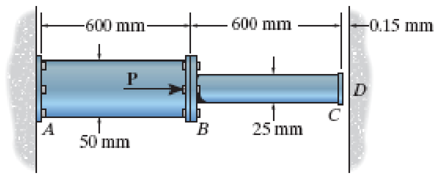
HW#4 Key Solutions

4-46. If the gap between C and the rigid wall at D is initially 0.15 mm, determine the support reactions at A and D when the force $\mathbf{P}$ = 200 kN is applied. The assembly is made of A36 steel.



Equation of Equilibrium: Referring to the free-body diagram of the assembly shown in Fig. a,

$$\xrightarrow{+} \Sigma F_x = 0; \qquad 200(10^3) - F_D - F_A = 0 \qquad \textbf{(1)}$$

Compatibility Equation: Using the method of superposition, Fig. b,

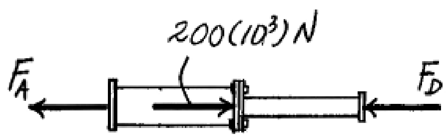
$$(\xrightarrow{+}) \qquad \delta = \delta_P - \delta_{F_D}$$

$$0.15 = \frac{200(10^3)(600)}{\frac{\pi}{4}(0.05^2)(200)(10^9)} - \left[\frac{F_D(600)}{\frac{\pi}{4}(0.05^2)(200)(10^9)} + \frac{F_D(600)}{\frac{\pi}{4}(0.025^2)(200)(10^9)}\right]$$

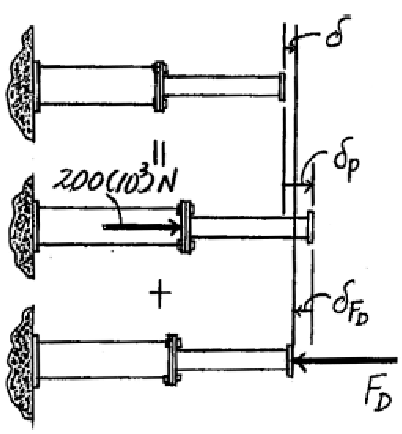
$$F_D = 20\,365.05 \text{ N} = 20.4 \text{ kN} \qquad \textbf{Ans.}$$

Substituting this result into Eq. (1),

$$F_A = 179\,634.95 \text{ N} = 180 \text{ kN} \qquad \textbf{Ans.}$$

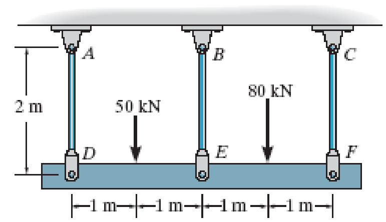


(a)



(b)

4–55. The three suspender bars are made of A-36 steel and have equal cross-sectional areas of 450 mm^2. Determine the average normal stress in each bar if the rigid beam is subjected to the loading shown.



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

$$+\uparrow \Sigma F_y = 0; \qquad F_{AD} + F_{BE} + F_{CF} - 50(10^3) - 80(10^3) = 0 \qquad (1)$$

$$\circlearrowleft + \Sigma M_D = 0; \qquad F_{BE}(2) + F_{CF}(4) - 50(10^3)(1) - 80(10^3)(3) = 0 \qquad (2)$$

Referring to the geometry shown in Fig. *b*,

$$\delta_{BE} = \delta_{AD} + \left(\frac{\delta_{CF} - \delta_{AD}}{4}\right)(2)$$

$$\delta_{BE} = \frac{1}{2}\left(\delta_{AD} + \delta_{CF}\right)$$

$$\frac{F_{BE}\cancel{L}}{\cancel{AE}} = \frac{1}{2}\left(\frac{F_{AD}\cancel{L}}{\cancel{AE}} + \frac{F_{CF}\cancel{L}}{\cancel{AE}}\right)$$

$$F_{AD} + F_{CF} = 2F_{BE} \qquad (3)$$

Solving Eqs. (1), (2) and (3) yields

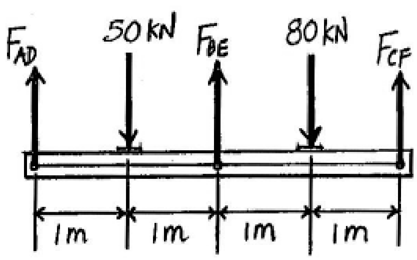
$$F_{BE} = 43.33(10^3)\text{ N} \qquad F_{AD} = 35.83(10^3)\text{ N} \qquad F_{CF} = 50.83(10^3)\text{ N}$$

