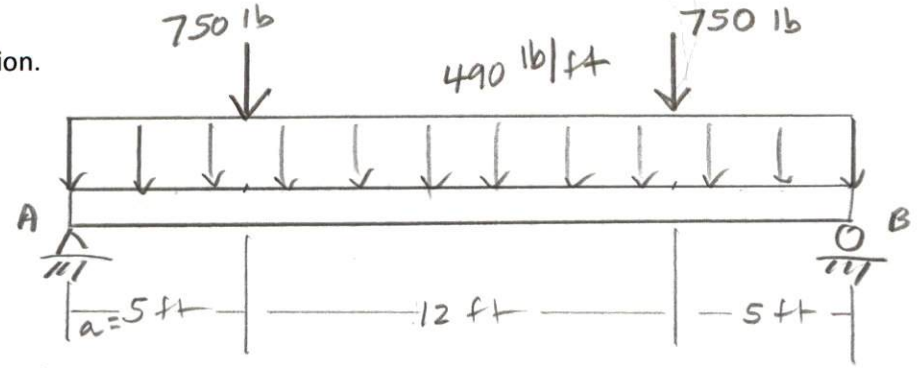


$$A = \frac{\pi d^2}{4} = \frac{\pi (0.75\,\text{in})^2}{4}$$

$$\tau = \frac{P}{A} = \frac{80\ \text{kip}/3}{\frac{\pi (0.75\,\text{in})^2}{4}} = 60.4\ \text{ksi}$$

3. Select a solid, rectangular, California redwood beam section for a 22-ft simple span carrying a uniform load of 490 lb/ft across the entire span and point loads 5 ft from the ends of 750 lb each.

Solution.



Step 1.

$L = 22\ ft \times \frac{12 in}{ft} = 264\ in.$

$w = 490\ lb/ft$

$P = 750\ lb$

$a = 5\ ft$

Table 15-2

$\sigma_{Allow} = 1350\ psi$

$\tau_{allow} = 100\ psi$

Step 2. Table 13-1 case 3 and case 4

$$V_{MAX} = P + \frac{wL}{2} = 750\ lb + \frac{\frac{490\ lb}{ft}(22\ ft)}{2} = 6140\ lb$$

$$M_{MAX} = Pa + \frac{wL^2}{8} = 750\ lb(5\ ft) + \frac{\frac{490\ lb}{ft}(22\ ft)^2}{8} = 33{,}395\ lb\cdot ft$$

Step 3.

$$S_{req} = \frac{M_{MAX}}{\sigma_{allow}} = \frac{33{,}395\ lb\cdot ft\left(\frac{12 in}{ft}\right)}{1350\ lb/in^2} = 296.8\ in^3$$

Step 4.

$$A_{req} = \frac{1.5\,V_{MAX}}{\tau_{allow}} = \frac{1.5(6140\ lb)}{100\ lb/in^2} = 92.1\ in.^2$$

Step 5. Table A-6(a)

8×16 $A = 116\ in^2$ $S = 300\ in^3$ $wt = 32.3\ lb/ft$

$\boxed{\text{Use, 8×16 Beam}}$ (Neglect Beam wt)

Check,

$$M_{wt} = \frac{32.3\ lb/ft\ (22ft)^2}{8} = 1954.15\ lb\cdot ft$$

$$\frac{M_{wt}}{M_{MAX}} = \frac{1954.15\ lb\cdot ft}{33395\ lb\cdot ft} = 0.06 = 6\%$$

$$\frac{Extra\ S}{S_{req}} = \frac{300\ in^3 - 296.8\ in^3}{296.8\ in^3} = 0.011 = 1.1\% < 6\%$$

