MAE 3315
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SOLUTION HW #6

Problem #1:

First, take the Aluminum as a reference material.

$$A_{ti}^* = \frac{E_{ti}}{E_{al}} A_{ti} = \frac{15x10^6\, psi}{10x10^6\, psi} A_{ti} = 1.5 A_{ti}$$

$$A_{al}^* = \frac{E_{al}}{E_{al}} A_{al} = \frac{10x10^6\, psi}{10x10^6\, psi} A_{al} = 1 A_{al}$$

To calculate the centroid,

$$z_c^* = \frac{\sum A_i^* z_i}{\sum A_i^*} = \frac{1.5 A_{ti}(0.65in) + A_{al}(0.25in)}{1.5 A_{ti} + A_{al}}$$

$$z_c^* = \frac{1.5(0.3in)(1in)(0.65in) + (0.5in)(1in)(0.25in)}{1.5(0.3in)(1in) + 1(0.5in)(1in)} = 0.439in$$

Finally, to calculate the moment of inertia,

$$I_y = \sum I_{yi}^* = \frac{E_{ti}}{E_{al}}\left(I_0 + Ad^2\right)_{ti} + \left(I_0 + Ad^2\right)_{al}$$

$$I_y = \frac{15x10^6\, psi}{10x10^6\, psi}\left(\frac{1}{12}(1in)(0.3in)^3 + (1in)(0.3in)(0.439 - 0.65)^2\right) +$$
$$+\left(\frac{1}{12}(1in)(0.5in)^3 + (1in)(0.5in)(0.439 - 0.25)^2\right) = 5.169x10^{-2}\, in^4$$

Problem #2:

Part a) Centroid of the section.

Just as before, take the Aluminum as a reference material and substituting $t = 0.04in$ and $a = 12t = 0.48in$,

$$A_{ti}^{*} = \frac{E_{ti}}{E_{al}} A_{ti} = \frac{16x10^{6} psi}{10x10^{6} psi}(2at) = \frac{16x10^{6} psi}{10x10^{6} psi}(2(0.48in)(0.04in) = 0.06144in^{2}$$

$$A_{al1}^{*} = \frac{E_{al}}{E_{al}} A_{al1} = \frac{10x10^{6} psi}{10x10^{6} psi} at = 0.0192in^{2}$$

$$A_{al2}^{*} = \frac{E_{al}}{E_{al}} A_{al2} = \frac{10x10^{6} psi}{10x10^{6} psi}(a-2t)(t) = 0.016in^{2}$$

$$A_{al3}^{*} = \frac{E_{al}}{E_{al}} A_{al3} = \frac{10x10^{6} psi}{10x10^{6} psi} at = 0.0192in^{2}$$

To calculate the centroid,

$$z_{c}^{*} = \frac{\sum A_{i}^{*} z_{i}}{\sum A_{i}^{*}} = \frac{(0.06144)(a+t/2)+(0.0192)(a/2)+(0.016)(a-t/2)+(0.0192)(a/2)}{0.06144+0.0192+0.016+0.0192}$$

$$z_{c}^{*} = \frac{(0.06144)(0.5)+(0.0192)(0.24)+(0.016)(0.46)+(0.0192)(0.24)}{0.11584}$$

$$z_{c}^{*} = 0.408in$$

Part b) Equivalent moment of inertia based on Aluminum.

