

Chapter 1 Basic Concepts in Strength of Materials

1.1 to 1.11 Answers in text.

$$\underline{1.12} \quad W = m \cdot g = 1400 \text{ kg} \cdot 9.81 \text{ m/s}^2 = 13\,734 \text{ (kg} \cdot \text{m)/s}^2 = 14 \times 10^3 \text{ N}$$

$$W = 13.7 \text{ kN}$$

$$\underline{1.13} \quad \text{Total Weight} = m \cdot g = 3500 \text{ kg} \cdot 9.81 \text{ m/s}^2 = 34.34 \text{ kN}$$

$$\text{Each Front Wheel: } F_F = \left(\frac{1}{2}\right) (0.40)(34.34 \text{ kN}) = \mathbf{6.87 \text{ kN}}$$

$$\text{Each Rear Wheel: } F_R = \left(\frac{1}{2}\right) (0.60)(34.34 \text{ kN}) = \mathbf{10.32 \text{ kN}}$$

1.14 Loading = Total Force / Area

$$\text{Total Force} = m \cdot g = 5900 \text{ kg} \cdot 9.81 \text{ m/s}^2 = 57.9 \text{ kN}$$

$$\text{Area} = (4.5 \text{ m})(3.5 \text{ m}) = 15.8 \text{ m}^2$$

$$\text{Loading} = 57.9 \text{ kN}/15.8 \text{ m}^2 = 3.66 \text{ kN/m}^2 = \mathbf{3.66 \text{ kPa}}$$

$$\underline{1.15} \quad \text{Force} = m \cdot g = 35 \text{ kg} \cdot 9.81 \text{ m/s}^2 = 343 \text{ N}$$

$$K = \text{Spring Scale} = 4800 \text{ N/m} = F/\Delta L$$

$$\Delta L = \frac{F}{K} = \frac{343 \text{ N}}{4800 \text{ N/m}} = 0.0715 \text{ m} = 71.5 \times 10^{-3} \text{ m} = \mathbf{71.5 \text{ mm}}$$

$$\underline{1.16} \quad m = \frac{w}{g} = \frac{3250 \text{ lb}}{32.2 \text{ (ft/s}^2\text{)}} = 101 \frac{\text{lb} \cdot \text{s}^2}{\text{ft}} = \mathbf{101 \text{ slugs}}$$

$$\underline{1.17} \quad m = \frac{w}{g} = \frac{11\,600 \text{ lb}}{32.2 \text{ (ft/s}^2\text{)}} = 360 \frac{\text{lb} \cdot \text{s}^2}{\text{ft}} = \mathbf{360 \text{ slugs}}$$

$$\underline{1.19} \quad p = 1700 \text{ psi} \cdot 6.895 \text{ (kPa/psi)} = \mathbf{11\,722 \text{ kPa}}$$

$$\underline{1.20} \quad \sigma = 24\,300 \text{ psi} \cdot 6.895 \text{ (kPa/psi)} = 167\,549 \text{ kPa} = \mathbf{168 \text{ MPa}}$$

1.21 $s_u = 14\,000 \text{ psi} \cdot 6.895 \text{ (kPa/psi)} = 96\,500 \text{ kPa} = \mathbf{96.5 \text{ MPa}}$
 $s_u = 76\,000 \text{ psi} \cdot 6.895 \text{ (kPa/psi)} = 524\,000 \text{ kPa} = \mathbf{524 \text{ MPa}}$

1.22 $n = \frac{3600 \text{ rev}}{\text{min}} \times \frac{2\pi \text{ rad}}{\text{rev}} \times \frac{1 \text{ min}}{60\text{s}} = \mathbf{377 \frac{\text{rad}}{\text{s}}}$

1.23 $A = 26.1 \text{ in}^2 \times \frac{(25.4 \text{ mm})^2}{\text{in}^2} = \mathbf{16\,839 \text{ mm}^2}$

1.24 $y = 0.08 \text{ in} \cdot 25.4 \text{ (mm/in)} = \mathbf{2.03 \text{ mm}}$

1.25 Dimensions: $18 \text{ in} \times 25.4 \text{ (mm/in)} = 457 \text{ mm}$

$12 \text{ in} \times 25.4 \text{ (mm/in)} = 305 \text{ mm}$

Area = $(18 \text{ in})^2 = \mathbf{324 \text{ in}^2}$

Area = $(457 \text{ mm})^2 = \mathbf{2.09 \times 10^5 \text{ mm}^2}$

Volume = $V = \text{Area} \times \text{Height}$

$V = 324 \text{ in}^2 \times 12 \text{ in} = \mathbf{3888 \text{ in}^3}$

$V = (1.5 \text{ ft})^2 \times 1.0 \text{ ft} = \mathbf{2.25 \text{ ft}^3}$

$V = (209 \times 10^3 \text{ mm}^2) \times 305 \text{ mm} = \mathbf{6.37 \times 10^7 \text{ mm}^3}$

$V = (0.457 \text{ m})^2 \times 0.305 \text{ m} = 0.0637 \text{ m}^3 = \mathbf{6.37 \times 10^{-2} \text{ m}^3}$

1.26 $A = \pi D^2/4 = \pi(0.505 \text{ in})^2/4 = \mathbf{0.200 \text{ in}^2}$

$A = 0.200 \text{ in}^2 \times \frac{(25.4 \text{ mm})^2}{\text{in}^2} = \mathbf{129 \text{ mm}^2}$

1.27 $\sigma = \frac{P}{A} = \frac{2800 \text{ N}}{(\pi D^2/4)} = \frac{2800 \text{ N}}{[\pi(10 \text{ mm})^2]/4} = 35.7 \frac{\text{N}}{\text{mm}^2} = \mathbf{35.7 \text{ MPa}}$

1.28 $\sigma = \frac{P}{A} = \frac{18 \times 10^3 \text{ N}}{(12)(30) \text{ mm}^2} = 50.7 \frac{\text{N}}{\text{mm}^2} = \mathbf{50.7 \text{ MPa}}$