Fails

$\boxed{\text{Try } 8 \times 18}$ $A = 131\ in^2$ $S = 383\ in^3$ $wt = 36.5\ lb/ft$

$$M_{wt} = \frac{36.5\ lb/ft\ (22ft)^2}{8} = 2208.25\ lb\ ft$$

$$\frac{M_{wt}}{M_{MAX}} = \frac{2208.25}{33395} = 0.66 = 6.6\%$$

$$\frac{Extra\ S}{S_{req}} = \frac{383 - 296.8}{296.8} = 0.29 = 29\% > 6.6\% \checkmark$$

ok, bending

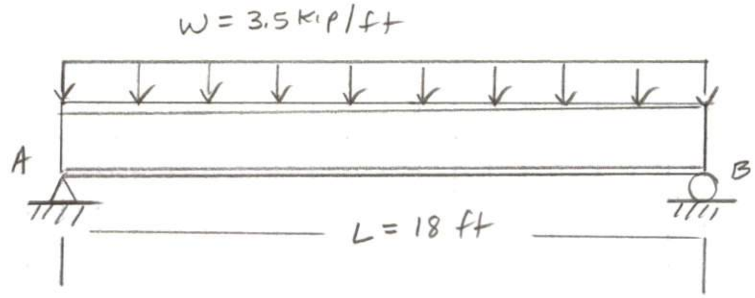
$$\frac{Extra\ A}{A_{req}} = \frac{131 - 61.4}{61.4} = 1.13 = 113\% > 6.6\% \checkmark$$

ok, Shear

$\boxed{\text{use, } 8 \times 18 \text{ Rectangular Section}}$

4. Select the lightest wide flange steel beam section for a simply supported beam with an 18-ft span length carrying a uniform load of 3.5 Kip/ft which includes the beam weight. The beam is supported laterally for its entire length. Use A36 steel.

Solution.



Step 1.

A36 Steel

$\sigma_{allow} = 24$ ksi

$\tau_{allow} = 14.5$ ksi

$L = 18 \text{ ft} \left(\frac{12 \text{ in}}{\text{ft}}\right) = 216$ in.

$w = 3.5$ kip/ft

Step 2. Table 13-1, case 4

$$V_{MAX} = \frac{wL}{2} = \frac{3.5 \text{ kip/ft} (18 \text{ ft})}{2} = 31.5 \text{ kip}$$

$$M_{MAX} = \frac{wL^2}{8} = \frac{3.5 \text{ kip/ft} (18 \text{ ft})^2}{8} = 141.75 \text{ kip}\cdot\text{ft}$$

Step 3.

$$S_{req} = \frac{M_{MAX}}{\sigma_{allow}} = \frac{141.75 \text{ kip}\cdot\text{ft} \left(\frac{12 \text{ in}}{\text{ft}}\right)}{24 \text{ ksi}} = 70.875 \text{ in}^3$$

Step 4. Table A-1(a)

W 14 × 53 $S = 77.8 \text{ in}^3$

W 16 × 50 $S = 81.0 \text{ in}^3$

W 18 × 46 $S = 78.8 \text{ in}^3$ lightest

Select W 18 × 46

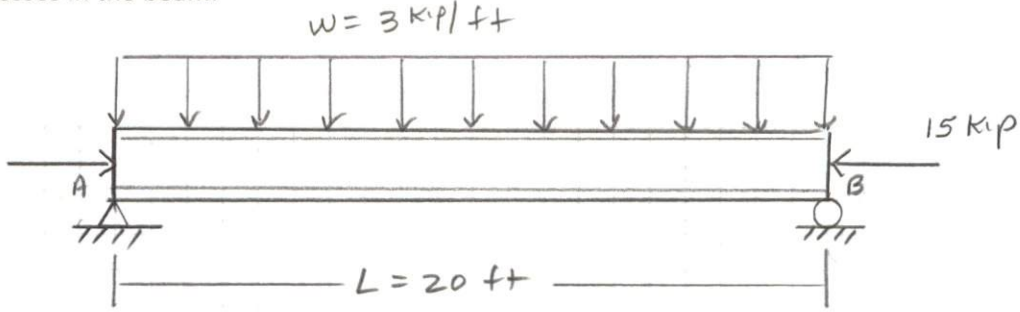
$d = 18.06$ in

$t_w = 0.360$ in

$$\tau_{avg} = \frac{31.5 \text{ kip}}{18.06 \text{ in} (0.36 \text{ in})} = 4.8 \text{ ksi} < \tau_{allow} = 14.5 \text{ ksi}$$

✓ ok, shear

5. A W16x50 section has a simple span of 20-ft. The beam is subjected to a compressive axial force of 15 kip acting at the centroid and a uniform distributed load of w = 3 kip/ft. Determine the maximum compressive and tensile stresses in the beam.



