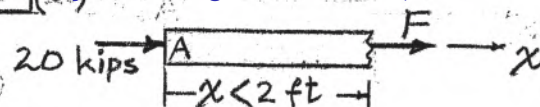
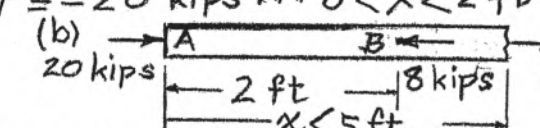
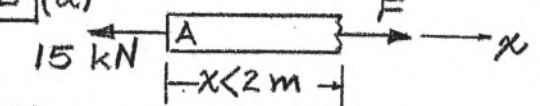
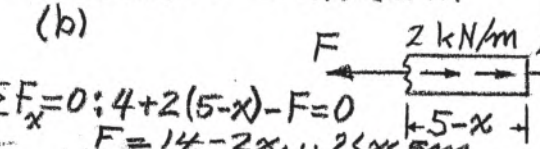
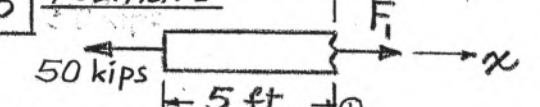


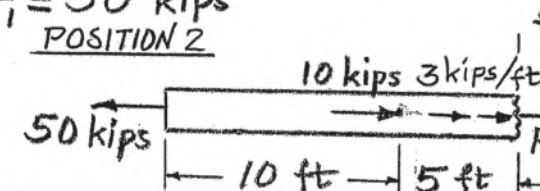
1.1 (a) 
 20 kips
 $x < 2 \text{ ft}$
 $\sum F_x = 0: F + 20 = 0$
 $F = -20 \text{ kips} \dots 0 < x < 2 \text{ ft}$ ANS.

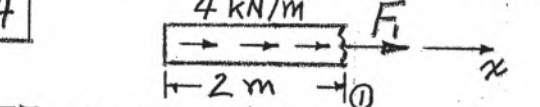
(b) 
 20 kips
 2 ft
 8 kips
 $x < 5 \text{ ft}$
 $\sum F_x = 0: F + 20 - 8 = 0$
 $F = -12 \text{ kips} \dots 2 < x < 5 \text{ ft}$ ANS.

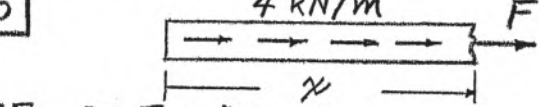
1.2 (a) 
 15 kN
 $x < 2 \text{ m}$
 $\sum F_x = 0: F - 15 = 0$
 $F = 15 \text{ kN} \dots 0 < x < 2 \text{ m}$ ANS.

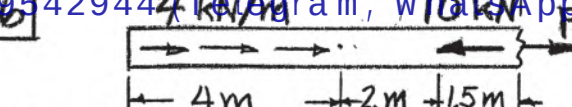
(b) 
 2 kN/m
 4 kN
 $5-x$
 $\sum F_x = 0: 4 + 2(5-x) - F = 0$
 $F = 14 - 2x \dots 2 < x < 5 \text{ m}$
 $F_x = 6 \text{ kN}$ ANS.

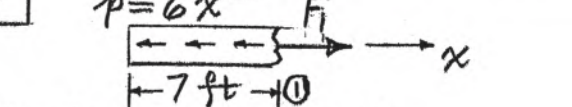
1.3 POSITION 1 
 50 kips
 5 ft
 $\sum F_x = 0: F_1 - 50 = 0$
 $F_1 = 50 \text{ kips}$ ANS.

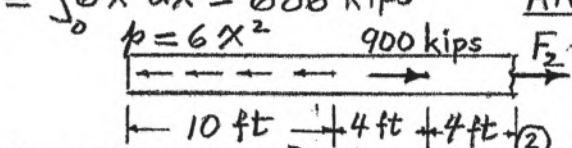
POSITION 2 
 50 kips
 10 kips
 3 kips/ft
 10 ft
 5 ft
 $\sum F_x = 0: F_2 + 3(5) + 10 - 50 = 0$
 $F_2 = 25 \text{ kips}$ ANS.

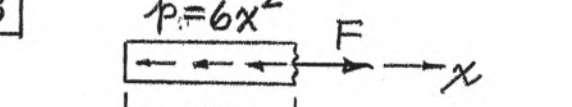
1.4 
 4 kN/m
 2 m
 $\sum F_x = 0: F_1 + 4(2) = 0$
 $F_1 = -8 \text{ kN}$ ANS.

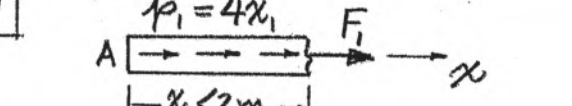
1.5 
 4 kN/m
 x
 $\sum F_x = 0: F + 4x = 0$
 $F = -4x \text{ kN} \dots 0 < x < 4 \text{ m}$ ANS.

1.6 
 4 kN/m
 10 kN
 4 m
 2 m
 1.5 m
 $\sum F_x = 0: F_2 - 10 + 4(4) = 0$
 $F_2 = -6 \text{ kN}$ ANS.

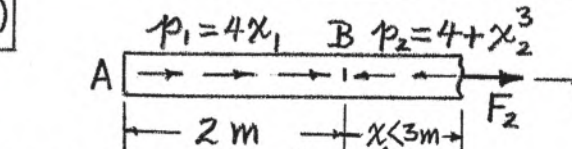
1.7 
 $p = 6x^2$
 7 ft
 $\sum F_x = 0: F_1 - \int p dx = 0$
 $F_1 = \int_0^7 6x^2 dx = 686 \text{ kips}$ ANS.

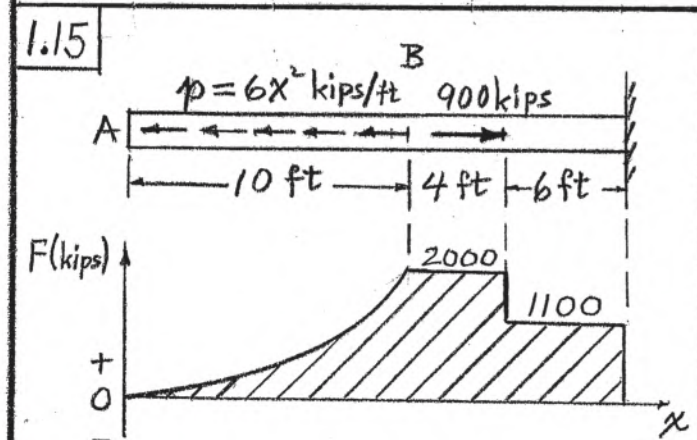
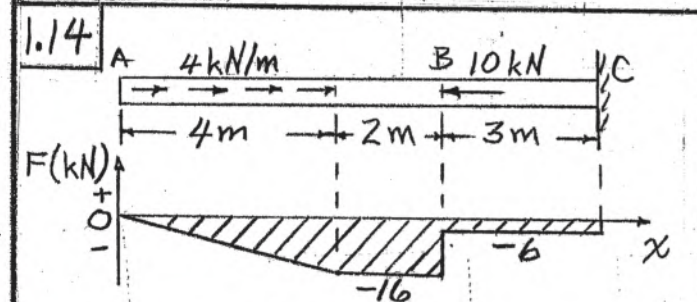
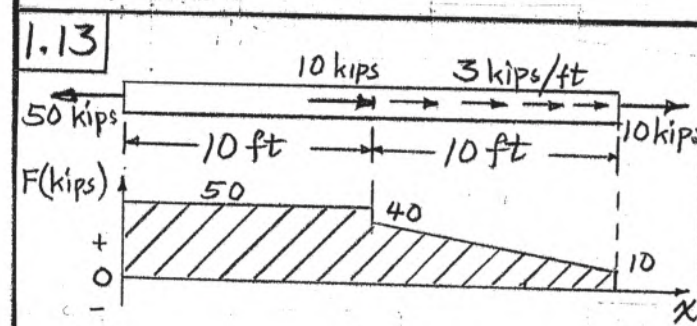
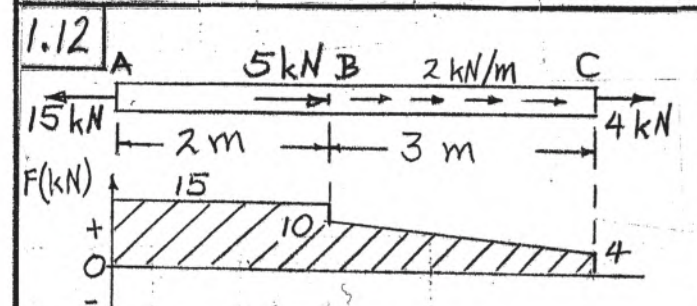
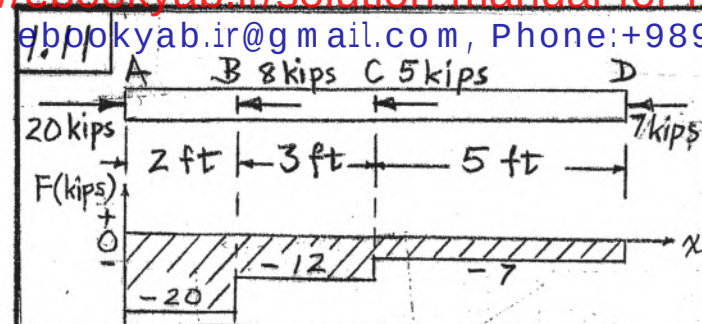

 $p = 6x^2$
 900 kips
 10 ft
 4 ft
 4 ft
 $\sum F_x = 0: F_2 + 900 - \int p dx = 0$
 $F_2 = \int_0^{10} 6x^2 dx - 900 = 1100 \text{ kips}$ ANS.

1.8 
 $p = 6x^2$
 x
 $\sum F_x = 0: F - \int p dx = 0$
 $F = \int_0^x 6x^2 dx = 2x^3$ ANS.

1.9 
 $p_1 = 4x_1$
 $x_1 < 2 \text{ m}$
 $\sum F_x = 0: F_1 + \int p_1 dx_1 = 0$
 $F_1 = - \int_0^{x_1} 4x_1 dx_1 = -2x_1^2 \text{ kN}$ ANS.

$F_B = -2(2^2) = -8 \text{ kN}$ ANS.

1.10 
 $p_1 = 4x_1$
 2 m
 $p_2 = 4 + x_2^3$
 $x_2 < 3 \text{ m}$
 $\sum F_x = 0: F_2 + 2(2^2) - \int p_2 dx_2 = 0$
 $F_2 = \int_0^{x_2} (4 + x_2^3) dx_2 - 8$
 $F_2 = 4x_2 + x_2^4/4 - 8$ ANS.
 $F_2 \text{ AT } x_2 = 2 \text{ m} = 4 \text{ kN}$ ANS.
 $F_2 \text{ AT } x_2 = 3 \text{ m} = 24.25 \text{ kN}$ ANS.



