SOLUTIONS MANUAL

Second Edition

ADVANCED MECHANICS OF MATERIALS

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1.4-3 $p = (\alpha_a - \alpha_s)TtE_aE_s/[R(E_a - E_s)]$
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1.6-1 Consider equilibrium; note that M = 0 at inflection point
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1.9-3 $P_Y = 2.30\sigma_Y A$ at $u_D = \sigma_Y L/E$

$P_{fp} = 2.73\sigma_Y A$ at $u_D = 4\sigma_Y L/3E$

2.3-1(a) Pure shear

(b) Hydrostatic in a plane, or uniaxial stress

(c) Fully hydrostatic (3D)

2.3-2(a) $\sigma_1 = 82.1$, $\sigma_2 = 0$, $\sigma_3 = -52.1$ (in MPa)

(b) $\sigma_1 = 127.6$, $\sigma_2 = -12.9$, $\sigma_3 = -195$ (in MPa)

(c) $\sigma_1 = 114$, $\sigma_2 = 68.4$, $\sigma_3 = -163$ (in MPa)

(d) $\sigma_1 = 297$, $\sigma_2 = 99.6$, $\sigma_3 = -177$ (in MPa)

(e) $\sigma_1 = 22.4$, $\sigma_2 = 0$, $\sigma_3 = -22.4$ (in MPa)

(f) $\sigma_1 = 74.6$, $\sigma_2 = -19.4$, $\sigma_3 = -55.2$ (in MPa)

(g) $\sigma_1 = 200$, $\sigma_2 = -100$, $\sigma_3 = -100$ (in MPa)

2.3-3, 2.3-4 ($\underset{\sim}{n}_3 = \underset{\sim}{n}_1 \times \underset{\sim}{n}_2$)

	ℓ_1	m_1	n_1	ℓ_2	m_2	n_2
(a)	0	0.973	0.230	0	-0.230	0.973
(b)	0.080	0.792	0.605	0.787	-0.423	0.449
(c)	-0.309	0.925	0.223	0.911	0.219	0.353
(d)	0.806	-0.582	0.111	0.427	0.700	0.573
(e)	0.632	0.707	0.316	-0.447	0	0.894
(f)	0.651	0.502	0.570	-0.083	0.793	-0.604
(g)	0.577	0.577	0.577	[any normal to $\underset{\sim}{n}_1$]		

2.3-5 $\sigma_1 = \sigma_2 = 0$, $\sigma_3 = -80$ MPa

2.4-1(a,b) [Proof required]

2.5-1(a,b) [Proof required] (c) $B = E/3(1 - 2\nu)$

(d) [Proof required]

2.5-2 $\epsilon_1 = 0.000457$, $\epsilon_2 = -0.000066$, $\epsilon_3 = -0.000303$

2.5-3 $A = tr_i/(1 - \nu)$

2.5-4 $\Delta T = 347^oC$

2.5-5 [Set of equations required]

2.5-6 $\tan\theta = \sqrt{\nu}$, $\sigma_x = E\epsilon_s/(1 - \nu)$

2.5-7 $p = 2Et(r - a)/[(1 - \nu)r^2]$, maximum at $r = 2a$

2.6-1 Case 1 (a) $\sigma_1 = 30$ MPa, $\sigma_2 = 20$ MPa, $\sigma_3 = -20$ MPa

(b) $n_1 = 1$, $\ell_2 = m_2 = -\ell_3 = m_3 = 0.707$

(c) $\tau_{oct} = 21.6$ MPa, $\tau_{max} = 25$ MPa

(d) $\tau_e = 45.8$ MPa

(e) $U_{od} = 350/G$ N·mm/mm^3 (G in MPa)

Case 2 (a) $\sigma_1 = 35.1$ MPa, $\sigma_2 = 7.1$ MPa, $\sigma_3 = -27.2$ MPa

(b) $\ell_1 = 0.636$, $m_1 = 0.384$, $n_1 = 0.669$

$\ell_2 = 0.240$, $m_2 = 0.725$, $n_2 = -0.645$

(c) $\tau_{oct} = 25.5$ MPa, $\tau_{max} = 31.2$ MPa

(d) $\sigma_e = 54.1$ MPa

(e) $U_{od} = 487/G$ N·mm/mm^3 (G in MPa)

2.6-2

	(a)	(b)	(c)	(d), s_x	(e), s_1	(f)
(a)	67.1	55.2	117	-10	72.1	2285/G
(b)	161	132	280	-53.3	154	13,070/G
(c)	138	121	257	48.3	107	11,000/G

(d)	237	194	412	107	224	28,300/G
(e)	22.4	18.3	38.7	0	22.4	250/G
(f)	64.9	54.7	116	0	74.6	2250/G
(g)	150	141	300	0	200	15,000/G

2.7-1 $K_t = 2.0$ for small load, $K_t \approx 1$ for large load

2.7-2 $r/D = 1/4$, stress ratio = 1.14

2.7-3 $a/b = 2$, $\sigma_{max} = 1.5\sigma_1$

2.7-4(a) $\nu = 1/3$ (b) $a/b = 1/\nu$, $\sigma_A = \sigma_B = -(1 + \nu)\sigma_o$

2.7-5(a) [Proof required] (b) $\sigma_{max} = 159T/D^3$ (c) $T_{fp} = 0.0565\tau_Y D^3$

2.7-6 Cut away a central strip of width w

2.7-7 Residual $\sigma_B = \sigma_Y(1 - K_t)$ (compressive)

2.8-1(a) $p_o = 0.591\sqrt{PE/LR}$ (b) $p_o = 0.418\sqrt{PE/LR}$ (c) $p_o = 0.091\sqrt{PE/LR}$

2.8-2(a) $T = PR\phi$ (b) $p_o = 0.296(\phi/R)\sqrt{PE}$ (c) $\sigma = 298$ MPa

2.8-3 [Argument resembles that of Problem 1.7-8]

3.2-1(a) [Derivation required] (b) $\tau = \sigma_{tf}\sigma_{cf}(\sigma_{tf} + \sigma_{cf})$

3.2-2 Expand square in third quadrant of Fig. 3.3-1 to triple size

3.2-3(a) -240 MPa to 40 MPa (b) -120 MPa to 25 MPa

3.2-4 $T = 7.57$ kN·m

3.2-5 $r = 61.4$ mm

3.3-1 Results in first quadrant ($\sigma_x > \sigma_y > 0$; then $\sigma_y > \sigma_x > 0$):

(a) 45° to x and z axes; then 45° to y and z axes

(b) $\sigma_x = \sigma_1$, $\sigma_y = \sigma_2$, $0 = \sigma_3$; then $\sigma_y = \sigma_1$, $\sigma_x = \sigma_2$, $0 = \sigma_3$

(c) $\sigma_x = \sigma_Y$, then $\sigma_y = \sigma_Y$

3.3-2(a) $\sigma_x^2 + 4\tau_{xy}^2 = \sigma_Y^2$ (b) $\sigma_x^2 + 3\tau_{xy}^2 = \sigma_Y^2$

(c) $\sigma_1^2 - \sigma_1\sigma_3 + \sigma_3^2 = \sigma_Y^2$ (d) $\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2 = \sigma_Y^2$

3.3-3(a) 1,3,2 (b) 1,3,2 (c) 3, 1 and 2 tied (d) 3,2,1

3.3-4(a) $\sigma_Y = 110$ MPa (b) $\sigma_Y = 105.4$ MPa

3.3-5(a) -120 MPa to 50 MPa (b) -137.6 MPa to 67.6 MPa

3.3-6(a) $\sigma_Y = 400$ MPa (τ_{max} theory) or $\sigma_Y = 346$ MPa (von M. theory)

