M01 Axial Loading & Stress

1	$\sigma=\begin{cases}(47.5-20.0x)\ \text{MPa} & (0<x\le 0.5\text{m})\\(32.5-20.0x)\ \text{MPa} & (0.5<x\le 1.25\text{m})\end{cases}$
2	$\sigma_{\text{ave}}=\frac{P}{A}\sin^2\theta \qquad \tau_{\text{ave}}=\frac{P}{2A}\sin 2\theta$
3	$\theta\approx 63.6^0\approx 1.11\,\text{rad} \qquad \sigma_{AB}=\sigma_{BC}=316\ \text{MPa}$
4	$\sigma_{a\text{-}a}=12.2\ \text{MPa} \qquad \tau_{a\text{-}a}=0 \qquad \sigma_{b\text{-}b}=4.41\ \text{MPa} \qquad \tau_{b\text{-}b}=5.88\ \text{MPa}$

M02 Elastic Deformation of Axially Loaded Bars

1	$\delta_B=2.20\ \text{mm} \qquad \delta_A=2.517\ \text{mm}$
2	$\delta_F=2.23\ \text{mm}$
3	$\delta_{A/B}=-1.03\ \text{mm}$
4	$\delta=\frac{PL}{\pi E r_1 r_2}$

M03 Mechanical Behavior & Strength Check

1	$\nu=0.300$
2	$\varepsilon_e=0.00207\quad \text{mm/mm} \qquad \varepsilon_p=0.0729\quad \text{mm/mm}$
3	$P_{\max}=11.3\ \text{kN}$
4	$d_{AB}=3.54\ \text{mm} \qquad d_{AC}=3.23\ \text{mm} \qquad L_{AB\cdot\text{final}}=750.49\ \text{mm}$

M04 Pin Shearing & Bearing Stresses

1	$\sigma_b=48.3\ \text{MPa} \qquad \tau_{\text{ave}}=18.4\ \text{MPa}$
2	$d=28\ \text{mm} \qquad b=62.3\ \text{mm} \qquad h=34.3\ \text{mm}$
3	$\tau_{\text{ave}}=80.8\ \text{MPa} \qquad \sigma_b=126.95\ \text{MPa} \qquad \sigma_b=203\ \text{MPa}$

M05 Torsional Stresses

1	$\tau_{AB\max}=1.04\ \text{MPa} \qquad \tau_{BC\max}=3.11\ \text{MPa}$

2	$\lvert\tau\rvert_{\max} = 33.0\ \text{MPa}$ at the fixed end $\lvert\tau\rvert_{\min} = 0$ at 0.7m from the fixed end
3	$t_0 = 133\ \text{N}\cdot\text{m/m}$ $\tau_A = 0.255\ \text{MPa}$ $\tau_B = 0.141\ \text{MPa}$
4	$r' = \dfrac{1}{\sqrt[4]{2}} r$

M06 Torsional Deformation

1	percent increase in shear stress = 6.67% percent increase in angle of twist per unit length = 6.67%
2	$d_{\min} = 201\ \text{mm}$ $\phi = 0.0576\ \text{rad} = 3.30^0$
3	$t_{\min} = 1.60\ \text{mm}$
4	$T_B = \dfrac{1}{2} t_0 L + T_A$ $\phi_{A/B} = \dfrac{2L\left(t_0 L + 3T_A\right)}{3\pi G\left(r_0^4 - r_i^4\right)}$

M07 Bending Internal Forces - Diagrams

a	$A_y = 815.63\ \text{N}\ \uparrow$ $B_y = 1484.38\ \text{N}\ \uparrow$
b	$A_y = \dfrac{M_0}{3a}\ \downarrow$ $B_y = \dfrac{M_0}{3a}\ \uparrow$
c	$A_y = 0$ $M_A = mL\ \uparrow\downarrow$
d	$A_y = 10\ \text{kN}\ \uparrow$ $B_y = 130\ \text{kN}\ \uparrow$
e	$A_y = 16.5\ \text{kN}\ \uparrow$ $B_y = 0.5\ \text{kN}\ \downarrow$
f	$A_y = 65\ \text{kN}\ \uparrow$ $B_y = 5\ \text{kN}\ \downarrow$
g	$A_y = 82.5\ \text{kN}\ \uparrow$ $B_y = 37.5\ \text{kN}\ \uparrow$
h	$A_y = 180\ \text{kN}\ \uparrow$ $M_A = 535\ \text{kN}\cdot\text{m}\ \downarrow\uparrow$