$$I_{y} = \sum I_{yi}^{*} = \frac{E_{ti}}{E_{al}}\left(I_{0} + Ad^{2}\right)_{ti} + \left(I_{0} + Ad^{2}\right)_{al}$$

$$I_{y} = \frac{16x10^{6} psi}{10x10^{6} psi}\left(\frac{1}{12}(2a)(t^{3}) + (2a)(t)(0.408-0.5)^{2}\right) + \left(\frac{1}{12}(t)(a^{3}) + at(0.408-0.24)^{2}\right) +$$
$$+\left(\frac{1}{12}(a-2t)(t^{3}) + (a-2t)(t)(0.408-0.46)^{2}\right) + \left(\frac{1}{12}(t)(a^{3}) + at(0.408-0.24)^{2}\right)$$

$$I_{y} = 2.395x10^{-3} in^{4}$$

$$I_z = \sum I_{zi}^* = \frac{E_{ti}}{E_{al}}\left(I_0 + Ad^2\right)_{ti} + \left(I_0 + Ad^2\right)_{al}$$

$$I_z = \frac{16x10^6\,psi}{10x10^6\,psi}\left(\frac{1}{12}(t)(2a)^3 + (2a)(t)(0)^2\right) + \left(\frac{1}{12}(a)(t^3) + at(0.22)^2\right) +$$
$$+\left(\frac{1}{12}(t)(a-2t)^3 + (a-2t)(t)(0)^2\right) + \left(\frac{1}{12}(a)(t^3) + at(0.22)^2\right)$$

$$I_z = 6.796x10^{-3}\,in^4$$

And because symmetry,

$$I_{yz} = 0$$

Part c) Max. bending stress and location.

To calculate the constants,

$$k_y^* = \frac{I_y^*}{I_y^* I_z^* - \left(I_{yz}^*\right)^2} = \frac{1}{I_z^*} = 147.1$$

$$k_z^* = \frac{I_z^*}{I_y^* I_z^* - \left(I_{yz}^*\right)^2} = \frac{1}{I_y^*} = 417.5$$

$$k_{yz}^* = \frac{I_{yz}^*}{I_y^* I_z^* - \left(I_{yz}^*\right)^2} = 0$$

Therefore,

$$\sigma_x = (147.1)(50)y + (417.5)(200)z$$

To calculate the neutral axis,

$$\tan\alpha = \frac{I_y M_z - I_{yz} M_y}{I_z M_y - I_{yz} M_z}$$

But $I_{yz} = 0$, $M_y = 200 lb \cdot in$, and $M_z = 50 lb \cdot in$ as a result,

$$\tan\alpha = \frac{I_y M_z}{I_z M_y}$$

$$\alpha = ArcTan\left(\frac{(2.395x10^{-3})(50)}{(6.796x10^{-3})(200)}\right)$$

$$\alpha = 5^{\circ} \quad \text{[CLOCKWISE]}$$

Therefore, there are only 2 possible locations for the maximum bending stress. The first one, the most top-right point; and the second one, the most bottom-left point.

For the first point $y = 0.48in$ and $z = 0.52in - 0.408in = 0.112in$

$$(\sigma_x)_{TOP-RIGHT} = (147.1)(50)(0.48) + (417.5)(200)(0.112)$$

$$(\sigma_x)_{TOP-RIGHT} = 12.86Ksi$$

For the second point $y = -0.24in$ and $z = -0.408in$

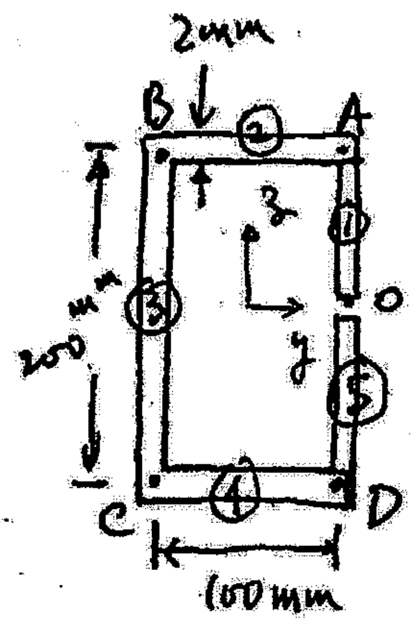
$$(\sigma_x)_{BOTTOM-LEFT} = (147.1)(50)(-0.24) + (417.5)(200)(-0.408)$$

$$\boxed{(\sigma_x)_{BOTTOM-LEFT} = -35.87Ksi}$$

Therefore, the bending stress is the highest at the bottom-left corner and it's in compression.