W16 X 50 Table A-1(a)

$A = 14.7 \text{ in}^2$

$S = 81.0 \text{ in}^3$

Axial Load

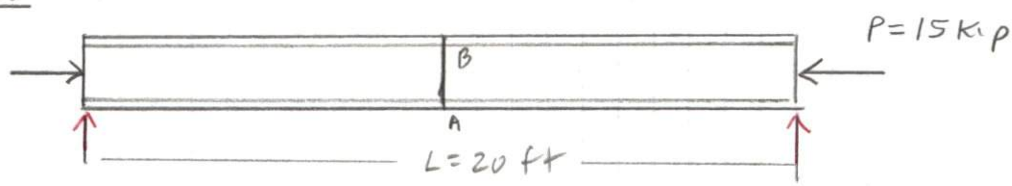
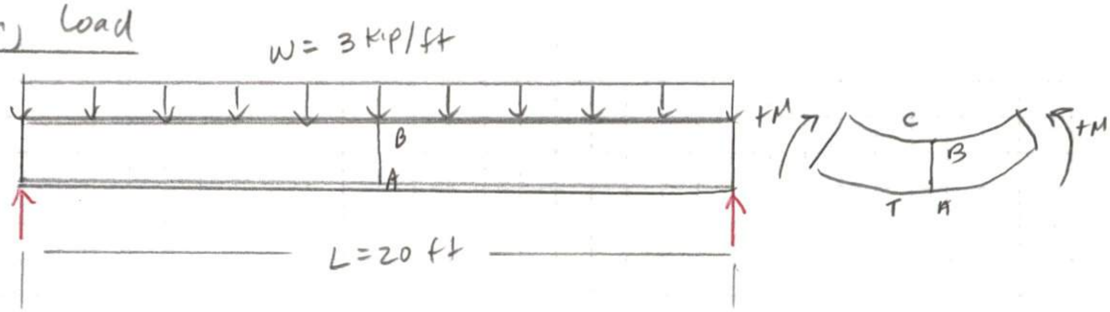


Table 18-1

$$\sigma_A = \sigma_B = \frac{P}{A} = \frac{-15 \text{ kip}}{14.7 \text{ in}^2} = -1.0 \text{ ksi} \quad \text{(constant Compressive stress)}$$

Beam Bending Load



AT midspan

$$M_{MAX} = \frac{wL^2}{8} = \frac{3 \text{kip/ft} \, (20 \text{ft})^2}{8} = 150 \text{ kip}\cdot\text{ft}$$

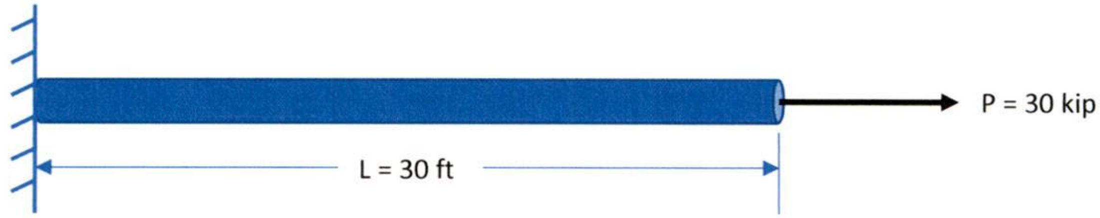
Normal Stress at A

$$\sigma_A = -1.0 \text{ ksi} + \frac{150 \text{ K.p}\cdot\text{ft} \left(\frac{12 \text{in}}{\text{ft}}\right)}{81 \text{ in}^3} = 21.2 \text{ ksi} \quad (T)$$