(b) $\sigma_Y = 542$ MPa (τ_{max} theory) or $\sigma_Y = 542$ MPa (von M. theory)

3.3-7 $P = 62.8$ N (τ_{max} theory) or $P = 69.2$ N (von M. theory)

3.3-8(a) SF = 3.73 (b) SF = 4.11

3.3-9(a) $t = 5.89$ mm (b) $t = 5.89$ mm

3.3-10(a) $r = 9.66$ mm (b) $r = 9.27$ mm

3.3-11 $r = [4(SF)\sqrt{M^2 + kT^2}/\pi\sigma_Y]^{1/3}$: $k = 1$ in (a), $k = 0.75$ in (b)

3.5-1 $a = 5.24$ mm

3.5-2(a) $P = 1.51$ MN (b) $P = 4.52$ MN (c) $P = 1.54$ MN

3.5-3(a) $P = 173$ kN (b) $P = 59.2$ kN (c) $M = 1.29$ kN·m

3.5-4(a) SF = 0.779 (b) SF = 0.728 (c) SF = 0.917

3.5-5(a) $a = 28.1$ mm (b) $a = 24.7$ mm (c) $a = 20.3$ mm

3.5-6(a) $P = 12.4$ kN (b) $P = 31.9$ kN (c) $P = 17.9$ kN

3.5-7 First quadrant of ellipse with aspect ratio 0.75

3.5-8 [Rather lengthy expressions]

3.5-9(a) $T = 1.02$ MN·m (b) $T = 1.15$ MN·m (c) $T = 1.36$ MN·m

3.6-1 $N \approx 1000$ cycles

3.6-2 $2A = [(SF)(P_{max} - P_{min})/\sigma_{fs}] + [(P_{max} + P_{min})/\sigma_u]$

3.6-3(a) SF = 1.08 (b) SF = 0.69

3.6-4 Depth = 77.3 mm based on stress, 88.6 mm based on deflection
3.6-5(a) SF = 0.95 (b) SF = 0.52
3.6-6 SF = 4.74
3.6-7(a) About 26,000 cycles (b) About 600 repetitions
3.6-8(a) Yes (b) No (c) No (d) No (e) Yes

4.1-1 Energy expended = $W^2/4k$
4.1-2 $\theta = \arcsin(C/WL)$
4.1-3 $F_1 = k_1 a\theta$, $F_2 = 2k_2 a\theta$, where $\theta = C/[a^2(k_1 + 4k_2)]$
4.1-4 $\theta = \arcsin(W/2kL)$
4.1-5 $F_A = P/7$, $F_B = 2P/7$, $F_C = 4P/7$
4.1-6 $\theta = 4W/9ka$, $v = 13W/18k$
4.1-7 $U = (AEg^2/4L) + (P^2L/4AE)$
4.1-8(a) $u = (F/2\pi GL)\ln(R/r)$ (b) $\theta = (T/4\pi GL)(R^2 - r^2)/R^2r^2$
4.1-9 $T/\theta = 9GJ/20L$
4.2-1 $\theta = PL^2/2EI$
4.2-2 Change in length = $P\nu d/AE$
4.2-3(a) $\Delta V = Fhr(1 - \nu)/2Et$ (b) $\Delta V = Fr^2(2 - \nu)/Et$
4.2-4 [Proof required]
4.2-5 [Explanation required]
4.2-6 [Proof required]
4.2-7 $\Delta V = Fh(1 - 2\nu)/E$
4.3-1 [Proof required]
4.3-2 [Proof required]
4.3-3(a,b,c) [Proof required]
4.4-1 $\theta = qL^3/6EI$, $v = 17qL^4/384EI$
4.5-1 $u_C = qL^2/2Ebh$, $v_C = 2qL^3/Ebh^2$
4.5-2(a) $v_A = 14Fa^3/3EI$, $\theta_A = 2Fa^2/EI$
(b) $v_C = 5Fa^3/6EI$, $\theta_C = 3Fa^2/2EI$
(c) $\theta_{AC} = 23Fa^2/12EI$
4.5-3 $v_C = 5q_LL^4/768EI$, $\theta_C = 7q_LL^3/5760EI$
4.5-4(a) $u_A = 5QL^3/3EI$, $v_A = QL^3/EI$, $w_A = 0$
(b) $u_A = 0$, $v_A = 0$, $w_A = (4FL^3/3EI) + (2FL^3/GK)$
4.5-5(a) $v_C = (qb^4/8EI) + (qa^3b/3EI) + (qab^3/2GK)$
(b) $w_D = (qb^3c/6EI) + (qab^2c/2GK)$
(c) $\theta_{xC} = (qb^3/6EI) + (qab^2/2GK)$
4.5-6 $\alpha = \pi/8$ or $\alpha = 5\pi/8$
4.5-7(a) 4.127PL/AE (rightward) (b) 8.954PL/AE (downward)
(c) 0.752PL/AE (rightward) (d) 12.504PL/AE (downward)
(e) 5.590PL/AE (separation)
4.6-1 $\theta_C = 1.15PR^2/EI$ at 60.3° clockwise from line AC
4.6-2 Exact: $v_C = 0.0621PL^3/EI$
Simple approximation: $v_C = 0.0519PL^3/EI$
Better approximation: $v_C = 0.0644PL^3/EI$

4.6-3 u_O = CRL/EI, v_O = CL(R + L/2)/EI,
$w_O = (CL/EI)(R + L/2) + \pi(CR^2/4EI) - (CR^2/GJ)(1 - \pi/4)$

4.6-4(a) $u_A = 3\pi QR^3/EI$, $v_A = 0$, $w_A = 0$
(b) $u_A = 0$, $v_A = 0$, $w_A = (\pi FR^3/EI) + (3\pi FR^3/GJ)$

4.6-5 Spring constant = $2EI/\pi R^3$

4.6-6 $u_A = 0$, $v_A = 0$, $w_A = \pi PR^3/GK$
$\theta_{xA} = -2PR^2/GK$, $\theta_{yA} = 0$, $\theta_{zA} = 0$

4.6-7(a) $u_B = 2qR^4/3EI$ (b) $v_C = -0.226qR^4/EI$

4.6-8(a) $u_A = \pi^2 qR^4/EI$, $v_A = -3\pi qR^4/2EI$, $w_A = 0$
(b) $u_A = 9\pi R^4/2EI$, $v_A = \pi^2 qR^4/EI$, $w_A = 0$
(c) $u_A = 0$, $v_A = 0$, $w_A = 2\pi^2 qR^4/GJ$

4.6-9(a) $\theta_{xA} = 0$, $\theta_{yA} = 0$, $\theta_{zA} = 0$
(b) $\theta_{xA} = 0$, $\theta_{yA} = 0$, $\theta_{zA} = 4\pi qR^3/EI$
(c) $\theta_{xA} = \pi qR^3(3/GJ + 1/EI)$, $\theta_{yA} = 0$, $\theta_{zA} = 0$

4.6-10(a) $u_O = 0.163qR^4/EI$ (to right), $v_O = 0.215qR^4/EI$ (down)
(b) $v_O = \pi qR^2/4EA$ (up)