Problem #3:

For Figure 5.30:



The moment of inertia is,

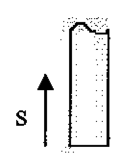
$$I_y = \frac{1}{12}\left[(0.102)(0.202)^3 - 0.098(0.198)^3\right] = 6.667x10^{-6}m^4$$

Because symmetry, the shear flow of each section is,

$$q_s = -\frac{V_z Q_y}{I_y}$$

Where Q_y is, $Q_y = A^* z^*$ for each section.

For Section #1: $0 \le s \le 0.1$ $(0 \to A)$

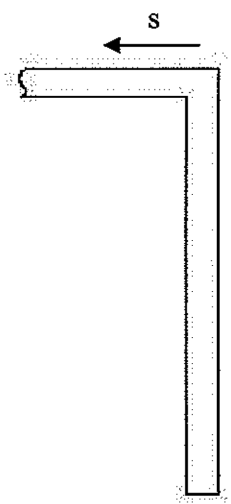


$$Q_1 = st\frac{s}{2} = 1x10^{-3}s^2$$

$$q_1 = -\frac{V_z Q_1}{I_y} = -\frac{5000\left(1x10^{-3} s^2\right)}{6.667x10^{-6}} = -7.5x10^5 s^2$$

$$q_1^A = -7.5x10^5 (0.1)^2 = -7500$$

For Section #2: $0 \le s \le 0.1 \ (A \rightarrow B)$



$$Q_2 = stz_c = s(0.002)(0.1) = 2x10^{-4} s$$

$$q_2 = q_1^A - \frac{V_z Q_2}{I_y} = -7500 - \frac{5000\left(2x10^{-4} s\right)}{6.667x10^{-6}} = -7500 - 1.5x10^5 s$$

$$q_2^B = -7500 - 1.5x10^5 (0.1) = -22500$$

For Section #3: $0 \le s \le 0.2 \ (B \rightarrow C)$

$$Q_3 = st\left(0.1 - \frac{s}{2}\right) = 2x10^{-4} s - 1x10^{-3} s^2$$

$$q_3 = q_2^B - \frac{V_z Q_3}{I_y} = -22500 - \frac{5000\left(2x10^{-4} s - 1x10^{-3} s^2\right)}{6.667x10^{-6}} = -22500 - 1.5x10^5 s + 7.5x10^5 s^2$$

$$q_3^C = -22500 - 1.5x10^5 (0.2) + 7.5x10^5 (0.2)^2 = -22500$$

NOTE: $q_C = q_B$!

For Section #4: $0 \le s \le 0.1 \quad (C \rightarrow D)$

$$Q_4 = stz_c = s(0.002)(-0.1) = -2x10^{-4}s$$

$$q_4 = q_3^C - \frac{V_z Q_4}{I_y} = -22500 - \frac{5000(-2x10^{-4}s)}{6.667x10^{-6}} = -22500 + 1.5x10^5 s$$

$$q_4^D = -22500 + 1.5x10^5(0.1) = -7500$$

NOTE: $q_D = q_A$!

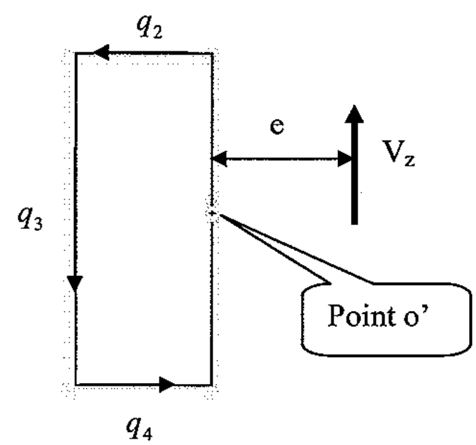
For Section #5: $0 \le s \le 0.1 \quad (D \rightarrow E)$

