Answers to Problems

E.1 Concrete is stone (gravel) held in place by mortar (sand and cement). Under compression it is resistive like stone, while under tension the mortar is weak.

E.2 (a) $0.126\,\texttt{mm} = 126\,\mu\texttt{m}$, (b) 2.42×10^{-6} mm $= 2.4\,\texttt{nm}$

E.3 (a) $\theta = \tan^{-1}(0.00368) \simeq 0.211^\circ \simeq 0.00368\,\texttt{rad}$,
(b) $\theta = \tan^{-1}(2.36 \times 10^{-5}) \simeq 0.00135^\circ \simeq 2.36 \times 10^{-5}$ rad.

E.4 (a) 2.65×10^8 Pa, (b) (i) 0.001325, (ii) 50.066 m, (c) 2.914×10^8 Pa, 0.001457, 50.073 m, (d) 2.12×10^8 Pa, 0.00106, 50.053m

E.5 (a) 0.19353 GPa, (b) (i) 0.00968, (ii) 3.9 cm, (c) 0.23224 GPa, 0.001161, 4.6 cm

E.6 (a) $59\,\mu$m, (b) $1\,\mu$m, The automobile is 60 times heavier than the bookbag.

E.7 $\Delta R \sim -\frac{1}{2}\,\frac{\Delta L}{L_0}\,R_0$

E.8 $\Delta l \sim +\frac{1}{2}\,\frac{\Delta L}{L_0}\,l_0$

E.9 (a) (i) $V(x) = \frac{\pi}{3}\,\tan^2(\theta)\,x^3$, (ii) $\rho_{\text{ice}}\,g\,\frac{\pi}{3}\,\tan^2(\theta)\,x^3$, (b) $\rho_{\text{ice}}\,g\,x/3 \propto x$

E.10 (a) 225 GPa, (b) 0.133 mm, (c) 4.41 cm of steel and 10.59 cm of silicon carbide

E.11 (a) $\frac{3}{2}\,Y$, (b) $2\,Y$

E.12 (a) $\frac{2\,n}{n+1}\,Y$, (b) $\frac{n+1}{2}\,Y$

E.13 (a) $\frac{2}{n+1}\,Y$, (b) $\frac{n+1}{2\,n}\,Y$

E.14 $Y_{(12)} = \frac{L_1+L_2}{L_1+\frac{Y_1}{Y_2}\,L_2}\,Y_1$, As $L_1 \to 0$, $Y_{(12)} \to Y_2$; as $L_2 \to 0$, $Y_{(12)} \to Y_1$. For non-zero values of $\{L_1, L_2\}$, $Y_1 < Y_{(12)} < Y_2$.

E.15 $Y_{[12]} = \frac{A_1\,Y_1+L_2\,Y_2}{A_1+A_2}$ is the area-weighted average value of the constituent moduli. As $A_1 \to 0$, $Y_{[12]} \to Y_2$; as $A_2 \to 0$, $Y_{[12]} \to Y_1$. In general, $Y_1 < Y_{[12]} < Y_2$.

E.16 The Young's modulus, Y_{Al}, does not depend on the shape of the bar.

E.17 (a) $Y_A > Y_B > Y_C$, since nickel is stiffer than copper. (b) (i) $\frac{1800}{11} \simeq 163.64$ GPa, (ii) 150 GPa, (iii) $\frac{1800}{13} \simeq 138.46$ GPa, (c) yes, (d) (i) 4.9 cm, (ii) 5.3 cm, (iii) 5.8 cm

E.18 (a) $Y_A > Y_B > Y_C$, since nickel is stiffer than copper. (b) (i) $\frac{520}{3} \simeq 173.33$ GPa, (ii) 160 GPa, (iii) $\frac{440}{3} \simeq 146.67$ GPa, (c) yes, (d) (i) 4.6 cm, (ii) 5.0 cm, (iii) 5.45 cm

E.19 $\frac{80}{\ln(200/120)} \simeq 156.6$ GPa

E.20 $\frac{L_1+L_2+L_3}{Y_{(123)}} = \frac{L_1}{Y_1} + \frac{L_2}{Y_2} + \frac{L_3}{Y_3}$, $Y_{(123)} = \frac{(L_1+L_2+L_3)\,Y_1\,Y_2\,Y_3}{L_1\,Y_2\,Y_3+L_2\,Y_3\,Y_1+L_3\,Y_1\,Y_2}$

E.21 $Y_{[123]} = \frac{A_1\,Y_1+A_2\,Y_2+A_3\,Y_3}{A_1+A_2+A_3}$

E.22 (a) (i) series, $Y_s = \frac{800}{61} \simeq 13.1$ GPa; parallel, $Y_p = 57.5$ GPa, (ii) series, $Y_s = \frac{800}{23} \simeq 34.8$ GPa; parallel, $Y_p = 152.5$ GPa, (b) (i) series, $M_{S,s} = \frac{64}{5} = 12.8$ GPa; parallel, $M_{S,p} = 27.5$ GPa, (ii) series, $M_{S,s} = \frac{320}{11} \simeq 29.1$ GPa; parallel, $M_{S,p} = 62.5$ GPa

E.23 (a) parallel, $M_{S,[\text{W,Al}]} = 93.5$ GPa, (b) series, $M_{S,(\text{W,Al})} = \frac{8372}{187} \simeq 44.8$ GPa

E.24 (a) (i) no, (ii) series, $M_{S,s} = \frac{3750}{11} \simeq 341$ kPa, (b) parallel is different, $M_{S,p} = 360$ kPa

E.25 (a) tilt angle $= \tan^{-1}(2/5) \simeq 21.8^\circ$, The top box shifts 48 cm, so the CofM of the stack remains over the bottom box, and thus the pile does not come crashing down.