1.16

$\theta = \tan^{-1}(\frac{10}{13}) = 37.569^\circ$

TRANSMIT F_{CD} TO POINT D.

$\Sigma M_A = 0$

$-10(13) - (F_{CD} \cos \theta)(10) = 0$

$F_{CD} = -16.4$ kips

ANS.

$\Sigma M_D = 0: F_{BA}(13 \cos \theta)(\sin \theta) - 10(13 \cos \theta)(\cos \theta) = 0$

$F_{BA} = 13.0$ kips

(b) $A = \pi(1^2)/4 = 0.785$ in.²

$\tau_{AB} = \frac{13.0}{0.785} = 16.6$ ksi

ANS.

$\tau_{CD} = \frac{-16.4}{0.785} = -20.9$ ksi

ANS.

1.17 (a)

$\Sigma M_C = 0$

$F_{BA}(3) - 25(3) = 0$

$F_{BA} = 25.0$ kN

ANS.

$\Sigma M_B = 0: 15(3) - F_{DC}(3) = 0$

$F_{DC} = 15.0$ kN

ANS.

$\Sigma F_y = 0: -25 - F_{BC} \cos 45^\circ = 0$

$F_{BC} = -35.4$ kN

ANS.

(b)

$\tau_{BA} = \frac{25.0(10^3)}{(\pi/4)(0.02^2)} = 79.6$ MPa

ANS.

$\tau_{DC} = \frac{15.0(10^3)}{(\pi/4)(0.025^2)} = 30.6$ MPa

ANS.

$\tau_{BC} = \frac{-35.4(10^3)}{(\pi/4)(0.03^2)} = -50.1$ MPa

ANS.

1.18

$\theta = \tan^{-1}(3/4) = 36.9^\circ$

$F_{CA} = 75 \times 10^6 (5 \times 10^{-4}) = 37.5$ kN

$\Sigma M_B = 0$

$2P(4 \cos \theta) \cos \theta - F_{CA}(4 \cos \theta) = 0$

$P = \frac{F_{CA}}{2 \cos \theta} = \frac{37.5}{2 \cos 36.9^\circ}$

$P = 23.4$ kN

ANS.

1.19 BD = 5 m

$$AC^2 = AB^2 - BC^2$$

$$AC^2 = 4^2 - (5 - DC)^2 \quad (1)$$

ALSO

$$AC^2 = 3^2 - DC^2 \quad (2)$$

SOLVE (1) AND (2) TO OBTAIN:

$$DC = 1.8 \text{ m}$$

$$AC = 2.4 \text{ m}$$

$$CE = 2.4 \sin \theta = 1.44 \text{ m}$$

REFER TO F.B.D. IN SOLUTION OF PROB. 1.18.

$$\sum M_A = 0: -P(4) - 2P(1.44) - F_{CD}(2.4) = 0$$

$$F_{CD} = -2.867P = V_D = \tau_D A_D$$

$$\tau_D = 50 \times 10^6 = \frac{-2.867P}{2(\pi/4)(0.015^2)}$$

$$P = 6164 \text{ N} = 6.2 \text{ kN}$$

ANS.

1.20 $\sum M_C = 0$

$$F_{BA}(15) - P(15) = 0$$

$$F_{BA} = P = V_A = \tau_A A_A$$

$$\tau_A = 10 = \frac{P}{(\pi/4)(1.25^2)}$$

$$P = 12.3 \text{ kips}$$

ANS.

1.21 REFER TO F.B.D. IN SOLUTION OF PROB. 1.20.

$$\sum F_y = 0: -F_{BC} \sin 45^\circ - P = 0$$

$$F_{BC} = -P / \sin 45^\circ = -\tau_{BC} A_{BC}$$

$$P = \tau_{BC} A_{BC} \sin 45^\circ = 50(2.5) \sin 45^\circ$$

$$P = 88.4 \text{ kips}$$

ANS.

1.22 $\sum M_B = 0$

$$\left(\frac{2}{\sqrt{13}}\right) F_{AC}(12) - 25(14) = 0$$

$$F_{AC} = 52.581 \text{ kips}$$

$$\tau_{AC} = \frac{F_{AC}}{A_{AC}} = \frac{52.581}{(\pi/4)(1.5^2)} = 29.755$$

$$\tau_{AC} \approx 29.8 \text{ ksi}$$

ANS.

1.23 REFER TO THE F.B.D. IN PROB. 1.22.

$$\sum F_x = 0: B_x - \frac{2}{\sqrt{13}}(52.581) + 25 = 0$$

$$B_x = 4.167 \text{ kips}$$

$$\sum F_y = 0: B_y - \frac{3}{\sqrt{13}}(52.581) = 0$$

$$B_y = 43.750 \text{ kips}$$

$$B = \sqrt{4.167^2 + 43.750^2} = 43.948 \text{ kips}$$

$$\tau_{AVE} = \frac{B}{A} = \frac{43.948}{(\pi/4)(1.5^2)} = 24.869$$

$$\tau_{AVE} \approx 24.9 \text{ ksi}$$

ANS.

1.24 (a)

$$\sum M_C = 0$$

$$-(F_{AB} \cos 45^\circ)5 - (F_{AB} \sin 45^\circ)5 = 0$$

$$-40(1) - 30(4) = 0$$

$$F_{AB} = -22.627 \text{ kN}$$

$$\tau_{AB} = \frac{22.627(10^3)}{(0.03)(0.02)} = -37.712 \times 10^6 \text{ Pa}$$

$$\approx -37.7 \text{ MPa}$$

ANS.

(b)

$$\tau_x = \tau_{AB}$$

1.25 REFER TO THE F.B.D. IN PROB. 1.24.

$$\sum F_x = 0: C_x + 30 - 22.627 \cos 45^\circ = 0$$

$$C_x = -14.0 \text{ kN}$$

$$\sum F_y = 0: C_y - 40 + 22.627 \sin 45^\circ = 0$$

$$C_y = 24.0 \text{ kN}$$

$$C = \sqrt{14.0^2 + 24.0^2} = 27.784 \text{ kN}$$

$$\tau_{AVE} = \frac{C}{A} = \frac{27.784(10^3)}{(\pi/4)(0.03^2)} = 39,306.3 \times 10^3 \text{ Pa}$$

$$\approx 39.3 \text{ MPa}$$

ANS.

1.26

$$\sum M_C = 0:$$

$$(F_{BA} \sin 45^\circ)6 - (1.5P)19 - 8P = 0$$

$$F_{BA} = 3.226P$$

$$F_{BA} = 30(\pi/4)(3/8)^2 = 3.313 \text{ kips}$$

$$3.226P = 3.313$$

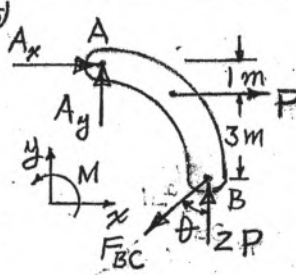
$$P = 1.027 \text{ kips} \approx 1.0 \text{ kips}$$

ANS.

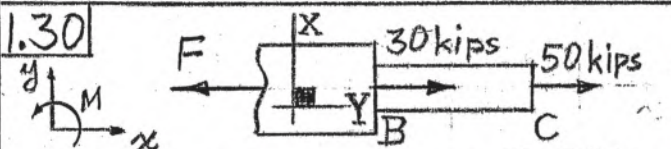
1.27 REFER TO THE F.B.D. IN PROB. 1.26.

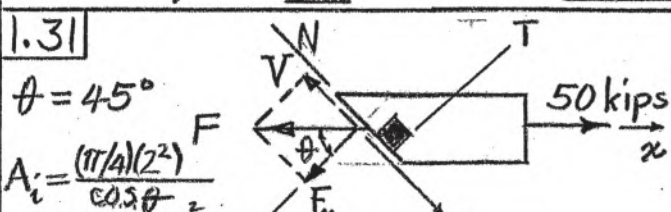
$$\begin{aligned}\Sigma F_x = 0: C_x - (3.226 P) \cos 45^\circ &= 0 \\ C_x &= 2.281 P \\ \Sigma F_y = 0: C_y - P - 1.5Q + (3.226 P) \sin 45^\circ &= 0 \\ C_y &= 0.219 P \\ C &= \sqrt{(2.281 P)^2 + (0.219 P)^2} = 2.291 P \\ \tau_{AVE} = 10 &= \frac{2.291 P}{(\pi/4)(1^2)} \\ P &= 3.428 \text{ kips} \approx 3.4 \text{ kips} \quad \text{ANS.}\end{aligned}$$

1.28 $F = 75 \times 10^6 (0.02)(0.025)$
 $F_{BC} = 37.5 \text{ kN}$
 $\theta = \tan^{-1}(\frac{6.5}{6.0}) = 47.291^\circ$
 $\Sigma M_A = 0:$
 $P(1) + 2P(4) - F_{BC} \cos \theta (4) - F_{BC} \sin \theta (4) = 0$
 $P = 23.551 \text{ kN} \approx 23.6 \text{ kN} \quad \text{ANS.}$



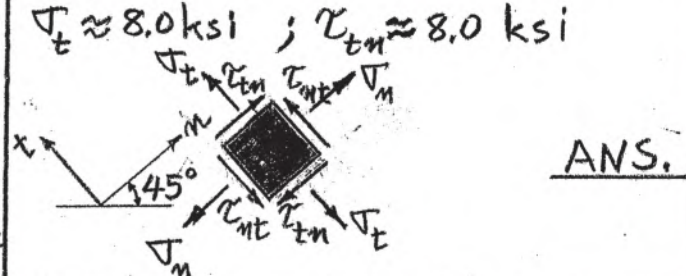
1.29 $F_{BC} = V_C = 25 \times 10^6 (\pi/4)(0.03^2) = 17.671 \text{ kN}$
 REFER TO THE F.B.D. IN PROB. 1.28.
 $\Sigma M_A = 0: P(1) + 2P(4) - F_{BC} \cos \theta (4) - F_{BC} \sin \theta (4) = 0$
 $P = 11.098 \text{ kN} \approx 11.1 \text{ kN} \quad \text{ANS.}$

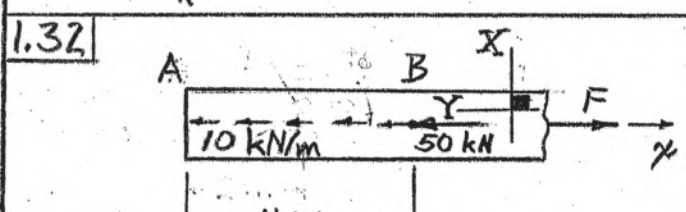
1.30 $\Sigma F_x = 0: 50 + 30 - F = 0; F = 80 \text{ kips}$
 $\tau_x = \frac{80}{(\pi/4)(5^2)} = 4.074 \text{ ksi} \approx 4.1 \text{ ksi}$

 ANS.