Normal Stress at B

$$\sigma_B = -1.0 \text{ ksi} - \frac{150 \text{ kip}\cdot\text{ft} \, (12)}{81 \text{ in}^3} = -23.2 \text{ ksi} \quad (C)$$

6. The titanium rod shown has a 30-kip load applied to the rod causing it to deform by 0.37 inches.
   A. Determine the diameter of the rod to the nearest ¼ in.
   B. Determine the strain in the rod.



A. $A = \frac{\pi d^2}{4}$ $\quad \delta = \frac{P L_o}{A E}$ $\quad \epsilon = \frac{\delta}{L_o}$

$\delta = 0.37 \text{ in.}$

$P = 30 \text{ kip}$

$E = 16.5 \times 10^3 \text{ ksi}$ Table A-7(a)

$$A = \frac{P L_o}{\delta E} = \frac{30 \text{ kip}\left(30 \text{ ft}\left(\frac{12 \text{ in}}{\text{ft}}\right)\right)}{0.37 \text{ in.}\left(16.5 \times 10^3 \text{ ksi}\right)} = 1.769 \text{ in}^2$$

$$A = \frac{\pi d^2}{4} = 1.769 \text{ in}^2$$

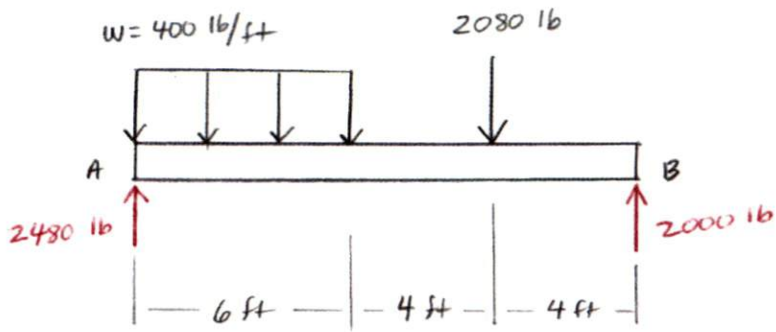
$$d = \sqrt{\frac{4(1.769 \text{ in.}^2)}{\pi}} = 1.5008 \text{ in.}$$

use, $d = 1\text{-}\frac{1}{2}$ in. (Rod diameter)