$$Q_5 = st\left(-0.1 + \frac{s}{2}\right) = -2x10^{-4}s + 1x10^{-3}s^2$$

$$q_5 = q_4^D - \frac{V_z Q_5}{I_y} = -7500 - \frac{5000(-2x10^{-4}s + 1x10^{-3}s^2)}{6.667x10^{-6}} = -7500 + 1.5x10^5 s - 7.5x10^5 s^2$$

$$q_5^E = -7500 + 1.5x10^5(0.1) - 7.5x10^5(0.1)^2 = 0$$

To calculate the Shear Center, we can take summation of moments at middle-right point (point o'). In that way, q_1 and q_5 will not contribute to the total summation of moments.



Therefore,

$$V_z e = \left(\int q_2 ds\right)0.1 + \left(\int q_3 ds\right)0.1 + \left(\int q_4 ds\right)0.1$$

$$V_z e = \left(\int_0^{0.1} \left(-7500 - 1.5x10^5 s \right) ds \right) 0.1 + \left(\int_0^{0.2} \left(-22500 - 1.5x10^5 s + 7.5x10^5 s^2 \right) ds \right) 0.1 +$$
$$+ \left(\int_0^{0.1} \left(-22500 + 1.5x10^5 s \right) ds \right) 0.1$$

$$V_z e = \left(-7500s - 1.5x10^5 \frac{s^2}{2} \right) \Bigg|_0^{0.1} 0.1 + \left(-22500s - 1.5x10^5 \frac{s^2}{2} + 7.5x10^5 \frac{s^3}{3} \right) \Bigg|_0^{0.2} 0.1 +$$
$$+ \left(-22500s + 1.5x10^5 \frac{s^2}{2} \right) \Bigg|_0^{0.1} 0.1$$

$$V_z e = \left[-7500(0.1) - 1.5x10^5 \frac{(0.1)^2}{2} \right] 0.1 + \left[-22500(0.2) - 1.5x10^5 \frac{(0.2)^2}{2} + 7.5x10^5 \frac{(0.2)^3}{3} \right] 0.1 +$$
$$+ \left[-22500(0.1) + 1.5x10^5 \frac{(0.1)^2}{2} \right] 0.1$$

$$V_z e = -850$$

$$5000e = -850$$

$$e = \frac{-850}{5000} = -0.170m$$

NOTE: Please, realize that "e" does NOT depend on the value of V_z (it cancels out).

For Figure 5.32:

Assuming that the bottom-left stringer is the origin,

$$y_c = \frac{\sum y_i A_i}{\sum A_i} = \frac{(2h)(2A_0)+(2h)(2A_0)}{2A_0 + A_0 + A_0 + 2A_0} = \frac{4}{3}h$$

$$z_c = \frac{\sum z_i A_i}{\sum A_i} = \frac{(h)(2A_0)+(h)(A_0)}{2A_0 + A_0 + A_0 + 2A_0} = \frac{1}{2}h$$

To calculate the moment of inertia,

$$I_y = \sum_i A_i z_i^2 = (2A_0)(h/2)^2 + (A_0)(h/2)^2 + (A_0)(h/2)^2 + (2A_0)(h/2)^2 = \frac{3}{2}A_0 h^2$$

Again, because symmetry, the shear flow of each section is,

$$q_s = -\frac{V_z Q_y}{I_y}$$

For Section #1: (The upper horizontal thin sheet).

$$Q_1 = (2A_0)(h/2) = A_0 h$$

$$q_1 = -\frac{V_z Q_1}{I_y} = -\frac{V_z(A_0 h)}{\frac{3}{2}A_0 h^2} = -\frac{2}{3}\frac{V_z}{h}$$

For Section #2: (The semicircular thin sheet).

