Applied Fluid Mechanics 8th edition Untener Solutions Manual

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Online Instructor's Manual

to accompany

Applied Fluid Mechanics

Eighth Edition

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CHAPTER ONE

THE NATURE OF FLUIDS AND THE STUDY OF FLUID MECHANICS

Conversion factors

1.1 $1750 \text{ mm}(1\text{m}/10^3\text{mm}) = \mathbf{1.75\,m}$

1.2 $1800 \text{ mm}^2[1\text{m}^2/(10^3\text{ mm})^2] = \mathbf{1.8\times10^{-3}\ m^2}$

1.3 $3.65\times10^3 \text{ mm}^3[1\text{m}^3/(10^3\text{ mm})^3] = \mathbf{3.65\times10^{-6}\ m^3}$

1.4 $2.05\text{ m}^2[(10^3\text{ mm})^2/\text{m}^2] = \mathbf{2.05\times10^{6}\ mm^2}$

1.5 $0.391\text{ m}^3[(10^3\text{ mm})^3/\text{m}^3] = \mathbf{391\times10^{6}\ mm^3}$

1.6 $55.0\text{ gal}(0.00379\text{ m}^3/\text{gal}) = \mathbf{0.208\ m^3}$

1.7 $\dfrac{80\text{km}}{\text{h}}\times\dfrac{10^3\text{ m}}{\text{km}}\times\dfrac{1\text{h}}{3600\text{s}} = \mathbf{22.2\ m/s}$

1.8 $25.3\text{ ft}(0.3048\text{ m/ft}) = \mathbf{7.71\ m}$

1.9 $1.86\text{ mi}(1.609\text{ km/mi})(10^3\text{ m/km}) = \mathbf{2993\ m}$

1.10 $8.65\text{ in}(25.4\text{ mm/in}) = \mathbf{220\ mm}$

1.11 $3570\text{ ft}(0.3048\text{ m/ft}) = \mathbf{1088\ m}$

1.12 $560\text{ ft}^3(0.0283\text{m}^3/\text{ft}^3) = \mathbf{15.85\ m^3}$

1.13 $6250\text{ cm}^3[1\text{m}^3/(100\text{ cm})^3] = \mathbf{6.25\times10^{-3}m^3}$

1.14 $8.45\text{ L}(1\text{ m}^3/1000\text{ L}) = \mathbf{8.45\times10^{-3}m^3}$

1.15 $6.0\text{ ft/s}(0.3048\text{ m/ft}) = \mathbf{1.83\ m/s}$

1.16 $\dfrac{2500\text{ ft}^3}{\text{min}}\times\dfrac{0.0283\text{ m}^3}{\text{ft}^3}\times\dfrac{1\text{min}}{60\text{ s}} = \mathbf{1.18\ m^3/s}$

Consistent units in an equation

1.17 $\upsilon = \dfrac{s}{t} = \dfrac{0.60\text{ km}}{10.6\text{ s}}\times\dfrac{10^3\text{ m}}{\text{km}} = \mathbf{56.6\ m/s}$

1.18 $\upsilon = \frac{s}{t} = \frac{1.50\ \text{km}}{6.2\ \text{s}} \times \frac{3600\ \text{s}}{\text{h}} = \mathbf{871\ km/h}$

1.19 $\upsilon = \frac{s}{t} = \frac{1000\ \text{ft}}{15\ \text{s}} \times \frac{1\ \text{mi}}{5280\ \text{ft}} \times \frac{3600\ \text{s}}{\text{h}} = \mathbf{45.5\ mi/h}$

1.20 $\upsilon = \frac{s}{t} = \frac{1.0\ \text{mi}}{5.7\ \text{s}} \times \frac{3600\ \text{s}}{\text{h}} = \mathbf{632\ mi/h}$

1.21 $a = \frac{2s}{t^2} = \frac{(2)(3.2\ \text{km})}{(4.7\ \text{min})^2} \times \frac{10^3\ \text{m}}{\text{km}} \times \frac{1\ \text{min}^2}{(60\ \text{s})^2} = \mathbf{8.05 \times 10^{-2}\ m/s^2}$

1.22 $t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{(2)(13\ \text{m})}{9.18\ \text{m/s}^2}} = \mathbf{1.63\ s}$

1.23 $a = \frac{2s}{t^2} = \frac{(2)(3.2\ \text{km})}{(4.7\ \text{min})^2} \times \frac{10^3\ \text{m}}{\text{km}} \times \frac{1\ \text{ft}}{0.3048\ \text{m}} \times \frac{1\ \text{min}^2}{(60\ \text{s})^2} = \mathbf{0.264\ \frac{ft}{s^2}}$

1.24 $t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{(2)(53\ \text{in})}{32.2\ \text{ft/s}^2} \times \frac{1\ \text{ft}}{12\ \text{in}}} = \mathbf{0.524\ s}$

1.25 $KE = \frac{m\upsilon^2}{2} = \frac{(15\ \text{kg})(1.2\ \text{m/s})^2}{2} = 10.8\ \frac{\text{kg}\ .\ \text{m}^2}{\text{s}^2} = \mathbf{10.8 N \cdot m}$

1.26 $KE = \frac{m\upsilon^2}{2} = \frac{(3600\ \text{kg})}{2} \times \left(\frac{16\ \text{km}}{\text{h}}\right)^2 \times \frac{(10^3\ \text{m})^2}{\text{km}^2} \times \frac{1\ \text{h}^2}{(3600\ \text{s})^2} = \mathbf{35.6 \times 10^3\ \frac{kg \cdot m^2}{s^2}}$

$\boldsymbol{KE} = \mathbf{35.6\ kN \cdot m}$

1.27 $KE = \frac{m\upsilon^2}{2} = \frac{75\ \text{kg}}{2} \times \left(\frac{6.85\ \text{m}}{\text{s}}\right)^2 = 1.76 \times 10^3\ \frac{\text{kg} \cdot \text{m}}{\text{s}^2} = \mathbf{1.76\ kN \cdot m}$

1.28 $m = \frac{2(KE)}{\upsilon^2} = \frac{(2)(38.6\ \text{N} \cdot \text{m})}{1} \times \left(\frac{\text{h}}{31.5\ \text{km}}\right)^2 \times \frac{1\ \text{kg} \cdot \text{m}}{\text{s}^2 \cdot \text{N}} \times \frac{(3600\ \text{s})^2}{\text{h}^2} \times \frac{1\ \text{km}^2}{(10^3\ \text{m})^2}$

$m = \frac{(2)(38.6)(3600)^2}{(31.5)^2(10^3)^2}\ \mathbf{kg = 1.008\ kg}$

1.29 $m = \frac{2(KE)}{\upsilon^2} = \frac{(2)(94.6\ \text{m N} \cdot \text{m})}{(2.25\ \text{m/s})^2} \times \frac{10^{-3}\ \text{N}}{\text{mN}} \times \frac{1\ \text{kg} \cdot \text{m}}{\text{s}^2 \cdot \text{N}} \times \frac{10^3\ \text{g}}{\text{kg}} = \mathbf{37.4\ g}$

1.30 $\upsilon = \sqrt{\frac{2(KE)}{m}} = \sqrt{\frac{2(15\ \text{N} \cdot \text{m})}{12\ \text{kg}} \times \frac{1\ \text{kg} \cdot \text{m/s}^2}{\text{N}}} = \mathbf{1.58\ m\ /\ s}$