1.29 $\sigma = \frac{P}{A} = \frac{1150 \text{ lb}}{(0.40 \text{ in})^2} = \mathbf{7188 \text{ psi}}$

1.30 $\sigma = \frac{P}{A} = \frac{1850 \text{ lb}}{[\pi(0.375 \text{ in})^2]/4} = \mathbf{16\,750 \text{ psi}}$

1.31 Load on Shelf = $W = mg = 1650 \text{ kg} \cdot 9.81 \text{ m/s}^2 = 16\,187 \text{ N}$

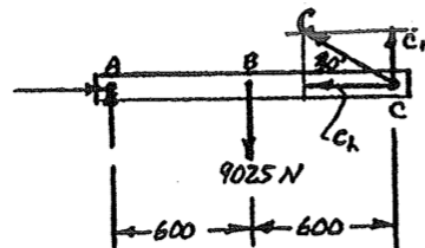
$W/2 = 8093 \text{ N}$ On each side

$\sum M_A = 0 = (8093 \text{ N})(600 \text{ mm}) - C_V(1200 \text{ mm})$

$C_V = 4047 \text{ N}$

$C = C_V / \sin 30^\circ = 8093 \text{ N}$

$\sigma = \frac{P}{A} = \frac{C}{A} = \frac{9025 \text{ N}}{[\pi(12 \text{ mm})^2]/4} = \mathbf{71.6 \text{ MPa}}$



1.32 $\sigma = \frac{P}{A} = \frac{70000 \text{ lb}}{[\pi(10 \text{ in})^2]/4} = \mathbf{891 \text{ psi}}$

$$\underline{1.33} \quad \sigma = \frac{P}{A} = \frac{(29500 \text{ lb})/3}{(3.5 \text{ in})^2} = \mathbf{803 \text{ psi}}$$

$$\underline{1.34} \quad \sigma = \frac{P}{A} = \frac{3500 \text{ N}}{(8.0 \text{ mm})^2} = \mathbf{54.7 \text{ MPa}}$$

$$\underline{1.35} \quad W = m \cdot g = 4200 \text{ kg} \cdot 9.81 \text{ m/s}^2 = 41.2 \text{ kN}$$

$$AB_x = AB \sin 35^\circ$$

$$AB_y = AB \cos 35^\circ$$

$$BC_x = BC \sin 55^\circ$$

$$BC_y = BC \cos 55^\circ$$

$$\sum F_x = 0 = AB_x - BC_x$$

$$0 = AB \sin 35^\circ - BC \sin 55^\circ$$

$$AB = BC \cdot \frac{\sin 55^\circ}{\sin 35^\circ} = 1.428 BC$$

$$\sum F_y = 0 = AB_y + BC_y - 41.2 \text{ kN} = AB \cos 35^\circ + BC \cos 55^\circ - 41.2 \text{ kN}$$

$$0 = (1.428 BC) \cos 35^\circ + BC \cos 55^\circ - 41.2 \text{ kN}$$

$$41.2 \text{ kN} = BC[1.170 + 0.574] = 1.743 BC$$

$$BC = \frac{41.2 \text{ kN}}{1.743} = 23.63 \text{ kN}$$

$$AB = 1.428 BC = 33.75 \text{ kN}$$

$$\text{Stress in Rod AB: } \sigma_{AB} = \frac{AB}{A} = \frac{33.75 \times 10^3 \text{ N}}{[\pi(20 \text{ mm})^2]/4} = \mathbf{107.4 \text{ MPa}}$$

$$\text{Stress in Rod BC: } \sigma_{BC} = \frac{BC}{A} = \frac{23.63 \times 10^3 \text{ N}}{[\pi(20 \text{ mm})^2]/4} = \mathbf{75.2 \text{ MPa}}$$

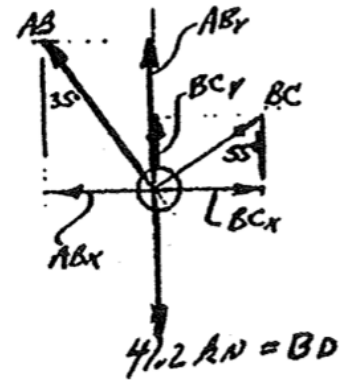
$$\text{Stress in Rod BD: } \sigma_{BD} = \frac{BD}{A} = \frac{41.2 \times 10^3 \text{ N}}{[\pi(20 \text{ mm})^2]/4} = \mathbf{131.1 \text{ MPa}}$$

$$\underline{1.36} \quad F = 0.01097 m \cdot R \cdot n^2 = (0.01097)(0.40)(0.60)(3000)^2 \text{ N}$$

$$F = 23\,695 \text{ N}$$

$$A = \frac{\pi(16 \text{ mm})^2}{4} = 201 \text{ mm}^2$$

$$\sigma = \frac{F}{A} = \frac{23695 \text{ N}}{201 \text{ mm}^2} = \mathbf{118 \text{ MPa}}$$



1.37 $A = (30 \text{ mm})^2 = 900 \text{ mm}^2$

For AB: $F_{AB} = (110 - 40 + 80) \text{ kN} = 150 \text{ kN}$

$$\sigma_{AB} = \frac{F_{AB}}{A} = \frac{150 \times 10^3 \text{ N}}{900 \text{ mm}^2} = \mathbf{167 \text{ MPa Tension}}$$

For BC: $F_{BC} = 110 - 40 = 70 \text{ kN}$

$$\sigma_{BC} = \frac{F_{BC}}{A} = \frac{70 \times 10^3 \text{ N}}{900 \text{ mm}^2} = \mathbf{77.8 \text{ MPa Tension}}$$

For CD: $F_{CD} = 110 \text{ kN}$

$$\sigma_{CD} = \frac{F_{CD}}{A} = \frac{110 \times 10^3 \text{ N}}{900 \text{ mm}^2} = \mathbf{122 \text{ MPa Tension}}$$