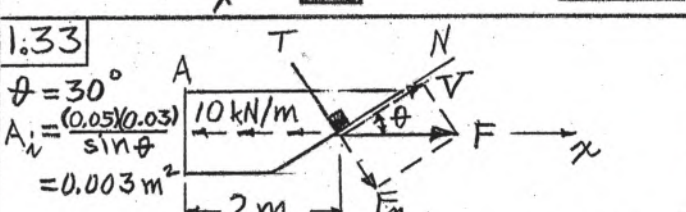
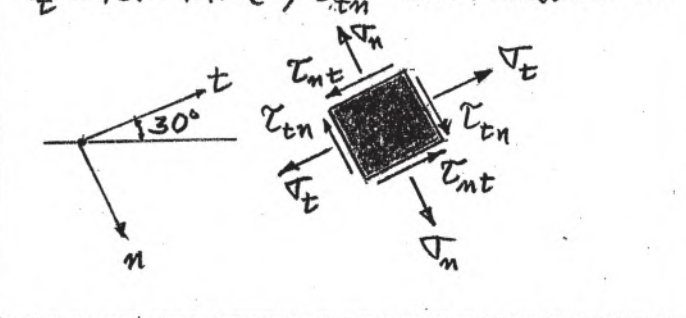
1.31 $\theta = 45^\circ$
 $A_i = \frac{(\pi/4)(2^2)}{\cos \theta} = 4.443 \text{ in.}^2$
 $\Sigma F_x = 0: 50 - F = 0; F = 50 \text{ kips}$
 $\tau_m = \frac{F_n}{A_i} = \frac{F \cos \theta}{A_i} = 7.958 \text{ ksi} \approx 8.0 \text{ ksi}$


1.31 CONT'D

$$\tau_{nt} = \frac{V}{A_i} = \frac{F \sin \theta}{A_i} = 7.958 \text{ ksi} \approx 8.0 \text{ ksi}$$

SIMILARLY, A F.B.D. SHOWING THE T PLANE YIELDS THE FOLLOWING:
 $\tau_t \approx 8.0 \text{ ksi}; \tau_{tn} \approx 8.0 \text{ ksi}$
 ANS.

1.32 $\Sigma F_x = 0: F - 50 - 10(4) = 0; F = 90 \text{ kN}$
 $\tau_x = \frac{90(10^3)}{(\pi/4)(0.06^2)} = 3.183 \times 10^6 \text{ N} \approx 31.8 \text{ MPa}$

 ANS.

1.33 $\theta = 30^\circ$
 $A_i = \frac{(0.05)(0.03)}{\sin \theta} = 0.003 \text{ m}^2$
 $\Sigma F_x = 0: F - 10(2) = 0; F = 20 \text{ kN}$
 $\tau_n = \frac{F_n}{A_i} = \frac{F \sin \theta}{A_i} = 3.333 \text{ MPa} \approx 3.3 \text{ MPa}$
 $\tau_{nt} = \frac{V}{A_i} = \frac{F \cos \theta}{A_i} = 5.774 \text{ MPa} \approx 5.8 \text{ MPa}$
 SIMILARLY, A F.B.D. SHOWING THE T PLANE YIELDS THE FOLLOWING:
 $\tau_t = 10.0 \text{ MPa}; \tau_{tn} = 5.774 \text{ MPa} \approx 5.8 \text{ MPa}$



1.34 THE F.B.D. OF THE ENTIRE TRUSS YIELDS $C_y = 140$ kN.

JOINT AT C

$$\sum F_y = 0: 140 + \frac{2}{\sqrt{13}} F_{CB} = 0$$

$$F_{CB} = -252.389 \text{ kN}$$

$$\sum F_x = 0: \frac{3}{\sqrt{13}} (252.389) - F_{CD} = 0$$

$$F_{CD} = 210.0 \text{ kN}$$

$$\theta = 60^\circ$$

$$A = (0.04)(0.08) - (0.025)(0.065)$$

$$= 0.001575 \text{ m}^2$$

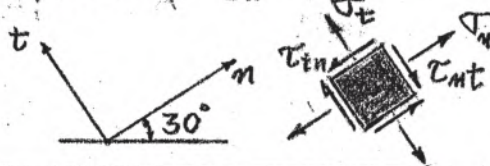
$$A_i = \frac{A}{\sin \theta}$$

$$\sigma_n = \frac{F_n}{A_i} = \frac{F \sin^2 \theta}{A} = 100.0 \text{ MPa}$$

$$\tau_{nt} = \frac{V}{A_i} = \frac{F \sin \theta \cos \theta}{A} = 57.7 \text{ MPa}$$

SIMILARLY, A F.B.D. SHOWING THE T PLANE YIELDS THE FOLLOWING:

$$\sigma_t = 33.3 \text{ MPa}; \tau_{tn} = 57.7 \text{ MPa}$$



1.36 THE F.B.D. OF THE ENTIRE TRUSS YIELDS $C_y = 25$ kips.

JOINT AT C

$$\sum F_y = 0: 25 + \frac{3}{\sqrt{13}} F_{CB} = 0$$

$$F_{CB} = -30.0 \text{ kips}$$

$$\sum F_x = 0: \frac{2}{\sqrt{13}} (30.0) - F_{CD} = 0$$

$$F_{CD} = 16.641 \text{ kips}$$

$$\theta = 75^\circ$$

$$A = (6)(8) - (5.5)(7.5) = 6.75 \text{ in}^2$$

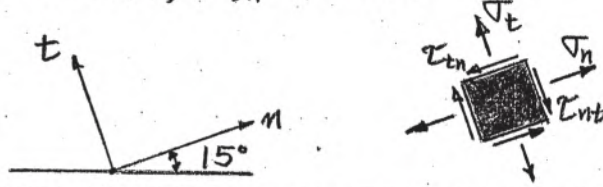
$$A_i = \frac{A}{\sin \theta}$$

$$\sigma_n = \frac{F_n}{A_i} = \frac{F \sin^2 \theta}{A} = 2.3 \text{ ksi}$$

$$\tau_{nt} = \frac{V}{A_i} = \frac{F \sin \theta \cos \theta}{A} = 0.6 \text{ ksi}$$

SIMILARLY, A F.B.D. SHOWING THE T PLANE YIELDS THE FOLLOWING:

$$\sigma_t = 0.2 \text{ kips}; \tau_{tn} = 0.6 \text{ ksi}$$



1.35 FROM PROB. 1.34, $F_{BC} = -252.389$ kN

$$\theta = \tan^{-1}\left(\frac{2}{3}\right) = 33.69^\circ$$

$$F = -252.389 \text{ kN}$$

$$A = 0.001575 \text{ m}^2$$

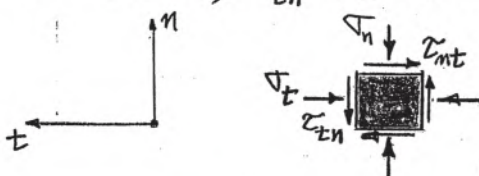
$$A_i = \frac{A}{\sin \theta}$$

$$\sigma_n = \frac{F_n}{A_i} = \frac{F \sin^2 \theta}{A} = 49.3 \text{ MPa}$$

$$\tau_{nt} = \frac{V}{A_i} = \frac{F \sin \theta \cos \theta}{A} = 74.0 \text{ MPa}$$

SIMILARLY, A F.B.D. SHOWING THE T PLANE YIELDS THE FOLLOWING:

$$\sigma_t = 110.9 \text{ MPa}; \tau_{tn} = 74.0 \text{ MPa}$$



1.37 FROM PROB. 1.36, $F_{CD} = 16.641$ kips

JOINT AT D

$$\sum F_x = 0: 16.641 + \frac{2}{\sqrt{13}} F_{BD} - \frac{2}{\sqrt{13}} F_{DA} = 0 \dots (1)$$

$$\sum F_y = 0: \frac{3}{\sqrt{13}} F_{DA} + \frac{3}{\sqrt{13}} F_{DB} - 75 = 0 \dots (2)$$

SOLVE SIMULTANEOUSLY TO GET $F_{DB} = 30.07$ kips

$$\theta = \tan^{-1}\left(\frac{3}{2}\right) = 56.31^\circ$$

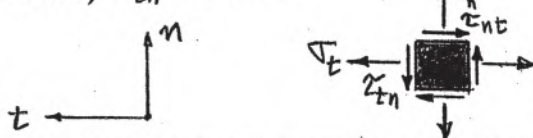
$$A = 6.75 \text{ in}^2; A_i = \frac{A}{\sin \theta}$$

$$\sigma_n = \frac{F_n}{A_i} = \frac{F \sin^2 \theta}{A} = 3.1 \text{ ksi}$$

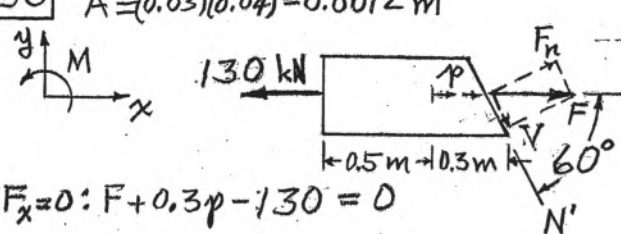
$$\tau_{nt} = \frac{V}{A_i} = \frac{F \sin \theta \cos \theta}{A} = 2.1 \text{ ksi}$$

SIMILARLY, A F.B.D. SHOWING THE T PLANE YIELDS THE FOLLOWING:

$$\sigma_t = 1.4 \text{ ksi}; \tau_{tn} = 2.1 \text{ ksi}$$



1.38 $A = (0.03)(0.04) = 0.0012 \text{ m}^2$



$$\sum F_x = 0: F + 0.3p - 130 = 0$$

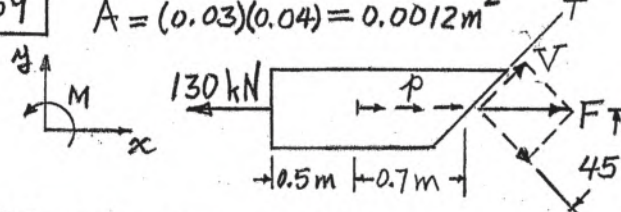
$$F = 130 - 0.3p$$

$$\sigma_n = 80 \times 10^6 = \frac{F_n}{A_i} = \frac{(130 - 0.3p)(10^3) \sin^2 60^\circ}{A}$$

$$(130 - 0.3p)(10^3) = \frac{80 \times 10^6 (0.0012)}{\sin^2 60^\circ}$$

$$p = 6.667 \approx 6.7 \text{ kN/m} \quad \text{ANS.}$$

1.39 $A = (0.03)(0.04) = 0.0012 \text{ m}^2$



$$\sum F_x = 0: F + 0.7p - 130 = 0$$

$$F = 130 - 0.7p$$

$$\tau_{nt} = 50 \times 10^6 = \frac{V}{A_i} = \frac{(130 - 0.7p)(10^3) \sin^2 45^\circ}{A}$$

$$(130 - 0.7p)(10^3) = \frac{50 \times 10^6 (0.0012)}{\sin^2 45^\circ}$$

$$p = 14.286 \approx 14.3 \text{ kN/m} \quad \text{ANS.}$$

1.40

(a) $P_{\text{MAX}} = -45,000(\pi/4)(3^2) = -318,086 \text{ lb}$
 $P_{\text{MAX}} \approx -318.1 \text{ kips} \quad \text{ANS.}$