1.31 $\upsilon = \sqrt{\frac{2(KE)}{m}} = \sqrt{\frac{2(212\text{ m N}\cdot\text{m})}{175\text{ g}} \times \frac{10^{-3}\text{ N}}{\text{mN}} \times \frac{10^{3}\text{ g}}{\text{kg}} \times \frac{1\text{ kg}\cdot\text{m}}{\text{s}^2\cdot\text{N}}}$ **= 1.56 m/s**

1.32 $KE = \frac{m\upsilon^2}{2} = \frac{(1\text{ slug})(4\text{ ft/s})^2}{2} \times \frac{1\text{ lb}\cdot\text{s}^2/\text{ft}}{\text{slug}}$ **= 8.00 lb · ft**

1.33 $KE = \frac{m\upsilon^2}{2} = \frac{w\upsilon^2}{2g} = \frac{(8000\text{ lb})(10\text{ mi})^2}{(2)(32.2\text{ ft/s}^2)(\text{h})^2} \times \frac{1\text{ h}^2}{(3600\text{ s})^2} \times \frac{(5280\text{ ft})^2}{\text{mi}^2}$

$KE = \frac{(8000)(10)^2(5280)^2}{(2)(32.2)(3600)^2}\text{ lb}\cdot\text{ft}$ **= 26700 lb · ft**

1.34 $KE = \frac{m\upsilon^2}{2} = \frac{w\upsilon^2}{2g} = \frac{(150\text{ lb})(20\text{ ft/s})^2}{(2)(32.2\text{ ft/s}^2)}$ **= 932 lb · ft**

1.35 $m = \frac{2(KE)}{\upsilon^2} = \frac{2(15\text{ lb}\cdot\text{ft})}{(2.2\text{ ft/s}^2)^2} = 6.20\,\frac{\text{lb}\cdot\text{s}^2}{\text{ft}}$ **= 6.20 slugs**

1.36 $w = \frac{2g(KE)}{\upsilon^2} = \frac{2(32.2\text{ ft})(38.6\text{ lb}\cdot\text{ft})(\text{h}^2)}{\text{s}^2(19.5\text{ mi})^2} \times \frac{1\text{ mi}^2}{(5280\text{ ft})^2} \times \frac{(3600\text{ s})^2}{\text{h}^2}$

$w = \frac{(2)(32.2)(38.6)(3600)^2}{(19.5)^2(5280)^2}\text{ lb}$ **= 3.04 lb**

1.37 $\upsilon = \sqrt{\frac{2g(KE)}{w}} = \sqrt{\frac{2(32.2\text{ ft/s}^2)(10\text{ lb}\cdot\text{ft})}{30\text{ lb}}}$ **= 4.63 ft/s**

1.38 $\upsilon = \sqrt{\frac{2g(KE)}{w}} = \sqrt{\frac{2(32.2\text{ ft/s}^2)(30\text{ oz}\cdot\text{in})}{6.0\text{ oz}} \times \frac{1\text{ ft}}{12\text{ in}}}$ **= 5.18 ft/s**

1.39 $\text{ERA} = \frac{39\text{ runs}}{141\text{ innings}} \times \frac{9\text{ innings}}{\text{game}}$ **= 2.49 runs/game**

1.40 $\frac{3.12\text{ runs}}{\text{game}} \times \frac{1\text{ game}}{9\text{ innings}} \times 150\text{ innings}$ **= 52 runs**

1.41 $40\text{ runs} \times \frac{1\text{ game}}{2.79\text{ runs}} \times \frac{9\text{ innings}}{\text{game}}$ **= 129 innings**

1.42 $\text{ERA} = \frac{49\text{ runs}}{123\text{ innings}} \times \frac{9\text{ innings}}{\text{game}}$ **= 3.59 runs/game**

The definition of pressure

1.43 $p = F/A = 2500\ \text{lb}/[\pi(2.00\ \text{in})^2/4] = \mathbf{796\ lb/in^2} = \mathbf{796\ psi}$

1.44 $p = F/A = 6500\ \text{lb}/[\pi(1.50\ \text{in})^2/4] = \mathbf{3678\ psi}$

1.45 $$p = \frac{F}{A} = \frac{14.0\ \text{kN}}{\pi(75\ \text{mm})^2/4} \times \frac{10^3\ \text{N}}{\text{kN}} \times \frac{(10^3\ \text{mm})^2}{\text{m}^2} = 3.17 \times 10^6\ \frac{\text{N}}{\text{m}^2} = \mathbf{3.17\ MPa}$$

1.46 $$p = \frac{F}{A} = \frac{38.8 \times 10^3\ \text{N}}{\pi(50.0\ \text{mm})^2/4} \times \frac{(10^3\ \text{mm})^2}{\text{m}^2} = 19.8 \times 10^6\ \frac{\text{N}}{\text{m}^2} = \mathbf{19.8\ MPa}$$

1.47 $$p = \frac{F}{A} = \frac{6000\ \text{lb}}{\pi(8.0\ \text{in})^2/4} = \mathbf{119\ psi}$$

1.48 $$p = \frac{F}{A} = \frac{1800\ \text{lb}}{\pi(2.50\ \text{in})^2/4} = \mathbf{3667\ psi}$$

1.49 $$F = pA = \frac{20.5 \times 10^6\ \text{N}}{\text{m}^2} \times \frac{\pi(50\ \text{mm})^2}{4} \times \frac{1\ \text{m}^2}{(10^3\ \text{mm})^2} = \mathbf{40.25\ kN}$$

1.50 $$F = pA = (6000\ \text{lb/in}^2)\left(\pi[2.00\ \text{in}]^2/4\right) = \mathbf{18850\ lb}$$

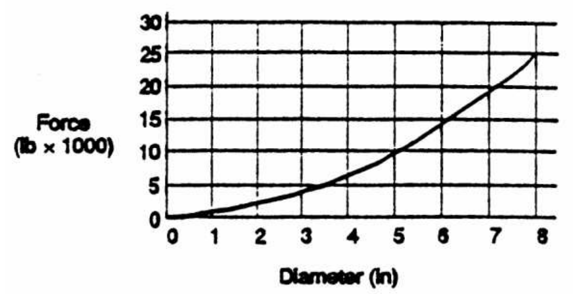
1.51 $$p = \frac{F}{A} = \frac{F}{\pi D^2/4} = \frac{4F}{\pi D^2}: \text{Then } D = \sqrt{\frac{4F}{\pi p}}$$

$$D = \sqrt{\frac{4(20000\ \text{lb})}{\pi(5000\ \text{lb/in}^2)}} = \mathbf{2.26\ in}$$

1.52 $$D = \sqrt{\frac{4F}{\pi p}} = \sqrt{\frac{4(30 \times 10^3\ \text{N})}{\pi(15.0 \times 10^6\ \text{N/m}^2)}} = 50.5 \times 10^{-3}\ \text{m} = \mathbf{50.5\ mm}$$

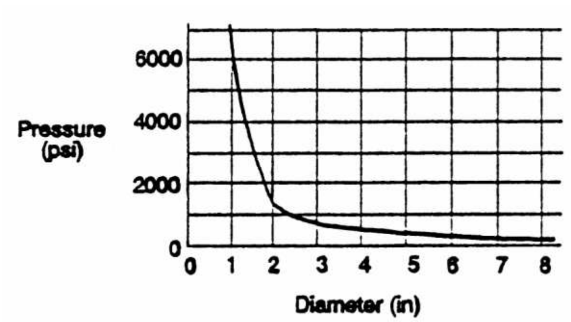
1.53 $F = pA = \dfrac{p[\pi D^2]}{4} = \dfrac{500\,\text{lb}(\pi)(D\,\text{in})^2}{\text{in}^2\;4}$ = **392.7 D^2 lb**