$$Q_2 = (A_0)(h/2) = \frac{A_0 h}{2}$$

$$q_2 = q_1 - \frac{V_z Q_2}{I_y} = -\frac{2}{3}\frac{V_z}{h} - \frac{V_z\left(\frac{A_0 h}{2}\right)}{\frac{3}{2}A_0 h^2} = -\frac{2}{3}\frac{V_z}{h} - \frac{1}{3}\frac{V_z}{h} = -\frac{V_z}{h}$$

For Section #3: (The lower horizontal thin sheet).

$$Q_3 = (A_0)(-h/2) = -\frac{A_0 h}{2}$$

$$q_3 = q_2 - \frac{V_z Q_3}{I_y} = -\frac{V_z}{h} - \frac{V_z\left(-\frac{A_0 h}{2}\right)}{\frac{3}{2}A_0 h^2} = -\frac{V_z}{h} + \frac{1}{3}\frac{V_z}{h} = -\frac{2}{3}\frac{V_z}{h}$$

Taking summation of moments at the center of the vertical line that defined the semicircle,

$$V_z e = q_1(2h)\left(\frac{h}{2}\right) + q_2(2\overline{A}_2) + q_3(2h)\left(\frac{h}{2}\right)$$

$$V_z e = -\frac{2}{3}V_z h - \frac{V_z}{h}\left(2\frac{1}{2}\pi\left(\frac{h}{2}\right)^2\right) - \frac{2}{3}V_z h$$

$$V_z e = -\frac{4}{3}V_z h - \frac{1}{4}V_z h\pi$$

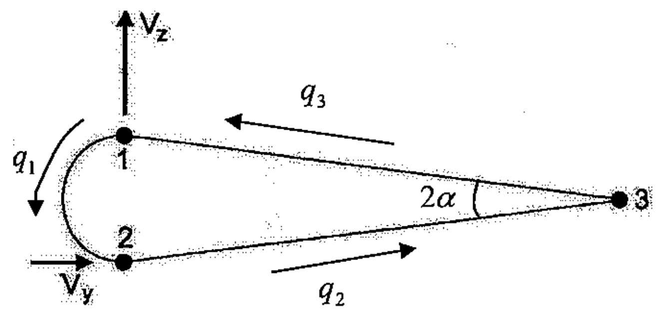
As we can see, V_z cancels out and "e" is independent of it, as we said before.

$$e = h\left[-\frac{4}{3} - \frac{1}{4}\pi\right]$$

$$e = -2.12h$$

Problem #4:

Part a)



$\sum F_y = 0:$ $$q_2 l_{23} Cos(\alpha) = q_3 l_{31} Cos(\alpha)$$

And since $l_{23} = l_{31}$,

$$q_2 = q_3$$

$\sum F_z = 0$ $$V_z = -q_1(0.2) + q_2 l_{23} Sin(\alpha) + q_3 l_{31} Sin(\alpha)$$

Since $l_{23} Sin(\alpha) = 0.1$ and $q_2 = q_3$

$$V_z = -q_1(0.2) + q_2 0.2$$

$$V_z = 0.2(q_2 - q_1)$$

Taking summation of moments at point 3,

$$-V_z 0.8 = 2\overline{A} q_1 = 2q_1\left(\frac{1}{2}\pi(0.1)^2 + \frac{1}{2}(0.8)(0.2)\right)$$

$$-(5000)0.8 = q_1(0.01\pi + 0.16)$$

$$q_1 = -20897 N/m = -20.9 kN/m$$

Then,

$$q_2 = q_1 - \frac{V_z Q_2}{I_y}$$

Where,

$$I_y = (0.1)^2 A + (-0.1)^2 A = 2x10^{-5} m^4$$

$$Q_2 = -0.1A = -0.0001 m^2$$

$$q_2 = q_1 - \frac{V_z(-0.0001)}{2x10^{-5}} = -20897 - \frac{5000(-0.0001)}{2x10^{-5}} = 4103 N/m = 4.10 kN/m$$