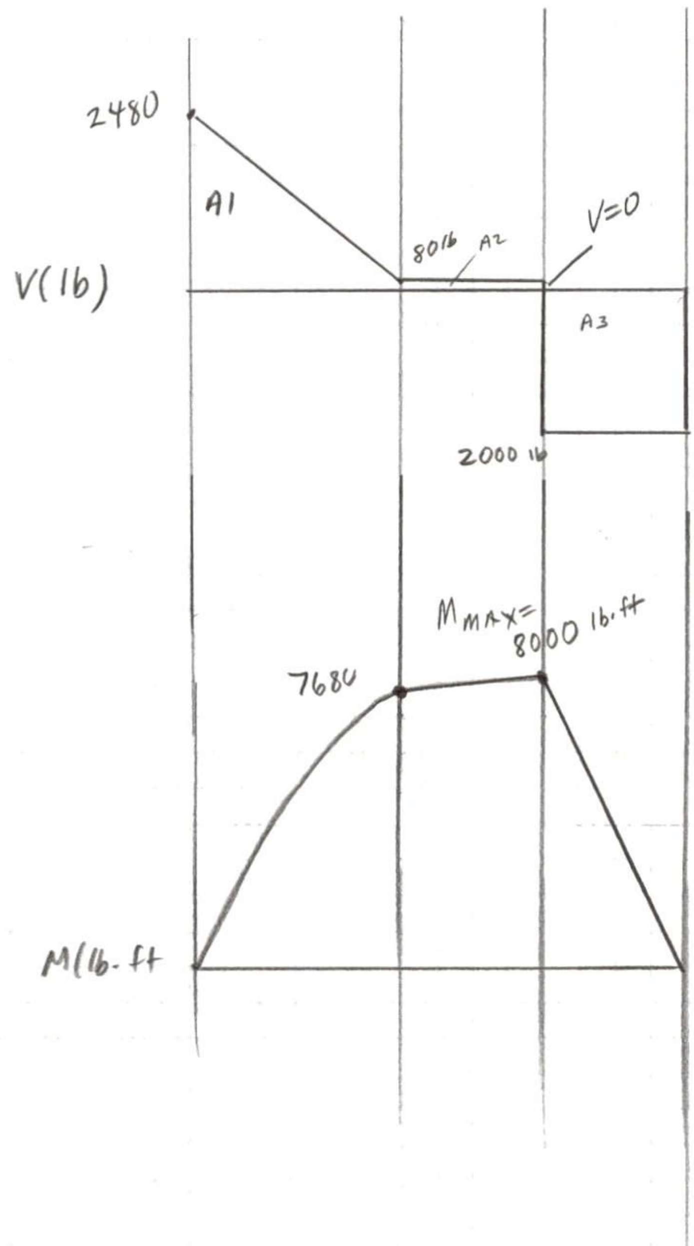
B. $$\epsilon = \frac{\delta}{L_o} = \frac{0.37 \text{ in}}{30 \text{ ft}\left(\frac{12 \text{ in}}{\text{ft}}\right)} = 0.001028$$

or 1.028×10^{-3}

7. Draw the shear and bending moment diagrams for the beam due to the loading shown. Locate the section with zero shear (if any) and determine the moment at the section.



Solution.



A1

$\frac{1}{2}(6ft)(2400\ lb) + 6ft(80\ lb)$

$= 7680\ lb.ft$

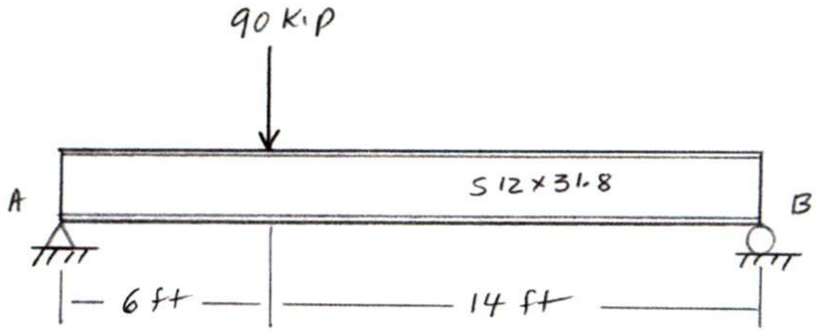
A2

$4ft\ (80lb) = 320\ lb.ft$

A3

$4f\ (2000\ lb) = 8000\ lb.ft$

8. An American Standard S12 x 31.8 beam is simply supported and loaded as shown. Determine if the beam is satisfactory for shear. Use A36 steel.



Solution.

A36 Steel

$\tau_{allow} = 14.5 \text{ ksi}$

Table A-2(a)

S12 X 31.8

$d = 12.00 \text{ in.}$

$t_w = 0.35 \text{ in.}$

Table 13-1, case 2

$$V_{MAX} = \frac{Pb}{L} = \frac{90 \text{ kip}\,(14 \text{ ft})}{20 \text{ ft}}$$

$$= 63 \text{ kip}$$

$$\tau_{avg} = \frac{V_{MAX}}{d\,t_w} = \frac{63 \text{ kip}}{(12.0 \text{ in.})(0.35 \text{ in.})} = 15 \text{ ksi} > \tau_{allow} = 14.5 \text{ ksi}$$

∴ Beam is not satisfactory for shear