D(in)	D^2(in^2)	F(lb)
1.00	1.00	393
2.00	4.00	1571
3.00	9.00	3534
4.00	16.00	6283
5.00	25.00	9817
6.00	36.00	14137
7.00	49.00	19242
8.00	64.00	25133



1.54 $p = \dfrac{F}{A} = \dfrac{F}{\pi D^2/4} = \dfrac{4F}{\pi D^2} = \dfrac{4(5000\,\text{lb})}{\pi(D\,\text{in})^2} = \dfrac{6366}{D^2}$ psi

D(in)	D^2(in^2)	p(psi)
1.00	1.00	6366
2.00	4.00	1592
3.00	9.00	707
4.00	16.00	398
5.00	25.00	255
6.00	36.00	177
7.00	49.00	130
8.00	64.00	99



1.55 (Variable Answers) Example: w = 160 lb (4.448 N/lb) = **712 N**

$p = \dfrac{F}{A} = \dfrac{712\,\text{N}}{\pi(20\,\text{mm})^2/4} \times \dfrac{(10^3\,\text{mm})^2}{\text{m}^2}$ = 2.77 × 10^6 Pa = **2.27 MPa**

p = 2.27 × 10^6 Pa (1 psi/6895 Pa) = **329 psi**

1.56 (Variable Answers) using p = 2.27 MPa
$F = pA$ = (2.27 × 10^6 N/m^2)(π(0.250 m)^2/4) = 111 × 10^3 N = **111 kN**
F = 111 kN (1 lb/4.448 N) = **25050 lb**

Bulk modulus

1.57 $\Delta p = -E(\Delta V / V) = -130000 \text{ psi}(-0.01) = \mathbf{1300\ psi}$

$\Delta p = -896 \text{ MPa}(-0.01) = \mathbf{8.96\ MPa}$

1.58 $\Delta p = -E(\Delta V / V) = -3.59 \times 10^6 \text{ psi}(-0.01) = \mathbf{35900\ psi}$

$\Delta p = -24750 \text{ MPa}(-0.01) = \mathbf{247.5\ MPa}$

1.59 $\Delta p = -E(\Delta V / V) = -189000 \text{ psi}(-0.01) = \mathbf{1890\ psi}$

$\Delta p = -1303 \text{ MPa}(-0.01) = \mathbf{13.03\ MPa}$

1.60 $\Delta V / V = -0.01; \Delta V = 0.01\, V = 0.01 \text{ AL}$

Assume area of cylinder does not change.

$\Delta V = A(\Delta L) = 0.01 \text{AL}$

Then $\Delta L = 0.01 \text{ L} = 0.01(12.00 \text{ in}) = \mathbf{0.120\ in}$

1.61 $\dfrac{\Delta V}{V} = \dfrac{-p}{E} = \dfrac{-3000 \text{ psi}}{189000 \text{ psi}} = -0.0159 = \mathbf{-1.59\%}$

1.62 $\dfrac{\Delta V}{V} = \dfrac{-20.0 \text{ MPa}}{1303 \text{ MPa}} = -0.0153 = \mathbf{-1.53\%}$

1.63 Stiffness = Force/Change in Length = F/ΔL

Bulk Modulus = $E = \dfrac{-P}{\Delta V / V} = \dfrac{-pV}{\Delta V}$

But $p = F/A; V = AL; \Delta V = -A(\Delta L)$

$$E = \frac{-F}{A} \times \frac{AL}{-A(\Delta L)} = \frac{FL}{A(\Delta L)}$$

$$\frac{F}{(\Delta L)} = \frac{EA}{L} = \frac{189000 \text{ lb}\, \pi (0.5 \text{ in})^2}{\text{in}^2 (42 \text{ in})4} = \mathbf{884\ lb/in}$$

1.64 $\dfrac{F}{(\Delta L)} = \dfrac{EA}{L} = \dfrac{189000 \text{ lb}\, \pi (0.5\text{in})^2}{\text{in}^2 (10.0 \text{ in})(4)} = \mathbf{3711\ lb/in}$ **4.2 times higher**

1.65 $\dfrac{F}{(\Delta L)} = \dfrac{EA}{L} = \dfrac{189000 \text{ lb}\, \pi (2.00 \text{ in})^2}{\text{in}^2 (42.0 \text{ in})(4)} = \mathbf{14137\ lb/in}$ **16 times higher**

1.66 Use large diameter cylinder and short storkes.

Force and mass

1.67 $m = \dfrac{w}{g} = \dfrac{810 \text{ N}}{9.18 \text{ m/ s}^2} \times \dfrac{1 \text{ kg} \cdot \text{m/s}^2}{\text{N}} = \mathbf{82.6\ kg}$

1.68 $m = \dfrac{w}{g} = \dfrac{1.85 \times 10^3\ \text{N}}{9.18\ \text{m/s}^2} \times \dfrac{1\ \text{kg}\cdot\text{m/s}^2}{\text{N}} = \mathbf{189\ kg}$

1.69 $w = mg = 825\ \text{kg} \times 9.81\ \text{m/s}^2 = 8093\ \text{kg}\cdot\text{m/s}^2 = \mathbf{8093\ N}$

1.70 $w = mg = 450\ \text{g} \times \dfrac{1\ \text{kg}}{10^3\ \text{g}} \times 9.81\ \text{m/s}^2 = 4.41\ \text{kg}\cdot\text{m/s}^2 = \mathbf{4.41\ N}$

1.71 $m = \dfrac{w}{g} = \dfrac{7.8\ \text{lb}}{32.2\ \text{ft/s}^2} = 0.242\dfrac{\text{lb}\cdot\text{s}^2}{\text{ft}} = \mathbf{0.242\ slugs}$

1.72 $m = \dfrac{w}{g} = \dfrac{42.0\ \text{lb}}{32.2\ \text{ft/s}^2} = \mathbf{1.304\ slugs}$

1.73 $w = mg = 1.58\ \text{slugs} \times 32.2\ \text{ft/s}^2 \times \dfrac{1\ \text{lb}\cdot\text{s}^2/\text{ft}}{\text{slug}} = \mathbf{50.9\ lb}$

1.74 $w = mg = 0.258\ \text{slugs} \times 32.2\ \text{ft/s}^2 \times \dfrac{1\ \text{lb}\cdot\text{s}^2/\text{ft}}{\text{slug}} = \mathbf{8.31\ lb}$

1.75 $m = \dfrac{w}{g} = \dfrac{160\ \text{lb}}{32.2\ \text{ft/s}^2} = \mathbf{4.97\ slugs}$

$w = 160\ \text{lb} \times 4.448\ \text{N/lb} = \mathbf{712\ N}$

$m = 4.97\ \text{slugs} \times 14.59\ \text{kg/slug} = \mathbf{72.5\ kg}$

1.76 $m = \dfrac{w}{g} = \dfrac{1.00\ \text{lb}}{32.2\ \text{ft/s}^2} = \mathbf{0.0311\ slugs}$

$w = 0.0311\ \text{slugs} \times 14.59\ \text{kg/slug} = \mathbf{0.453\ Kg}$

$m = 1.00\ \text{lb} \times 4.448\ \text{N/lb} = \mathbf{4.448\ N}$

1.77 $F = w = mg = 1000\ \text{kg} \times 9.81\ \text{m/s}^2 = 9810\ \text{kg}\cdot\text{m/s}^2 = \mathbf{9810\ N}$

1.78 $F = 9810\ \text{N} \times 1.0\ \text{lb}/4.448\ \text{N} = \mathbf{2205\ lb}$

1.79 (Variable Answer) See problem 1.75 for method.

