Chapter 1 Basic Concepts in Strength of Materials

1.1 to 1.11 Answers in text.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

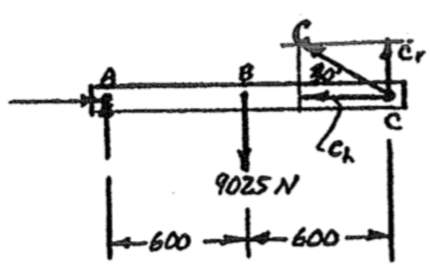
$W/2 = 8093$ N On each side

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

$C_V = 4047 \text{ N}$

$C = C_V / \sin 30° = 8093 \text{ N}$

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

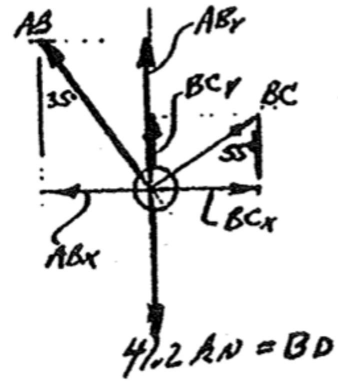


1.32 $\sigma = \frac{P}{A} = \frac{70000 \text{ lb}}{[\pi(10 \text{ in})^2]/4} = \mathbf{891\ psi}$

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

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

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



$AB_X = AB \sin 35°$

$AB_Y = AB \cos 35°$

$BC_X = BC \sin 55°$

$BC_Y = BC \cos 55°$

$\sum F_X = 0 = AB_X - BC_X$

$0 = AB \sin 35° - BC \sin 55°$

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

$\sum F_V = 0 = AB_Y + BC_Y - 41.2 \text{ kN} = AB \cos 35° + BC \cos 55° - 41.2 \text{ kN}$

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\sigma_{AB} = \frac{F_{AB}}{A} = \frac{150\times10^3\text{ N}}{900\text{ mm}^2} = \mathbf{167\ MPa}\text{ Tension}$$

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

$$\sigma_{BC} = \frac{F_{BC}}{A} = \frac{70\times10^3\text{ N}}{900\text{ mm}^2} = \mathbf{77.8\ MPa}\text{ Tension}$$

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

$$\sigma_{CD} = \frac{F_{CD}}{A} = \frac{110\times10^3\text{ N}}{900\text{ mm}^2} = \mathbf{122\ MPa}\text{ Tension}$$

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

$$\sigma_{AB} = \frac{F_{AB}}{A_1} = \frac{-17.52\times10^3\text{ N}}{491\text{ mm}^2} = \mathbf{-35.7\ MPa}\text{ Compression}$$

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

$$\sigma_{BC} = \frac{F_{BC}}{A_1} = \frac{-21.97\times10^3\text{ N}}{491\text{ mm}^2} = \mathbf{-44.7\ MPa}\text{ Compression}$$

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

$$\sigma_{CD} = \frac{F_{CD}}{A_2} = \frac{-9.65\times10^3\text{ N}}{201\text{ mm}^2} = \mathbf{-48.0\ MPa}\text{ Compression}$$

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

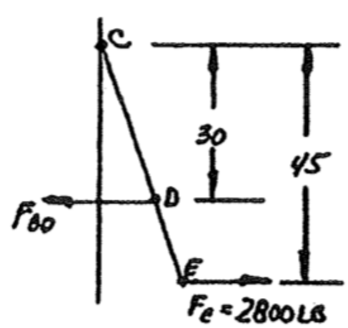
For AB: $F_{AB} = 2500 + 2(8000\cos 30°) = 16\,356\text{ lb}$

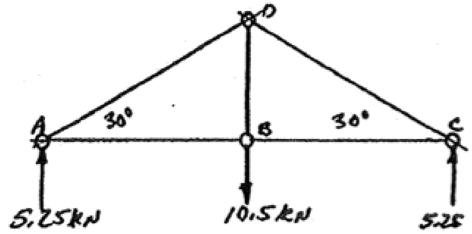
$$\sigma_{AB} = \frac{F_{AB}}{A} = \frac{16\,356\text{ lb}}{0.799\text{ in}^2} = \mathbf{20\,471\ psi}\text{ Tension}$$

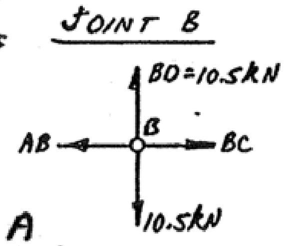
1.40 $\sum M_C = 0 = 2800(45) - F_{BD}(30)$