1.38 Areas: A-C; $A_1 = \pi(25)^2/4 = 491 \text{ mm}^2$

C-D; $A_2 = \pi(16)^2/4 = 201 \text{ mm}^2$

For AB: $F_{AB} = -9.65 - 12.32 + 4.45 = -17.52 \text{ kN}$

$$\sigma_{AB} = \frac{F_{AB}}{A_1} = \frac{-17.52 \times 10^3 \text{ N}}{491 \text{ mm}^2} = \mathbf{-35.7 \text{ MPa Compression}}$$

For BC: $F_{BC} = -9.65 - 12.32 = -21.97 \text{ kN}$

$$\sigma_{BC} = \frac{F_{BC}}{A_1} = \frac{-21.97 \times 10^3 \text{ N}}{491 \text{ mm}^2} = \mathbf{-44.7 \text{ MPa Compression}}$$

For CD: $F_{CD} = -9.65 \text{ kN}$

$$\sigma_{CD} = \frac{F_{CD}}{A_2} = \frac{-9.65 \times 10^3 \text{ N}}{201 \text{ mm}^2} = \mathbf{-48.0 \text{ MPa Compression}}$$

1.39 $A = \frac{\pi[(1.90)^2 - (1.61)^2]}{4} = 0.799 \text{ in}^2$ [$1 \frac{1}{2}$ in Pipe-Appendix A-9(a)]

For BC: $\sigma_{BC} = \frac{F_{BC}}{A} = \frac{2500 \text{ lb}}{0.799 \text{ in}^2} = \mathbf{3129 \text{ psi Tension}}$

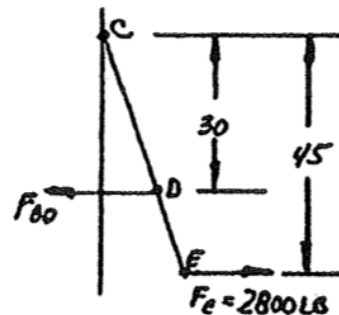
For AB: $F_{AB} = 2500 + 2(8000 \cos 30^\circ) = 16\,356 \text{ lb}$

$$\sigma_{AB} = \frac{F_{AB}}{A} = \frac{16\,356 \text{ lb}}{0.799 \text{ in}^2} = \mathbf{20\,471 \text{ psi Tension}}$$

1.40 $\sum M_C = 0 = 2800(45) - F_{BD}(30)$

$F_{BD} = 4200 \text{ lb}$

$$\sigma_{BD} = \frac{F_{BD}}{A} = \frac{4200 \text{ lb}}{(2.0)(0.65) \text{ in}^2} = \mathbf{3231 \text{ psi Tension}}$$



1.41 $AD \sin 30^\circ = 5.25 \text{ kN}$

$AD = 10.5 \text{ kN} = CD$

$AB = AD \cos 30^\circ = 9.09 \text{ kN} = BC$

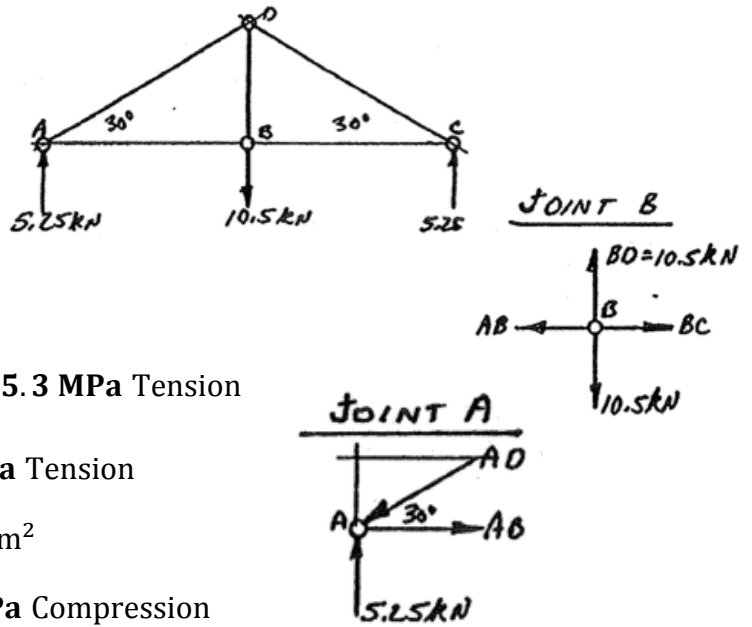
Stresses:

$AB, BC: \sigma_{AB} = \sigma_{BC} = \frac{9.09 \times 10^3 \text{ N}}{(12)(30) \text{ mm}^2} = 25.3 \text{ MPa Tension}$

$BD: \sigma_{BD} = \frac{10.5 \times 10^3 \text{ N}}{(2)(10)(30) \text{ mm}^2} = 17.5 \text{ MPa Tension}$

$AD, CD: A = (30)^2 - (20)^2 = 500 \text{ mm}^2$

$\sigma_{AD} = \sigma_{CD} = \frac{-10.5 \times 10^3 \text{ N}}{500 \text{ mm}^2} = -21.0 \text{ MPa Compression}$

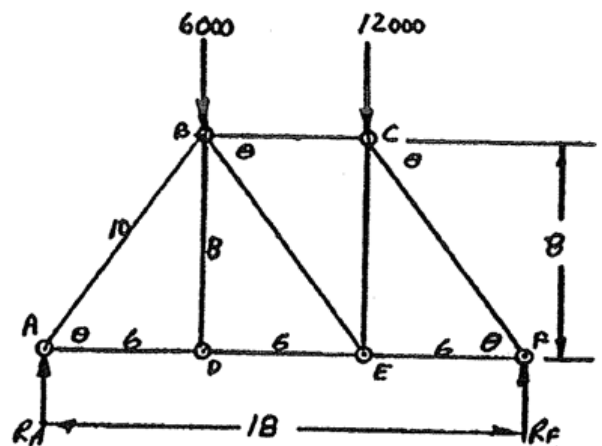
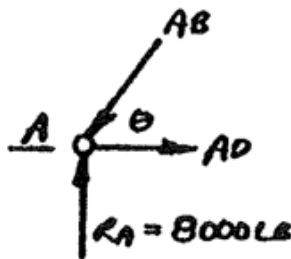