Density, specific weight, and specific gravity

1.80 $\gamma_B = (sg)_B \gamma_w = (0.876)(9.81\ \text{kN/m}^3) = \mathbf{8.59\ kN/m^3}$

$\rho_B = (sg)_B \rho_w = (0.876)(1000\ \text{kg/m}^3) = \mathbf{876\ kg/m^3}$

1.81 $\rho = \dfrac{\gamma}{g} = \dfrac{12.02\ \text{N}}{\text{m}^3} \times \dfrac{\text{s}^2}{9.81\ \text{m}} \times \dfrac{1\ \text{kg}\cdot\text{m/s}^2}{\text{N}} = \mathbf{1.225\ kg/m^3}$

1.82 $\gamma = \rho g = 1.964\ \text{kg/m}^3 \times 9.81\ \text{m/s}^2 \times \dfrac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2} = \mathbf{19.27\ N/m^3}$

1.83 $\text{sg} = \dfrac{\gamma_o}{\gamma_w @ 4^\circ\text{C}} = \dfrac{8.860\ \text{kN/m}^3}{9.81\ \text{kN/m}^3} = \mathbf{0.903\ at\ 5^\circ C}$

$\text{sg} = \dfrac{\gamma_o}{\gamma_w @ 4^\circ\text{C}} = \dfrac{8.483\ \text{kN/m}^3}{9.81\ \text{kN/m}^3} = \mathbf{0.865\ at\ 50^\circ C}$

1.84 $\gamma = \dfrac{w}{V}; V = \dfrac{w}{\gamma} = \dfrac{3.50\ \text{kN}}{130.4\ \text{kN/m}^3} = \mathbf{0.0268\ m^3}$

1.85 $V = AL = \pi D^2 L/4 = \pi(0.150\ \text{m})^2(0.100\ \text{m})/4 = 1.767 \times 10^{-3}\ \text{m}^3$

$\rho_o = \dfrac{m}{V} = \dfrac{1.56\ \text{kg}}{1.767 \times 10^{-3}\ \text{m}^3} = \mathbf{883\ kg/m^3}$

$\gamma_o = \rho_o g = 883\ \text{kg/m}^3 \times 9.81\ \text{m/s}^2 \times \dfrac{1\ \text{N}}{1\ \text{kg}\cdot\text{m/s}^2} = 8.66 \times \dfrac{10^3\ \text{N}}{\text{m}^3} = \mathbf{8.66\dfrac{kg}{m^3}}$

$\text{sg} = \rho_o / \rho_w @ 4^\circ\text{C} = 883\ \text{kg/m}^3 / 1000\ \text{kg/m}^3 = \mathbf{0.883}$

1.86 $\gamma = (\text{sg})(\gamma_w @ 4^\circ\text{C}) = 1.258(9.81\ \text{kN/m}^3) = 12.34\text{kN/m}^3 = w/V$

$w = \gamma V = (12.34\ \text{kN/m}^3)(0.50\ \text{m}^3) = \mathbf{6.17\ kN}$

$m = \dfrac{w}{g} = \dfrac{6.17\ \text{kN}}{9.18\ \text{m/s}^2} \times \dfrac{10^3\ \text{N}}{\text{kN}} \times \dfrac{1\ \text{kg}\cdot\text{m/s}^2}{\text{N}} = \mathbf{629\ kg}$

1.87 $w = \gamma V = (\text{sg})(\gamma_w)(V) = (0.68)(9.81\ \text{kN/m}^3)(0.095\ \text{m}^3) = 0.634\ \text{kN} = \mathbf{634\ N}$

1.88 $\gamma = \rho g = (1200\ \text{kg/m}^3)(9.81\text{m/s}^2)\left(\dfrac{1\text{N}}{\text{kg}\cdot\text{m/s}^2}\right) = \mathbf{11.77\ kN/m^3}$

$\text{sg} = \dfrac{\rho}{\rho_w @ 4^\circ\text{C}} = \dfrac{1200\ \text{kg/m}^3}{1000\ \text{kg/m}^3} = \mathbf{1.20}$

1.89 $V = \dfrac{w}{\gamma} = \dfrac{32.0\ \text{N}}{(0.826)(9.81\ \text{kN/m}^3)} \times \dfrac{1\ \text{kN}}{10^3\ \text{N}} = \mathbf{3.95 \times 10^{-3} m^3}$

1.90 $\gamma = \rho g = \dfrac{1080\ \text{kg}}{\text{m}^3} \times \dfrac{9.81\ \text{m}}{\text{s}^2} \times \dfrac{1\text{N}}{1\text{kg}\cdot\text{m/s}^2} \times \dfrac{1\ \text{kN}}{10^3\ \text{N}} = \mathbf{10.59\ kN/m^3}$

$\text{sg} = \rho/\rho_w = \dfrac{1080\ \text{kg/m}^3}{1000\ \text{kg/m}^3} = \mathbf{1.08}$

1.91 $\rho = (\text{sg})(\rho_w) = (0.789)(1000\ \text{kg/m}^3) = \mathbf{789\ kg/m^3}$

$\gamma = (\text{sg})(\gamma_w) = (0.789)(9.81\ \text{kN/m}^3) = \mathbf{7.74\ kN/m^3}$

1.92 $w_o = 35.4\text{ N} - 2.25\text{ N} = 33.15\text{ N}$

$V_o = Ad = (\pi D^2/4)(d) = \pi(.150\text{m})^2(.20\text{ m})/4 = 3.53\times10^{-3}\text{ m}^3$

$\gamma_o = \frac{w}{V} = \frac{33.15\text{ N}}{3.53\times10^{-3}\text{ m}^3} = 9.38\times10^3\text{ N/m}^3 = \mathbf{9.38\ kN/m^3}$

$\text{sg} = \frac{\gamma_o}{\gamma_w} = \frac{9.38\text{ kN/m}^3}{9.81\text{ kN/m}^3} = \mathbf{0.956}$

1.93 $V = Ad = (\pi D^2/4)(d) = \pi(10\text{ m})^2(6.75\text{ m})/4 = 530.1\text{ m}^3$

$w = \gamma V = (0.68)(9.81\text{ kN/m}^3)(530.1\text{ m}^3) = 3.536\times10^3\text{kN} = \mathbf{3.536\ MN}$

$m = \rho V = (0.68)(1000\text{ kg/m}^3)(530.1\text{ m}^3) = 360.5\times10^3\text{ kg} = \mathbf{360.5\ Mg}$

1.94 $w_{castor\ oil} = \gamma_{co}\cdot V_{co} = (9.42\text{ kN/m}^3)(0.03\text{ m}^3) = 0.283\text{ kN}$

$V_m = \frac{w}{\gamma_m} = \frac{0.283\text{ kN}}{(13.54)(9.81\text{ kN/m}^3)} = \mathbf{2.13\times10^{-3}m^3}$