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

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







1.41 $AD \sin 30° = 5.25$ kN

$AD = 10.5$ kN $= CD$

$AB = AD \cos 30° = 9.09$ kN $= BC$

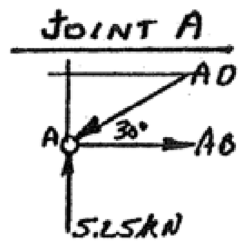
Stresses:

AB, BC: $\sigma_{AB} = \sigma_{BC} = \frac{9.09\times10^3 \text{ N}}{(12)(30)\text{ mm}^2} = \mathbf{25.3\ MPa}$ Tension

BD: $\sigma_{BD} = \frac{10.5\times10^3 \text{ N}}{(2)(10)(30)\text{ mm}^2} = \mathbf{17.5\ MPa}$ Tension

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

$\sigma_{AD} = \sigma_{CD} = \frac{-10.5\times10^3 \text{ N}}{500 \text{ mm}^2} = \mathbf{-21.0\ MPa}$ Compression

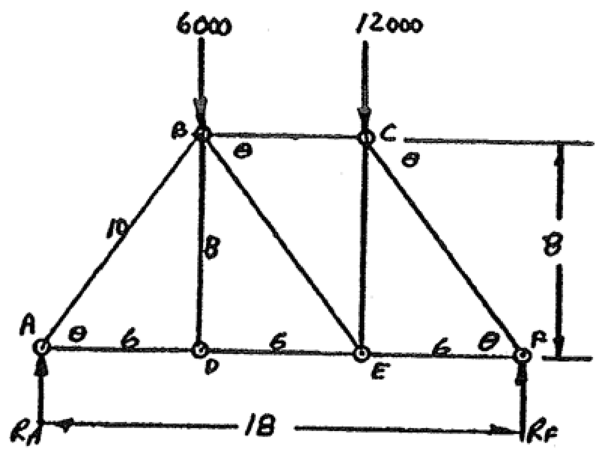


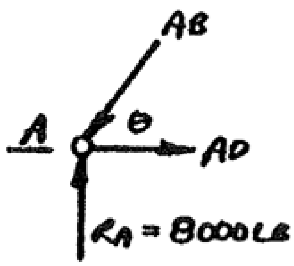
1.42 $\sum M_A = 0 = 6000(6) + 12\,000(12) - R_F(18)$

$R_F = 10\,000$ lb

$\sum M_F = 0 = 12\,000(6) + 6000(12) - R_A(18)$

$R_A = 8000$ lb

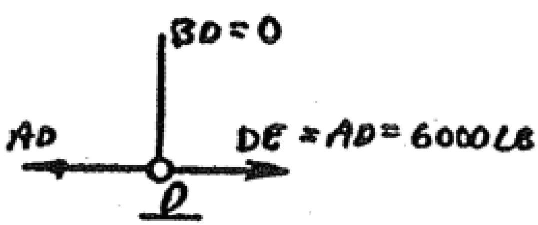


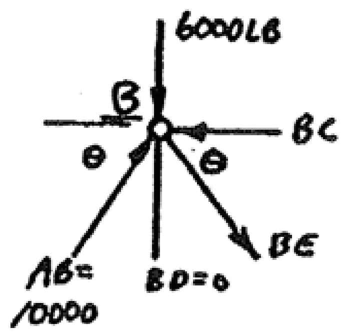


$R_A = AB \sin\theta = AB(0.8)$

$AB = \frac{R_A}{0.8} = \frac{8000}{0.8} = 10\,000$ lb Compression

$AD = AB\cos\theta = 10\,000(0.6) = 6000$ lb Tension





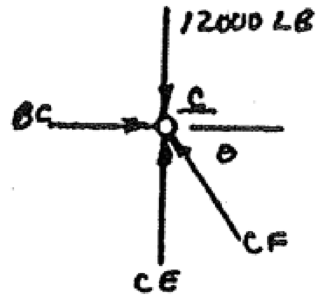
$BE \sin\theta + 6000 - AB\sin\theta = 0$

$BE = \frac{AB\sin\theta - 6000}{\sin\theta} = \frac{10\,000(0.8) - 6000}{0.8} = 2500$ lb Tension

$BC = AB\cos\theta + BE\cos\theta = 10\,000(0.6) + 2500(0.6)$

[Continued on next page]

