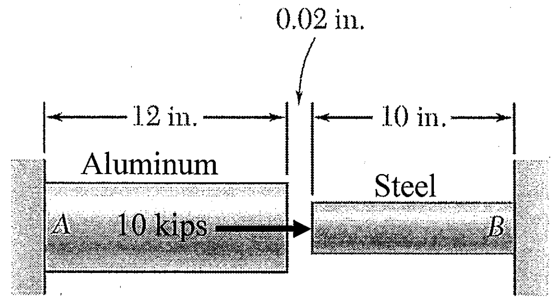
1) GIVEN: Before the 10 kip load is applied, a 0.02-in. gap exists between the ends of the rods when at room temperature (70 °F). (B9.46)

Aluminum	Steel
$A = 2.8\ in^2$	$A = 1.2\ in^2$
$E = 10.4 \times 10^6$ psi	$E = 29.0 \times 10^6$ psi
$\alpha = 13.3 \times 10^{-6}/°F$	$\alpha = 9.6 \times 10^{-6}/°F$



REQ'D: (a) What will be the gap once the 10 kip load is applied?

$$\Delta L = \frac{PL}{AE} = \frac{(10000\ lb)(10\ in)}{1.2\ in^2(29\times10^6\ psi)} = 2.874\times10^{-3}\ in \quad \text{SHORTER}$$

$$\text{NEW GAP} = 0.02\ in + 2.874\times10^{-3}\ in = \underline{\underline{0.02287\ in}}$$

(b) At what temperature will the gap just close?

$$\delta_{T_A} + \delta_{T_S} = 0.02287\times10^{-3}\ in$$

$$\Delta T(\alpha_A L_A + \alpha_S L_S) = 0.02287\ in$$

$$\Delta T = \frac{0.02287\ in}{(13.3\times10^{-6}/°F)(12\ in) + (9.6\times10^{-6}/°F)(10\ in)} = \underline{89.5\ °F} \quad \text{INCREASE TO CLOSE GAP}$$

$$T = 70°F + 89.5°F = \underline{\underline{159.5\ °F}} \quad \text{REQ'D TEMP. FOR GAP TO BE CLOSED.}$$

(d) What will be the maximum stress if the bars are heated to 320 °F?

$$\delta_{AT} - \delta_{AP} + \delta_{ST} - \delta_{SP} = GAP \qquad \Delta T = 320°F - 70°F = \underline{250\ °F}$$

$$\alpha_A L_A \Delta T - \frac{PL_A}{A_A E_A} + \alpha_S L_S \Delta T - \frac{P \cdot L_S}{A_S E_S} = GAP$$

$$(13.3\times10^{-6}/°F)(12\ in)(250°F) - \frac{P(12\ in)}{2.8\ in^2(10.4\times10^6\ psi)} + (9.6\times10^{-6}/°F)(10\ in)(250°F) - \frac{P(10\ in)}{1.2\ in^2(29\times10^6\ psi)} = 0.02287\ in$$

$$63.9\times10^{-3} - P(0.6994\times10^{-6}) = 0.02287\ in$$

$P = 58.66$ kips DUE TO ΔT

$$P_{AL} = P = 58.66\ kips$$

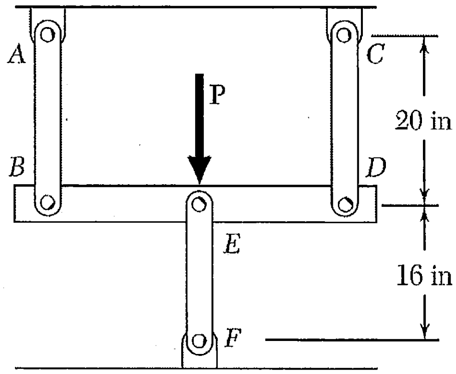
$$\sigma_{AL} = \frac{58.66\ kips}{2.8\ in^2} = \underline{\underline{20.95\ ksi\ (C)}}$$

$$P_S = 58.66 + 10\ kips = 68.66\ kips$$

$$\sigma_S = \frac{68.66\ kips}{1.2\ in^2} = \underline{\underline{57.22\ ksi\ (C)}}$$

2) GIVEN: Three steel rods ($E = 29 \times 10^6$ psi) support an 8.5-kip load **P**. Each of the rods AB and CD has a 0.32-in^2 cross-sectional area and rod EF has a 1-in^2 cross-sectional area. (B9.29)

Neglect any deformation of rod BED.



REQ'D: (a) Find the change in length of rod EF
(b) Find the stress in each rod.