(b) $\delta = \frac{FL}{AE} = \frac{-318,086(5)}{(\pi/4)(3^2)(30 \times 10^6)} = -0.007499 \text{ in.}$
 $\delta = -0.00750 \text{ in.} \quad \text{ANS.}$

$\epsilon_t = M \epsilon_L = -0.3 \left(\frac{-0.007499}{5} \right)$
 $= 4.4994 \times 10^{-4}$

$\Delta D = \epsilon_t D$
 $= 4.4994 \times 10^{-4}(3) = 0.0013498 \text{ in}$
 $\Delta D \approx 0.00135 \text{ in.} \quad \text{ANS.}$

1.41

(a) $u_R = \frac{1}{2} \epsilon_p \sigma_p = \frac{\sigma_p^2}{2E}$

$$\sigma_p = \sqrt{2u_R(E)} = \sqrt{2(4 \times 10^{-5})(120 \times 10^9)}$$

$$= 30.984 \times 10^7 \text{ Pa} \approx 309.8 \text{ MPa}$$

$$\epsilon_p = \sigma_p / E = 309.8 \times 10^6 / 120 \times 10^9 = 0.00258 \quad \text{ANS.}$$

(b) $P = \sigma_p A = 30.984 \times 10^7 (10 \times 10^{-4})$
 $= 309.84 \times 10^3 \text{ N} \approx 309.8 \text{ kN} \quad \text{ANS.}$

1.42

(a) $E = \frac{\sigma_p}{\epsilon_p} = \frac{(8,800 / (\pi/4)(0.5^2))}{(0.003/2)}$
 $= 29.879 \times 10^6 \approx 29.9 \times 10^6 \text{ psi} \quad \text{ANS.}$

(b) $\mu = \left| \frac{\epsilon_t}{\epsilon_L} \right| = \left| \frac{-(0.00025/0.5)}{(0.003/2)} \right|$
 $= 0.33333 = \frac{1}{3} \quad \text{ANS.}$

(c) $u_R = \frac{\sigma_p^2}{2E} = \frac{[(8,800 / (\pi/4)(0.5^2))]^2}{2(29.879 \times 10^6)}$
 $= 33.613 \approx 33.6 \text{ lb.in./in.}^3 \quad \text{ANS.}$

1.43

(a) $\mu = \left| \frac{\epsilon_t}{\epsilon_L} \right| = \left| \frac{(0.1/60)}{-(1.3/200)} \right|$
 $= 0.25641 \approx 0.256 \quad \text{ANS.}$

(b) $D_2 = D_1 + \epsilon_t(D_1) = 40 + \frac{0.1}{60}(40)$
 $= 40.06666 \approx 40.0667 \text{ mm} \quad \text{ANS.}$

(c) $E = \frac{\sigma}{\epsilon_L} = \frac{(600 \times 10^3) / (0.04)(0.06)}{(1.3/200)}$
 $= 38.462 \times 10^9 \text{ Pa} \approx 38.5 \text{ GPa} \quad \text{ANS.}$

1.44

(a) $\sigma_p = \epsilon_p E = (0.0045/3.5)(30 \times 10^3)$
 $= 38.571 \approx 38.6 \text{ ksi} \quad \text{ANS.}$

(b) $u_R = \frac{\sigma_p^2}{2E} = \frac{38.571^2}{2(30 \times 10^3)}$
 $= 24.795 \times 10^{-3} \approx 24.8 \times 10^{-3} \text{ kip.in./in.}^3 \quad \text{ANS.}$

1.45

$$(a) \mu = \left| \frac{\epsilon_T}{\epsilon_L} \right| = \left| \frac{(-0.04/30)}{(1.2/300)} \right| = 0.33333 = \frac{1}{3} \text{ ANS.}$$

$$(b) W_2 = W_1 + \epsilon_T W_1 = 15 + \frac{0.04}{30}(15) = 14.98 \text{ mm ANS.}$$

$$(c) \sigma = \frac{F}{A} = \frac{130 \times 10^3}{(0.015)(0.030)} = 288.889 \times 10^6 \approx 288.9 \text{ MPa ANS.}$$

$$(d) E = \frac{\sigma}{\epsilon_L} = \frac{288.889 \times 10^6}{(1.2/300)} = 72.222 \times 10^9 \approx 72.2 \text{ GPa ANS.}$$

1.46

$$(a) \mu = \left| \frac{\epsilon_T}{\epsilon_L} \right| = \left| \frac{(0.03/25)}{(-0.60/100)} \right| = 0.2 \text{ ANS.}$$

$$(b) W_2 = W_1 + \epsilon_T W_1 = 35 + \frac{0.03}{25}(35) = 35.042 \text{ mm ANS.}$$

$$(c) E = \frac{\sigma}{\epsilon_L} = \frac{(600 \times 10^3 / (0.025)(0.035))}{(0.60/100)} = 114.286 \times 10^9 \approx 114.3 \text{ GPa ANS.}$$

$$1.47 \quad A_i = 2.54469 \times 10^{-4} \text{ m}^2; A_f = 2.51368 \times 10^{-4} \text{ m}^2$$

σ (MPa)	$\epsilon \times 10^4$	σ (MPa)	$\epsilon \times 10^4$
0	0	69.557	24.58
6.956	1.192	73.034	30.52
13.911	2.383	76.512	38.54
20.867	3.575	79.912	48.78
27.823	4.758	82.077	62.52
34.778	5.950	82.077	75.13
41.734	7.142	79.990	104.58
48.690	8.333	74.783	125.33
55.645	11.00	66.413	142.23
62.601	15.27	51.480	162.25
66.079	20.09		

$$(a) \sigma = 82.5 \text{ MPa ANS.}$$

$$(b) \sigma_f = 51.5 \text{ MPa ANS.}$$

$$(c) \%EL = (1.95 \times 100) / 120 = 1.625 \text{ ANS.}$$

$$\%ROA = \frac{(2.54469 - 2.51368)(100)}{2.54469} = 1.219 \text{ ANS.}$$

1.48

PLOT INITIAL PART OF DATA

GIVEN IN PROB. 1.48 TO GET:

$$(a) \sigma_p = 51 \text{ MPa ANS.}$$

$$(b) \sigma_y = 74 \text{ MPa ANS.}$$

$$(c) E = \left(\frac{\sigma}{\epsilon} \right)_p = \frac{51 \times 10^6}{9 \times 10^{-4}} = 56.7 \text{ GPa ANS.}$$

1.49

REVERT TO PLOTS OF PROBS. 1.47 AND 1.48 TO GET:

$$(a) u_T \approx \sigma_{ave}(\epsilon_f) \approx 70 \times 10^6 (162.25 \times 10^{-4}) \approx 1135.8 \text{ kN} \cdot \text{m/m}^3 \text{ ANS.}$$

$$(b) u_R = \frac{\sigma_p^2}{2E} = \frac{(51 \times 10^6)^2}{2(56.7 \times 10^9)} = 22.937 \text{ kN} \cdot \text{m/m}^3 \text{ ANS.}$$

1.50

$$A_i = 0.19635 \text{ in}^2$$

σ (ksi)	$\epsilon \times 10^4$	σ (ksi)	$\epsilon \times 10^4$
0	0	63.153	85.0
8.149	2.0	62.643	100.0
16.297	4.5	66.208	135.0
24.446	7.5	71.301	165.0
32.595	10.5	76.394	200.0
40.744	13.0	81.487	245.0
48.892	15.5	89.127	335.0
57.041	17.5	96.766	502.5
61.115	20.0	99.313	750.0
63.153	25.0	101.859	1000.0
64.171	35.0	101.859	1250.0
65.190	50.0	94.729	1600.0
65.190	65.0	86.580	2000.0
64.171	75.0	84.034	2250.0

$$(a) \sigma_u = 101 \text{ ksi ANS.}$$

$$(b) \sigma_f = 83 \text{ ksi ANS.}$$

1.51 PLOT INITIAL PART OF DATA

GIVEN IN PROB. 1.50 TO GET:

$$(a) E = \left(\frac{\sigma}{\epsilon} \right)_p = \frac{57 \times 10^3}{17.5 \times 10^{-4}} = 32.6 \times 10^3 \text{ ksi} \quad \text{ANS.}$$

$$(b) \sigma_{xy} = 65.5 \text{ ksi} \quad \text{ANS.}$$

$$(c) \sigma_{xy} = 61.5 \text{ ksi} \quad \text{ANS.}$$

$$(d) \sigma_p = 57.0 \text{ ksi} \quad \text{ANS.}$$

1.52

$$A_i = 0.19635 \text{ in}^2; A_f = 0.08296$$

$$(a) \%EL = \left(\frac{0.45}{2.0} \right) 100 = 22.5 \quad \text{ANS.}$$

$$(b) \%ROA = \left(\frac{0.19635 - 0.08296}{0.19635} \right) 100 = 57.7 \quad \text{ANS.}$$

1.53 REFER TO PLOTS OF PROBS.

1.50 AND 1.51 TO GET:

$$(a) u_R = \frac{\sigma_p^2}{2E} = \frac{57.0^2}{2(32.6 \times 10^3)} \approx 0.05 \text{ kip} \cdot \text{in.}/\text{in}^3 \quad \text{ANS.}$$

$$(b) u_T \approx \sigma_{ave} (\epsilon_f) \approx 92(0.225) \approx 20.7 \text{ kip} \cdot \text{in.}/\text{in}^3 \quad \text{ANS.}$$

1.54

$$A_i = 28.274 \text{ in}^2$$

σ (psi)	$\epsilon \times 10^4$	σ (psi)	$\epsilon \times 10^4$
0	0	3996.6	12.5
1000.9	2.5	4498.8	15.0
1998.3	5.0	5001.1	25.0
2999.2	8.0	4799.5	30.0
3501.5	10.0	4000.1	35.0

$$(a) \sigma_u = 5050 \text{ psi} \quad \text{ANS.}$$

$$(b) \epsilon_u = 23.75 \times 10^{-4} \quad \text{ANS.}$$

1.55 * GIVEN VALUES

$$\sigma = \sigma_u \left[\frac{2\epsilon}{\epsilon_u} - \left(\frac{\epsilon}{\epsilon_u} \right)^2 \right]$$