4.6-11 $v = (FR^3/EI)[1 + \cos\phi + 0.5(\pi - \phi)\sin\phi]$

4.6-12(a) Use Eqs. 4.6-1; neglect effect of α (b) $w = 4PR^3n/Gc^4$
(c) $\theta = 4nRC(2 + \nu)/Ec^4$ (d) $u = 2(2 + \nu)FH^3/3\pi Ec^4\alpha$

4.7-1 a/b = 0.732

4.7-2 Force = 0.85W

4.7-3 Separation = $Pb^3(4a + b)/[12EI(a + b)]$

4.7-4 $H_B = qa^3/[8b(a + b)]$

4.7-5 Reaction = $(5qa/4) - (6EIg/a^3)$

4.7-6 $v_A = 0.0709FL^3/EI$

4.7-7 T = F/(2 + c), where $c = 6I/5AL^2$

4.7-8 u_C = 20,900F/EL

4.7-9 [Discussion required]

4.7-10 $M_C = (5Fa/16) + (qa^2/4)$

4.7-11 For EI = GK, $M_C = [Fa(a + 2b)/4 + qa^2(a + 3b)/6]/(a + b)$

4.7-12 $M_O = (FL/8) - (2\beta EI/L)$, $v_C = (FL^3/192EI) + (\beta L/4)$

4.7-13(a) $H\int_0^L y^2 ds = EI\alpha L\Delta T$ (b) M = 0 everywhere

4.7-14 [Discussion required]

4.7-15 $\theta = 0.149CR/EI$

4.7-16(a) C = 0.307FR (b) $v = 0.0704FR^3/EI$

4.7-17(a) M_C = 0.182PR (b) M_A = 0.242PR
(c) $u_C = 0.0708PR^3/EI$ (d) M_C = 0.151PR
(e) $u_B = -0.722PR^3/EI$ (f) $v_C = -0.0260M_CR^2/EI$

4.7-18(a) $v_C = 0.149PR^3/EI$ (b) $\Delta_{BD} = -0.137PR^3/EI$

(c) $M_C = 0$, $w_C = (\pi R^2 M_o/4)(1/GK + 1/EI)$ (d) $T_C = M_o/\pi$

(e) $M_C = 2PR/\pi[1 + (GK/EI)]$ (f) $M_B = 0.429\ qR^2$

(g) $v_C = -\rho R^5\omega^2/6EI$

4.7-19 $M_A = (2T_o a/b)[(bEI + aGK)/(bEI+ 2aGK)]$

4.7-20 $M_C = qL^2/8$, $Q = 5qL/8$

4.8-1 $w = 4PR^3n/Gc^4$; lateral displacement increments cancel

4.10-1 $F_1 = -0.667P$, $F_2 = 0.0833P$, $F_3 = 0.750P$

4.10-2 $P = kL$; $d^2\Pi/d\theta^2 < 0$ if $P > kL$

4.10-3 $d^2\Pi/d\theta^2 > 0$ if $h < 2R$

4.10-4 $u_D = 2.083L\alpha\Delta T$, $v_D = 0$. Bar stresses are zero

4.11-1 $v_L = -qL^4/8EI$, $M_o = -qL^2/2$

4.11-2(a) $v_L = -FL^3/4EI$, $M_o = -FL/2$ (b) $v_L = -FL^3/3EI$, $M_o = -FL$

(c) $v_L = -FL^3/12EI$, $M_o = 0$ (d) $v_L = -0.328FL^3/EI$, $M_o = -0.813FL$

4.11-3 $\theta_L = M_L L/3EI$

4.11-4(a) $v_C = -FL^3/64EI$, $M_C = FL/8$

(b) $v_C = -qL^4/96EI$, $M_C = qL^2/12$

(c) $v_C = -q_L L^4/192EI$, $M_C = q_L L^2/24$

4.11-5 $v_L = -0.308F/k$

4.11-6(a) $u = qLx/2EA$, $\sigma = qL/2A$

(b) $u = (q/EA)(Lx - x^2/2)$, $\sigma = q(L - x)/A$

4.11-7(a) $v = ax^2(L - x)$ (b) $v_W = -0.00549WL^3/EI$

(b) Stable if $EI > \gamma bL^4/420$

4.11-8 $P = 0.7222EA_0u_L/L$ (0.12% high)

4.12-1 $v_o = 0.142FR^3/EI$, $M_o = 4FR/3\pi$

4.12-2 $v_o = \rho R^5\omega^2/18EI$, $M_o = \rho R^3\omega^2/9$

4.12-3 First term: v_L errs by -4.5%; M_o errs by -41%

4.12-4(a) First term: $v_{L/2}$ errs by -1.45%; $M_{L/2}$ errs by -18.9%

(b) First term: $v_{L/2}$ errs by +0.38%; $M_{L/2}$ errs by +3.2%

(c) First term: $v_{L/2}$ errs by +0.38%; $M_{L/2}$ errs by +3.2%

4.12-5 First term: u_L errs by +3.2%; σ_o errs by -18.9%

4.13-1 All results are exact

5.2-1 Deformation due to weight displaces equal weight of water.

5.2-2 $k = \rho g/\ell$

5.2-3 [Proof required]

5.2-4 $w = w_o e^{-\beta x}$, where $\beta^2 = k/T$

5.2-5(a) $\theta = -(T_o\lambda/k)e^{-\lambda x}$, $T = T_o e^{-\lambda x}$, where $\lambda^2 = k/GJ$

(b) Replace T, θ, G, J by P, u, E, A respectively. $\lambda^2 = k/EA$

5.3-1(a,b) [Proof required]

5.3-2(a) $P_o = kw_o/\beta + k\theta_o/2\beta^2$, $M_o = kw_o/2\beta^2 + k\theta_o/2\beta^3$

(b) $w = w_o A_{\beta x} + (\theta_o/\beta) B_{\beta x}$, $\theta = -2\beta w_o B_{\beta x} + \theta_o C_{\beta x}$, etc.

5.3-3 Force = $0.2169 P_o$ = 10.8 kN

5.3-4(a) $w_{max}/w_{min} = -0.2079$, $M_{max}/M_{min} = -23.1$

(b) $F_+ = 0.6448 \beta M_o$, $F_- = -0.6726 \beta M_o$

5.3-5 P_o = 45.2 kN. Upward w: initial uniform pressure decreases.

5.3-6 σ = 190 MPa, at x = 99.9 mm from loaded end

5.3-7 $w = (2\beta^2 M_o/k) B_{\beta x}$, $\theta = (2\beta^3 M_o/k) C_{\beta x}$, etc.

5.3-8(a) $a = 1/2\beta$

(b) M_{max} = Fa, at x = 0. $M_{min} = -0.1040F/\beta$, at $\beta x = \pi/2$

5.3-9(a) $a = 1/\beta$ = 490 mm (b) F = 488 N

5.3-10 Q = 168 kN

5.3-11 $w_B = P[(3EI/L^3) + (k/2\beta)]^{-1}$

5.3-12 Depth = 104.5 mm

5.3-13 M_{cusp} = 2.71 kN·m

5.3-14 $M_A = M_B = (\beta a - 1)P/4\beta$. AB is simply supported for $\beta a = 1$.