1.42 $\sum M_A = 0 = 6000(6) + 12000(12) - R_F(18)$

$R_F = 10000 \text{ lb}$

$\sum M_F = 0 = 12000(6) + 6000(12) - R_A(18)$

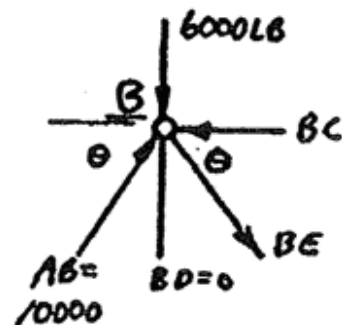
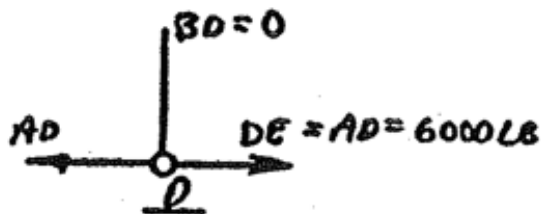
$R_A = 8000 \text{ lb}$



$R_A = AB \sin \theta = AB(0.8)$

$AB = \frac{R_A}{0.8} = \frac{8000}{0.8} = 10000 \text{ lb Compression}$

$AD = AB \cos \theta = 10000(0.6) = 6000 \text{ lb Tension}$



$BE \sin \theta + 6000 - AB \sin \theta = 0$

$BE = \frac{AB \sin \theta - 6000}{\sin \theta} = \frac{10000(0.8) - 6000}{0.8} = 2500 \text{ lb Tension}$

$BC = AB \cos \theta + BE \cos \theta = 10000(0.6) + 2500(0.6)$

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$BC = 7500 \text{ lb Compression}$

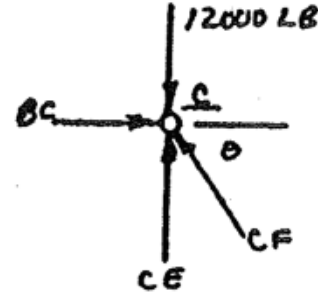
$$BC = CF \cos \theta$$

$$CF = \frac{BC}{\cos \theta} = \frac{7500}{0.6} = 12\,500 \text{ lb Compression}$$

$$CE = 12\,000 - CF \sin \theta = 12\,000 - 12\,500(0.8)$$

$$CE = 2000 \text{ lb Compression}$$

$$EF = CF \cos \theta = 12\,500 \text{ lb}(0.6) = 7500 \text{ lb Tension}$$



Areas of members: Appendixes A-5(a) and A-6(a)

$$AD, DE, EF - 2(0.484 \text{ in}^2) = 0.968 \text{ in}^2$$

$$BD, BE, CE - 0.484 \text{ in}^2$$

$$AB, BC, CF - 2(1.21 \text{ in}^2) = 2.42 \text{ in}^2$$

Stresses:

$$\sigma_{AD} = \sigma_{DE} = 6000/0.968 = +6198 \text{ psi}$$

$$\sigma_{EF} = 7500/0.968 = +7748 \text{ psi}$$

$$\sigma_{BD} = 0$$

$$\sigma_{BE} = 2500/0.484 = +5165 \text{ psi}$$

$$\sigma_{CE} = -2000/0.484 = -4132 \text{ psi}$$

$$\sigma_{AB} = -10\,000/2.42 = -4132 \text{ psi}$$

$$\sigma_{BC} = -7500/2.42 = -3099 \text{ psi}$$

$$\sigma_{CF} = -12\,500/2.42 = -5165 \text{ psi}$$

[NOTE: Compression members must be checked for column buckling.]

$$\underline{1.43} \sum M_C = 0 = (12.5)(4.0) - AB(2.5)$$

$$AB = 20 \text{ kN}$$

$$\sigma = \frac{20 \times 10^3 \text{ N}}{(20)^2 \text{ mm}^2} = \mathbf{50 \text{ MPa}}$$

$$\underline{1.44} A = \frac{\pi(0.505)^2}{4} = 0.200 \text{ in}^2$$

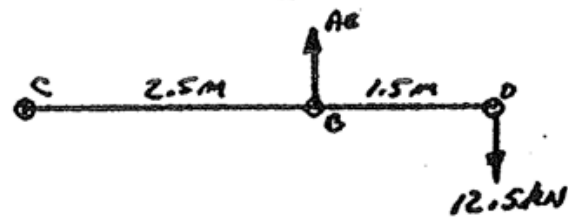
$$\sigma = \frac{F}{A} = \frac{12\,600 \text{ lb}}{0.200 \text{ in}^2} = \mathbf{63\,000 \text{ psi}}$$

$$\underline{1.45} A = (2.65)(1.40) + 2[(1.40)(0.5)(t)] = 4.41 \text{ in}^2$$

$$\sigma = \frac{F}{A} = \frac{52\,000 \text{ lb}}{4.41 \text{ in}^2} = \mathbf{11\,791 \text{ psi}}$$

$$\underline{1.46} A = (80)(40) - (60)(15) + \frac{\pi(40)^2}{4} = 3557 \text{ mm}^2$$

$$\sigma = \frac{F}{A} = \frac{640 \times 10^3 \text{ N}}{3557 \text{ mm}^2} = \mathbf{180 \text{ MPa}}$$