$\epsilon \times 10^4$	σ (psi)	$\epsilon \times 10^4$	σ (psi)
0	0	20	5188
5	2181	25	5200*
10	3773	30	5011
15	4776	35	4245
			2889

$$E_{SEL.} = 4.1 \times 10^6 \text{ psi} \quad \text{ANS.}$$

1.56

$$(a) E = 32 \times 10^3 \text{ ksi} \quad \text{ANS.}$$

$$(b) \sigma_p = 195 \text{ ksi} \quad \text{ANS.}$$

$$(c) \epsilon_u = \epsilon_f = 0.050 \quad \text{ANS.}$$

$$(d) u_T = \sigma_{ave} (\epsilon_f) = 230 \times 0.050 = 11.5 \text{ kip} \cdot \text{in.}/\text{in}^3 \quad \text{ANS.}$$

1.57

$$\sigma_{ALL} = \frac{P}{A}$$

$$A = \frac{P}{\sigma_{ALL}} = \frac{20}{5} = 4.0 \text{ in}^2 \quad \text{ANS.}$$

1.58

$$\sigma_{ALL} = \frac{P}{A}$$

$$P = \sigma_{ALL} A = \left(\frac{150 \times 10^6}{2.5} \right) (0.03)(0.04) = 72.0 \text{ kN} \quad \text{ANS.}$$

1.59

$$\sigma = \frac{P}{A} = \frac{400 \times 10^3}{(\pi/4)(0.06^2)} = 141.5 \text{ MPa}$$

$$F.S. = \frac{\sigma_y}{\sigma} = \frac{250}{141.5} = 1.767 \quad \text{ANS.}$$

$$\sigma_{ALL} = 141.5 \text{ MPa} \quad \text{ANS.}$$

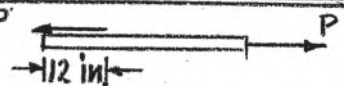
1.60

$$\sigma = \frac{P}{A} = \frac{100}{(1.5)(2.0)} = 33.333 \text{ ksi}$$

$$F.S. = \frac{\sigma_y}{\sigma} = \frac{60}{33.333} = 1.80 \quad \text{ANS.}$$

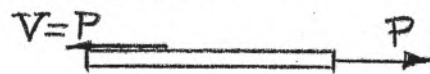
$$\sigma_{ALL} = 33.333 \approx 33.3 \text{ ksi} \quad \text{ANS.}$$

1.61

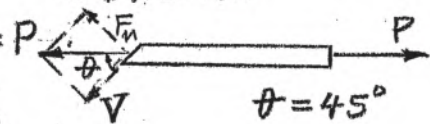
$$V = P$$


$$P = V = \sigma_{ALL} (A) = 70(12 \times 8) = 6720 \text{ lb} \approx 6.7 \text{ kips} \quad \text{ANS.}$$

1.62 THREE POSSIBILITIES:

GLUE $V=P$ 

$$P_1 = V = \tau_{ALL}(A) = 0.45 \times 10^6 (0.3)(0.5) = 67.5 \text{ kN}$$

GRAIN $F=P$ 

$$V = P_2 \cos \theta \quad A_i = \frac{A}{\sin \theta}$$

$$F_n = P_2 \sin \theta$$

$$P_2 = \frac{V}{\cos \theta} = \frac{\tau_{ALL}(A_i)}{\cos \theta} = \frac{\tau_{ALL}(A)}{\sin \theta \cos \theta}$$

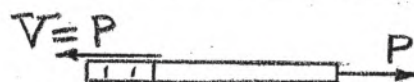
$$P_2 = \frac{0.25 \times 10^6 (0.3)(0.5)}{\sin 45^\circ \cos 45^\circ} = 75.0 \text{ kN}$$

$$P_3 = \frac{F_n}{\sin \theta} = \frac{\tau_{ALL}(A_i)}{\sin \theta} = \frac{\tau_{ALL}(A)}{\sin^2 \theta}$$

$$P_3 = \frac{0.3 \times 10^6 (0.3)(0.5)}{\sin^2 45^\circ} = 90.0 \text{ kN}$$

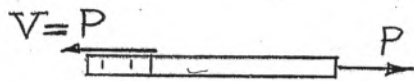
$$P_{MAX} = P_1 = 67.5 \text{ kN} \quad \text{ANS.}$$

1.63

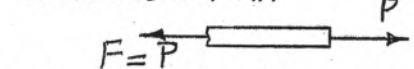
$V=P$ 

$$P = V = \tau_{ALL}(A) = 75 (\pi/4) (0.375^2) = 8.283 \approx 8.3 \text{ kips} \quad \text{ANS.}$$

1.64

$V=P$ 

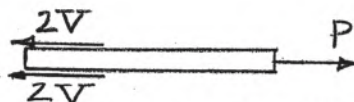
$$P_1 = V = \tau_{ALL}(A_P) = 50 \times 10^6 (\pi/4) (0.01^2) = 3.927 \approx 3.9 \text{ kN}$$

$F=P$ 

$$P_2 = F = \tau_{ALL}(A_B) = 25 \times 10^6 (\pi/4) (0.015^2) = 4.418 \approx 4.4 \text{ kN}$$

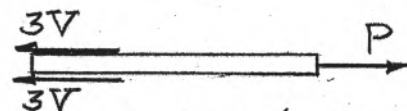
$$P_{MAX} = P_1 = 3.9 \text{ kN} \quad \text{ANS.}$$

1.65

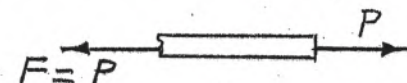
$2V$ 

$$P = 4V = 4 \tau_{ALL}(A) = 4(25) (\pi/4) (0.75^2) = 44.179 \approx 44.2 \text{ kips} \quad \text{ANS.}$$

1.66

$3V$ 

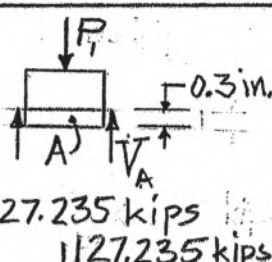
$$P_1 = 6V = 6 \tau_{ALL}(A) = 6(150 \times 10^6 (\pi/4) (0.03^2)) = 636.173 \approx 636.2 \text{ kN}$$

$F=P$ 

$$P_2 = F = \tau_{ALL}(A) = 100 \times 10^6 (0.02)(0.40) = 800.0 \text{ kN}$$

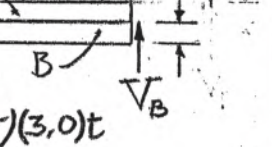
$$P_{MAX} = 636.2 \text{ kN} \quad \text{ANS.}$$

1.67

$P_A = V_A = (\tau_{ALL})_A (\pi d_A) t_A$ 

$$= 90 (\pi) (1.5)(0.3) = 127.235 \text{ kips}$$

THEREFORE

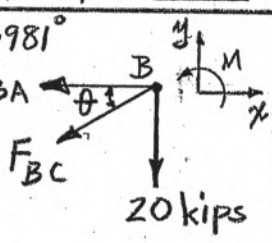
$V_B = V_A = 127.235 \text{ kips}$ 

$$= (\tau_{ALL})_B (\pi d_B) t = 50 (\pi) (3.0) t$$

$$t = \frac{127.235}{50 (\pi) (3.0)} = 0.270 \text{ in.} \quad \text{ANS.}$$

$$P_{MIN} = 127.235 \approx 127.0 \text{ kips} \quad \text{ANS.}$$

1.68

$\theta = \tan^{-1}(\frac{12}{15}) = 38.65981^\circ$ 

$$\sum F_y = 0:$$

$$-20 - F_{BC} \sin \theta = 0$$

$$F_{BC} = -32.016 \text{ kips}$$

$$\sum F_x = 0: -(-32.016) \cos \theta - F_{BA} = 0$$

$$F_{BA} = 25.0 \text{ kips}$$

$$\delta = \frac{FL}{AE}$$

$$\delta_{AB} = \frac{25.0 (15 \times 12)}{1.5 (30 \times 10^3)}$$

$$= 0.10 \text{ in.} \quad \text{ANS.}$$

1.69 FROM PROB. 1.68, $F_{BC} = -32.016 \text{ kips}$
 AND $\theta = 38.65981^\circ$

$\Sigma F_x = 0:$
 $-32.016 - F_{CD} = 0$
 $F_{CD} = -32.016 \text{ kips}$
 $L_{CD} = 12 \sin \theta$
 $= 7.49634 \text{ ft}$
 $\delta_{CD} = \frac{-32.016(7.49634 \times 12)}{15 \times 10^3(1.5)(3.0)}$
 $= -0.0427 \approx -0.04 \text{ in. ANS.}$

1.70 $\Sigma M_C = 0:$
 $10(11.25) + F_{EB} \sin \theta(7.5) = 0$
 $F_{EB} = -27.042 \text{ kips}$
 $L_{EB} = \frac{7.5}{\cos \theta}$
 $= 9.01388 \text{ ft}$
 $\delta_{EB} = \frac{-27.042(9.01388 \times 12)}{2.5(30 \times 10^3)}$
 $= -0.0390 \approx -0.04 \text{ in. ANS.}$

1.71 $\Sigma M_C = 0:$
 $P_1(4.5) + F_{EB} \sin \theta(3) = 0$
 $F_{EB} = -2.70416 P_1$
 $L_{EB} = \frac{3.0}{\cos \theta}$
 $= 3.60555 \text{ m}$
 $\delta_{EB} = -0.003 = \frac{-2.70416 P_1(3.60555)}{(0.025)(0.040)(70 \times 10^9)}$
 $P_1 = 21538 \text{ N}$
 $\approx 21.5 \text{ kN ANS.}$

1.72 $\Sigma M_D = 0:$
 $F(6) - P(12) = 0 ; F = 2P$
 $\delta_C = 0.25 = \frac{2P(5 \times 12)}{0.75(30 \times 10^3)} + \frac{2P(5 \times 12)}{0.35(30 \times 10^3)}$
 $P = 14.915 \approx 14.9 \text{ kips ANS.}$

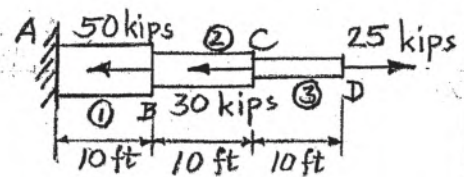
1.73 REFER TO SOLUTION OF PROB. 1.72.
 LEADING TO $F = 2P = 2(25) = 50 \text{ kips}$
 $\delta_C = \frac{50(5 \times 12)}{(0.8)(1.0)(16 \times 10^3)} + \frac{50(5 \times 12)}{(0.24)(22 \times 10^3)}$
 $= 0.803 \approx 0.80 \text{ in. ANS.}$

1.74 (a) $\Sigma M_B = 0: F(1.0) - P(2.0) = 0$
 $F = 2P = 2(20) = 40 \text{ kN}$
 $\delta_A = \delta_{ROD} + \delta_{SPRING}$
 $= \frac{40 \times 10^3(3.0)}{(\pi/4)(0.015^2)(200 \times 10^9)} + \frac{40}{500}$
 $= 0.003395 + 0.080$
 $\delta_A = 0.083395 \text{ m} \approx 83.4 \text{ mm ANS.}$
 (b) $\delta_{SPRING} = 0.080 = 80.0 \text{ mm ANS.}$