5.4-1 [Proof required]

5.4-2 [Proof required]

5.4-3 [Proof required]

5.4-4 [Proof required]

5.4-5 $w_{max} = P/K + Ps^3/192EI$, $M_{max} = Ps/8$

5.4-6 [Argument required]

5.4-7 $\theta = M_o h/[4EI(1 + \beta h)]$

5.4-8 Force load: factors 0.595, 0.841

Moment load: factors 0.707, 1.000

5.4-9 $\sigma \approx 176$ MPa

5.5-1 M = 13,860 N·mm, $\Delta\sigma$ = 141 MPa

5.5-2 Depth = 139 mm

5.5-3 Maximum σ_{long} = 61.6 MPa, maximum σ_{cross} = 45.1 MPa

5.5-4 Separation = $\pi/2\beta$

5.5-5 $k = 0.264(P^4/EIg^4)^{1/3}$

5.5-6(a) $s \approx 0.179/\beta$ (b) $s = 0.0257/\beta$

5.5-7 Separation = $1.86/\beta$

5.5-8(a) w_{max} = 16.4 mm, 200 mm left of load 2P

(b) M_{max} = 4.38 kN·m, beneath load 2P

5.5-9 $x = 5\pi/4\beta$, $P_o = 71.9\beta M_o$

5.5-10 a = 1280 mm, M = -4.73 kN·m

5.5-11(a) w_{max} = 4.07 mm, σ_{max} = 97.3 MPa

(b) w_{max} = 6.45 mm (at center load),

σ_{max} = 70.0 MPa (at side load)

5.5-12(a) $\sigma = 0.0146P$ (b) $\sigma = 0.0226P$ (c) $\sigma = 0.0110P$

5.5-13(a) w = 0.297 mm, M = 4.20 kN·m

(b) w = 0.228 mm, M = 0.622 kN·m

(c) w = 0.170 mm

(d) w = 0.223 mm, M = 4.00 kN·m at load P

5.5-14 [Derivation required]

5.5-15 New couple is $0.586M_o$ (acting on portion to right)

5.5-16 Bending moment = $0.268F/\beta$

5.6-1(a) $w = q(1 - D_{\beta x})/k$ (b) $M = (q/2\beta^2)B_{\beta x}$

(c) $w = q(1 - A_{\beta x})/k$ (d) $M_{max} = 0.104q/\beta^2$, $M_{min} = -q/2\beta^2$

5.6-2 [Sketches required]

5.6-3 [Proof required]

5.6-4(a) $M_{center} = 8840q$ (b) $M_{ends} = -582q$ (c) $M_{\pi/4} = 27{,}847q$

(d) $M_{max} = 27{,}850q$ (e) $M_{min} = -29{,}149q$

5.6-5 $M_{center} = 126{,}200q$, $M_{supports} = -215{,}000q$

5.6-6 $M_{max} = 0.0806(q_2 - q_1)/\beta^2$

5.6-7 $w = (q/2k)(2 + B_{\beta\ell}C_{\beta a} - C_{\beta\ell}D_{\beta a} - D_{\beta b})$

$M = (q/4\beta^2)(B_{\beta b} + B_{\beta a}C_{\beta\ell} - B_{\beta\ell}A_{\beta a})$

5.7-1 $w = -EI(d^2w/dx^2) = 0$ @ $x = 0$, $d^2w/dx^2 = d^3w/dx^3 = 0$ @ $x = L$

5.7-2 [Proof required]

5.7-3 $p = (2P/bL)(2 - 3a/L) + (6P/bL^2)(2a/L - 1)x$, $w = p/k_o$

5.7-4(a) $L/3 < a < 2L/3$ (b) $w_{max} = 4P/3k_obL$, $w_{min} = P/k_obL$

5.7-5 $P = 3kLw_o/8$

5.7-6(a) $M = PL/8$ (b) $M_{min} = -4PL/27$, at $x = L/3$

5.7-7 Energy expended = $3W^2/2k_obL$

5.7-8(a) $w_{max} = (P/\pi R^2k_o)(1 + 4a/R)$ (b) $a = R/4$

5.7-9(a) $p = (F/4ab)(1 + 3x_ox/a^2 + 3y_oy/b^2)$

(b) Central "diamond;" edge in 1st quadrant: $3x_o/a + 3y_o/b = 1$

6.1-1 $\tau = Gy(d\theta/d\phi)/(r_n - y)$

6.2-1 [Derivation required]

6.2-2 [Derivation required]

6.2-3 [Derivation required]

6.2-4 [Derivation required]

6.2-5(a) A, exact; $\int dA/r$, -0.1%; R, 0.5%; r_n, 0.1%; e, -0.7%

(b) A, exact; $\int dA/r$, -0.02%; R, ≈ exact; r_n, 0.03%; e, -0.2%

6.2-6 $e = c^2/4R$; [proof required]

6.2-7 For a/b = 1.2, 1.6, 3.0, and 8.0:

(a) 0.0102, 0.0264, 0.0617, 0.1129

(b) 0.0104, 0.0278, 0.0667, 0.1167

(c) 1.056, 1.166, 1.469, 2.276

(d) 0.922, 0.822, 0.656, 0.503

6.2-8 $a/b \approx 2.65$

6.2-9 $b/a = 0.194$

6.3-1 At $r = b$, $\sigma_\phi = 101$ MPa. At $r = a$, $\sigma_\phi = -224$ MPa

6.3-2 At $r = b$, $\sigma_\phi = 315$ MPa. At $r = a$, $\sigma_\phi = -77.5$ MPa

6.3-3(a) 13.3% low (b) 46.5% low

6.3-4 P = 62.5 kN

6.3-5 F = 6.33 kN

6.3-6 $t_i = 116$ mm

6.3-7 s = 1.91 mm

6.3-8 Stress probably 283 MPa at most

6.4-1(a,b,c,d) [Derivation required]
6.4-2(a) Radial force (not radial stress) largest at $r_1 = r_n$
(b) [Proof required] (c) $r_1 = b \exp(1 - b/r_n)$
6.4-3 $\sigma_r = 14.7$ MPa
6.4-4 $\tau_1 = 28.6$ MPa, in straight parts but not much beyond
6.4-5(a) $\sigma_r \approx 21$ MPa (b) $\sigma_r \approx -101$ MPa
(c) $\sigma_r = 3M/2Rht$ (d) 2.8% high
6.4-6 $\sigma_r = -0.00937P/t$
6.4-7(a) $\sigma_r = 73.1$ MPa (b) $\sigma_r = 39.4$ MPa
6.4-8(a) $\sigma_r = 34.4$ MPa (b) t = 18.9 mm
6.4-9 [Sketches required]
6.4-10 $\sigma_y = -2P^2x^2/E_f b^2 t h^3$
6.5-1 [Sketches required]
6.5-2 $\sigma_\phi = -107$ MPa (inner), $\sigma_\phi = 169$ MPa (outer), $\tau_{max} = 218$ MPa
6.5-3(a) $\sigma_\phi = 13.0(10^{-6})M$, $\sigma_z = \pm 19.7(10^{-6})M$
(b) $\sigma_r = 4.5(10^{-6})M$ (c) $\tau_{max} = 16.3(10^{-6})M$ } MPa if M is N·mm
(d) Reduce flange width and increase its thickness
6.5-4(a) $\sigma_\phi = 166$ MPa (inside), $\sigma_\phi = -244$ MPa (outside)
(b) $\sigma_z = \pm 234$ MPa (c) Deforming ÷ nondeforming = 0.83
(d) $\sigma_r = 65.6$ MPa (e) $\tau_{max} = 200$ MPa
6.5-5(a) $\sigma_\phi = 338$ MPa (inside), $\sigma_\phi = -110$ MPa (outside)
(b) $\sigma_z = \pm 172$ MPa (c) Deforming ÷ nondeforming = 0.85
(d) $\sigma_r = 36$ MPa (e) $\tau_{max} = 131$ MPa
6.6-1 [Sketches required]
6.6-2(a) $\sigma_r \approx 0.68$ MPa (b) $\tau_{max} \approx 4.5$ MPa
6.7-1 [Derivation required]
6.7-2 $v_o = (FR/EA)(0.785 + 5.318 + 0.429 + 2.180)$. Ratio = 1.53
6.7-3 With $q = pta/R$, $v_A = (\pi qR^2/2A)[3(R/e - 1)/E + k/G] = 1575p/E$
6.7-4(a) [Derivation required]
(b) $v_T = \frac{PR}{EA}\left[\frac{4}{\pi} - \frac{\pi}{4} - \frac{2e}{\pi R} + \left(\frac{\pi}{4} - \frac{2}{\pi}\right)\frac{R}{e} + \frac{\pi k(1+\nu)}{2}\right]$
(c) Ratio = 2.89
7.1-1 $A_s = A_p(E_p/E_s)x/(L - x)$
7.1-2(a) $\sigma_x = q(L - x)/A$ (b) $u = (q/EA)[Lx - (x^2/2)]$
(c) $\sigma_x = q(L - x)/A$ (d) $d(A\sigma_x)/dx + q = 0$; $q = q(x)$
7.2-1 $\sigma_x = 0$, $\sigma_y = 2Ea_1x$, $\tau_{xy} = 0$ (pure bending)
7.2-2 $\epsilon_{x'} = \epsilon_x \cos^2\theta + \epsilon_y \sin^2\theta + \gamma_{xy}\sin\theta\cos\theta$
$\gamma_{x'y'} = 2(\epsilon_y - \epsilon_x)\sin\theta\cos\theta + \gamma_{xy}(\cos^2\theta - \sin^2\theta)$
7.2-3 $\sigma_x = (qy/2I)(x - L)^2/(1 - \nu^2)$. M correct if $\nu = 0$
7.3-1(a) $\partial N_x/\partial x + \partial N_{xy}/\partial y + B_x t = 0$, etc. (b) [Derivation required]
7.3-2(a) Equilibrium not satisfied (b) Valid
(c) Equilibrium not satisfied (d) Valid
7.3-3 $\tau_{xy} = (3P/4c)[1 - (y^2/c^2)]$

7.3-4 $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{1+\nu}{1-\nu}\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 v}{\partial x\,\partial y}\right) = 0$, etc.

7.3-5 [Sketches required]

7.3-6 u = 0 on x and y axes; top edge and curved edge free; $\sigma_x = My/I$ on right edge. Set v = 0 at some point.

7.4-1(a,b) [Derivation required]

7.4-2 Equilibrium satisfied, but not compatibility across x = 1

7.4-3 [Sketches required]

7.4-4 $F = (a_1 y^3 + a_2 x^3)/6 + c_1 xy + c_2 y + c_3 x + c_4$, $\tau_{xy} = -c_1$

7.4-5 g(y) = 5 - 43.7y, f = -16.3x - 6, compatibility satisfied

7.4-6 [Argument required]

7.5-1(a,b,c,d) [Proof required]

7.5-2 [Proof required]

7.5-3 [Proof required]

7.5-4 Add $qx^2/2$ to right hand side of Eq. 7.5-7

7.5-5 $\tau_{xy} = (qx/2I)(c^2 - y^2)$, $\sigma_y = -(c^2 y/2 - y^3/6 + c^3/3)q/I$
Compatibility not satisfied

7.5-6 [Discussion required]

7.6-1 $u = -\nu\rho g x(y - L)/E + c_1 y + c_2$
$v = \rho g(y^2 - 2Ly + \nu x^2)/2E - c_1 x + c_3$
$c_2 = c_3 = 0$, may set $c_1 = 0$

7.6-2 $\sigma_x = \rho g x$, $u = (\rho g/2E)[x^2 - L^2 + \nu(y^2 + z^2)]$,
$v = -\nu\rho g xy/E$, $w = -\nu\rho g xz/E$

7.6-3 $u = [a_1 xy - a_2(y^2 + \nu x^2)/2]/E + a_3 y/G$
$v = [a_2 xy - a_1(x^2 + \nu y^2)/2]/E$

7.6-4 $u = P[3(x^2 - L^2)y + \nu y^3]/4Ec^3 + Py(3c^2 - y^2)/4Gc^3$
$v = P[L^2(3x - 2L) - x(x^2 - 3\nu y^2)]/4Ec^3$

7.7-1 [Proof required]

7.7-2 σ_A = 42 kPa, σ_B = -33.8 kPa

7.7-3(a,b,c) [Proof required]

7.7-4 Uniaxial stress $\sigma_y = 4a_1$ (in direction $\theta = \pi/2$)

7.7-5 Cylinder, internal pressure (Eqs. 8.2-2)

7.7-6(a) Stresses due to torque $T = 2\pi C$
(b) $F = A \sin 2\theta + B \cos 2\theta + C\theta + D$ (A,B,C,D = constants)

7.7-7(a) $\sigma_r = \sigma_{\theta a} \ln(r/a)$ (b) [Proof required]
(c) [Derivation required] (d) $|M| = (2a^3\sigma_{za}/9)\sin(\alpha/2)$
(e) Green wood is stronger in tension than in compression

7.8-1 $g = a_5 r^4 + a_6 r^2 + a_7/r^2 + a_8$

7.8-2(a) $F_y = 0$ (b) $F_x = 9.9495\sigma_o b$

7.8-3(a) SCF = 2 (b) SCF = 4

7.8-4(a) $\theta = \pm\pi/4$ or $\pm 3\pi/4$ ($\sigma_\theta > 0$); $\theta = 0$ or π ($\sigma_\theta < 0$)
(b) For example: $\sigma_x = \sigma_o$, $\sigma_y = 3\sigma_o$

7.8-5 σ_θ = 137 MPa (max), σ_θ = -97.1 MPa (min; 90° away)

7.9-1(a) [Proof required] (b) [Proof required]
(c) Top surface: $\sigma_r = 49.29P/r$, $Mc/I = 48.99P/r$
Midline: $\sigma_{r\theta} = 0$, $VQ/It = 4.32P/r$

7.9-2 $\sigma_1 = -\sigma_3 = \sqrt{2}\,P/\pi a$, $\sigma_2 = 0$

7.9-3 $\sigma_x = -\frac{2q}{\pi}\left[\arctan\frac{a}{b} - \frac{ab}{a^2+b^2}\right]$, $\sigma_y = -\frac{2q}{\pi}\left[\arctan\frac{a}{b} + \frac{ab}{a^2+b^2}\right]$

7.9-4 $F = (M/\pi)(\theta + \sin\theta\cos\theta)$

7.9-5(a) [Proof required]

(b) E.g. at $y = -c$: $\sigma_x = 2.68P/c$, $Mc/I = 3.00P/c$

7.9-6(a) $\sigma_r = (-P/r)[2.141 \cos\beta - 1.363 \sin\beta]$ (b) [Proof required]

7.9-7(a) $\sigma_r = (2P/\pi r)\cos(\beta + \lambda)$ (b) $\beta + \lambda = \pi/2$

(c) Line OA collinear with force P

7.9-8 [Proof required]

7.10-1 For $T = T_o$: $a_1 = 0$, $a_2 = E\alpha T_o$.