1.47 Direct Shear - Single Shear

$$A_S = \left[\frac{\pi(12.0)^2}{4} \right] \text{ mm}^2 = 113 \text{ mm}^2$$

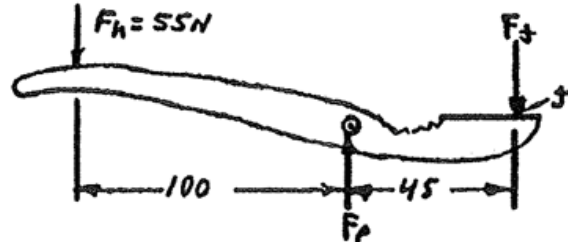
$$\tau = \frac{F}{A_S} = \frac{16.5 \times 10^3 \text{ N}}{113 \text{ mm}^2} = \mathbf{146 \text{ MPa}}$$

1.48 $\sum F_J = 0 = 55(145) - F_P(45)$

$$F_P = 177 \text{ N}$$

$$A_S = \frac{\pi(3.0)^2}{4} = 7.07 \text{ mm}^2$$

$$\tau = \frac{F_P}{A_S} = \frac{177 \text{ N}}{7.07 \text{ mm}^2} = \mathbf{25.1 \text{ MPa}}$$



Pin is in single shear

1.49 From Problem 1-46: $F = 23\,695 \text{ N}$

$$A_S = 2 \left[\frac{\pi(10)^2}{4} \right] = 157 \text{ mm}^2 \text{ Double Shear}$$

$$\tau = \frac{F}{A_S} = \frac{23\,695 \text{ N}}{157 \text{ mm}^2} = \mathbf{151 \text{ MPa}}$$

1.50 $A_S = (3.0)(3.5) = 10.5 \text{ in}^2$

$$\tau = \frac{F}{A_S} = \frac{1650 \text{ lb}}{10.5 \text{ in}^2} = \mathbf{157 \text{ psi}}$$

1.51 $A_S = [2(35) + \pi(8)](50) = 475.7 \text{ mm}^2$

$$\tau = \frac{F}{A_S} = \frac{38.6 \times 10^3 \text{ N}}{475.7 \text{ mm}^2} = \mathbf{81.1 \text{ MPa}}$$

1.52 $L = \sqrt{0.4^2 + 0.6^2} = 0.721 \text{ in}$

$$A_S = \left[2(1.60) + \frac{\pi(0.8)}{2} + 2(0.721) \right] 0.194$$

$$A_S = 1.144 \text{ in}^2$$

$$\tau = \frac{F}{A_S} = \frac{45\,000 \text{ lb}}{1.144 \text{ in}^2} = \mathbf{39\,324 \text{ psi}}$$

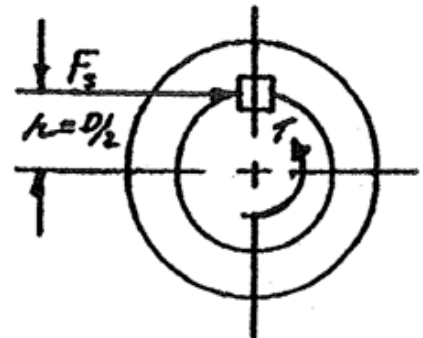


1.53 $T = F_S \cdot R$

$$F_S = \frac{T}{R} = \frac{95 \text{ N}\cdot\text{m}}{35 \text{ mm}/2} \cdot \frac{10^3 \text{ mm}}{\text{m}} = 5429 \text{ N}$$

$$A_S = b \cdot L = (10)(22) = 220 \text{ mm}^2$$

$$\tau = \frac{F_S}{A_S} = \frac{5429 \text{ N}}{220 \text{ mm}^2} = \mathbf{24.7 \text{ MPa}}$$



$$\underline{1.54} \quad F_S = \frac{T}{r} = \frac{8000 \text{ lb} \cdot \text{in}}{1.0 \text{ in}}$$

$$A_S = b \cdot L = (0.50)(2.25) = 1.125 \text{ in}^2$$

$$\tau = \frac{F_S}{A_S} = \frac{8000 \text{ lb}}{1.125 \text{ in}^2} = \mathbf{7111 \text{ psi}}$$

$$\underline{1.55} \quad \text{Pin: Double Shear; } A_S = 2[\pi(0.5)^2/4] = 0.393 \text{ in}^2$$

$$\tau = \frac{F}{A_S} = \frac{20\,000 \text{ lb}}{0.393 \text{ in}^2} = \mathbf{50\,930 \text{ psi}}$$

Collar: Shear Collar from Connector Body

$$A_S = \pi dt = \pi(0.875)(0.1875) = 0.5154 \text{ in}^2$$

$$\tau = \frac{F}{A_S} = \frac{20\,000 \text{ lb}}{0.5154 \text{ in}^2} = \mathbf{38\,800 \text{ psi}}$$

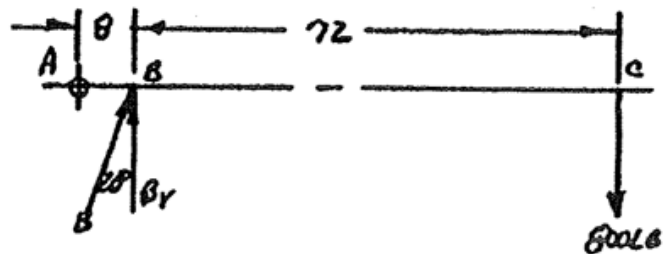
$$\underline{1.56} \quad \sum M_A = 0 = 800(80) - B_V(8)$$

$$B_V = 8000 \text{ lb}$$

$$B = \frac{B_V}{\cos 20^\circ} = 8513 \text{ lb}$$

$$A_S = 2 \left[\frac{\pi(0.375)^2}{4} \right] = 0.221 \text{ in}^2$$

$$\tau = \frac{B}{A_S} = \frac{8513 \text{ lb}}{0.221 \text{ in}^2} = \mathbf{38\,540 \text{ psi}}$$



$$\underline{1.57} \quad A_S = (40)(12) = 480 \text{ mm}^2$$

$$\tau = \frac{F}{A_S} = \frac{88 \times 10^3 \text{ N}}{480 \text{ mm}^2} = \mathbf{183 \text{ MPa}}$$