$BC = 7500$ lb Compression



$BC = CF\cos\theta$

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

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

$CE = 2000$ lb Compression

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

Areas of members: Appendixes A-5(a) and A-6(a)
$AD, DE, EF - 2(0.484\text{ in}^2) = 0.968\text{ in}^2$
$BD, BE, CE - 0.484\text{ in}^2$
$AB, BC, CF - 2(1.21\text{ in}^2) = 2.42\text{ in}^2$

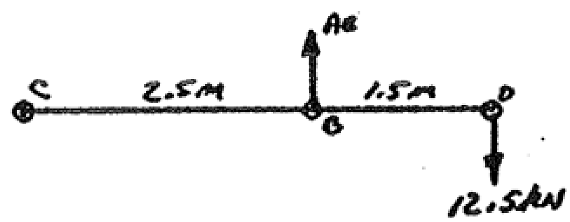
Stresses:
$\sigma_{AD} = \sigma_{DE} = 6000/0.968 = +6198$ psi
$\sigma_{EF} = 7500/0.968 = +7748$ psi
$\sigma_{BD} = 0$
$\sigma_{BE} = 2500/0.484 = +5165$ psi
$\sigma_{CE} = -2000/0.484 = -4132$ psi
$\sigma_{AB} = -10\,000/2.42 = -4132$ psi
$\sigma_{BC} = -7500/2.42 = -3099$ psi
$\sigma_{CF} = -12\,500/2.42 = -5165$ psi

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

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

$AB = 20$ kN

$\sigma = \frac{20\times10^3\text{ N}}{(20)^2\text{ mm}^2} = \mathbf{50\ MPa}$



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

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

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

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

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

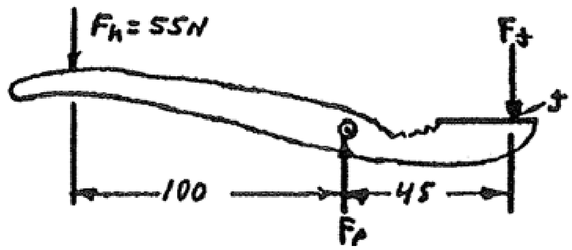
$\sigma = \frac{F}{A} = \frac{640\times10^3\text{ N}}{3557\text{ mm}^2} = \mathbf{180\ MPa}$

1.47 Direct Shear – Single Shear

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

$$\tau = \frac{F}{A_S} = \frac{16.5\times10^3 \text{ N}}{113 \text{ mm}^2} = \mathbf{146\ MPa}$$

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



Pin is in single shear

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

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

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

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

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

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

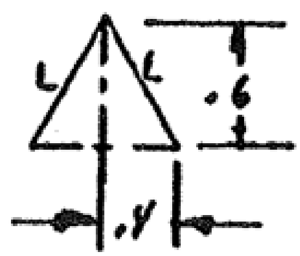
1.50 $A_S = (3.0)(3.5) = 10.5 \text{ in}^2$

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

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

$$\tau = \frac{F}{A_S} = \frac{38.6\times10^3 \text{ N}}{475.7 \text{ mm}^2} = \mathbf{81.1\ MPa}$$

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

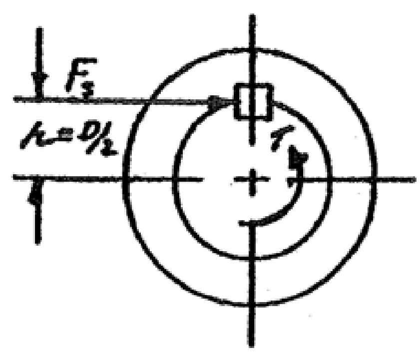


$$A_S = \left[2(1.60) + \frac{\pi(0.8)}{2} + 2(0.721)\right] 0.194$$

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

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

1.53 $T = F_S \cdot R$



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

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

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

1.54 $F_S = \frac{T}{R} = \frac{8000\ \text{lb}\cdot\text{in}}{1.0\ \text{in}} = 8000\ \text{lb}$

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

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

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

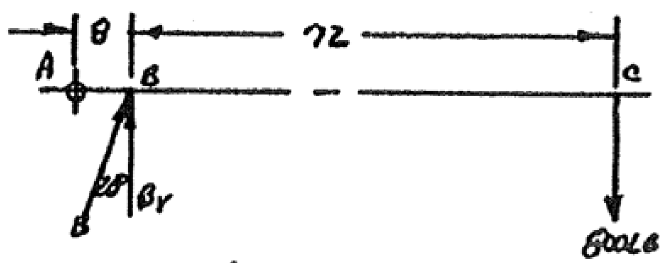
$\tau = \frac{F}{A_S} = \frac{20\,000\ \text{lb}}{0.393\ \text{in}^2} = \mathbf{50\,930\ psi}$