BY SYMMETRY, OR BY $\Sigma M_E = 0$:

$$P_{CD} = P_{AB}$$

$$+\uparrow \Sigma F_y = 0: \quad P_{AB} + P_{CD} + P_{EF} - P = 0$$

$$P = 2P_{AB} + P_{EF}$$

$$\delta_{AB} = \frac{P_{AB}L_{AB}}{EA_{AB}} \qquad \delta_{CD} = \frac{P_{CD}L_{CD}}{EA_{CD}} \qquad \delta_{EF} = \frac{P_{EF}L_{EF}}{EA_{EF}}$$

SINCE $L_{AB} = L_{CD}$ AND $A_{AB} = A_{CD}$, $\delta_{AB} = \delta_{CD}$

SINCE POINTS A, C, AND F ARE FIXED, $\delta_B = \delta_{AB}$, $\delta_D = \delta_{CD}$, $\delta_E = \delta_{EF}$

SINCE MEMBER BED IS RIGID, $\delta_E = \delta_B = \delta_C$

$$\frac{P_{AB}L_{AB}}{EA_{AB}} = \frac{P_{EF}L_{EF}}{EA_{EF}} \qquad \therefore P_{AB} = \frac{A_{AB}}{A_{EF}} \cdot \frac{L_{EF}}{L_{AB}} P_{EF} = \frac{0.32}{1} \cdot \frac{16}{20} P_{EF} = 0.256 P_{EF}$$

$$P = 2P_{AB} + P_{EF} = 2(0.256 P_{EF}) + P_{EF} = 1.512 P_{EF}$$

$$P_{EF} = \frac{P}{1.512} = \frac{8.5}{1.512} = 5.6217 \text{ kips}$$

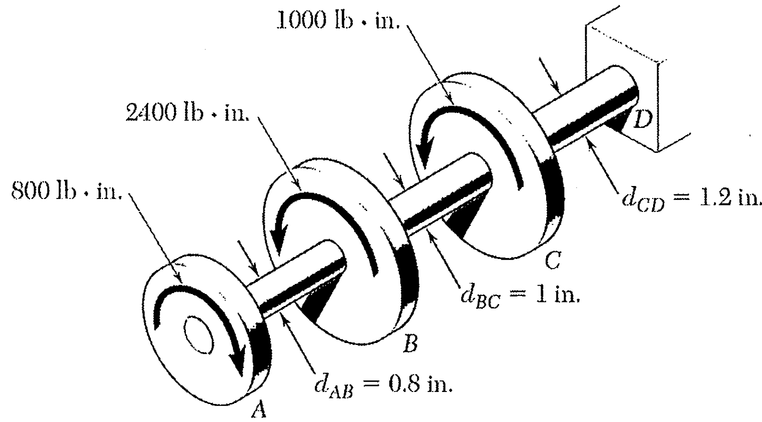
$$P_{AB} = P_{CD} = 0.256(5.6217) = 1.43916 \text{ kips}$$

(a) $$\delta_{EF} = \frac{P_{EF}L_{EF}}{EA_{EF}} = \frac{(5.6217)(16)}{(29 \times 10^3)(1)} = 0.0031016 \text{ in.}$$ $\delta_{EF} = 0.00310$ in.

(b) $$\sigma_{AB} = \sigma_{CD} = \frac{P_{AB}}{A_{AB}} = \frac{1.43916}{0.32} = 4.4974 \text{ ksi}$$ $\sigma_{AB} = \sigma_{CD} = 4.50$ ksi

$$\sigma_{EF} = \frac{P_{EF}}{A_{EF}} = \frac{5.6217}{1} = 5.6217 \text{ ksi}$$ $\sigma_{EF} = 5.62$ ksi

3) GIVEN: Solid steel shaft with pulleys spaced every 6 in and torques as shown. $G_{steel} = 11.2 \times 10^6$ psi (B10.9)



REQ'D: (a) Torque in each segment

$$T_{AB} = \underline{\underline{-800 \text{ in}\cdot\text{lb}}}$$

$$T_{BC} = -800 \text{ in}\cdot\text{lb} + 2400 \text{ in}\cdot\text{lb} = \underline{\underline{1600 \text{ in}\cdot\text{lb}}}$$

$$T_{CD} = +1600 \text{ in}\cdot\text{lb} + 1000 \text{ in}\cdot\text{lb} = \underline{\underline{2600 \text{ in}\cdot\text{lb}}}$$

(b) Maximum shear stress in [redacted] shaft. In which [redacted] SEGMENT does it occur?

$$\tau_{AB} = \frac{T_{AB} C_{AB}}{J_{AB}} = \frac{800 \text{ in}\cdot\text{lb}(0.4 \text{ in})}{\frac{\pi}{32}(0.8 \text{ in})^4 = 40.21\times10^{-3} \text{ in}^4} = \underline{7.958 \text{ ksi}}$$

$$\tau_{BC} = \frac{T_{BC} C_{BC}}{J_{BC}} = \frac{1600 \text{ in}\cdot\text{lb}(0.5 \text{ in})}{\frac{\pi}{32}(1.0 \text{ in})^4 = 98.17\times10^{-3} \text{ in}^4} = \underline{8.148 \text{ ksi}}$$

$$\tau_{CD} = \frac{T_{CD} C_{CD}}{J_{CD}} = \frac{2600 \text{ in}\cdot\text{lb}(0.6 \text{ in})}{\frac{\pi}{32}(1.2 \text{ in})^4 = 203.6\times10^{-3} \text{ in}^4} = \underline{7.663 \text{ ksi}}$$

$$\boxed{\tau_{max} = 8.15 \text{ ksi} \quad \text{IN SEGMENT BC}}$$

(c) The angle of twist at end A of the shaft. Show direction of twist.