1.75 AS IN PROB. 1.74, $F = 2P$ AND
 (a) $\delta_A = \delta_{ROD} + \delta_{SPRING}$
 $0.010 = \frac{2P(3.0)}{(\pi/4)(0.025^2)(70 \times 10^9)} + \frac{2P}{1200 \times 10^3}$
 $P = 5431 \text{ N} \approx 5.4 \text{ kN ANS.}$
 (b) $\delta_{ROD} = \frac{2(5431)(3.0)}{(\pi/4)(0.025^2)(70 \times 10^9)}$
 $= 0.000948 \text{ m} \approx 0.95 \text{ mm ANS.}$

1.76

(a)



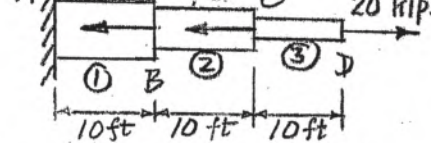
$D_1 = 2.0 \text{ in.}$
 $D_2 = 1.0 \text{ in.}$
 $D_3 = 0.5 \text{ in.}$
 $F_{AB} = -55 \text{ kips}; F_{BC} = -5 \text{ kips}; F_{CD} = 25 \text{ kips}$
 $\delta = \frac{FL}{AE}$
 $\delta_C = \delta_{AB} + \delta_{BC} = \frac{-55(10 \times 12)}{(\pi/4)(2.0^2)(30 \times 10^3)} + \frac{-5(10 \times 12)}{(\pi/4)(1.0^2)(30 \times 10^3)}$
 $= -95.493 \times 10^{-3} \approx -0.095 \text{ in. ANS.}$

(b)

$$\delta_D = \delta_{AB} + \delta_{BC} + \delta_{CD} = -95.493 \times 10^{-3} + \frac{25 \times (10 \times 12)}{(\pi/4)(0.5^2)(30 \times 10^3)}$$

$$= 413.803 \times 10^{-3} \approx 0.414 \text{ in. ANS.}$$

1.77



$A_1 = 1.25 \text{ in.}^2$
 $A_2 = 0.90 \text{ in.}^2$
 $D_3 = 0.625 \text{ in.}$
 $F_{AB} = -(40 + P_2); F_{BC} = 20 - P_2; F_{CD} = 20 \text{ kips}$
 $\delta = \frac{FL}{AE}$
 $\delta_C = \delta_{AB} + \delta_{BC} = \frac{-(40 + P_2)(10 \times 12)}{1.25(10 \times 10^3)} + \frac{(20 - P_2)(10 \times 12)}{0.90(10 \times 10^3)} = 0.25$

SOLVE FOR P_2 TO GET

$P_2 = -16.018 \approx -16.0 \text{ kips} \rightarrow \text{ANS.}$

1.78

$P_1 = 150 \text{ kN}; P_2 = 100 \text{ kN}; P_3 = 125 \text{ kN};$
 $A_1 = 0.50 A_2 = 0.75 A_3$
 $\therefore A_2 = 2.0 A_1; A_3 = (\frac{4}{3}) A_1$
 $F_{AB} = -175 \text{ kN}; F_{BC} = -25 \text{ kN};$
 $F_{CD} = -125 \text{ kN}; \delta = \frac{FL}{AE}$
 $\delta_D = \delta_{AB} + \delta_{BC} + \delta_{CD} = 3.5 \text{ mm.}$

$$\frac{-175(10^3)(0.75)}{A_1(120 \times 10^9)} + \frac{-25(10^3)(0.50)}{2.0 A_1(120 \times 10^9)} + \frac{-125(10^3)(1.25)}{(4/3) A_1(120 \times 10^9)} = -0.0035$$

 $A_1 = 0.0006064 \text{ m}^2 = 606.4 \text{ mm}^2 \text{ ANS.}$
 $A_2 = 0.0012128 \text{ m}^2 = 1,212.8 \text{ mm}^2 \text{ ANS.}$
 $A_3 = 0.0008085 \text{ m}^2 = 808.5 \text{ mm}^2 \text{ ANS.}$

1.79

REFER TO THE SKETCH IN PROB. 1.78.

$P_1 = 75 \text{ kN}; P_2 = 150 \text{ kN}; P_3 = 200 \text{ kN}$
 $A_1 = 1200 \text{ mm}^2; A_2 = 2000 \text{ mm}^2; A_3 = 450 \text{ mm}^2$
 $E_1 = 75 \text{ GPa}; E_2 = 100 \text{ GPa}; E_3 = 150 \text{ GPa}$
 $F_{AB} = -125 \text{ kN}; F_{BC} = -50 \text{ kN}; F_{CD} = -200 \text{ kN}$
 $\delta = \frac{FL}{AE}$
 $\delta_B = \frac{-125(10^3)(0.75)}{(0.0012)(75 \times 10^9)} = -0.001042 \text{ m}$
 $= -1.042 \text{ mm ANS.}$
 $\delta_C = \delta_B + \delta_{BC} = -0.001042 + \frac{-50(10^3)(0.50)}{(0.0020)(100 \times 10^9)}$
 $= -0.001042 - 0.000125 = -0.001167 \text{ m}$
 $= -1.167 \text{ mm ANS.}$
 $\delta_D = \delta_C + \delta_{CD} = -0.001167 + \frac{-200(10^3)(1.25)}{(0.00045)(150 \times 10^9)}$
 $= -0.001167 - 0.003704 = -0.004871 \text{ m}$
 $= -4.871 \text{ mm ANS.}$

1.80

$D_1 = 1.5 \text{ in.}; D_2 = 0.75 \text{ in.}$
 $P_1 = 50 \text{ kips}; P_2 = 20 \text{ kips}$
 $F_{AB} = -30 \text{ kips}; F_{BC} = 20 \text{ kips}$
 $\delta_C = \delta_{AB} + \delta_{BC} = 0$

$$\frac{-30 a}{(\pi/4)(1.5^2)(15 \times 10^3)} + \frac{20 b}{(\pi/4)(0.75^2)(25 \times 10^3)} = 0$$

 $\frac{a}{b} = 1.6 \text{ ANS.}$

1.81

REFER TO SKETCH IN PROB. 1.80.

$P_1 = 50 \text{ kips}; P_2 = 30 \text{ kips}$
 $E_1 = 10 \times 10^3 \text{ ksi}; E_2 = 20 \times 10^3$
 $a = 18 \text{ in.}; b = 10 \text{ in.}$
 $F_{AB} = -20 \text{ kips}; F_{BC} = 30 \text{ kips}$
 $\delta_C = \delta_{AB} + \delta_{BC} = 0$

$$\frac{-20(18)}{(\pi/4) D_1^2 (10 \times 10^3)} + \frac{30(10)}{(\pi/4) D_2^2 (20 \times 10^3)} = 0$$

 $\frac{D_1^2}{D_2^2} = \frac{36}{15} = 2.4$
 $\frac{D_1}{D_2} = 1.549 \text{ ANS.}$

1.82 (a) $\delta_A = \delta_{\text{SPRING}} + \delta_{\text{TUBE}}$

$$\delta_A = \frac{P}{k} + \frac{FL}{AE} = \frac{75}{1200} + \frac{(75 \times 10^3)(0.25)}{\frac{\pi}{4}(0.045^2 - 0.043^2)(3.5 \times 10^9)}$$

$$= 0.0625 + 0.03876 = 0.10126 \text{ m} \approx 101.3 \text{ mm} \text{ ANS.}$$
 (b) $\delta_B = \delta_{\text{TUBE}} = 0.03876 \text{ m} \approx 38.8 \text{ mm} \text{ ANS.}$
 (c) $\delta_D = \delta_A + \delta_{\text{ROD}} = 0.10126 + \frac{FL}{AE}$

$$= 0.10126 + \frac{(75 \times 10^3)(0.9)}{\frac{\pi}{4}(0.015^2)(70 \times 10^9)}$$

$$= 0.10672 \text{ m} \approx 106.7 \text{ mm} \text{ ANS.}$$

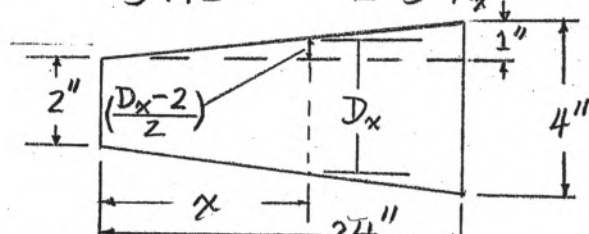
1.83 $\delta_D = \delta_{\text{SPRING}} + \delta_{\text{TUBE}} + \delta_{\text{ROD}}$

$$0.050 = \frac{P}{k} + \left(\frac{PL}{AE}\right)_{\text{TUBE}} + \left(\frac{PL}{AE}\right)_{\text{ROD}}$$

$$= \frac{P}{1200} + \frac{(P \times 10^3)(0.25)}{\frac{\pi}{4}(0.045^2 - 0.043^2)(3.5 \times 10^9)} + \frac{(P \times 10^3)(0.9)}{\frac{\pi}{4}(0.015^2)(70 \times 10^9)}$$

SOLVE TO GET $P \approx 35.1 \text{ kN} \text{ ANS.}$

1.84 $\delta = \int \frac{F}{AE} dx = \frac{F}{E} \int \frac{dx}{A_x}$



$$\frac{D_x - 2}{2x} = \frac{1}{24}; D_x = \frac{x + 24}{12}$$

$$A_x = \left(\frac{\pi}{4}\right)\left(\frac{x + 24}{12}\right)^2 = \left(\frac{\pi}{576}\right)(x + 24)^2$$

$$\delta = \frac{250}{20 \times 10^3} \left(\frac{576}{\pi}\right) \int_0^{24} \frac{dx}{(x + 24)^2}$$

$$= 2.29183 \left[-\frac{1}{(24 + x)} \right]_0^{24}$$

$$= 0.04775 \approx 0.048 \text{ in. ANS.}$$

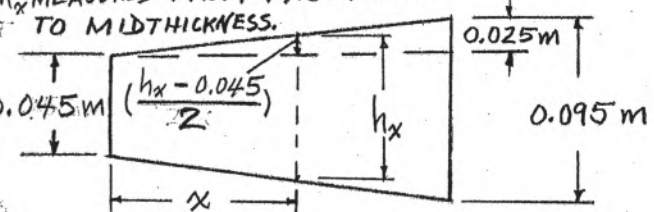
1.85 AS IN PROB. 1.84, WE OBTAIN
 $A_x = \left(\frac{\pi}{576}\right)(x + 18)^2$

$$\delta = \frac{F}{E} \int \frac{dx}{A_x} = \frac{P}{15 \times 10^3} \left(\frac{576}{\pi}\right) \int_0^{24} \frac{dx}{(x + 18)^2} = 0.05$$

$$0.12223 P \left[-\frac{1}{(18 + x)} \right]_0^{24} = 0.05$$
 SOLVE TO GET $P = 128.85 \text{ kips} \approx 128.9 \text{ kips} \text{ ANS.}$