Thus,

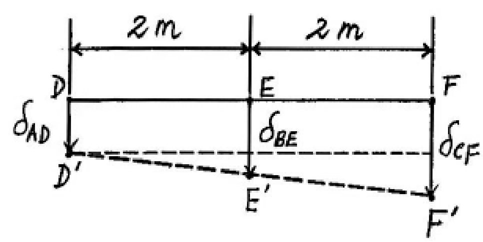
$$\sigma_{BE} = \frac{F_{BE}}{A} = \frac{43.33(10^3)}{0.45(10^{-3})} = 96.3\text{ MPa} \qquad \textbf{Ans.}$$

$$\sigma_{AD} = \frac{F_{AD}}{A} = \frac{35.83(10^3)}{0.45(10^{-3})} = 79.6\text{ MPa} \qquad \textbf{Ans.}$$

$$\sigma_{CF} = 113\text{ MPa} \qquad \textbf{Ans.}$$

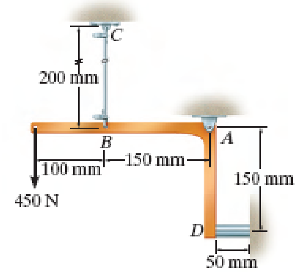


(a)



(b)

4–62. The rigid link is supported by a pin at A, a steel wire BC having an unstretched length of 200 mm and cross-sectional area of 22.5 mm^2, and a short aluminum block having an unloaded length of 50 mm and cross-sectional area of 40 mm^2. If the link is subjected to the vertical load shown, determine the average normal stress in the wire and the block. $E_{st} = 200$ GPa, $E_{al} = 70$ GPa.



Equations of Equilibrium:

$\zeta + \Sigma M_A = 0; \qquad 450(250) - F_{BC}(150) - F_D(150) = 0$

$$750 - F_{BC} - F_D = 0 \qquad \textbf{[1]}$$

Compatibility:

$$\delta_{BC} = \delta_D$$

$$\frac{F_{BC}(200)}{22.5(10^{-6})200(10^9)} = \frac{F_D(50)}{40(10^{-6})70(10^9)}$$

$$F_{BC} = 0.40179\, F_D \qquad \textbf{[2]}$$

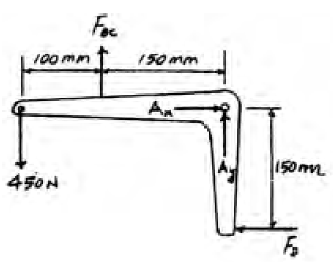
Solving Eqs. [1] and [2] yields:

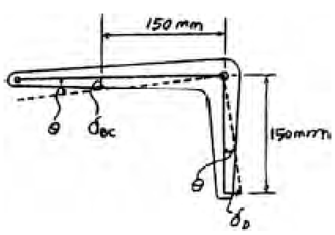
$$F_D = 535.03 \text{ N} \qquad F_{BC} = 214.97 \text{ N}$$

Average Normal Stress:

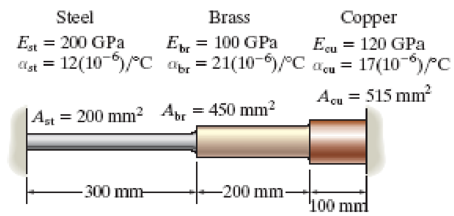
$$\sigma_D = \frac{F_D}{A_D} = \frac{535.03}{40(10^{-6})} = 13.4 \text{ MPa} \qquad \textbf{Ans.}$$

$$\sigma_{BC} = \frac{F_{BC}}{A_{BC}} = \frac{214.97}{22.5(10^{-6})} = 9.55 \text{ MPa} \qquad \textbf{Ans.}$$





•4–69. Three bars each made of different materials are connected together and placed between two walls when the temperature is $T_1 = 12°\text{C}$. Determine the force exerted on the (rigid) supports when the temperature becomes $T_2 = 18°\text{C}$. The material properties and cross-sectional area of each bar are given in the figure.