For $T = T_o y/c$: $a_1 = E\alpha T_o/c$, $a_2 = 0$

7.10-2 $\sigma_x = -E\alpha T_o y/c = -E\alpha T$

7.10-3 $\sigma_x = \sigma_y = -E\alpha az/(1 - \nu)$, $\sigma_z = 0$

$u = v = 0$, $w = (\alpha az^2/2)[(1 + \nu)/(1 - \nu)]$

7.10-4 $\sigma_\theta = \sigma_z = \pm(E\alpha/2)(T_a - T_b)/(1 - \nu)$; + inside, - outside

7.10-5(a,b,c) [Proof required]

7.10-6 $\sigma_r = E\alpha k(r^2 - a^2)/4$, $\sigma_\theta = E\alpha k(3r^2 - a^2)/4$

7.10-7 $T = T_b + (T_a - T_b)\ln(r/b)/\ln(a/b)$

7.11-1(a,b) [Proof required]

7.11-2 $u = T(b^2 - a^2)yz/\pi G a^3 b^3$

7.12-1 [Proof required]

7.12-2 $\beta = (T/\pi a^3 b^3 G)(a^2 + b^2)/(1 - k^4)$, $\tau_{max} = (2T/\pi ab^2)/(1 - k^4)$

7.12-3(a) $k = G\beta/2h$, $\beta = 15\sqrt{3}\,T/Gh^4$, $\tau_{max} = 15\sqrt{3}\,T/2h^3$

(b) Fails; $\nabla^2\phi = -2G\beta$ not satisfied

7.12-4(a) [Proof required] (b) [Proof required]

(c) Stress ratio $= 4a(b - 2a)/(4a^2 - b^2)$. SCF $\rightarrow$ 2 as $b \rightarrow 0$

8.2-1 [Proof required]

8.2-2 At $r = b$: $\sigma_\theta = p_i$ and $\sigma_\theta = 1.5\ p_i$ respectively

8.2-3(a) $p_i = 87.2$ MPa (b) $p_i = 101$ MPa

8.2-4 $p_i = 139$ MPa

8.2-5 $F_i = 11/16$ of total; $W_i = 3/8$ of total

8.2-6(a) $a^2 = b^2(\sigma_{max} + p_i)/(\sigma_{max} - p_i)$

(b) $a^2 = b^2\sigma_Y/(\sigma_Y - 2p_i)$

(c) $a^2 = b^2(\sigma_Y^2 + p_i\sqrt{4\sigma_Y^2 - 3p_i^2})/(\sigma_Y^2 - 3p_i^2)$

(d) $a = 1.291b$, $a = 1.414b$, $a = 1.353b$

8.2-7(a) $p_o = (p_i/2)(1 + b^2/a^2)$, $\sigma_\theta = -(p_i/2)(1 - b^2/a^2)$

(b) $\tau_{max} = p_i/2$ at $r = b$

8.2-8 $1 < (p_i/p_o) < (3a^2/b^2 + 1)/(a^2/b^2 + 3)$

8.2-9(a) $2(\sigma_t - \sigma_r) - r(d\sigma_r/dr) = 0$

(b) $(d^2u/dr^2) + (2/r)(du/dr) - 2u/r^2 = 0$

(c) $u = Ar + B/r^2$; A and B are integration constants

8.3-1 [Sketches required]

8.3-2 $p_i = 6 + 1.52p_c$

8.3-3 [Several equations constitute the required answers]

8.3-4(a) $\Delta = (2a^2bp_c/E)/(a^2 - b^2)$

(b) $\Delta L = (2\nu a^2Lp_c/E)/(a^2 - b^2)$

8.3-5 $p_c = 9p_i/16$

8.3-6 $p_i = 1.215\bar{\sigma}_\theta$, $p_c = 0.1947\bar{\sigma}_\theta$

8.3-7 $2\Delta = 0.0907$ mm

8.3-8 [Proof required]

8.3-9 $\sigma_\theta = -144kp_o/[25 + 39k - 15(1 - k)\nu]$

8.3-10(a) $p_c = 9.375$ MPa (b) $p_i = 34.8$ MPa

8.3-11 [Proof required]

8.3-12 [Proof required]

8.3-13 [Proof required]

8.3-14(a) $\sigma_r = -87.3$ MPa (b) $\sigma_\theta = 216$ MPa (c) $\sigma_\theta = 216$ MPa

8.3-15(a) a = 9.09 mm, c = 6.74 mm

(b) $\sigma_e = 347$ MPa at r = b, $\sigma_e = 363$ MPa at r = c

(c) $\sigma_e = 351$ MPa at r = b, $\sigma_e = 349$ MPa at r = c

8.3-16 Factor = 1.25 for both

8.3-17 $\tau_{max} = 3\sqrt{3}\, p_i b/2a$ at r = c, $p_i = 0.1925\sigma_Y(a/b)$

8.4-1(a) [Proof required] (b) $\rho_s/\rho = 3E_s/E$ (s for spokes)

8.4-2 [Proof required]

8.4-3 [Proof required]

8.4-4 a/b = 1.08

8.4-5 [Proof required]

8.4-6 $\sigma_r = -89.3$ MPa, $\sigma_\theta = 161$ MPa

8.4-7 $T = 57.4(10^6)$ N·mm, $\tau_{net} = 85.8$ MPa

8.4-8(a) $\omega = 19{,}900$ rpm (b) $\omega = 13{,}850$ rpm

8.4-9 Yes (barely)

8.4-10(a) $\sigma_o = (\rho\omega^2/6a)(c^3 - a^3)$ (b) $\sigma_\theta = 91.7$ MPa

8.4-11(a) $\omega_o^2 = 8p_c/[(3 + \nu)\rho a^2(1 - b^2/a^2)]$ (b) $\omega = \omega_o/\sqrt{3}$

(c) $P = 4\pi\mu p_c b^2 h\omega_b/(3\sqrt{3})$

8.4-12(a) $p_c = 42.15$ MPa (b) $\omega = 6450$ rpm

8.4-13 [Explanations required]

8.5-1 $h_o = 61.1$ mm

8.5-2(a) $h_0 =$ 25.7 mm, $h_{0.2} =$ 25.0 mm, $h_{0.4} =$ 23.0 mm

(b) $h_0 =$ 54.7 mm, $h_{0.2} =$ 48.9 mm, $h_{0.4} =$ 35.0 mm

(c) $h_0 =$ 84.1 mm, $h_{0.2} =$ 71.7 mm, $h_{0.4} =$ 44.4 mm

(d) $h_0 =$ 141.3 mm, $h_{0.2} =$ 113.7 mm, $h_{0.4} =$ 59.3 mm

8.5-3(a) $k = \rho\omega^2\left[\int_b^a hr^2dr \Big/ \int_b^a \frac{h}{r}dr\right]$ where $h = h(r)$