M08 Bending Internal Forces - Applications

1	$A_y = F_y = 1\ \text{kN}\ \uparrow$ $C_y = D_y = 3.6\ \text{kN}\ \uparrow$

2	$a=\frac{L}{\sqrt{2}}$
3	$a=\frac{\sqrt{3}}{2}L$
4	$a=0.207L$

M09 Bending Normal Stresses

1	$P_{\text{max}}=1.67\text{ kN}$
2	$\sigma_{\text{smaller}}=74.7\text{ MPa}$ percent decrease in stress $=53.0\%$
3	$b_{\text{min}}=53.1\text{ mm}$
4	$a_{\text{min}}=160\text{ mm}$

M10 Bending Shearing Stresses & Rational Design of Beams

1	$b_{\text{min}}=211\text{ mm}$ $h_{\text{min}}=264\text{ mm}$
2	$a=L/4$ $\tau_{\text{max}}=\frac{3wL}{8bd}$
3	$\tau_{\text{max}}=14.7\text{ MPa}$ at cross-section B
4	$d=d_0\sqrt{\frac{x}{L}}$

M11 Bending Deflections by Integration

1	$w_1=\frac{P}{6EI}\left[-3x_1(L-a)^2+3a(L-a)^2+2(L-a)^3\right]\downarrow$ $0<x_1\le a$ $w_2=\frac{P}{6EI}\left[-x_2^3+3(L-a)x_2^2\right]\downarrow$ $0<x_2\le L-a$
2	$w=\frac{M_0}{6EIL}\left(-3Lx^2+x^3+2L^2x\right)\downarrow$ $\theta_A=\frac{M_0L}{3EI}\uparrow\downarrow$ $w_{\text{max}}=\frac{0.0642M_0L^2}{EI}\downarrow$ at $x=\left(1-\frac{1}{\sqrt{3}}\right)L$

3	$w_1 = \frac{M_0}{6EIL}\left(x_1^3 - L^2 x_1\right)\downarrow \qquad w_2 = \frac{M_0}{6EIL}\left(3Lx_2^2 - 8L^2 x_2 + 5L^3\right)\downarrow$ $\theta_C = \frac{4M_0 L}{3EI}\ \uparrow\downarrow \qquad w_C = \frac{5M_0 L^2}{6EI}\downarrow$
4	$w_1 = \frac{w}{24EI}\left(x_1^4 - 4ax_1^3 + 6a^2 x_1^2\right)\downarrow \qquad w_2 = \frac{wa^3}{24EI}\left(4x_2 - a\right)\downarrow$ $\theta_B = \frac{wa^3}{6EI}\ \uparrow\downarrow \qquad w_B = \frac{wa^3}{24EI}\left(4L - a\right)\downarrow$

M12 Bending Deflections by Integration & Applications

1	$w_1 = \frac{Px_1}{12EI}\left(x_1^2 - L^2\right)\downarrow \qquad w_2 = \frac{P}{24EI}\left(4x_2^3 - 7L^2 x_2 + 3L^3\right)\downarrow$ $w_{\max} = w\left(x_2 = 0\right) = \frac{PL^3}{8EI}\downarrow$
2	$w_1 = \frac{P}{6EI}\left(x_1^3 - 3a\left(a+b\right)x_1 + a^2\left(2a+3b\right)\right)\downarrow \qquad w_3 = \frac{Pax_3}{2EI}\left(x_3 - b\right)\downarrow$ $\theta_A = -\frac{Pab}{2EI}\ \uparrow\downarrow \qquad w\left(x_3 = b/2\right) = -\frac{Pab^2}{8EI}\downarrow$
3	$\sigma_{\max} = 582\ \text{MPa}$
4	$F = 1.375\ \text{N}$

M13 Bending Deflections by Superposition

1	$M_0 = \frac{Pa}{6}$
2	$I - 40b$
3	$w_D = \frac{9.11\times 10^5}{EI}\ \text{N}\cdot\text{m}^3\downarrow$
4	$w_A = \frac{308}{EI}\ \text{kN}\cdot\text{m}^3\downarrow \qquad \theta_A = \frac{79.7}{EI}\ \text{kN}\cdot\text{m}^2\uparrow\downarrow$

M14 Bending Deflections by Moment-Area Theorems

1	$\theta_C = \frac{5Pa^2}{2EI}\uparrow\downarrow \qquad w_B = \frac{25Pa^3}{6EI}\ \downarrow$
2	$\theta_B = -\frac{7wa^3}{12EI}\uparrow\downarrow \qquad w_C = \frac{25wa^4}{48EI}\ \downarrow$

