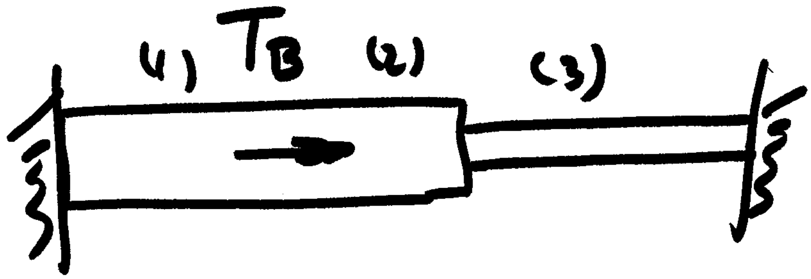
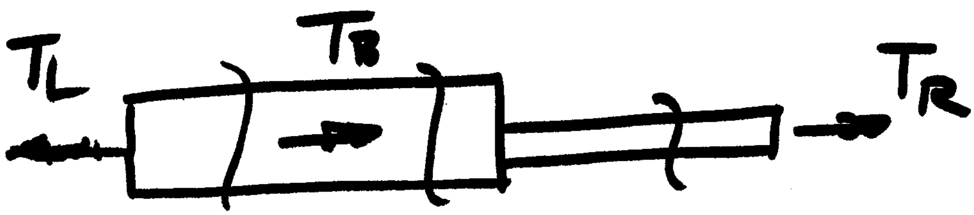
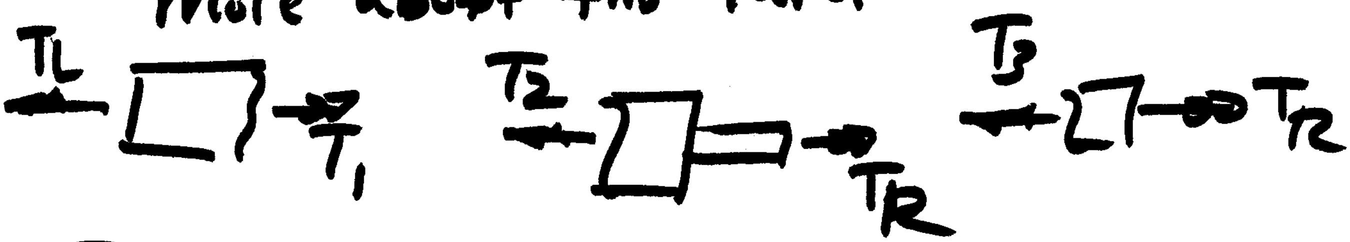
6.80





$$\overrightarrow{\Sigma T} \quad -T_L + T_B + T_R = 0 \qquad (1)$$

Note that although we have assumed T_R as shown, it really is opposite. More about this later



$T_1 = T_L$ $\qquad$ $T_2 = T_R$ $\qquad$ $T_3 = T_R$

$T_2 = T_3$

$$\phi_1 + \phi_2 + \phi_3 = 0$$

$$\frac{T_1 L_1}{I_{p1} G_1} + \frac{T_2 L_2}{I_{p2} G_2} + \frac{T_3 L_3}{I_{p3} G_3} = 0 \qquad (2)$$

Section (1)

$\tau_{ALL} = 50$ ksi

$d_o = 3.5$

$d_i = 3.26$

$G = 12.5 \times 10^6$ psi

Section (2)

$\tau_{ALL} = 50$ ksi

$d_o = 3.5$

$d_i = 3.26$

$G = 12.5 \times 10^6$ psi

Section (3)

$\tau_{ALL} = 18$ ksi

$d_o = 2$

$G = 5.6 \times 10^6$ psi

Rewrite eqn. # (1)

$$-T_1 + T_B + T_3 = 0$$

or $T_B = T_1 - T_3$

Rewrite eqn # (2)

$$\frac{T_1 L_1}{I_{p_1} G_1} + T_3 \left(\frac{L_2}{I_{p_2} G_2} + \frac{L_3}{I_{p_3} G_3} \right) = 0$$

It appears that we have 3 unknowns. However, we know the stress & Torque eqns.

$$\tau = \frac{T\, d/2}{I_p}$$

The key to this problem is to understand that while one of the sections may be at the allowable stress, the other two will be <u>less</u> than the allowable stresses, if the structure is safe.

We will have to guess which one, and check our answers.

Assume section (3) is critical:

$$|T_3| = \frac{\tau_3 I_{p_3}}{d_3/2} = \frac{18\times10^3 \frac{\pi}{32}(2)^4}{2/2}$$

$$|T_3| = 28.27 \text{ kip}\cdot\text{in}$$

if so, $T_2 = T_3 = 28.27$ kip in

& $T_3 = T_1 - T_3$

Note that T_1 & T_3 must have opposite signs.

$$T_1 + T_3\left(\frac{L_2}{J_{p_2}G_2} + \frac{L_3}{J_{p_3}G_3}\right)\frac{I_{p_1}G_1}{L_1} = 0$$

$$T_1 + T_3\left(\frac{L_2}{L_1}\frac{I_{p1}}{I_{p2}}\frac{G_1}{G_2} + \frac{L_3}{L_1}\frac{I_{p1}}{I_{p3}}\frac{G_1}{G_3}\right) = 0$$

$$T_1 + T_3\left(\frac{22}{30} + \frac{18}{30}\,\frac{\pi/32\,[3.5^4 - 3.26^4]}{\pi/32 \quad 24}\,\frac{12.5}{5.6}\right) = 0$$

$$T_1 + 3.84\,T_3 = 0$$

$$T_1 = -3.84\,T_3 \implies |T_1| = 108.6 \text{ kip in}$$

Check stress in 1 & 2:

$$\tau_1 = \frac{(108.6 \times 10^3)\frac{3.5}{2}}{\frac{\pi}{32}(3.5^4 - 3.26^4)} = 52.14 \text{ ksi} > 50 \text{ ksi}$$

Not SAFE!

$$\tau_2 = \frac{(28.27 \times 10^3)\frac{3.5}{2}}{\frac{\pi}{32}(3.5^4 - 3.26^4)} = 13.56 \text{ ksi}$$

Suppose element (2) controls:

$$\tau_2 = \frac{T_2 \; d/2}{I_{p2}}$$

$$T_2 = \frac{(50 \text{ ksi}) \frac{\pi}{32} (3.5^4 - 3.26^4)}{3.5/2}$$

$T_2 = 104.1$ kip·in This is even higher than when section (3) controlled the structure, ⇒ **Not safe!**

So, **section (1) must control.**

$$T_1 = \frac{(50 \text{ ksi}) \frac{\pi}{32} (3.5^4 - 3.26^4)}{3.5/2}$$

$T_1 = 104.1$ kip·in

If $T_1 = 104.1$ kip·in

& $T_1 = -3.84 T_3$ then

$T_3 = -27.11$ kip·in $= T_2$

$T_B = T_1 - T_3 = 104.1 - (-27.11)$

$T_B = 131.2$ kip·in

Final Answer gives

$\tau_1 = 50.0$ ksi

$\tau_2 = 13.0$ ksi

$\tau_3 = 17.26$ ksi