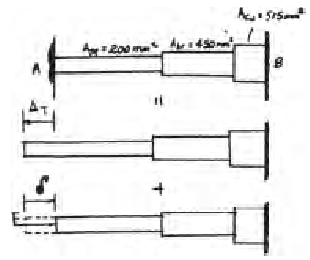


$(\overset{+}{\leftarrow})\qquad 0 = \Delta_T - \delta$

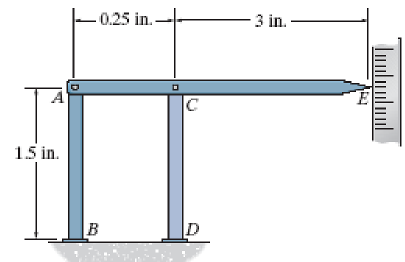
$$0 = 12(10^{-6})(6)(0.3) + 21\,(10^{-6})(6)(0.2) + 17\,(10^{-6})(6)(0.1)$$

$$-\frac{F(0.3)}{200(10^{-6})(200)(10^9)} - \frac{F(0.2)}{450(10^{-6})(100)(10^9)} - \frac{F(0.1)}{515(10^{-6})(120)(10^9)}$$

$$F = 4203\ \text{N} = 4.20\ \text{kN}$$ **Ans.**



*4–76. The device is used to measure a change in temperature. Bars AB and CD are made of A-36 steel and 2014-T6 aluminum alloy respectively. When the temperature is 75°F, ACE is in the horizontal position. Determine the vertical displacement of the pointer at E when the temperature rises to 150°F.



Thermal Expansion:

$$(\delta_T)_{CD} = \alpha_{al}\Delta T L_{CD} = 12.8(10^{-6})(150 - 75)(1.5) = 1.44(10^{-3})\ \text{in.}$$

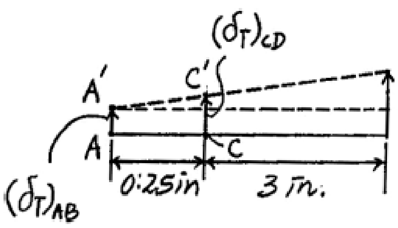
$$(\delta_T)_{AB} = \alpha_{st}\Delta T L_{AB} = 6.60(10^{-6})(150 - 75)(1.5) = 0.7425(10^{-3})\ \text{in.}$$

From the geometry of the deflected bar AE shown Fig. b,

$$\delta_E = (\delta_T)_{AB} + \left[\frac{(\delta_T)_{CD} - (\delta_T)_{AB}}{0.25}\right](3.25)$$

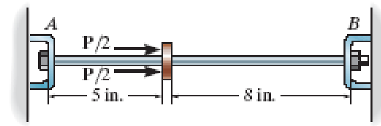
$$= 0.7425(10^{-3}) + \left[\frac{1.44(10^{-3}) - 0.7425(10^{-3})}{0.25}\right](3.25)$$

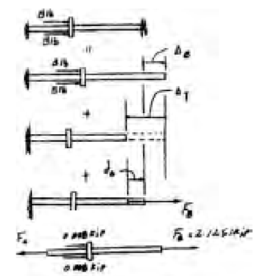
$$= 0.00981\ \text{in.}$$ **Ans.**



(a)

4–114. The 2014-T6 aluminum rod has a diameter of 0.5 in. and is lightly attached to the rigid supports at A and B when $T_1 = 70°\text{F}$. If the temperature becomes $T_2 = -10°\text{F}$, and an axial force of $P = 16$ lb is applied to the rigid collar as shown, determine the reactions at A and B.





$$\xrightarrow{+} \quad 0 = \Delta_B - \Delta_T + \delta_B$$

$$0 = \frac{0.016(5)}{\frac{\pi}{4}(0.5^2)(10.6)(10^3)} - 12.8(10^{-6})[70° - (-10°)](13) + \frac{F_B(13)}{\frac{\pi}{4}(0.5^2)(10.6)(10^3)}$$

$F_B = 2.1251 \text{ kip} = 2.13 \text{ kip}$ **Ans.**

$\xrightarrow{+} \Sigma F_x = 0; \qquad 2(0.008) + 2.1251 - F_A = 0$

$F_A = 2.14 \text{ kip}$ **Ans.**