$$\phi_{TOTAL_A} = \phi_{AB} + \phi_{BC} + \phi_{CD} \qquad \text{WHERE} \qquad \phi = \frac{TL}{JG}$$

$$= \frac{T_{AB} L_{AB}}{J_{AB} G} + \frac{T_{BC} L_{BC}}{J_{BC} G} + \frac{T_{CD} L_{CD}}{J_{BC} G}$$

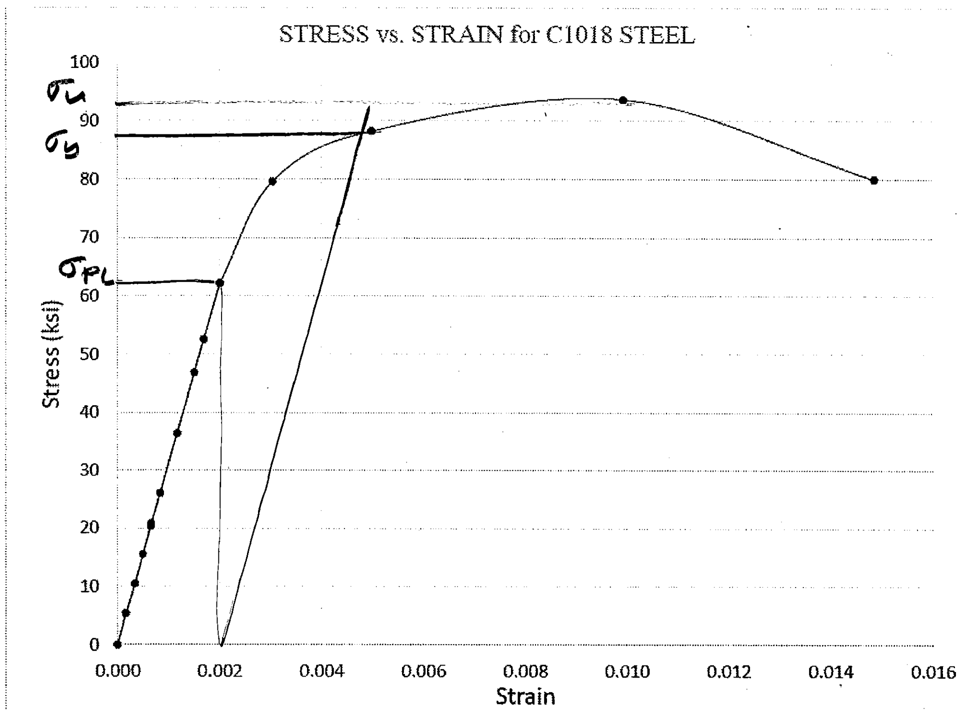
$$= \frac{-800 \text{ in}\cdot\text{lb}(6 \text{ in})}{40.21\times10^{-3} \text{ in}^4 (11.2\times10^6 \text{ psi})} + \frac{1600 \text{ in}\cdot\text{lb}(6 \text{ in})}{98.17\times10^{-3} \text{ in}^4 (11.2\times10^6 \text{ psi})} + \frac{2600 \text{ in}\cdot\text{lb}(6 \text{ in})}{203.6\times10^{-3} \text{ in}^4 (11.2\times10^6 \text{ psi})}$$

$$= -0.010658 \text{ rad} + 0.008731 \text{ rad} + 0.006841 \text{ rad}$$

$$= \underline{\underline{0.004914 \text{ rad}}} \quad \text{DEFLECTION AT A}$$

4) A) GIVEN: Stress strain plot.

Initial diameter	= 0.514 in
Gage length	= 2.00 in
Final diameter	= 0.378 in
Final length	= 2.36 in



REQ'D: (a) Stress at proportional limit.

$$\sigma_{PL} = \underline{\underline{62 \text{ ksi}}}$$

(b) 0.2 % offset yield stress

$$\sigma_y = \underline{\underline{87 \text{ ksi}}}$$

(c) Modulus of elasticity.

$$E = \frac{\sigma}{\varepsilon} = \frac{62 \text{ ksi}}{.002} = \underline{\underline{31 \times 10^6 \text{ psi}}}$$

(d) Ultimate Strength.

$$\sigma_u = \underline{\underline{93 \text{ ksi}}}$$

(e) Percent elongation and area reduction.

$$\% EL = \frac{L_f - L_o}{L_o} = \frac{2.36 - 2.00}{2.00} \times 100\% = \underline{\underline{18\%}}$$

$$\% AR = \frac{A_o - A_f}{A_o} \times 100\% = \frac{(0.514 in)^2 - (0.378 in)^2}{(0.514 in)^2} = \underline{\underline{46\%}}$$

$\frac{\pi}{4}$ CANCEL OUT