1.95 $w = \gamma V = (2.32)(9.81\text{ kN/m}^3)(1.42\times10^{-4}\text{ m}^3) = 3.23\times10^{-3}\text{ kN} = \mathbf{3.23\ N}$

1.96 $\gamma = (\text{sg})(\gamma_w) = 0.876(62.4\text{ lb/ft}^3) = \mathbf{54.7\ lb/ft^3}$

$\rho = (\text{sg})(\rho_w) = 0.876(1.94\text{ slugs/ft}^3) = \mathbf{1.70\ slugs/ft^3}$

1.97 $\rho = \frac{\gamma}{g} = \frac{0.0765\text{ lb/ft}^3}{32.2\text{ ft/s}^2}\times\frac{1\text{ slug}}{1\text{ lb}\cdot\text{s}^2/\text{ft}} = \mathbf{2.38\times10^{-3}slugs/ft^3}$

1.98 $\gamma = \rho g = 0.00381\text{ slug/ft}^3(32.2\text{ ft/s}^2)\frac{1\text{ lb}\cdot\text{s}^2/\text{ft}}{\text{slug}} = \mathbf{0.1227\ lb/ft^3}$

1.99 $\text{sg} = \gamma_o/(\gamma_w @ 4^\circ\text{C}) = 56.4\text{ lb/ft}^3/62.4\text{ lb/ft}^3 = \mathbf{0.904\ at\ 40^oF}$

$\text{sg} = \gamma_o/(\gamma_w @ 4^\circ\text{C}) = 54.0\text{ lb/ft}^3/62.4\text{ lb/ft}^3 = \mathbf{0.865\ at\ 120^oF}$

1.100 $V = w/\gamma = 500\text{ lb}/834\text{ lb/ft}^3 = \mathbf{0.600\ ft^3}$

1.101 $\gamma = \frac{w}{V} = \frac{7.50\text{ lb}}{1\text{ gal}}\times\frac{7.48\text{ gal}}{\text{ft}^3} = \mathbf{56.1\ lb/ft^3}$

$\rho = \frac{\gamma}{g} = \frac{56.1\text{ lb/ft}^3}{32.2\text{ ft/s}^2} = 1.74\frac{\text{lb}\cdot\text{s}^2}{\text{ft}^4} = \mathbf{1.74\ \ slugs/ft^3}$

$\text{sg} = \frac{\gamma_o}{\gamma_w @ 4^\circ\text{C}} = \frac{5.61\text{ lb/ft}^3}{62.4\text{ lb/ft}^3} = \mathbf{0.899}$

1.102 $w = \gamma V = (1.258)\frac{(62.4\text{ lb})}{\text{ft}^3}(50\text{ gal})\frac{(1\text{ ft}^3)}{7.84\text{ gal}} = \mathbf{525\ lb}$

1.103 $w = \gamma V = \rho g V = \frac{1.32\text{ lb.s}^2}{\text{ft}^4}\times\frac{32.2\text{ ft}}{8^2}25.0\text{ gal}\times\frac{1\text{ft}^3}{7.84\text{ gal}} = \mathbf{142\ lb}$

1.104 $$sg = \frac{\rho}{\rho_w} = \frac{1.20\text{ g}}{\text{cm}^3} \times \frac{\text{m}^3}{1000\text{ kg}} \times \frac{1\text{ kg}}{10^3\text{ g}} \times \frac{(10^2\ \text{cm})^3}{\text{m}^3} = \mathbf{1.20}$$

$\rho = (sg)(\rho_w) = 1.20(1.94\text{ slugs/ft}^3) = \mathbf{2.33\ slugs/ft^3}$
$\gamma = (sg)(\gamma_w) = (1.20)(62.4\text{ lb/ft}^3) = \mathbf{74.9\ lb/ft^3}$

1.105 $$V = \frac{w}{\gamma} = \frac{5.0\text{ lb ft}^3}{(0.826)62.4\text{ lb}} \times \frac{0.0283\text{ m}^3}{\text{ft}^3} \times \frac{(10^2\ \text{cm})^3}{\text{m}^3} = \mathbf{2745\ cm^3}$$

1.106 $\gamma = (sg)(\gamma_w) = (1.08)(62.4\text{ lb/ft}^3) = \mathbf{67.4\ lb/ft^3}$

1.107 $\rho = (0.79)(1.94\text{ slugs/ft}^3) = \mathbf{1.53\ slugs/ft^3}$; $\boldsymbol{\rho} = \mathbf{0.79\ g/cm^3}$

1.108 $$\gamma_o = \frac{w}{V} = \frac{(7.95 - 0.50)\text{lb}}{\left(\pi(6.0\text{ in})^2/4\right)(8.0\text{ in})} \times \frac{1728\text{ in}^3}{\text{ft}^3} = \mathbf{56.9\ lb/ft^3}$$

$sg = \gamma_o/\gamma_w = 56.9\text{ lb/ft}^3/62.4\text{ lb/ft}^3 = \mathbf{0.912}$

1.109 $$V = A \cdot d = \frac{\pi D^2}{4} \cdot d = \frac{\pi(30\text{ ft})^2}{4} \times 22\text{ ft} = 15550\text{ ft}^3 \times 7.48\text{ gal/ft}^3 = \mathbf{1.16 \times 10^5\ gal}$$

$w = \gamma V = (0.68)(62.4\text{ lb/ft}^3)(15550\text{ ft}^3) = \mathbf{6.60 \times 10^5\ lb}$

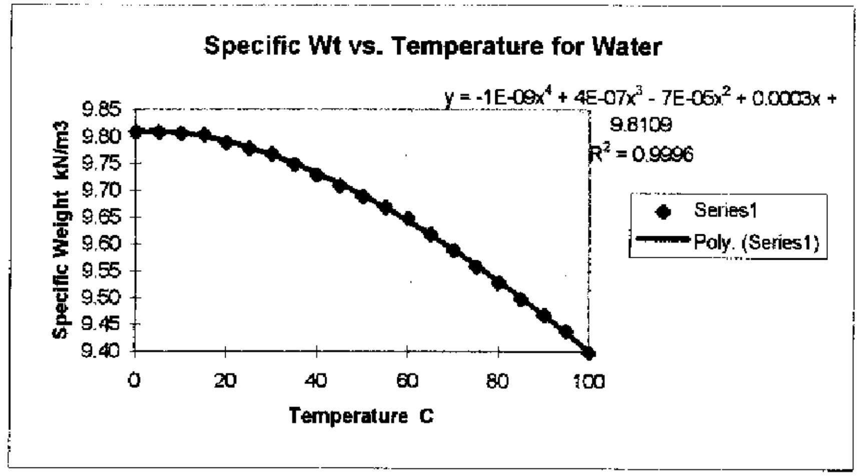
1.110 $w_{co} = \gamma_{co} V = (59.69\text{ lb/ft}^3)(5\text{ gal})(1\text{ ft}^3/7.48\text{ gal}) = \mathbf{39.90\ lb}$