$$\underline{1.58} \quad A_S = (40)(120) = 4800 \text{ mm}^2$$

$$\tau = \frac{F}{A_S} = \frac{88.2 \times 10^3 \text{ N}}{4800 \text{ mm}^2} = \mathbf{18.4 \text{ MPa}}$$

$$\underline{1.59} \quad A_S = \pi dt = \pi(12)(8) = 301.6 \text{ mm}^2$$

$$\tau = \frac{F}{A_S} = \frac{22.3 \times 10^3 \text{ N}}{301.6 \text{ mm}^2} = \mathbf{73.9 \text{ MPa}}$$

$$\underline{1.60} \quad A_S = 2[\pi(12)^2/4] = 226.2 \text{ mm}^2 \text{ Two Rivets - Single Shear}$$

$$\tau = \frac{F}{A_S} = \frac{10.2 \times 10^3 \text{ N}}{226.2 \text{ mm}^2} = \mathbf{45.1 \text{ MPa}}$$

$$\underline{1.61} \quad A_S = 4[\pi(12)^2/4] = 452.4 \text{ mm}^2 \text{ Two Rivets - Double Shear}$$

$$\tau = \frac{F}{A_S} = \frac{10.2 \times 10^3 \text{ N}}{452.4 \text{ mm}^2} = \mathbf{22.55 \text{ MPa}}$$

Structural Shapes

1-62 [Appendix A-4(a)] 2×4 wood board is 1.50 in×3.50 in cross section. $A = 5.25 \text{ in}^2$

1-63 [Appendix A-4(a)] 4×12 wood board is 11.25 in×3.50 in cross section. $A = 39.38 \text{ in}^2$

1-64 [Appendix A-4(a)] 1 in size; 0.75 in: 2 in; 1.50 in: 3 in; 2.50 in: 4 in; 3.50 in:
 _____ 6 in; 5.50 in: 8 in; 7.25 in: 10 in; 9.25 in: 12 in; 11.25 in.

1-65 [Appendix A-4(b)] Metric size similar to U.S. 2×4: 45 mm×90 mm; $A = 4050 \text{ mm}^2$

1-66 [App. A-4(b)] Metric size similar to U.S. 2×10: 45 mm×240 mm; $A = 10\,800 \text{ mm}^2$

| <u>1-67</u> | <u>U.S. size</u> | <u>Actual width</u> | <u>Conversion</u> | <u>Closest SI size</u> | <u>Difference</u> |
|-------------|------------------|---------------------|-------------------|------------------------|-------------------|
| | 1 in | 0.75 in | 19.05 mm | 19 mm | -0.05 mm |
| | 2 in | 1.50 in | 38.1 mm | 40 mm | +1.90 mm |
| | 3 in | 2.50 in | 63.5 mm | 65 mm | +1.50 mm |
| | 4 in | 3.50 in | 88.9 mm | 90 mm | +1.10 mm |
| | 6 in | 5.50 in | 139.7 mm | 140 mm | +0.30 mm |
| | 8 in | 7.25 in | 184.15 mm | 190 mm | +5.85 mm |
| | 10 in | 9.25 in | 234.95 mm | 240 mm | +5.05 mm |
| | 12 in | 11.25 in | 285.75 mm | 290 mm | +4.25 mm |

1-68 [Appendix A-5(a)] L 6×6×3/4 weighs 28.8 lb/ft
 6.0 ft length weighs: $(6 \text{ ft})(28.8 \text{ lb/ft}) = 172.8 \text{ lb}$; $A = 8.46 \text{ in}^2$

_____ 1-69 [Appendix A-5(b)] Angle 1.50×1.25×0.188 weighs 1.633 lb/ft
 53.5 in length weighs: $(53.5 \text{ in})(1.0 \text{ ft}/12 \text{ in})(1.633 \text{ lb/ft}) = 7.28 \text{ lb}$; $A = 0.480 \text{ in}^2$

1-70 [Appendix A-5(c)] Angle 40×20×3 (mm) weighs 12.883 N/m
 1.45 m length weighs: $(1.45 \text{ m})(12.883 \text{ N/m}) = 18.68 \text{ N}$; $A = 171 \text{ mm}^2$

1-71 [Appendix A-6(a)] C 7×14.75 weighs 14.75 lb/ft; Depth = 7.00 in; $A = 4.33 \text{ in}^2$
 148 in long section weighs: $(14.75 \text{ lb/ft})(148 \text{ in})(1 \text{ ft}/12 \text{ in}) = 181.92 \text{ lb}$

_____ 1-72 [App. A-6(b)] Aluminum C 9×4.983 weighs 4.983 lb/ft; Depth = 9.00 in; $A = 4.237 \text{ in}^2$
 37.5 in long section weighs: $(4.983 \text{ lb/ft})(37.5 \text{ in})(1 \text{ ft}/12 \text{ in}) = 15.57 \text{ lb}$

1-73 [App. A-6(d)] Aluminum C 80×40 mm weighs 16.51 N/m; Depth = 80 mm; $A = 608 \text{ mm}^2$
 3.80 m long section weighs: $(16.1 \text{ N/m})(3.80 \text{ m}) = 61.18 \text{ N}$

1-74 [Appendix A-7(a)] W 10×60 beam weighs 60.0 lb/ft; Depth = 10.2 in; $A = 17.60 \text{ in}^2$
 290 in length weighs: $(290 \text{ in})(1 \text{ ft}/12 \text{ in})(60.0 \text{ lb/ft}) = 1450 \text{ lb}$

1-75 [Appendix A-7(b)] S 24×121 beam weighs 121 lb/ft; Depth = 24.5 in; $A = 35.5 \text{ in}^2$
240 in length weighs: $(240 \text{ in})(1 \text{ ft}/12 \text{ in})(121 \text{ lb}/\text{ft}) = 2420 \text{ lb}$