(b) Error = 14.2%

8.6-1(a) $\sigma_r = \sigma_Y \ln(r/a)$, $\sigma_\theta = \sigma_Y + \sigma_r$

(b) $p_{fp} = \sigma_Y \ln(a/b)$

8.6-2(a) a = 317.5 mm

(b) a = 210 mm, $W_b/W_a = 0.344$

(c) a = 184 mm, $W_c/W_a = 0.226$

8.6-3 p_{fp} = 352 MPa
8.6-4 Single: impossible. Compound: a/b = 4.93, wt. ratio = 5.92
8.6-5 $p_{fp} = 2\sigma_Y \ln(a/b)$
8.6-6 p_{fp} = 605 MPa. Yielding before new p_i reaches p_{fp}
8.6-7 p_{fp} = 316 MPa. Yielding when new p_i reaches p_{fp}
8.6-8 [Proof required]
8.6-9 $p_i = 0.9375\sigma_Y$, c = 16.94 mm
8.6-10(a) $2(a/b)^2\ln(a/b)/[(a/b)^2 - 1] = 1 + \beta$
(b) a/b = 1.548 (c) a/b = 2.22
8.7-1 [Derivation required]
8.7-2(a) $\omega_{fp}^2 = 2\sigma_Y \ln(a/b)/[\rho(a^2 - b^2)]$ (b) Factor = 1.267
8.7-3(a) $\sigma_r = \sigma_Y(1 - r^2/a^2)$, $\sigma_\theta = \sigma_Y$ for all r
(b) $\sigma_r = \sigma_Y(1 - 0.9524b/r - 0.0476r^2/b^2)$, $\sigma_\theta = \sigma_Y$ for all r
8.7-4(a) $\omega_{fp}^2 = 5.25\sigma_Y/\rho$ (b) Factor = 0.619 (c) No (SCF neglected)
8.7-5 [Proof required]
8.7-6 a/b = 4.85
9.2-1 $\beta = T/GJ$, $\tau_{max} = TR/J$, where $J = \pi(R^4 - b^4)/2$
9.3-1 Error = 303% (high)
9.3-2(a) $\tau = 3T/[2(1 + \pi)Rt^2]$, $\beta = \tau/Gt$
(b) τ ratio = 25.2, β ratio = 252
9.3-3 c/h = 3/7, β ratio = 4, $T_{thicker} = 0.857T_{total}$
9.3-4 GK = 63,280G N·mm^2, $\tau_{max} = 237(10^{-6})T$ MPa
9.3-5(a) $\tau_{max} = 12T/a^2b$, $\beta = 12T/Ga^3b$
(b) 100% error (high) for both
9.3-6 $\sigma = 3PL/2a^2t$, $\tau = (3P/4t)(1/a + 1/t)$
9.4-1(a) $\tau_{max} = 2T/\pi ab^2$ (b) $T/\beta = 3.101Gab^3$
9.4-2(a) Ratio = 1.354 (b) Ratio = 0.678
(c) Square: $T/\beta = 2.26Ga^4$ (table), $T/\beta = 2.40Ga^4$ (equation)
Rectang.: $T/\beta = 1.12Ga^4$ (table), $T/\beta = 1.13Ga^4$ (equation)
9.4-3 Square: $\tau = 4.81T/A^{1.5}$, $\beta = 7.09T/GA^2$
Circle: $\tau = 3.545T/A^{1.5}$, $\beta = 6.28T/GA^2$
9.4-4 Allowable T = 144 kN·mm, $\theta = 1.85^\circ$
9.5-1 [Derivation required]
9.5-2(a) τ ratio = $(1 + \eta^2)/(1 + \eta)$, β ratio = $2(1 + \eta^2)/(1 + \eta)^2$,
where $\eta = b/a$
(b) [Plot required] (c) [Proof required]
9.5-3 R = 3000 mm for open tube. May buckle
9.5-4 [Derivation required]
9.5-5(a) [Proof required] (b) τ ratio = 1.27, β ratio = 1.62
9.5-6(a) $T/\beta = 9.07GR^3t_o$; $\tau_{max} = 0.159T/R^2t_o$, outside at $\alpha = 0$
(b) $T/\beta = 9.425GR^3t_o$; $\tau_{max} = 0.106T/R^2t_o$, outside at $\alpha = 0$
(c) $\tau_{max} = 0.255T/Rt_o^2$, inside and very near $\alpha = \pm\pi$
9.5-7 $F = Ts/2\pi R^2$
9.5-8 $$\theta = \frac{T}{4\pi G t}\left(\frac{L}{r_L - r_o}\right)^3 \frac{L(2H+L)}{H^2(H+L)^2}$$

9.6-1 [Derivation required]
9.6-2 $l_i/t_i\Gamma_i$ same in all cells i; l_i = length of outer cell wall
9.6-3 Factor = 200
9.6-4 q decreases 4%, β increases less than 1%
9.6-5(a) $T/\beta = 10.83Ga^3t$, $q_{outer} = 0.0924T/a^2$, $q_{inner} = 0.0653T/a^2$

(b) $T/\beta = 2\pi Gt(a^3 + b^3)$, $q_{outer} = Ta/[2\pi(a^3 + b^3)]$,

$q_{inner} = Tb/[2\pi(a^3 + b^3)]$

9.6-6 T = 48,700 N·mm, $\beta = 3.53/G$ per mm
9.6-7 τ factor = β factor $\approx$ 1.78
9.7-1 Factor = 0.5; > 0.5 if noncircular (restraint of warping)
9.7-2(a) $\theta'''' - k^2\theta'' = -k^2T_q/GK$

(b) Free: $\theta'' = 0$, $\theta''' - k^2\theta' = 0$

Fixed: $\theta = 0$, $\theta' = 0$

Simply supported: $\theta = 0$, $\theta'' = 0$

(for all of the above) $\theta' = \dfrac{d\theta}{dx}$, $\theta'' = \dfrac{d^2\theta}{dx^2}$, etc.

9.7-3(a,b) σ_x = 16.1 MPa, $\theta = 9.02(10^{-3})$ rad
9.7-4(a) $\sigma = \pm 91.6$ MPa (b) 2.88 mm left, 0.45 mm up
9.7-5 Midspan: $\sigma_x = 2130(10^{-6})P$

Ends: $\tau_{zx} = 302(10^{-6})P$ in web, $\tau_{xy} = 261(10^{-6})P$ in flanges

9.8-1 [Plots required]
9.8-2 [Plots required]
9.9-1(a) $\omega = -1.261a^2$ at flange tips (b) $J_\omega = 3.363a^5t$
9.9-2(a) $\omega = \pm 8a^2/7$ at flange tips (b) $J_\omega = 1.905a^5t$
9.9-3(a) $\omega = \pm 2a^2$ at cut (b) $J_\omega = 3.70a^5t$
9.9-4(a) $\omega = (4R^2/\pi)\cos\alpha + R^2[\alpha - (\pi/2)]$ (b) $J_\omega = 0.0374R^5t$
9.9-5 $J_\omega = 7b^5t/24 + b^4ht/16$
9.10-1 $u_A = u_C = 0$, $u_B = u_D = (T/4Gbh)(b/t_b - h/t_h)$
9.10-2 [Proof required]
9.10-3 $u = \pm 0.213$ mm on top, $u = \pm 0.0838$ mm on bottom
9.10-4 [Proof required]
9.11-1 $f = (\alpha^2/2) + 2(1 - \cos\alpha) - \pi\alpha$
9.11-2 q_{max} in flange = $E(d^2\beta/dx^2)(0.653a^3t)$
9.12-1 At support: $\sigma_x = 0.285P$ at slit, $\sigma_x = -0.166P$ on top

At end: $\tau = 0.0284P$, $\theta_L = 0.000119P$

9.12-2 T = 27,000 N·mm

At ends: σ_x = 54.7 MPa at flange tips, q_{max}/t = 2.82 MPa

At middle: τ_{SV} = 7.67 MPa

9.12-3 At support: σ_x = 121 MPa, q_{max}/t = 4.11 MPa

At end: τ_{SV} = 14.5 MPa. θ reduction factor = 0.0645

9.12-4 $\sigma_x = 0.286P$
9.12-5 L/a = 8
9.12-6 Four constants: $\beta = 0$ at $x = 0$, $d\beta/dx = 0$ at $x = a + b$,