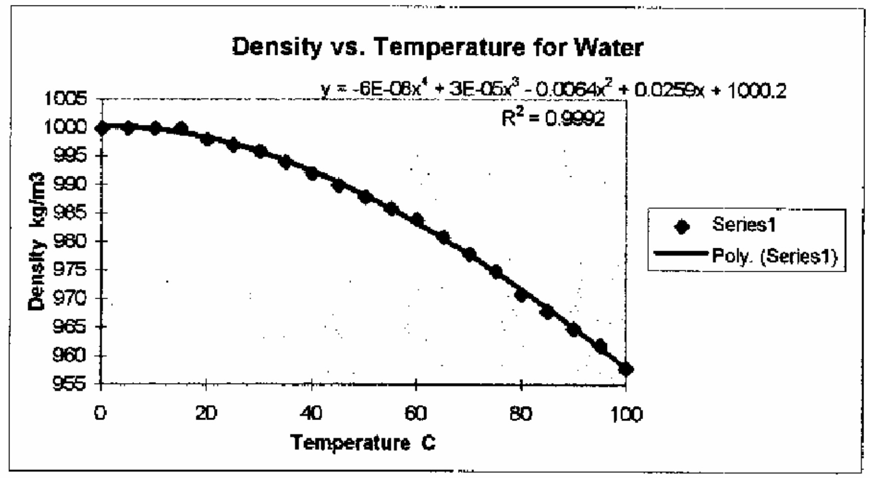
$$V_m = \frac{w}{\gamma_m} = \frac{39.90\text{ lb ft}^3}{13.54(62.4\text{ lb})} \times \frac{7.48\text{ gal}}{\text{ft}^3} = \mathbf{0.353\ gal}$$

1.111 $$w = \gamma V = (2.32)\frac{(62.4\text{ lb})}{\text{ft}^3}(8.64\text{ in}^3)\frac{(1\text{ ft}^3)}{1728\text{ in}^3} = \mathbf{0.724\ lb}$$

CURVE FIT FOR THE PROPERTIES OF WATER VS. TEMPERATURE
TABLE A.1

Temp.	Sp Wt	Density	Computed Sp Wt	% Diff	Computed Density	%Diff
0	9.81	1000	9.811	0.002	1000.2	0.020
5	9.81	1000	9.812	0.018	1000.2	0.017
10	9.81	1000	9.809	0.012	999.8	-0.015
15	9.81	1000	9.803	-0.017	999.2	-0.075
20	9.79	998	9.794	0.045	998.4	0.039
25	9.78	997	9.783	0.028	997.3	0.029
30	9.77	996	9.769	-0.015	996.0	-0.002
35	9.75	994	9.752	0.022	994.5	0.047
40	9.73	992	9.734	0.037	992.8	0.077
45	9.71	990	9.713	0.032	990.9	0.090
50	9.69	988	9.691	0.007	988.9	0.088
55	9.67	986	9.667	-0.035	986.7	0.072
60	9.65	984	9.641	-0.096	984.4	0.042
65	9.62	981	9.613	-0.070	982.0	0.103
70	9.59	978	9.584	-0.061	979.5	0.154
75	9.56	975	9.553	-0.069	976.9	0.195
80	9.53	971	9.521	-0.097	974.2	0.331
85	9.50	968	9.486	-0.144	971.5	0.357
90	9.47	965	9.450	-0.211	968.6	0.376
95	9.44	962	9.411	-0.302	965.7	0.388
100	9.40	958	9.371	-0.312	962.8	0.500





Computer Assignment 2: Sample Output - Equations for Specific Weight and Density versus Temperature are shown within the plots of the output.

1.112 Tank Size $= 75 \text{ People} \times \dfrac{1.7 \text{ gal per person}}{1 \text{ day}} \times 3 \text{ days} \times \dfrac{1 \text{ ft}^3}{7.48 \text{ gal}} = \underline{51.1 \text{ ft}^3}$

1.113 Required Volume $= 85 \text{ Gallons} \times \dfrac{1 \text{ ft}^3}{7.48 \text{ gal}} \times \dfrac{12^3 \text{ in}^3}{1^3 \text{ ft}^3} = 19{,}636 \text{ in}^3$

Tank Volume $= 19{,}636 \text{ in}^3 = \dfrac{\pi \times (\text{D})^2 \times (\text{h})}{4} = \dfrac{\pi \times (38 \text{ in})^2 \times (\text{h})}{4}$

Required Height $= \dfrac{19{,}636 \text{ in}^3 \times 4}{\pi \times (38 \text{ in})^2} = \underline{17.3 \text{ in}}$

1.114 Flow Rate $= \dfrac{80 \text{ N}}{5 \text{ s}} \times \dfrac{60 \text{ s}}{1 \text{ min}} = \underline{960 \dfrac{\text{N}}{\text{min}}}$

1.115 $V_{REQ.} = 1.5 \text{ m} \times 2.5 \text{ m} \times 25 \text{ cm} \times \dfrac{1 \text{ m}}{100 \text{ cm}} = 0.938 \text{ m}^3$

Time Required $= \dfrac{1 \text{ min}}{60 \text{ L}} \times \dfrac{1 \text{ L}}{0.001 \text{ m}^3} \times 0.938 \text{ m}^3 = \underline{15.6 \text{ min}}$

1.116 Flow Rate $= \dfrac{\text{Volume}}{\text{Time}} = \dfrac{\left(\dfrac{\pi \times (24 \text{ in})^2}{4} \times 18 \text{ in} \times \dfrac{1.0 \text{ gal}}{231 \text{ in}^3}\right)}{\left(90 \text{ s} \times \dfrac{1 \text{ min}}{60 \text{ s}}\right)} = \underline{23.5 \dfrac{\text{gal}}{\text{min}}}$

1.117 $\$17{,}000 = 7500 \dfrac{\$}{\text{year}} \times \text{X years}$

$\text{X} = \dfrac{\$17{,}000}{7500 \dfrac{\$}{\text{year}}} = \underline{2.27 \text{ years}}$

1.118 Annual Cost $= 2 \text{ HP} \times \dfrac{0.746 \text{ kW}}{1 \text{ HP}} \times 1 \text{ year} \times \dfrac{365 \text{ days}}{1 \text{ year}} \times \dfrac{24 \text{ hr}}{1 \text{ day}} \times \dfrac{\$0.10}{\text{kW} - \text{HR}} = \underline{\$1{,}307 / \text{Year}}$

1.119 Displacement $= \dfrac{\pi \times 7.5 \text{ cm}^2 \times 10.0 \text{ cm}}{4} \times \dfrac{0.001 \text{ L}}{1 \text{ cm}^3} = \underline{0.442 \text{ L}}$

1.120 $\text{Flow Rate} = \frac{2.2\ \text{L}}{1\ \text{rev}} \times \frac{80\ \text{rev}}{1\ \text{min}} \times \frac{1\ \text{m}^3}{1000\ \text{L}} \times \frac{60\ \text{min}}{1\ \text{hr}} = \underline{10.6 \frac{\text{m}^3}{\text{hr}}}$

1.121 $\text{Volume} = \frac{\pi \times 1\ \text{in}^2 \times 2.5\ \text{in}}{4} = \underline{1.963 \frac{in^3}{rev}}$

$$20 \frac{\text{gal}}{\text{min}} = \frac{1.963\ \text{in}^3}{1\ \text{rev}} \times \frac{1\ \text{gal}}{231\ \text{in}^3} \times \frac{\text{X rev}}{\text{min}}$$

$$\text{X} = \frac{20 \frac{\text{gal}}{\text{min}}}{\frac{1.963\ \text{in}^3}{1\ \text{rev}} \quad \frac{1\ \text{gal}}{231\ \text{in}^3}} = \underline{2{,}354\ \text{RPM}}$$

CHAPTER TWO

VISCOSITY OF FLUIDS

2.1 Shearing stress is the force required to slide one unit area layer of a substance over another.

2.2 Velocity gradient is a measure of the velocity change with position within a fluid.

2.3 Dynamic viscosity = shearing stress/velocity gradient.

2.4 Oil. It pours very slowly compared with water. It takes a greater force to stir the oil, indicating a higher shearing stress for a given velocity gradient.