1-76 [Appendix A-7(e)] IPE I 330×160 beam weighs 471.7 N/m; $A = 6261 \text{ mm}^2$
2.55 m length weighs: $(2.55 \text{ m})(471.7 \text{ N}/\text{m}) = 1203 \text{ N}$

Flange width = 160 mm; Flange thickness = 11.5 mm; web thickness = 7.50 mm

1-77 [Appendix A-7(f)] Wood I-shapes; 4 depths: 9.50 in; 11.75 in; 14.00 in; 16.00 in
[Note: Many other depths commercially available]

1-78 [Appendix A-8(a)] HSS6×4×1/4 tube: $t = 0.233 \text{ in}$ (design thickness); $A = 4.30 \text{ in}^2$

1-79 [Appendix A-8(c)] Steel 150×50×4 mm tube weighs 116 N/m; $A = 1536 \text{ mm}^2$
Inside dimensions: 142×42 mm

1.22 m length weighs: $(1.42 \text{ m})(116 \text{ N}/\text{m}) = 164.7 \text{ N}$

1-80 [Appendix A-9(a)] 6-in Schedule 40 steel pipe: OD = 6.625 in; ID = 6.065 in
Wall thickness = 0.280 in; $A = 5.581 \text{ in}^2$; AISC PIPE6STD.

1-81 [Appendix A-9(b)] 6-in Schedule 40 steel pipe is called: DN 150 size;
OD = 168.3 mm; ID = 154.1 mm; Wall thickness = 7.11 mm; $A = 3601 \text{ mm}^2$

1-82 [Appendix A-9(c)] Steel mechanical tube: 3-1/2×10; OD = 3.50 in; ID = 3.232 in;
Wall thickness = 10 gauge = 0.134 in; $A = 1.417 \text{ in}^2$

1-83 [Appendix A-9(d)] For tube in Problem 1-93, OD = 3.50 in = 88.9 mm;
 $A = 1.417 \text{ in}^2 \times (645.2 \text{ mm}^2/\text{in}^2) = 914.2 \text{ mm}^2$;
Closest SI metric tube: 90×3 mm; OD = 90 mm; $A = 820 \text{ mm}^2$

Chapter 2 Design Properties of Materials

Only those problems requiring numerical data are shown.

2-14 $s_u = 90$ ksi (621 MPa); $s_y = 60$ ksi (414 MPa); 25% Elongation [Appendix A-10]

Because % Elongation >5%, it is ductile.

2-15 1020 HR: 36% Elongation – **Greater ductility** [Appendix A-10]

1040 HR: 25% Elongation

2-16 SAE 1141 OQT 700: High sulfur alloy steel with 0.41% carbon, quenched in oil, tempered at 700°F. [Appendix A-10]

2-17 Yes, AISI 1141 steel has: $s_y = 172$ ksi @ OQT 700, $s_y = 129$ ksi @ OQT 900

By interpolation, $s_y \approx 150$ ksi @ OQT 800. [Appendix A-10]

2-18 $E = 30 \times 10^6$ psi (207 GPa) For all carbon and alloy steels. [Appendix A-10]

2-19 $Wt = \text{Density} \times \text{Volume} = (0.283 \text{ lb/in}^3)(1.0)(4.0)(14.5)\text{in}^3 = \mathbf{16.4 \text{ lb}}$

[Appendix A-10] Value of $\text{lb}_m = \text{Value of lb force } (Wt)$

2-20 Volume = Area \times Length = $\frac{\pi}{4}(50)^2 \times 250 = 4.909 \times 10^5 \text{ mm}^3$

Steel Bar: Mass = $\frac{7680 \text{ kg}}{\text{m}^3} \times \frac{4.909 \times 10^5 \text{ mm}^3}{1} \times \frac{1 \text{ m}^3}{(10^3 \text{ mm})^3} = 3.77 \text{ kg}$ [Appendix A-10]

$Wt = m \cdot g = 3.77 \text{ kg} \cdot 9.81 \text{ m/s}^2 = 36.98 \text{ kg} \cdot \text{m/s}^2 = \mathbf{36.98 \text{ N}}$

2-21 Magnesium would stretch more because it has a lower E .

$E_{Mag} = 45 \text{ GPa}$; $E_{Ti} = 114 \text{ GPa}$; Ti is stiffer. [Appendix A-11]

2-23 Alloy of aluminum with silicon and magnesium. Heat treated to T6 temper.

2-24

| | s_u | s_y | E | Density |
|---------|--------|--------|----------------------|-------------------------|
| 6061-0 | 18 ksi | 8 ksi | 10×10^6 psi | 0.10 lb/in ³ |
| 6061-T4 | 35 ksi | 21 ksi | 10×10^6 psi | 0.10 lb/in ³ |
| 6061-T6 | 45 ksi | 40 ksi | 10×10^6 psi | 0.10 lb/in ³ |

[Appendix A-14]

2-29 $s_{ut} = 40$ ksi; $s_{uc} = 140$ ksi [Appendix A-13]

2-31 Bending $\sigma_d = 1450$ psi; Tension $\sigma_d = 850$ psi; Compression 1000 psi Parallel to grain, 385 psi Perpendicular to grain; Shear $\tau_d = 95$ psi [Appendix A-15]

2-32 2000 to 7000 psi [Section 2-11]

2-44 Graphite fibers.