β and $d\beta/dx$ must both match between parts at $x = a$

9.13-1(a) $\theta_L = -0.073B_L/Gt^4$, $\sigma_x = \pm 82.0(10^{-6})B_L/t^4$

(b) $\theta_o = +0.075B_L/Gt^4$

9.13-2 $\tau/\sigma_x = 0.413$, $\tau_q/\sigma_x = 0.0413$

9.13-3 [Explanations required]

9.13-4 [Proof required]

9.14-1 $\sigma_o = 102$ MPa, $\sigma_x = 121$ MPa, $\tau_{SV} = 32.7$ MPa

9.14-2 $T = 2470$ N·mm, $\tau_{SV} = 154$ MPa

9.14-3(a) Factor = 3.60 (b) $\tau_{SV} = 0.0379T$, $\sigma_x = 0.127T$

(c) $\Delta = -0.0244TL/G$ (d) $\Delta = 0.0332FL/G$

9.14-4(a) Factor = 3.11 (b) $\sigma_o = -113$ MPa

9.15-1 [Proof required]

9.15-2 [Sketches required]

9.15-3(a,b) $T_{fp} = (\tau_Y t^2/2)[a + b - (4t/3)]$ (c) $T_{fp} = 19.06\tau_Y a^3$

9.15-4 $T = 31\pi\tau_Y R^3/48$

9.15-5 $L/b = 8.3$

10.1-1(a) [Proof required] (b) $h/b = 1$

10.1-2 [Proof required]

10.1-3 $\sigma_x = N/A + B\omega/J_\omega$ + (right hand side of Eq.10.1-5)

10.2-1(a) [Proof required]

(b) Factor: 0.707 for h = b, 0.503 for h = 10b

10.2-2 Diamond-shaped area with intercepts $y = \pm b/6$, $z = \pm h/6$

10.2-3 $\sigma_{xA} = 159$ MPa, $\sigma_{xB} = -182$ MPa

10.2-4 $\beta = -22.4^o$. Factor: 0.42 at A, 0.68 at B

10.2-5(a) $\lambda = -7.04^o$; $\sigma_{xA} = -105$, $\sigma_{xB} = -42.7$, $\sigma_{xC} = 148$ (all MPa)

(b) $\beta = 76.0^o$

10.2-6(a) $\sigma_x = \pm 184$ MPa, at flange tips

(b) $\sigma_x = \pm 102$ MPa, at web-flange intersection

(c) $\sigma_x = 4.79$ MPa, at right web-flange intersection

10.2-7 $M = 2.06(10^6)$ N·mm at $\beta = -60.9^o$

10.2-8 R = 114 mm

10.2-9 $\sigma_x = -127$ MPa at upper flange tip

$\sigma_x = 68.5$ MPa at lower corner

10.3-1(a) $27.7PL/b^3 \leq (\sigma_x)_{tens} \leq 32.0PL/b^3$

(b) Deflection of tip = $18.48PL^3/Eb^4$ for all orientations

10.3-2 9.48^o from horizontal

10.3-3 $P_y = -0.528P$, $P_z = -0.849P$

10.3-4(a,b) $\Delta = 0.340(10^6)q/E$, at 14.7^o to vertical

10.3-5(a) $H = 244q$ (b) $\Delta = 280{,}000q/E$ (parallel to z axis)

10.3-6 $\Delta = 7.66$ mm at 31.4^o above negative y axis

10.3-7 [Arguments required]

10.3-8 $\Delta = 0.115PL^3/EI$ at 34.6^o below positive y axis

10.4-1 [Proof required]

10.4-2(a,b) [Proof required]

10.4-3 τ_{ave} is P/th at x = 0, 0.444P/th at x = L/2, P/4th at x = L

10.4-4 $\alpha = 21.8^o$, $\tau = 0.00332V$

10.4-5(a) $q = V_z(1 - \cos\alpha)/\pi R$ (b) $q_{max} = 2V_z/\pi R$ at $\alpha = \pi$
10.4-6(a) $z = -h/12$ (b) [Proof required]
(c) $q_{max} = 1.35V_y/h$ at $y = 3h/20$ (d) [Proof required]
10.4-7 q_{max} = =.00990V at the centroid
10.4-8(a) $q = (3862 - 214.5z + 2.276z^2)10^{-6}V_y$
(b) $q = (10,300 - 1.788y^2)10^{-6}V_y$
(c) $q = 0$ at $z = \pm 24.24$ mm on flanges
(d) About 19% low
10.5-1 Respective e_y's, relative to $y = 0$: $-2R$, $-b/\sqrt{3}$, $-3\sqrt{2}\,b/4$
10.5-2 e_y is $2R[1 - (t/R)^2/3]$ left of origin
10.6-1 Rel. to vertical web (except as noted), $|e_y|$ distances are:
(a) $3b^2(a^2 + c^2)/[2c^3 + 6b(a^2 + c^2)]$ (left)
(b) $3b^2(c^2 - a^2)/[2c^3 + 6b(a^2 + c^2)]$ (left)
(c) $3b^2/(6b + c)$ (right)
(d) 0.155c (left)
(e) $bc^3/(a^3 + c^3)$ (right of left flange)
(f) $(b/2)(3b + 4c)/(3b + 2c)$ (left)
(g) $(b/2)(3b + 4c)/(3b + 8c)$ (left)
(h) $\sqrt{3}\,c/2$ (right of left vertex)
(i) $\sqrt{3}\,h/4$ (left of left vertex)
(j) 2R (left of centroid)
(k) $2R(\sin\alpha - \alpha\cos\alpha)/(\alpha - \sin\alpha\cos\alpha)$ (left of cntr. of arc)
(l) 0.510R (left)
10.6-2 e_y is $\pi R/2$ right of center of arc
10.6-3 Force = 3P/16 on each weld, very localized near tip of beam
10.6-4(a) [Proof required]
(b,c) [See answers for Problem 10.6-1, parts (e) and (h)]
10.6-5 Factor = 1.31
10.7-1 Relative to pole: e_y = 44.7 mm, e_z = 164.9 mm
10.7-2 [See answers already provided]
10.7-3 Relative to $x = y = 0$: 0.026a left, 1.021a below
10.8-1(a) 0.611R right of vertical web (b) $\beta = 2P/\pi^2R^2Gt$
11.2-1(a) P_c = 56.8 kN (b) P_c = 24.0 kN
11.2-2 Changes of slope at 0.7, 1.3, and 2.0 times $P/\sigma_Y A$
11.2-3 $P_c = 1.25A\sigma_Y$
11.2-4(a) $P_Y = n\sigma_Y A$ (b) $P_c = 4n\sigma_Y A/\pi$
11.3-1(a) f = 1.70 (b) f = 1.27 (c) f = 2.00 (d) f = 2.34
11.3-2 f = 1.137
11.3-3 $M_{fp} = bh^2\sigma_Y/12$
11.3-4 Linear for $0 < M < 3.60$ and for $4.52 < M < 5.11$ (kN·m)
11.3-5 [Proof required]
11.3-6(a) [Sketch required] (b) [Proof required]
(c) $M = \sigma_Y bc^2/3$ to yield again, $M_{fp} = \sigma_Y bc^2$
11.3-7(a,b) [Sketch required]
11.3-8(a) ρ = 7.143 m (b) Residual ρ = 13.8 m
11.3-9(a,b) R of mandrel = 22.0 mm