2.5 $N{\cdot}s/m^2$ or $Pa{\cdot}s$

2.6 $lb{\cdot}s/ft^2$

2.7 1 poise = 1 $dyne{\cdot}s/cm^2$ = 1 $g/(cm{\cdot}s)$

2.8 It does not conform to the standard SI system. It uses obsolete basic units of dynes and cm.

2.9 Kinematic viscosity = dynamic viscosity/density of the fluid.

2.10 m^2/s

2.11 ft^2/s

2.12 1 stoke = 1 cm^2/s

2.13 It does not conform to the standard SI system. It uses obsolete basic unit of cm.

2.14 A newtonian fluid is one for which the dynamic viscosity is independent of the velocity gradient.

2.15 A nonnewtonian fluid is one for which the dynamic viscosity **is** dependent on the velocity gradient.

2.16 Water, oil, gasoline, alcohol, kerosene, benzene, and others.

2.17 Blood plasma, molten plastics, catsup, paint, and others.

2.18 $6.5 \cdot 10^{-4}$ $Pa{\cdot}s$

2.19 $1.5 \cdot 10^{-3}$ $Pa{\cdot}s$

2.20 $2.0 \cdot 10^{-5}$ $Pa{\cdot}s$

2.21 $1.1 \cdot 10^{-5}$ Pa·s

2.22 $3.0 \cdot 10^{-1}$ Pa·s

2.23 1.90 Pa·s

2.24 $3.2 \cdot 10^{-5}$ lb·s/ft^2

2.25 $8.9 \cdot 10^{-6}$ lb·s/ft^2

2.26 $3.6 \cdot 10^{-7}$ lb·s/ft^2

2.27 $1.9 \cdot 10^{-7}$ lb·s/ft^2

2.28 $5.0 \cdot 10^{-2}$ lb·s/ft^2

2.29 $4.1 \cdot 10^{-3}$ lb·s/ft^2

2.30 $3.3 \cdot 10^{-5}$ lb·s/ft^2

2.31 $2.8 \cdot 10^{-5}$ lb·s/ft^2

2.32 $2.1 \cdot 10^{-3}$ lb·s/ft^2

2.33 $9.5 \cdot 10^{-5}$ lb·s/ft^2

2.34 $1.3 \cdot 10^{-2}$ lb·s/ft^2

2.35 $2.2 \cdot 10^{-4}$ lb·s/ft^2

2.36 Viscosity index is a measure of how greatly the viscosity of a fluid changes with temperature.

2.37 High viscosity index (VI).

2.38 Rotating drum viscometer.

2.39 The fluid occupies the small radial space between the stationary cup and the rotating drum. Therefore, the fluid in contact with the cup has a zero velocity while that in contact with the drum has a velocity equal to the surface speed of the drum.

2.40 A meter measures the torque required to drive the rotating drum. The torque is a function of the drag force on the surface of the drum which is a function of the shear stress in the fluid. Knowing the shear stress and the velocity gradient, Equation 2-2 is used to compute the dynamic viscosity.

2.41 The inside diameter of the capillary tube; the velocity of fluid flow; the length between pressure taps; the pressure difference between the two points a distance L apart.
See Eq. (2-5).

2.42 Terminal velocity is that velocity achieved by the sphere when falling through the fluid when the downward force due to gravity is exactly balanced by the buoyant force and the drag force on the sphere. The drag force is a function of the dynamic viscosity.

2.43 The diameter of the ball; the terminal velocity (usually by noting distance traveled in a given time); the specific weight of the fluid; the specific weight of the ball.

2.44 The Saybolt viscometer employs a container in which the fluid can be brought to a known, controlled temperature, a small standard orifice in the bottom of the container and a calibrated vessel for collecting a 60 mL sample of the fluid. A stopwatch or timer is required to measure the time required to collect the 60 mL sample.

2.45 No. The time is reported as Saybolt Universal Seconds and is a relative measure of viscosity.

2.46 Kinematic viscosity.

2.47 Standard calibrated glass capillary viscometer.

For questions 2.48 to 2.53, Refer to Section 2.8 and to Internet resource 19 for Tribology-abc. Tables for SAE viscosity grades for engine oils and automotive gear lubricants are listed on the Internet site, from standards SAE J300 and SAE J306 that can be used to determine appropriate values for viscosities and information on the testing procedures used. NOTE: It is essential that the latest version of the standards be used for critical applications. See References 14 and 15.

2.48 The kinematic viscosity of SAE 20 oil must be between 5.6 and 9.3 cSt at 100°C using ASTM D 445. Its dynamic viscosity must be over 2.6 cP at 150°C using ASTM D 4683, D 4741, or D 5481. The kinematic viscosity of SAE 20W oil must be over 5.6 cSt at 100°C using ASTM D 445. Its dynamic viscosity for cranking must be below 9500 cP at −15°C using ASTM D 5293. For pumping it must be below 60,000 cP at −20°C using ASTM D 4684.

2.49 SAE 0W through SAE 60 for engine crankcase oils, depending on operating conditions.

2.50 SAE 70W through SAE 250 for gear-type transmissions, depending on operating conditions.

2.51 From Internet resource 19: 100°C using ASTM D 445 testing method and at 150° C using ASTM D 4683, D 4741, or D 5481.

2.52 From Internet resource 19: At−25°C using ASTM D 5293; at −30°C using ASTM D 4684; at 100°C using ASTM D 445.

2.53 From Internet resource 19: The kinematic viscosity of SAE 5W-40 oil must be between 12.5 and 16.3 cSt at 100°C using ASTM D 445. Its dynamic viscosity must be over 2.9 cP at 150°C using ASTM D 4683, D 4741, or D 5481. The kinematic viscosity must be over 3.8 cSt at 100°C using ASTM D 445. Its dynamic viscosity for cranking must be below 6600 cP at −30°C using ASTM D 5293. For pumping it must be below 60 000 cP at−35°C using ASTM D 4684.

