List of Final Answers

For details, and where proofs are required, see following worked-out solutions

1.4-1 [Proof required]

1.4-2 $P = 2kv(a - L)/a$ where $a^2 = L^2 + v^2$

1.4-3 $p = (\alpha_a - \alpha_s)TtE_aE_s/[R(E_a - E_s)]$

1.5-1 [Proof required]

1.5-2 $\tau_{zx} = (P/A) - (Pd/J)y$, $\tau_{yz} = (Pd/J)x$, where $J = I_x + I_y$

1.6-1 Consider equilibrium; note that M = 0 at inflection point

1.6-2 [Proof required]

1.6-3(a,b) [Proof required]

(c) $\epsilon = ky$ if cross sections warp identically

1.6-4 Surfaces: $\sigma_t = 3M(1 + \sqrt{R})/bh^2\sqrt{R}$, $\sigma_c = -\sqrt{R}\,\sigma_t$, where $R = E_c/E_t$

1.6-5 $M_{max} = F^2/2q$

1.6-6(a) $F_a = 2EI/\rho L$ (b) $s = L - 2EI/\rho F_b$

1.6-7 $h_L/h_o = 3$, stress ratio = 9/8

1.7-1 $\sigma_A = -\tau L/c$, $\sigma_B = 2\tau L/c$, $v_C = -\tau L^3/2Ec^2$

1.7-2 $v_C = -5hPL^2/48EI$

1.7-3 $v_C = \alpha L^2 \Delta T/2c$

1.7-4 Doubtful, unless P is very small. Links become inclined.

1.7-5 $u_o = L - \rho\sin\theta$, $v_o = \rho(1 - \cos\theta)$; where $\theta = L/\rho$, $\rho = EI/M_o$

1.7-6 $a/b = 2.00$

1.7-7 $a/b = 0.732$

1.7-8(a) $y = Fx^3/3EI$ (b) $y = Fx^2(L - x)^2/3EIL$

1.7-9 $R_x = R + P(x^4 - 2Lx^3 + L^3x)/12EIL$

1.8-1(a) $u_D = 0$, $v_D = 4QL/\sqrt{3}\,AE$

(b) $u_D = PL/2.30AE$, $v_D = 0$

(c) $u_D = 1.188\alpha L\Delta T$, $v_D = 0$

1.8-2 $T/\theta = 9GJ/20L$

1.8-3 $0.0169PL^3/EI$ at load, $0.0039PL^3/EI$ at point opposite

1.8-4 Angle $= TL^3/8EI[3R(R + L) + L^2]$

1.8-5(a) $v = 5qL^4/384EI$ (b) $v = M_LL^2/16EI$, $\theta_L = M_LL/3EI$

(c) $v = PL^3/192EI$ (d) $v = qL^4/768EI$

1.8-6 Consider equilibrium. Match strain & curvature at interface.

1.8-7 $\sigma = 3Et(D + t)/L^2$

1.8-8 $L^4 = 72EID/q$

1.8-9 $\Delta T = \theta h/\alpha L$

1.9-1(a) $P = \sigma_Y AL/b$ (b) $P_{fp} = 2A\sigma_Y$

(c) $\sigma_{res} = \sigma_Y(L - 2b)/L = \sigma_Y(2a - L)/L$

1.9-2(a) $\sigma_1 = \sigma_Y$, $\sigma_2 = \sigma_Y/2$

(b) $(\sigma_1)_{res} = -\sigma_Y/2$, $(\sigma_2)_{res} = -\sigma_Y/4$, $u_{res} = \sigma_Y L/4E$

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 ($\mathbf{n}_3 = \mathbf{n}_1 \times \mathbf{n}_2$)

	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 $\mathbf{n}_1$]		

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^o to x and z axes; then 45^o 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) $v_C = -0.0260M_C R^2/EI$