1.86 $\delta = \int \frac{F}{AE} dx = \frac{F}{E} \int \frac{dx}{A_x}$

NOTE h_x MEASURED FROM MIDTHICKNESS TO MIDTHICKNESS.



$$\frac{h_x - 0.045}{2x} = \frac{0.025}{0.75} = \frac{1}{30}$$

$$h_x = 0.045 + \left(\frac{1}{15}\right)x$$

$$A_x = 4 \left[0.045 + \left(\frac{1}{15}\right)x\right](0.005) = 0.0009 + 0.00133x$$

$$\delta = \frac{200 \times 10^3}{30 \times 10^9} \int_0^{0.75} \frac{dx}{(0.0009 + 0.00133x)}$$

$$= 6.667 \times 10^{-6} \left(\frac{1}{0.00133}\right) \log(0.0009 + 0.00133x) \Big|_0^{0.75}$$

$$\delta = 5.013 \times 10^{-3} (-2.7218 + 3.0458)$$

$$= 0.00162 \text{ m} \approx 1.6 \text{ mm} \text{ ANS.}$$

1.87 AS IN PROB. 1.86, WE OBTAIN
 $h_x = 0.04 + 0.04x$

$$A_x = 2(0.04 + 0.04x)(0.006) + 2(0.030)(0.006)$$

$$A_x = 0.00084 + 0.00048x$$

$$\delta = \frac{F}{E} \int \frac{dx}{A_x} = \frac{P}{110 \times 10^9} \int_0^{0.75} \frac{dx}{(0.00084 + 0.00048x)} = 0.0035$$

$$P \left(\frac{1}{0.00048}\right) \log(0.00084 + 0.00048x) \Big|_0^{0.75} = 3.85 \times 10^8$$

$$P [-2.92082 + 3.07572] = 1.848 \times 10^5$$

$$P = 1193 \times 10^3 \text{ N} = 1193 \text{ kN} \text{ ANS.}$$

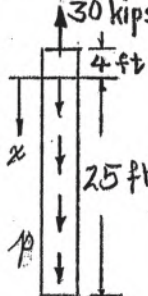
1.88 (a) $\sum F_x = 0$
 $p(25) - 30 = 0$
 $p = 1.2 \text{ kips/ft} \text{ ANS.}$
 (b) $\delta = \frac{F_1 L}{AE} + \int \frac{F_2 dx}{AE}$

$$\delta = \frac{1}{(61.8)(30 \times 10^3)} \left[30(4 \times 12) + \int_{4 \times 12}^{29 \times 12} (30 - 1.2x) dx \right]$$

$$\delta = 5.394 \times 10^{-4} (1440 + 4385 - 1325) = 2.427 \text{ in. ANS.}$$
 (c) AT $x = 15 \text{ ft}$, $F_2 = 30 - 1.2(15) = 12 \text{ kips}$

$$\sigma = \frac{F_2}{A} = \frac{12}{61.8} = 0.194 \text{ ksi}$$

$$= 194 \text{ psi} \text{ ANS.}$$



1.89 (a) $\sum F_x = 0$

$150(0.50) - P = 0$
 $P = 75.0 \text{ kN}$ ANS.

(b) $\sum F_x = 0$
 $F_2 + 150x - 75 = 0$
 $F_2 = 75 - 150x$
 $F_2 = 75 \text{ kN}$ AT $x = 0$.
 $\sigma_{\text{MAX}} = \frac{75 \times 10^3}{5 \times 10^{-4}} = 150 \text{ MPa}$ ANS.

(c) $\delta = \frac{FL}{AE} + \int \frac{F_2 dx}{AE}$
 $\delta = \frac{1}{5 \times 10^{-4} (70 \times 10^9)} \left[75 \times 10^3 (0.10) + \int_0^{0.5} (75 - 150x) dx \right]$
 $\delta \approx 0.00075 \text{ m} \approx 0.8 \text{ mm}$ ANS.

1.90 (a) BY EQ. (1.1): $F_2 - F_1 = \int_1^2 p dx$

$F_2 = P + \int_0^{0.3} 1000x dx$
 $0 = P - 500x^2 \Big|_0^{0.3}$
 $P = 45 \text{ N}$ ANS.

(b) AT $x = 0.2 \text{ m}$
 $F_2 = 45 - 500(0.2)^2$
 $= 25 \text{ N}$ ANS.

(c) $\delta = \int \frac{F dx}{AE} = \frac{1}{2 \times 10^{-5} (70 \times 10^9)} \int_0^{0.3} (45 - 500x^2) dx$
 $= 6.429 \times 10^{-6} \text{ m}$ ANS.

1.91 RETRACING THE STEPS USED IN PART II OF EXAMPLE 1.10, WE OBTAIN:
 EQUILIBRIUM $\Rightarrow$

$120 - F_C + F_A = 0$ (1)

DEFORMATION $\Rightarrow$

$F_A = -1.38616 F_C$ (2)

SOLVE SIMULTANEOUSLY TO GET:

$F_A = 69.710 \text{ kN}$
 $\sigma_{AB} = \left(\frac{F}{A} \right)_{AB} = \frac{69.710 \times 10^3}{\frac{\pi}{4} (0.06^2)} = 24.655 \text{ MPa}$ ANS.

$F_C = 50.290 \text{ kN}$

$\sigma_{BC} = \left(\frac{F}{A} \right)_{BC} = \frac{50.290 \times 10^3}{\frac{\pi}{4} (0.08^2)} = 10.005 \text{ MPa}$ ANS.

1.92

$\sum F_y = 0$

$2F_B + F_S - P = 0$ (1)

$\left(\frac{FL}{AE} \right)_B = \left(\frac{FL}{AE} \right)_S; \frac{F_B (1.5)}{600 \times 10^{-6} (100 \times 10^9)} = \frac{F_S (1.5)}{1500 \times 10^{-6} (200 \times 10^9)}$

$F_B = 0.2 F_S$ (2)

ASSUME BRASS CONTROLS.

$F_B = 20 \times 10^6 (600 \times 10^{-6}) = 12.0 \text{ kN}$

(2) $\Rightarrow F_S = \frac{12.0}{0.2} = 60.0 \text{ kN}$

$\sigma_S = \frac{60.0 \times 10^3}{1500 \times 10^{-6}} = 40.0 \text{ MPa} < (\sigma_S)_{\text{ALL}} \text{ OK}$

(1) $\Rightarrow P = 2(12.0) + 60.0 = 84.0 \text{ kN}$ ANS.

1.93 $\sum F_y = 0$

$F_S + F_A - P = 0$ (1)

$\delta_A = \delta_S; \frac{F_A (10)}{(0.4)(10 \times 10^3)} = \frac{F_S (10)}{(0.7)(30 \times 10^3)}$

$F_S = 5.25 F_A$ (2)

SOLVE SIMULTANEOUSLY TO GET

$F_A = 8.0 \text{ kips}$

$\sigma_A = \left(\frac{F}{A} \right)_A = \frac{8.0}{0.4} = 20.0 \text{ ksi}$ ANS.

$F_S = 42.0 \text{ kips}$

$\sigma_S = \left(\frac{F}{A} \right)_S = \frac{42.0}{0.7} = 60.0 \text{ ksi}$ ANS.

1.94 REFERTO F.B.D. IN PROB. 1.93.

$\sum F_x = 0: F_S + F_A - P = 0$ (1)

$\delta_A = \delta_S: \frac{F_A (h)}{(0.35)(10 \times 10^3)} = \frac{F_S (h)}{(0.5)(30 \times 10^3)}$

$F_S = 4.286 F_A$ (2)

ASSUME STEEL CONTROLS.

$F_S = 40(0.5) = 20.0 \text{ kips}$

(2) $\Rightarrow F_A = \frac{20.0}{4.286} = 4.666 \text{ kips}$

$\sigma_A = \left(\frac{F}{A} \right)_A = \frac{4.666}{0.35} = 13.331 < (\sigma_A)_{\text{ALL}} \text{ OK}$

(1) $\Rightarrow P = 20.0 + 4.666 \approx 24.7 \text{ kips}$ ANS.

$\delta_{\text{PLATE}} = \delta_S = \frac{20.0 (15)}{(0.5)(30 \times 10^3)}$

$= 0.020 \text{ in.}$

ANS.

1.95 $\sum F_x = 0$

$F_{AB} - 200 + F_{BC} = 0 \quad (1)$

$\delta_{AB} = \delta_{BC}; \left(\frac{FL}{AE}\right)_{AB} = \left(\frac{FL}{AE}\right)_{BC}$

$\frac{F_{AB}(0.25)}{(0.015)(0.03)(150 \times 10^9)} = \frac{F_{BC}(0.50)}{(0.05)(0.08)(150 \times 10^9)}$

$F_{AB} = 0.225 F_{BC} \quad (2)$

SOLVE (1) & (2) TO GET

$F_{BC} = 163.265 \text{ kN}$

$F_{AB} = 36.735 \text{ kN} \quad \begin{cases} a = 0.25 \text{ m} \\ b = 0.50 \text{ m} \end{cases}$

(a) $\sigma_{AB} = \frac{36.735 \times 10^3}{(0.015)(0.03)} = 81.633 \text{ MPa} \quad \text{ANS.}$

$\sigma_{BC} = \frac{163.265 \times 10^3}{(0.05)(0.08)} = 40.816 \text{ MPa} \quad \text{ANS.}$

(b) $\delta_B = \delta_{BC} = \frac{163.265(10^3)(0.5)}{(0.05)(0.08)(150 \times 10^9)} = 0.000136 \text{ m} = 0.136 \text{ mm} \quad \text{ANS.}$

1.96 REFER TO THE F.B.D. OF PROB. 1.95.

$\sum F_x = 0 \Rightarrow P = F_{AB} + F_{BC} \quad (1)$

$\delta_{AB} = \delta_{BC}; \left(\frac{FL}{AE}\right)_{AB} = \left(\frac{FL}{AE}\right)_{BC} \quad \begin{cases} a = 0.3 \text{ m} \\ b = 0.6 \text{ m} \end{cases}$

$\frac{F_{AB}(0.3)}{(\pi/4)(0.035^2)(200 \times 10^9)} = \frac{F_{BC}(0.6)}{(\pi/4)(0.075^2)(70 \times 10^9)}$

$F_{AB} = 1.2444 F_{BC} \quad (2)$

ASSUME ALLOWABLE IN BC CONTROLS.