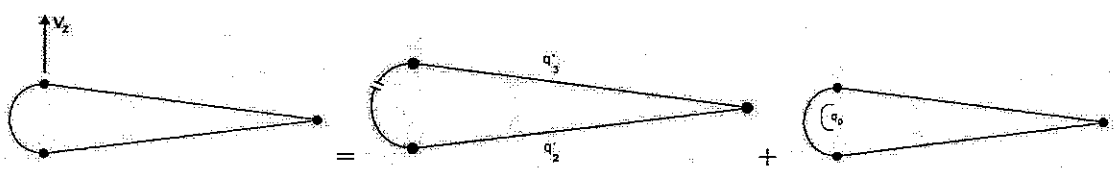
$$q_3 = q_2 = 4.10 kN/m$$

To calculate the twist angle,

$$\theta = \frac{1}{2G\bar{A}} \oint q \frac{ds}{t} = \frac{1}{2(27x10^9)(0.09571)(0.001)} [q_2 l_{23} + q_3 l_{31} + q_1 arc_{12}]$$

$$\theta = 0.1935x10^{-6} \left[4103\sqrt{0.1^2 + 0.8^2} + 4103\sqrt{0.1^2 + 0.8^2} - 20897(0.1\pi)\right]$$

$$\theta = 9.8710^{-6} rad/m = 5.65x10^{-4} \deg/m$$



$$\sum F_y = 0 \qquad \Rightarrow \qquad q_2' = q_3'$$

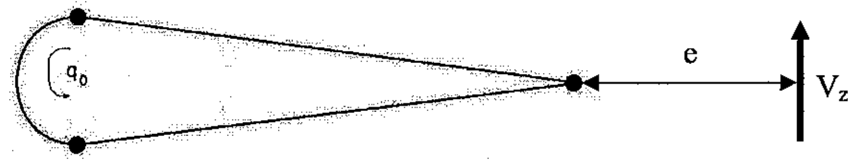
$$q_2' = -\frac{V_z Q_2}{I_y} = -\frac{(5000)(0.1)(0.001)}{2x10^{-5}} = -2.5x10^4 N/m$$

$$\theta = \frac{1}{2G\bar{A}} \oint q \frac{ds}{t} = 0 \qquad \Rightarrow \qquad \oint q ds = 0$$

$$q_0(0.1\pi) + (q_0 + q_2') l_{23} + (q_0 + q_3') l_{31} = 0$$

$$q_0(0.1\pi)+2(q_0-2.5x10^4)\sqrt{0.1^2+0.8^2}=0$$

$$q_0=\frac{(5.0x10^4)(0.806)}{0.1\pi+2(0.806)}=2.092x10^4\,N/m$$

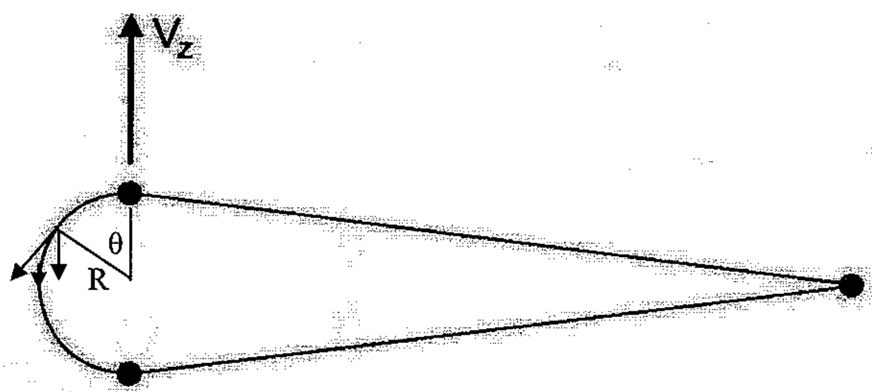


$$V_z e=q_0 2\overline{A}$$

$$e=\frac{(2.092x10^4)(0.1914)}{5000}=0.8m$$

$\sum F_y=0:$

$$-\int_0^{\pi} q_1 ds \cancel{Cos\theta}^{\,0} + q_2 l_{23} Cos(\alpha) - q_3 l_{31} Cos(\alpha) = 0$$