3	$\theta_B = \dfrac{3Pa^2}{4EI}$ ↑↓ $\quad w_C = \dfrac{13Pa^3}{12EI}$ ↓
4	$F = \dfrac{P}{4}$

M15 Bending Deflections by Singular Functions

1	$w = \dfrac{1}{EI}\left[0.25x^4 - 0.208\langle x-1.5\rangle^3 - 0.25\langle x-1.5\rangle^4 - 4.625\langle x-4.5\rangle^3 - 25.1x + 36.4\right]\ \mathrm{kN\cdot m^3}$ ↓
2	$w(x=7m) = \dfrac{835}{EI}\ \mathrm{kN\cdot m^3}$ ↓ $\quad \theta_A = \dfrac{279}{EI}\ \mathrm{kN\cdot m^2}$ ↑↓
3	$\theta = \dfrac{1}{EI}\left[-2.25x^2 + 0.5x^3 - 5.25\langle x-5\rangle^2 - 0.5\langle x-5\rangle^3 + 3.125\right]\ \mathrm{kN\cdot m^2}$ ↑↓ $w = \dfrac{1}{EI}\left[-0.75x^3 + 0.125x^4 - 1.75\langle x-5\rangle^3 - 0.125\langle x-5\rangle^4 + 3.125x\right]\ \mathrm{kN\cdot m^3}$ ↓
4	$w = \dfrac{w}{EI}\left[\dfrac{1}{24}x^4 - \dfrac{1}{4}L\langle x-L\rangle^3 - \dfrac{1}{24}\langle x-L\rangle^4 - \dfrac{1}{3}L^3x + \dfrac{7}{24}L^4\right]$ ↓ $\quad w_C = \dfrac{7wL^4}{24EI}$ ↓

M16 Statically Indeterminate Problems – Axially Loaded Members

1	$\sigma_{\mathrm{steel}} = 65.9\ \mathrm{MPa} \quad \sigma_{\mathrm{concrete}} = 8.24\ \mathrm{MPa}$
2	$\sigma_{AB} = \dfrac{7}{12}\dfrac{P}{A} \quad \sigma_{CD} = \dfrac{1}{3}\dfrac{P}{A} \quad \sigma_{EF} = \dfrac{1}{12}\dfrac{P}{A}$
3	$F_{AB} = F_{EF} = 1.85\ \mathrm{kN} \quad F_{CD} = 3.70\ \mathrm{kN}$
4	$F = \dfrac{1}{2}\alpha AE(T_B - T_A)$

M17 Statically Indeterminate Problems – Torque Loaded Members

1	$\tau_{AC\cdot\max} = 9.55\ \mathrm{MPa} \quad \tau_{CB\cdot\max} = 6.37\ \mathrm{MPa}$
2	$T_A = 55.6\ \mathrm{N\cdot m} \quad T_B = 222\ \mathrm{N\cdot m}$
3	$T_A = \dfrac{3}{4}t_0L \quad T_B = \dfrac{7}{12}t_0L$

M18 Statically Indeterminate Problems – Beams

1	$A_y = C_y = \dfrac{1}{10}w_0L$ ↑ $\quad B_y = \dfrac{4}{5}w_0L$ ↑

2	$F_{AC} = \dfrac{3E_2A_2wL_1^4}{8\left(E_2A_2L_1^3 + 3E_1I_1L_2\right)}$
3	$A_y = \dfrac{57}{128}wL \uparrow \quad M_A = -\dfrac{9}{128}wL^2 \uparrow\downarrow \quad B_y = \dfrac{7}{128}wL \uparrow$
4	$F_{\text{spring}} = \dfrac{5wkL^4}{4\left(6EI + kL^3\right)} \uparrow$

M19 Stress Transformation & Mohr's Circle

1	$\sigma_x = -193\ \text{MPa} \quad \sigma_y = -357\ \text{MPa} \quad \tau_{xy} = 102\ \text{MPa}$
2	$\sigma_{x'} = 49.7\ \text{MPa} \quad \tau_{x'y'} = -34.8\ \text{MPa}$
3	$\sigma_1 = 88.1\ \text{MPa} \quad \sigma_2 = -13.1\ \text{MPa} \quad \theta_p = 40.7^0$ $\tau_{\max} = 50.6\ \text{MPa} \quad \sigma_{\text{ave}} = 37.5\ \text{MPa} \quad \theta_s = 4.27^0$
4	$\sigma_1 = 150\ \text{MPa} \quad \sigma_2 = 137\ \text{MPa} \quad \sigma_3 = -46.8\ \text{MPa} \quad \tau_{\max} = 98.4\ \text{MPa}$