2.54 $\nu = SUS/4.632 = 500/4.632 = 107.9\ mm^2/s = 107.9 \cdot 10^{-6}\ m^2/s$

$\nu = 107.9 \cdot 10^{-6}\ m^2/s\ [(10.764\ ft^2/s)/(m^2/s)] = 1.162 \cdot 10^{-3}\ ft^2/s$

2.55 From Table 2.5: Viscosities at 40°C in mm^2/s of cSt

ISO Viscosity grade	Minimum	Nominal	Maximum
10	9.0	10.0	11.0
68	61.2	68.0	74.8
220	198	220	242
1000	900	1000	1100

2.56 η = 4500 cP [(1 Pa·s)/(1000 cP)] = **4.50 Pa·s**
η = 4.50 Pa·s [(1 lb·s/ft^2)/(47.88 Pa·s)] = **0.0940 lb·s/ft^2**

2.57 v = 5.6 cSt [(1 m^2/s)/(10^6 cSt)] = **5.60 × 10^{-6} m^2/s**
v = 5.60 × 10^{-6} m^2/s [(10.764 ft^2/s)/(m^2/s)] = **6.03 × 10^{-5} ft^2/s**

2.58 From Figure 2.14: v = 15.5 mm^2/s = 15.5 × 10^{-6} m^2/s

2.59 η = 6.5 × 10^{-3} Pa·s [(1 lb·s/ft^2)/(47.88 Pa·s)] = **1.36 × 10^{-4} lb·s/ft^2**

2.60 η = 0.12 poise [(1 Pa·s)/(10 poise)] = 0.012 Pa·s = 1.2 × 10^{-2} Pa·s. **SAE 10 oil**

2.61

$$\eta = \frac{(\gamma_s - \gamma_f)D^2}{18\upsilon} \text{ (Eq. 2-10)}$$

γ_f = 0.94(9.81 kN/m^3) = 9.22 kN/m^3
D = 1.6 mm = 1.6 × 10^{-3} m

$v = s/t$ = .250 m/10.4 s = 2.40 × 10^{-2} m/s

$$\mu = \frac{(77.0-9.22)\,\text{kN}(1.6\times10^{-3}\,\text{m})^2}{18\ \text{m}^3(2.40\times10^{-2}\ \text{m/s})}\times\frac{10^3\ \text{N}}{\text{kN}} = 0.402\frac{\text{N}\cdot\text{s}}{\text{m}^2} \quad = \mathbf{0.402\ Pa\cdot s}$$

2.62

$$\eta = \frac{(p_1 - p_2)D^2}{32\upsilon L} \text{ (Eq. 2-5)}$$

Use $\gamma_{Mercury}$ = 132.8 kN/m^3 (App. B)
γ_o = 0.90(9.81 kN/m^3) = 8.83 kN/m^3

Manometer Eq. using principles of Chapter 3:

$$p_1 + \gamma_o y + \gamma_o h - \gamma_m h - \gamma_o y = p_2$$

$$p_1 - p_2 = \gamma_m h - \gamma_o h = h(\gamma_m - \gamma_o) = 0.177\ \text{m}(132.8 - 8.83)\frac{\text{kN}}{\text{m}^3} = 21.94\frac{\text{kN}}{\text{m}^2}$$

$$\eta = \frac{(21.94\ \text{kN/m}^2)(0.0025\ \text{m})^2}{32(1.58\ \text{m/s})(0.300\ \text{m})} = 9.04\times10^{-6}\frac{\text{kN}\cdot\text{s}}{\text{m}^2}\times\frac{10^3\ \text{N}}{\text{kN}} \quad = \mathbf{9.04\times10^{-3}\ Pa\cdot s}$$

2.63 See Prob. 2.61. γ_f = 0.94(62.4 lb/ft^3) = 58.7 lb/ft^3: D = (0.063 in)(1 ft/12 in) = 0.00525 ft
$v = s/t$ = (10.0 in/10.4 s)(1 ft/12 in) = 0.0801 ft/s: γ_s = (0.283 lb/in^3)(1728 in^3/ft^3) = 489 lb/ft^3

$$\eta = \frac{(\gamma_s - \gamma_f)D^2}{18v} = \frac{(489-58.7)\text{lb/ft}^3(0.00525\ \text{ft})^2}{18(0.0801\ \text{ft/s})} = 0.00823\ \text{lb s/ft}^2 = 8.23\times10^{-3}\ \text{lb}\cdot\text{s/ft}^2$$

2.64 See Problem 2.62. Use $\gamma_m = 844.9$ lb/ft^3 (App. B): $\gamma_o = (0.90)(62.4$ lb/ft$^3) = 56.16$ lb/ft^3
$h = (7.00$ in$)(1$ ft/12 in$) = 0.5833$ ft: $D = (0.100$ in$)(1$ ft/12 in$) = 0.00833$ ft
$p_1 - p_2 = h(\gamma_m - \gamma_o) = (0.5833$ ft$)(844.9 - 56.16)$ lb/ft$^3 = 460.1$ lb/ft^2

$$\eta = \frac{(p_1 - p_2)D^2}{32 v L} = \frac{(460.1 \text{ lb/ft}^2)(0.00833 \text{ ft})^2}{32(4.82 \text{ ft/s})(1.0 \text{ ft})} = 0.000207 \text{ lb s/ft}^2 = 2.07 \times 10^{-4} \text{ lb·s/ft}^2$$

2.65 From Fig. 2.14, kinematic viscosity = 78.0 SUS

2.66 From Fig 2.14, kinematic viscosity = 257 SUS

2.67 $\nu = 4.632(188) = 871$ SUS

2.68 $\nu = 4.632(244) = 1130$ SUS

2.69 From Fig. 2.15, $A = 0.996$. At 100°F, $\nu = 4.632(153) = 708.7$ SUS.
At 40°F, $\nu = 0.996(708.7) = 706$ SUS

2.70 From Fig. 2.15, $A = 1.006$. At 100°F, $\nu = 4.632(205) = 949.6$ SUS.
At 190°F, $\nu = 1.006(949.6) = 955$ SUS

2.71 $\nu = 6250/4.632 = 1349$ mm^2/s

2.72 $\nu = 438/4.632 = 94.6$ mm^2/s

2.73 From Fig. 2.14, $\nu = 12.5$ mm^2/s

2.74 From Fig 2.14, $\nu = 37.5$ mm^2/s

2.75 $t = 80$°C = 176°F. From Fig. 2.15, $A = 1.005$. At 100°F, $\nu = 4690/4.632 = 1012.5$ mm^2/s.
At 176°F (80°C): $\nu = 1.005(1012.5) = 1018$ mm^2/s.

2.76 $t = 40$°C = 104°F. From Fig. 2.15, $A = 1.00$. At 100°F, $\nu = 526/4.632 = 113.6$ mm^2/s.
At 176°F (80°C): $\nu = 1.000(113.6) = 113.6$ mm^2/s.

Problem 2.77
Convert kinematic viscosity for ISO grades from mm^2/s to SUS

ISO VG*					
Nominal		Minimum		Maximum	
(mm^2/s)	(SUS)	(mm^2/s)	(SUS)	(mm^2/s)	(SUS)
2.2	32.0	1.98	28.8	2.42	35.2
3.2	34.3	2.88	30.87	3.52	37.7
4.6	39.5	4.14	35.55	5.06	43.5
6.8	46.5	6.12	41.85	7.48	51.2
10	57.5	9.00	51.75	11.0	63.3
15	76.5	13.5	68.9	16.5	84.2
22	107	19.8	96.3	24.2	118
32	151	28.8	135.9	35.2	166
46	214	41.4	192.6	50.6	235
68	316	61.2	284.4	74.8	348
100	463	90	417	110	510
150	695	135	625	165	764
220	1019	198	917	242	1121
320	1482	288	1334	352	1630
460	2131	414	1918	506	2344
680	3150	612	2835	748	3465
1000	4632	900	4169	1100	5095
1500	6948	1350	6253	1650	7643
2200	10190	1980	9171	2420	11209
3200	14822	2880	13340	3520	16305

*First four values are called VG 2, 3, 5, and 7

NOTES: For VG ≥ 100 values computed from SUS = 4.664*n(mm^2s)

Other values read from graph in Figure 2.14

Minimum = Nom*0.9; Maximum = Nom*1.1