2-45 S-glass, quartz fibers, tungsten fibers coated with silicon carbide

| <u>2-51</u> | <u>Material</u> | <u>Specific strength (in)</u> | <u>Ratio to SAE 1020</u> |
|-------------|----------------------------------|-------------------------------|--------------------------|
| | Graphite/Epoxy (High Strength) | 4.86×10^6 | 25.0 |
| | Aramid/Epoxy Composite | 4.00×10^6 | 20.6 |
| | Boron/Epoxy Composite | 3.60×10^6 | 18.5 |
| | Graphite/Epoxy (Ultra-high mod.) | 2.76×10^6 | 14.2 |
| | Glass/Epoxy Composite | 1.87×10^6 | 9.63 |
| | Titanium Ti-6Al-4V | 1.00×10^6 | 5.15 |
| | SAE 5160 OQT 700 Steel | 0.929×10^6 | 4.78 |
| | Aluminum 7075-T6 | 0.822×10^6 | 4.23 |
| | Aluminum 6061-T6 | 0.459×10^6 | 2.36 |
| | SAE 1020 HR Steel | 0.194×10^6 | 1.00 |

| <u>2-52</u> | <u>Material</u> | <u>Specific modulus (in)</u> | <u>Ratio to SAE 1020</u> |
|-------------|----------------------------------|------------------------------|--------------------------|
| | Graphite/Epoxy (Ultra-high mod.) | 8.28×10^8 | 7.81 |
| | Boron/Epoxy Composite | 4.00×10^8 | 3.77 |
| | Graphite/Epoxy (High Strength) | 3.45×10^8 | 3.25 |
| | Aramid/Epoxy Composite | 2.20×10^8 | 2.07 |
| | SAE 1020 HR Steel | 1.06×10^8 | 1.00 |
| | SAE 5160 OQT 700 Steel | 1.06×10^8 | 1.00 |
| | Titanium Ti-6Al-4V | 1.03×10^8 | 0.97 |
| | Aluminum 6061-T6 | 1.02×10^8 | 0.96 |
| | Aluminum 7075-T6 | 0.99×10^8 | 0.93 |
| | Glass/Epoxy Composite | 0.66×10^8 | 0.62 |

Solutions to Problems 2-58 to 2-69: Some data are approximated from Figure P2-66.

- The most accurate values are for ultimate strength (b.) and % elongation (f.).
- The elastic limit (d.) is estimated between the proportional limit (c.) and yield strength (a.).
- The modulus of elasticity (e.) is computed from [Δ stress / Δ strain], the slope of the straight-line part of each curve.
- Listed materials are found in Appendixes A-10 – A-14, matching s_u , s_y , E , and % elongation.

2-58 a. $s_y = 73$ ksi; Offset method
b. $s_u = 83$ ksi
c. $s_p = 60$ ksi
d. $s_{el} = 67$ ksi
e. $E = 10.0 \times 10^6$ psi
f. 11% elongation
g. Ductile
h. Aluminum
i. 7075-T6

2-59 a. $s_y = 173$ ksi; Yield point
b. $s_u = 187$ ksi
c. $s_p = 162$ ksi
d. $s_{el} = 168$ ksi
e. $E = 29.0 \times 10^6$ psi
f. 15% elongation
g. Ductile
h. Steel
i. SAE 4140 OQT 900

3-60 a. $s_y = 62$ ksi; Offset method
b. $s_u = 75$ ksi
c. $s_p = 50$ ksi
d. $s_{el} = 56$ ksi
e. $E = 16.7 \times 10^6$ psi
f. 15% elongation
g. Ductile
h. Copper alloy
i. C54400 Bronze-Hard

3-61 a. $s_y = 49$ ksi; Yield point
b. $s_u = 65$ ksi
c. $s_p = 46$ ksi
d. $s_{el} = 48$ ksi
e. $E = 26.5 \times 10^6$ psi
f. 36% elongation
g. Ductile
h. Steel
i. SAE 1020 CD

4-62 a. No yield strength-Brittle
b. $s_u = 55$ ksi
c. $s_p = 50$ ksi
d. $s_{el} = 53$ ksi
e. $E = 20.0 \times 10^6$ psi
f. 0.5% elongation
g. Brittle
h. Cast iron
i. ASTM A48 Grade 60

4-63 a. $s_y = 53$ ksi; Offset Method
b. $s_u = 59$ ksi
c. $s_p = 31$ ksi
d. $s_{el} = 42$ ksi
e. $E = 12.0 \times 10^6$ psi
f. 5.0% elongation
g. Borderline Ductile/
Brittle
h. Zinc
i. Cast ZA-12

5-64 a. $s_y = 35$ ksi; Yield point
b. $s_u = 57$ ksi
c. $s_p = 30$ ksi
d. $s_{el} = 27$ ksi
e. $E = 26.0 \times 10^6$ psi
f. 21% elongation
g. Ductile
h. Structural Steel
i. ASTM A36

5-65 a. $s_y = 19$ ksi; Offset Method
b. $s_u = 40$ ksi
c. $s_p = 14$ ksi
d. $s_{el} = 17$ ksi
e. $E = 6.0 \times 10^6$ psi
f. 5.0% elongation
g. Borderline Ductile/
Brittle
h. Magnesium
i. ASTM AZ 63A-T6

- 2-66 a. $s_y = 155$ ksi; Offset Method
b. $s_u = 170$ ksi
c. $s_p = 142$ ksi
d. $s_{el} = 149$ ksi
e. $E = 16.5 \times 10^6$ psi
f. 8% elongation
g. Ductile
h. Titanium
i. 6Al-4V

- 2-67 a. $s_y = 40$ ksi; Offset Method
b. $s_u = 45$ ksi
c. $s_p = 30$ ksi
d. $s_{el} = 35$ ksi
e. $E = 10.0 \times 10^6$ psi
f. 17% elongation
g. Ductile
h. Aluminum
i. 6061-T6

- 3-68 a. $s_y = 80$ ksi; Offset Method
b. $s_u = 90$ ksi
c. $s_p = 62$ ksi
d. $s_{el} = 71$ ksi
e. $E = 26.0 \times 10^6$ psi
f. 15% elongation
g. Ductile
h. Stainless Steel
i. SAE 430 – Full hard

- 3-69 a. $s_y = 80$ ksi; Offset Method
b. $s_u = 95$ ksi
c. $s_p = 55$ ksi
d. $s_{el} = 68$ ksi
e. $E = 26.0 \times 10^6$ psi
f. 2.0% elongation
g. Brittle – Does not yield
h. Malleable Iron
i. ASTM A220 Grade 80002