M20 Generalized Hooke's Law

1	N.A.
2	$\varepsilon_1 = 30.5\left(10^{-6}\right) \quad \varepsilon_2 = \varepsilon_3 = -10.7\left(10^{-6}\right)$
3	$\varepsilon_{x'} = -\varepsilon_{y'} = 2.52\left(10^{-3}\right)$
4	$\theta = \tan^{-1}\left(\dfrac{1}{\sqrt{\nu}}\right)$

M21 Strength Theory

1	NO.
2	N.A.

3	$(a)\quad \sigma_r=\sqrt{\sigma_x^2+\sigma_y^2-\sigma_x\sigma_y+3\tau_{xy}^2}$ $(b)\quad \sigma_r=\sqrt{\left(\sigma_x-\sigma_y\right)^2+4\tau_{xy}^2}$
4	Yes according to the maximum shear stress theory No according to the maximum distortion energy

M22 Combined Loading

1	$\sigma_x=11.9\text{ MPa}\quad \tau_{xy}=\tau_{yx}=-0.318\text{ MPa}$ all other stress components are zero.
2	$\sigma_E=-1.01\text{ MPa}\quad \tau_E=1.96\text{ MPa}$ all other stress components are zero. $\sigma_F=-27.7\text{ MPa}$ all other stress components are zero.
3	$\sigma_A=107\text{ MPa}\quad \tau_A=15.3\text{ MPa}$ all other stress components are zero. $\tau_B=14.8\text{ MPa}$ all other stress components are zero.
4	$\sigma_C=-103\text{ MPa}\quad \left(\tau_{xy}\right)_C=3.54\text{ MPa}$ all other stress components are zero.

M23 Core Area of Compression

1	$y=0.75-1.5x$
2	$e_y=r/4$
3	$\left(\sigma_C\right)_{\max}=11.0\text{ MPa}\quad \left(\sigma_C\right)_{\min}=0$

M24 Euler's Formula

1	$P_{cr}=22.7\text{ kN}$
2	$P_{cr}=272\text{ kN}$
3	$P_{cr}=1.30\text{ MN}$

4	$P_{cr} = 42.8\,\text{kN}$

M25 Design of Columns

1	The frame cannot support the load with the required F.S.
2	$P_{cr} = 12.1\,\text{kN}$
3	$d_{AB} = 68.8\,\text{mm} \quad d_{CD} = 40.2\,\text{mm}$
4	Member *AB* will buckle.

M26 Elastic Strain Energy

1	$U = 0.372\,\text{J}$
2	$U = \dfrac{w_0^2 L^5}{504EI}$
3	$U = 149\,\text{J}$
4	N.A.

M27 Work and Energy

1	$\left(\Delta_C\right)_h = \dfrac{2PL}{EA}$
2	$\left(\Delta_D\right)_v = \dfrac{3.50PL}{EA}$
3	$\Delta_B = \dfrac{PL}{15}\left(\dfrac{15\cos^2\theta}{EA} + \dfrac{5L^2\sin^2\theta}{EI}\right)$
4	$\theta_E = 3.15^0$

M28 Castigliano's Theorem

1	$\left(\Delta_D\right)_h = 4.12\text{ mm} \rightarrow$
2	$\theta_A = 0.289^0$
3	$F_{BC} = P\Big/\left(1+2\cos^3\phi\right)$
4	$F_{sp} = \dfrac{5wkL^4}{4\left(6EI+kL^3\right)}$

M29 Method of Virtual Forces

1	$\left(\Delta_B\right)_v = 0.01125\text{ mm}$
2	$\left(\Delta_E\right)_v = 0.1167\text{ mm}$
3	$\theta_A = 0.991\left(10^{-3}\right)\text{ rad}$
4	$\left(\Delta_C\right)_h = \dfrac{5wL^4}{8EI}$

M30 Dynamic Loading

1	$\sigma_{\max} = 216\text{ MPa}$
2	$\Delta_{\max} = 23.3\text{ mm} \quad \sigma_{\max} = 4.89\text{ MPa}$
3	$\sigma_{\max} = 359\text{ MPa}$
4	$h_{\max} = \dfrac{\sigma_{\max}L^2}{3Ec}\left(\dfrac{\sigma_{\max}I}{WLc}-2\right)$