$\sum F_z=0$

$$-\int_0^{\pi}(q_1 ds)Sin\theta + q_2 l_{23} Sin(\alpha) + q_3 l_{31} Sin(\alpha) + V_z = 0$$

$$-\int_0^{\pi}(q_1 R Sin\theta d\theta) + 2q_2 0.1 + V_z = 0$$

$$q_1(0.1)Cos\theta\Big|_0^{\pi} + 2q_2 0.1 = V_z$$

$$q_1(0.1)Cos(\pi) - q_1(0.1)Cos(0) + 2q_2 0.1 = V_z$$

$$-q_1(0.1) - q_1(0.1) + 2q_2 0.1 = V_z$$

$$-2q_1(0.1) + 2q_2 0.1 = V_z$$

$$V_z = 0.2(q_2 - q_1) \quad \text{The equation is checked!}$$

Part b)

$$\sum F_y = 0 \qquad \Rightarrow \qquad V_y = q_2 l_{23} Cos(\alpha) - q_3 l_{31} Cos(\alpha)$$

Since $l_{23}Cos(\alpha) = 0.80$

$$10{,}000 = q_2 0.8 - q_3 0.8 \quad \text{Equation \#1}$$

$$\sum F_z = 0 \qquad \Rightarrow \qquad V_z = q_2 l_{23} Sin(\alpha) + q_3 l_{31} Sin(\alpha) - \int_0^{\pi} (q_1 R Sin\theta d\theta)$$

Once again, $l_{23}Sin(\alpha) = l_{31}Sin(\alpha) = 0.1$,

$$5000 = q_2 0.1 + q_3 0.1 + q_1(0.1)Cos\theta\Big|_0^{\pi}$$

$$5000 = q_2 0.1 + q_3 0.1 - 2q_1(0.1) \quad \text{Equation \#2}$$

Taking summation of moments at point 3,

$$V_y 0.1 - V_z 0.8 = 2\overline{A}q_1 = 2q_1\left(\frac{1}{2}\pi(0.1)^2 + \frac{1}{2}(0.8)(0.2)\right)$$

$$(10{,}000)0.1 - (5{,}000)0.8 = q_1(0.01\pi + 0.16) \quad \text{Equation \#3}$$

Solving Equation #3,

$$q_1 = \frac{(10{,}000)0.1 - (5{,}000)0.8}{(0.01\pi + 0.16)} = -15672 N/m = -15.7 kN/m$$

Solving Equation #1 and #2 together,

$$q_2 = 15578 N/m = 15.6 kN/m$$

$$q_3 = 3078 N/m = 3.1 kN/m$$

$$\theta = \frac{1}{2G\bar{A}}\left[q_1 arc_{12} + q_2 l_{23} + q_3 l_{31}\right]$$

$$\theta = \frac{1}{2(27x10^9)(0.09571)(0.001)}\left[-15672(0.1\pi) + 15578\sqrt{0.1^2 + 0.8^2} + 3078\sqrt{0.1^2 + 0.8^2}\right]$$

$$\theta = 0.1935x10^{-6}\left[-15672(0.1\pi) + 15578\sqrt{0.1^2 + 0.8^2} + 3078\sqrt{0.1^2 + 0.8^2}\right]$$

$$\theta = 1.9577x10^{-3} rad/m$$

Problem #5:

Assuming that the bottom-left stringer (#2) is the origin,

$$y_c = \frac{\sum y_i A_i}{\sum A_i} = \frac{(80)(10)+(80)(10)}{15+15+10+10} = 32cm$$

$$z_c = \frac{\sum z_i A_i}{\sum A_i} = \frac{(40)(15)+(20)(10)}{15+15+10+10} = 16cm$$

The moment of inertia is,

$$I_y = \sum_i A_i z_i^2 = (15)(40-16)^2 + (15)(16)^2 + (10)(16)^2 + (10)(20-16)^2 = 15{,}200cm^4$$

$$I_z = \sum_i A_i y_i^2 = (15)(32)^2 + (15)(32)^2 + (10)(80-32)^2 + (10)(80-32)^2 = 76{,}800cm^4$$

$$I_{yz} = \sum_i A_i y_i z_i = (15)(-32)(40-16) + (15)(-32)(-16) + (10)(80-32)(-16) +$$
$$+ (10)(80-32)(20-16) = -9{,}600cm^4$$

The constants k_y, k_z, and k_{yz} are now determined,

$$k_y = \frac{I_y}{I_y I_z - I_{yz}^2} = \frac{15{,}200}{(15{,}200)(76{,}800)-(-9{,}600)^2} = 1.4137x10^{-5}cm^4$$

$$k_z = \frac{I_z}{I_y I_z - I_{yz}^2} = \frac{76{,}800}{(15{,}200)(76{,}800)-(-9{,}600)^2} = 7.1429x10^{-5}cm^4$$

$$k_{yz} = \frac{I_{yz}}{I_y I_z - I_{yz}^2} = \frac{-9{,}600}{(15{,}200)(76{,}800)-(-9{,}600)^2} = -8.9286x10^{-6}cm^4$$

The shear flow is,

$$q_s = -(k_y V_y - k_{yz} V_z)Q_z - (k_z V_z - k_{yz} V_y)Q_y$$

$$q_s = (k_{yz} V_z)Q_z - (k_z V_z)Q_y$$

Therefore,

$$q_{12} = (-8.9286x10^{-6})(5000)(-32)(15) - (7.1429x10^{-5})(5000)(40-16)(15) = -107.14N/cm$$

$$q_{23} = q_{12} + (-8.9286x10^{-6})(5000)(-32)(15) - (7.1429x10^{-5})(5000)(-16)(15) = 0N/cm$$

$$q_{34} = q_{23} + (-8.9286x10^{-6})(5000)(80-32)(10) - (7.1429x10^{-5})(5000)(-16)(10) = 35.71N/cm$$

Taking summation of moments at point 2,

$$V_z e_y = (80cm)(35.71N/cm)(20cm)$$

$$e_y = \frac{(80cm)(35.71N/cm)(20cm)}{5{,}000N} = 11.43cm$$

$$y_{sc} = 11.43 - 32 = -20.57cm$$

To calculate z_{sc} we need to assume a V_y and $V_z = 0$. In this case, the shear flow becomes

$$q_s = -(k_y V_y)Q_z + (k_{yz} V_y)Q_y$$

$$q_{12} = -(1.4137x10^{-5})V_y(-32)(15) + (-8.9286x10^{-6})V_y(40-16)(15) = 3.5714x10^{-3}V_y$$

$$q_{23} = q_{12} + (1.4137x10^{-5})V_y(-32)(15) + (-8.9286x10^{-6})V_y(-16)(15) = -1.0714x10^{-3}V_y$$

$$q_{34} = q_{23} + (1.4137x10^{-5})V_y(80-32)(10) + (-8.9286x10^{-6})V_y(-16)(10) = 7.1429x10^{-3}V_y$$

Once again, taking summation of moments at point 2,

$$V_y e_z = (80)(7.1429x10^{-3}V_y)(20)$$

As usually, V_y cancels out,

$$e_z = (80)(7.1429x10^{-3})(20) = 11.43cm$$

$$z_{sc} = -16 - 11.43 = -27.43cm$$