$F_{AB} = 1.2444(120 \times 10^6) \left(\frac{\pi}{4}\right)(0.075^2) = 659,711 \text{ N} = 659.711 \text{ kN}$

$\sigma_{AB} = \frac{659.711 \times 10^3}{(\pi/4)(0.035^2)} = 685.690 < (\sigma_{ALL})_{AB} \quad \text{OK}$

(1) & (2) $\Rightarrow P = 659.711 + \frac{659.711}{1.2444} = 1,189.855 \text{ kN} \quad \text{ANS.}$

1.97

$\sum F_x = 0$

$2F_M + F_A - 200 = 0 \quad (1)$

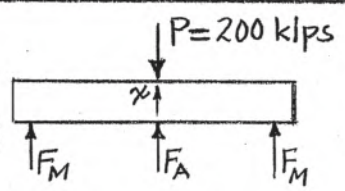
$\delta_M = \delta_A + 0.012$

$\frac{F_M(10)}{(3)(6.5 \times 10^3)} = \frac{F_A(10)}{(3)(10.0 \times 10^3)} + 0.012$

$F_M = 0.65 F_A + 23.4 \quad (2)$

SOLVE (1) & (2) TO GET

$F_A = 66.609 \text{ kips}; F_M = 66.696 \text{ kips}$



1.97 CONT'D

(a) $\sigma_A = \frac{66.609}{3} = 22.2 \text{ ksi} \quad \text{ANS.}$

$\sigma_M = \frac{66.696}{3} = 22.2 \text{ ksi} \quad \text{ANS.}$

(b) $\delta_M = \frac{66.609(10)}{(3)(10 \times 10^3)} + 0.012 = 0.022 + 0.012 = 0.034 \text{ in.} \quad \text{ANS.}$

1.98 REFER TO THE F.B.D. OF PROB. 1.97.

$\sum F_x = 0 \Rightarrow P = 2F_M + F_A \quad (1)$

$\delta_M = \delta_A + 0.01; F_M = F_A$

$\frac{F_A(10)}{(2.5)(6.5 \times 10^3)} = \frac{F_A(10)}{(2.5)(10 \times 10^3)} + 0.01$

$F_A = 46.429 \text{ kips} = F_M$

(1) $\Rightarrow P = 3(46.429) = 139.3 \text{ kips} \quad \text{ANS.}$

$\delta_M = \frac{46.429(10)}{2.5(10 \times 10^3)} + 0.01 = 0.029 \text{ in.} \quad \text{ANS.}$

1.99 $\sum F_x = 0$

$5F_S + F_C - 2000 = 0 \quad (1)$

$\delta_C = \delta_S; \left(\frac{FL}{AE}\right)_C = \left(\frac{FL}{AE}\right)_S$

$\frac{F_C(4)}{(0.12)(64)(30 \times 10^9)} = \frac{F_S(4)}{(0.00402)(200 \times 10^9)}$

$F_C = 4.537 F_S \quad (2)$

SOLVE (1) & (2) TO GET

$F_S = 209.710 \text{ kN}$

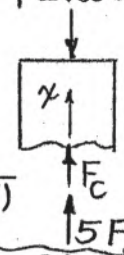
$F_C = 951.452 \text{ kN}$

$\sigma_S = \frac{F_S}{A_S} = 52.167 \text{ MPa} \approx 52.2 \text{ MPa} \quad \text{ANS}$

$\sigma_C = \frac{F_C}{A_C} = 7.822 \text{ MPa} \approx 7.8 \text{ MPa} \quad \text{ANS.}$

$A_C = \frac{\pi}{4}[0.4^2 - 5(0.032^2)] = 0.12164 \text{ m}^2$
 $A_S = 5\left(\frac{\pi}{4}\right)(0.032^2) = 0.00402 \text{ m}^2$

$P = 2000 \text{ kN}$



1.100 REFER TO THE F.B.D. OF PROB. 1.99.

$5F_S + F_C - P = 0 \quad (1)$

$\delta_C = \delta_S; \left(\frac{FL}{AE}\right)_C = \left(\frac{FL}{AE}\right)_S$

$\frac{F_C(3.5)}{(0.15423)(30 \times 10^9)} = \frac{F_S(3.5)}{(0.00481)(210 \times 10^9)}$

$F_S = 0.20791 F_C = 0.20791 [20 \times 10^6 (0.15423)] = 641.319 \text{ kN} \quad (\text{ASSUMING CONCRETE CONTROLS})$

CHECK: $\sigma_S = \frac{F_S}{A_S} = 133.330 \text{ MPa} < (\sigma_{ALL})_S \quad \text{OK}$

$F_C = 4.8097 F_S = 3084.552 \text{ kN}$

(1) $\Rightarrow P = 5(641.319) + 3084.552 = 6,291.747 \approx 6,291.1 \text{ kN} \quad \text{ANS.}$

$A_C = \frac{\pi}{4}[0.45^2 - 5(0.035^2)] = 0.15423 \text{ m}^2$
 $A_S = 5\left(\frac{\pi}{4}\right)(0.035^2) = 0.00481 \text{ m}^2$

1.101 $\Sigma F_x = 0$

$2F_s + F_A - 50 = 0 \quad (1)$

$\delta_A = \delta_s + 0.001$

$\left(\frac{FL}{AE}\right)_A = \left(\frac{FL}{AE}\right)_s + 0.001$

$\frac{F_A(15)}{(2)(2.5)(10 \times 10^3)} = \frac{F_s(15)}{(2)(2.5)(30 \times 10^3)} + 0.001$

$3F_A = F_s + 10 \quad (2)$

SOLVE (1) & (2) TO GET

$F_s = 20 \text{ kips}; \sigma_s = \left(\frac{F}{A}\right)_s = 4.0 \text{ ksi} \quad \text{ANS.}$

$F_A = 10 \text{ kips}; \sigma_A = \left(\frac{F}{A}\right)_A = 2.0 \text{ ksi} \quad \text{ANS.}$

1.102 REFER TO THE F.B.D. OF PROB. 1.101.

$2F_s + F_A - 60 = 0 \quad (1)$

$\delta_A = \delta_s + e; \left(\frac{FL}{AE}\right)_A = \left(\frac{FL}{AE}\right)_s + e$

$\frac{F_A(15)}{(1.5)(3.0)(10 \times 10^3)} = \frac{F_s(15)}{(1.5)(3.0)(30 \times 10^3)} + e$

$3F_A = F_s + 9000e \quad (2)$

$\sigma_s = 2\sigma_A \Rightarrow F_s = 2F_A \quad (3)$

SOLVE SIMULTANEOUSLY TO GET

$F_s = 24 \text{ kips}; F_A = 12 \text{ kips}; e = 0.00133 \text{ in.} \quad \text{ANS.}$

1.103

$\Sigma M_O = 0$

$0.10F_A - 0.15F_B = 0 \quad (1)$

$F_A = 1.5F_B \quad (1)$

$\Sigma F_y = 0; F_A + F_B - 50 = 0 \quad (2)$

SOLVE (1) & (2) TO GET

$F_A = 30 \text{ kN}; F_B = 20 \text{ kN}$

$\delta_A = \delta_B; \left(\frac{FL}{AE}\right)_A = \left(\frac{FL}{AE}\right)_B$

$\frac{(30)(0.30)}{A_A(75 \times 10^9)} = \frac{(20)(0.20)}{A_B(100 \times 10^9)}$

$A_A = 3A_B \quad (3)$

$F_B = \sigma_B A_B; 20 \times 10^3 = 15 \times 10^6 A_B$

$A_B = 1.333 \times 10^{-3} \text{ m}^2$

(3) $\Rightarrow$

$A_A = 4.0 \times 10^{-3} \text{ m}^2$

ANS.

ANS.

1.104 REFER TO THE F.B.D. OF PROB. 1.103.

$\Sigma M_O = 0; F_A b - F_B a = 0 \Rightarrow \frac{a}{b} = \frac{F_A}{F_B} \quad (1)$

$\Sigma F_y = 0; F_B + F_A - 60 = 0 \quad (2)$

$\delta_A = \delta_B; \left(\frac{FL}{AE}\right)_A = \left(\frac{FL}{AE}\right)_B$

$\frac{F_A(0.3)}{(0.0065)(75 \times 10^9)} = \frac{F_B(0.2)}{(0.0130)(100 \times 10^9)}$

$F_A = 0.25 F_B \quad (3)$

SOLVE (2) & (3) TO GET

$F_A = 12 \text{ kN}; F_B = 48 \text{ kN}$

(1) $\Rightarrow \frac{a}{b} = \frac{12}{48} = \frac{1}{4}$

ANS.

$\sigma_A = \left(\frac{F}{A}\right)_A = \frac{12 \times 10^3}{0.0065} = 1.846 \approx 1.9 \text{ MPa} \quad \text{ANS.}$

$\sigma_B = \left(\frac{F}{A}\right)_B = \frac{48 \times 10^3}{0.0130} = 3.692 \approx 3.7 \text{ MPa} \quad \text{ANS.}$

1.105

$\Sigma F_y = 0$

$F_W + F_M - 75 = 0 \quad (1)$

$\delta_W = \delta_M; \left(\frac{FL}{AE}\right)_W = \left(\frac{FL}{AE}\right)_M$

$\frac{F_W(10)}{(4)(5)(2 \times 10^6)} = \frac{F_M(10)}{(3)(5)(6.5 \times 10^6)}$

$F_W = 0.41026 F_M \quad (2)$

SOLVE (1) & (2) TO GET

$F_W = 21.818 \text{ kips}; F_M = 53.182 \text{ kips}$

(a) $\Sigma M_O = 0; 21.818(2.0) + 53.182(5.5) - 75a = 0$

$a = 4.482 \text{ in.} \quad \text{ANS.}$

(b) $\sigma_W = \left(\frac{F}{A}\right)_W = 1.091 \approx 1.1 \text{ ksi} \quad \text{ANS.}$

$\sigma_M = \left(\frac{F}{A}\right)_M = 3.545 \approx 3.5 \text{ ksi} \quad \text{ANS.}$

1.106 REFER TO THE F.B.D. OF PROB. 1.105.

$\Sigma F_y = 0; F_W + F_M - 60 = 0 \quad (1) \quad P = 60 \text{ kips}$

$\delta_W = \delta_M; \frac{F_W(12)}{(4d)(2 \times 10^6)} = \frac{F_M(12)}{(3d)(6.5 \times 10^6)}$

$F_W = 0.41026 F_M \quad (2)$

SOLVE (1) & (2) TO GET: $F_W = 17.455 \text{ kips}; F_M = 42.545 \text{ kips}$

(a) $(\sigma_{ALL})_W = 7.5 = \frac{F_W}{4d}$

$d = \frac{17.455}{(7.5)(4)} = 0.582 \text{ in.} \quad \text{ANS.}$

CHECK: $\sigma_M = \frac{F_M}{3d} = \frac{42.545}{3(0.582)} = 24.4 \text{ ksi} < (\sigma_{ALL})_M \quad \text{OK.}$

(b) $\Sigma M_O = 0; 17.455(2.0) + 42.545(5.5) - 60a = 0$

$a = 4.482 \text{ in.} \quad \text{ANS.}$

ANS.