(b) tilt angle $= \tan^{-1}(1) = 45°$, The top box shifts $120\,\mathtt{cm}$, so the CofM of the stack is displaced beyond the edge of the bottommost box and the pile collapses.

E.26 12 boxes in each orientation [This is consistent with their having been randomly stacked.]

E.27 The shear modulus does not depend on the geometry of the parallelepiped.

E.28 (a) 2500 marshmallows, $1\,\mathtt{m}^2$ platform, (b) (i) $\frac{9}{8}\times$ (original volume) $\simeq 8.44\,\mathtt{cm}^3$, (ii) length and radius scale by $\sqrt[3]{9/2} \simeq 1.04$, new length $26\,\mathtt{mm}$, new radius $10.163\,\mathtt{mm}$, (iii) $0.32\,\mathtt{g}/\mathtt{cm}^3$

E.29 (a) 0.003, (b) $6\,\mathtt{mm}$

E.30 (a) the 5 : 6 face, (b) the 6 : 10 face

E.31 the $W \times H$ face

E.32 (a) this is impossible, (b) series length fractions: W 0.7031, Al 0.2969, parallel area fractions: W 0.2874, Al 0.7126, (c) series height fractions: Mo 0.723, Al 0.277, parallel area fractions: Mo 0.35, Al 0.65, (d) use pure molybdenum

E.33 nylon rope $\simeq 0.7485\,\mathtt{m}$, steel wire $\simeq 0.7453\,\mathtt{m}$, [The steel wire stretches more than does the nylon rope.]

E.34 (a) (i) downward tension force from rope (to block) acting at leftmost end, upward force from rod 1, d_1 from the right end, downward force from rod 2, d_2 from the right end, (ii) $T_1 = M\,g\,\frac{L-d_2}{d_{12}}$, $T_2 - M\,g\,\frac{L-d_1}{d_{12}}$, (b) stress 1 $= T_1/A_1 = \frac{M\,g}{A_1}\,\frac{L-d_2}{d_{12}}$, tensile; stress 2 $= T_2/A_2 = \frac{M\,g}{A_2}\,\frac{L-d_1}{d_{12}}$, compressive, (c) strain 1 $= T_1/A_1 = \frac{M\,g}{Y_1\,A_1}\,\frac{L-d_2}{d_{12}}$, $\Delta l_1 = \frac{M\,g\,l}{Y_1\,A_1}\,\frac{L-d_2}{d_{12}}$, strain 2 $= T_2/A_2 = \frac{M\,g}{Y_2\,A_2}\,\frac{L-d_1}{d_{12}}$, $\Delta l_2 = \frac{M\,g\,l}{Y_2\,A_2}\,\frac{L-d_1}{d_{12}}$, (d) $\tan(\theta) = \frac{M\,g\,l}{d_{12}^2}\left(\frac{L-d_2}{Y_1\,A_1} + \frac{L-d_1}{Y_2\,A_2}\right)$, (e) $\tan(\theta) = \frac{M\,g\,l}{Y\,A\,d_{12}^2}\left(2\,L - d_1 - d_2\right)$

F.1 (a) $121.3\,\mathtt{kPa}$, (b) $111.3\,\mathtt{kPa}$, (c) $101.3\,\mathtt{kPa}$, *i.e.,* P_{atm}

F.2 approximately $40.5\,\mathtt{m}$

F.3 $\frac{\rho'}{\rho} \simeq 1 + \text{strain} = 1 + 1.82 \times 10^{-5}$, The density is increased by about $20\,\mathtt{g}/\mathtt{m}^3$.

F.4 h_3, h_1, h_2

F.5 (a) II, III, I, (b) II, III, I, (c) all equal

F.6 $0.86\,\mathtt{L}$

F.7 (a) $r \simeq 35\,\sqrt[3]{1.12} \simeq 36.34\,\mathtt{cm}$, (b) $r \simeq 35\,\sqrt[3]{0.9} \simeq 33.8\,\mathtt{cm}$, (c) $1.66\,\mathtt{m}$

F.8 (a) $39\,\mathtt{km}$ [This is much deeper than the deepest ocean.] (b) $69.3\,\mathtt{cm}$

F.9 $11\,\mathtt{km}$ [This is somewhat deeper than the deepest ocean.]

F.10 $56.1\,\mathtt{cm}$ of mercury

F.11 $\frac{P_{\text{in}} - P_{\text{atm}}}{\rho_0\,g}$

F.12 (a) $200\,\mathtt{N}$, (b) $5\,\mathtt{N}$

F.13 (a) $15\,\mathtt{N}$ [$\downarrow$], (b) $9.625\,\mathtt{N}$ [$\uparrow$]

F.14 (a) Two-thirds of the marshmallow floats above the cocoa. (b) Approximately 0.704 of the [expanded] marshmallow floats above the cocoa.

F.15 (a) $10.5\,\%$, or roughly $\frac{2}{19}$, (b) $8.3\,\%$, or roughly $\frac{1}{12}$

F.16 (a) $P_{\text{atm}} + 92\,h$, where h is the depth (in $\mathtt{cm}$) below the surface of the oil, (b) $P_{\text{atm}} + 196 \simeq 101576$, (c) $P_{\text{atm}} + 196 + 100.5\,h \simeq 101576 + 100.5\,h$, where h is the depth (in $\mathtt{cm}$) below the surface of the vinegar