Collar: Shear Collar from Connector Body

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

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

1.56 $\sum M_A = 0 = 800(80) - B_V(8)$



$B_V = 8000\ \text{lb}$

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

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

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

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

$\tau = \frac{F}{A_S} = \frac{88\times10^3\ \text{N}}{480\ \text{mm}^2} = \mathbf{183\ MPa}$

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

$\tau = \frac{F}{A_S} = \frac{88.2\times10^3\ \text{N}}{4800\ \text{mm}^2} = \mathbf{18.4\ MPa}$

1.59 $A_S = \pi d t = \pi(12)(8) = 301.6\ \text{mm}^2$

$\tau = \frac{F}{A_S} = \frac{22.3\times10^3\ \text{N}}{301.6\ \text{mm}^2} = \mathbf{73.9\ MPa}$

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

$\tau = \frac{F}{A_S} = \frac{10.2\times10^3\ \text{N}}{226.2\ \text{mm}^2} = \mathbf{45.1\ MPa}$

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

$\tau = \frac{F}{A_S} = \frac{10.2\times10^3\ \text{N}}{452.4\ \text{mm}^2} = \mathbf{22.55\ MPa}$

Structural Shapes

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

1-63 [Appendix A-4(a)] 4×12 wood board is 11.25 in×3.50 in cross section. $A = 39.38$ 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; $A = 4050$ mm^2

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

1-67

U.S. size	Actual width	Conversion	Closest SI size	Difference
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 ft)(28.8 lb/ft) = 172.8 lb; $A = 8.46$ 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 in)(1.0 ft/12 in)(1.633 lb/ft) = 7.28 lb; $A = 0.480$ 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 m)(12.883 N/m) = 18.68 N; $A = 171$ mm^2

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

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

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

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

1-75 [Appendix A-7(b)] S 24×121 beam weighs 121 lb/ft; Depth = 24.5 in; $A = 35.5\ in^2$

240 in length weighs: (240 in)(1 ft/12 in)(121 lb/ft) = 2420 lb

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

2.55 m length weighs: (2.55 m)(471.7 N/m) = 1203 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: $t = 0.233$ in (design thickness); $A = 4.30\ in^2$

1-79 [Appendix A-8(c)] Steel 150×50×4 mm tube weighs 116 N/m; $A = 1536\ mm^2$

Inside dimensions: 142×42 mm

1.22 m length weighs: (1.42 m)(116 N/m) = 164.7 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; $A = 5.581\ in^2$; 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; $A = 3601\ mm^2$

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; $A = 1.417\ in^2$

1-83 [Appendix A-9(d)] For tube in Problem 1-93, OD = 3.50 in = 88.9 mm;

$A = 1.417\ in^2 \times (645.2\ mm^2/in^2) = 914.2\ mm^2$;

Closest SI metric tube: 90×3 mm; OD = 90 mm; $A = 820\ mm^2$

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

[Appendix A-10] Value of lb_m = Value of lb force (Wt)

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

Steel Bar: $\text{Mass} = \frac{7680\ \text{kg}}{\text{m}^3} \times \frac{4.909\times10^5\ \text{mm}^3}{1} \times \frac{1\ \text{m}^3}{(10^3\ \text{mm})^3} = 3.77\ \text{kg}$ [Appendix A-10]

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

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

$E_{Mag} = 45$ GPa; $E_{Ti} = 114$ 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	$0.10\ \text{lb/in}^3$
6061-T4	35 ksi	21 ksi	10×10^6 psi	$0.10\ \text{lb/in}^3$
6061-T6	45 ksi	40 ksi	10×10^6 psi	$0.10\ \text{lb/in}^3$

[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

2-51

Material	Specific strength (in)	Ratio to SAE 1020
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

2-52

Material	Specific modulus (in)	Ratio to SAE 1020
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. $E = 10.0\times10^6$ 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. $E = 29.0\times10^6$ 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. $E = 16.7\times10^6$ 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. $E = 26.5\times10^6$ 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. $E = 20.0\times10^6$ 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. $E = 12.0\times10^6$ 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. $E = 26.0\times10^6$ 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. $E = 6.0\times10^6$ 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. $E = 16.5\times10^6$ 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. $E = 10.0\times10^6$ 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. $E = 26.0\times10^6$ 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. $E = 26.0\times10^6$ psi
f. 2.0% elongation
g. Brittle – Does not yield
h. Malleable Iron
i. ASTM A220 Grade 80002