

CHAPTER ONE

THE NATURE OF FLUIDS AND THE STUDY OF FLUID MECHANICS

Conversion factors

$$1.1 \quad 1250 \text{ mm}(1 \text{ m}/10^3 \text{ mm}) = \mathbf{1.25 \text{ m}}$$

$$1.2 \quad 1600 \text{ mm}^2[1 \text{ m}^2/(10^3 \text{ mm})^2] = \mathbf{1.6 \times 10^{-3} \text{ m}^2}$$

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

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

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

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

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

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

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

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

$$1.11 \quad 2580 \text{ ft}(0.3048 \text{ m/ft}) = \mathbf{786 \text{ m}}$$

$$1.12 \quad 480 \text{ ft}^3(0.0283 \text{ m}^3/\text{ft}^3) = \mathbf{13.6 \text{ m}^3}$$

$$1.13 \quad 7390 \text{ cm}^3[1 \text{ m}^3/(100 \text{ cm})^3] = \mathbf{7.39 \times 10^{-3} \text{ m}^3}$$

$$1.14 \quad 6.35 \text{ L}(1 \text{ m}^3/1000 \text{ L}) = \mathbf{6.35 \times 10^{-3} \text{ m}^3}$$

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

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

Consistent units in an equation

$$1.17 \quad v = \frac{s}{t} = \frac{0.50 \text{ km}}{10.6 \text{ s}} \times \frac{10^3 \text{ m}}{\text{km}} = \mathbf{47.2 \text{ m/s}}$$

$$1.18 \quad v = \frac{s}{t} = \frac{1.50 \text{ km}}{5.2 \text{ s}} \times \frac{3600 \text{ s}}{\text{h}} = \mathbf{1038 \text{ km/h}}$$

$$1.19 \quad v = \frac{s}{t} = \frac{1000 \text{ ft}}{14 \text{ s}} \times \frac{1 \text{ mi}}{5280 \text{ ft}} \times \frac{3600 \text{ s}}{\text{h}} = \mathbf{48.7 \text{ mi/h}}$$

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

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

$$1.22 \quad t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{(2)(13 \text{ m})}{9.81 \text{ m/s}^2}} = \mathbf{1.63 \text{ s}}$$

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

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

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

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

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

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

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

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

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

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

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

$$1.32 \quad KE = \frac{mv^2}{2} = \frac{(1 \text{ slug})(4 \text{ ft/s})^2}{2} \times \frac{1 \text{ lb} \cdot \text{s}^2/\text{ft}}{\text{slug}} = \mathbf{8.00 \text{ lb} \cdot \text{ft}}$$

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

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

$$1.34 \quad KE = \frac{mv^2}{2} = \frac{wv^2}{2g} = \frac{(150 \text{ lb})(20 \text{ ft/s})^2}{(2)(32.2 \text{ ft/s}^2)} = \mathbf{932 \text{ lb} \cdot \text{ft}}$$

$$1.35 \quad m = \frac{2(KE)}{v^2} = \frac{2(15 \text{ lb} \cdot \text{ft})}{(2.2 \text{ ft/s}^2)^2} = 6.20 \frac{\text{lb} \cdot \text{s}^2}{\text{ft}} = \mathbf{6.20 \text{ slugs}}$$

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

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

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

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

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

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

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

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

The definition of pressure

$$1.43 \quad p = F/A = 2500 \text{ lb}/[\pi(3.00 \text{ in})^2/4] = \mathbf{354 \text{ lb/in}^2 = 354 \text{ psi}}$$

$$1.44 \quad p = F/A = 8700 \text{ lb}/[\pi(1.50 \text{ in})^2/4] = \mathbf{4923 \text{ psi}}$$

$$1.45 \quad p = \frac{F}{A} = \frac{12.0 \text{ kN}}{\pi(75 \text{ mm})^2/4} \times \frac{10^3 \text{ N}}{\text{kN}} \times \frac{(10^3 \text{ mm})^2}{\text{m}^2} = 2.72 \times 10^6 \frac{\text{N}}{\text{m}^2} = \mathbf{2.72 \text{ MPa}}$$

$$1.46 \quad p = \frac{F}{A} = \frac{38.8 \times 10^3 \text{ N}}{\pi(40 \text{ mm})^2/4} \times \frac{(10^3 \text{ mm})^2}{\text{m}^2} = 30.9 \times 10^6 \frac{\text{N}}{\text{m}^2} = \mathbf{30.9 \text{ MPa}}$$

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

$$1.48 \quad p = \frac{F}{A} = \frac{18000 \text{ lb}}{\pi(2.50 \text{ in})^2/4} = \mathbf{3667 \text{ psi}}$$

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

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

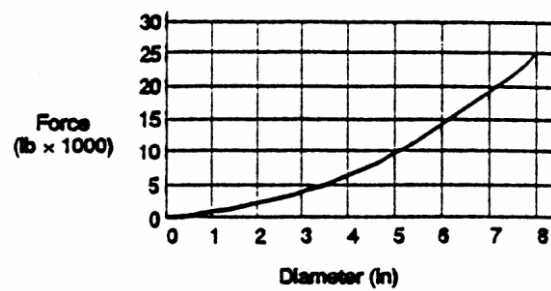
$$1.51 \quad p = \frac{F}{A} = \frac{F}{\pi D^2/4} = \frac{4F}{\pi D^2}: \text{ Then } D = \sqrt{\frac{4F}{\pi p}}$$

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

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

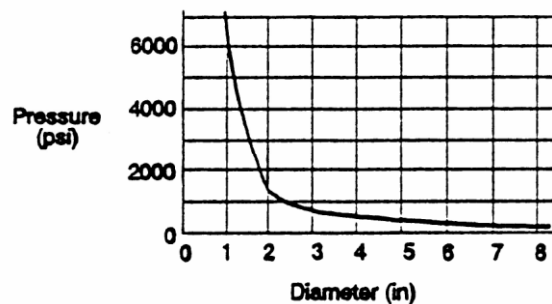
$$1.53 \quad F = pA = \frac{p[\pi D^2]}{4} = \frac{500 \text{ lb}(\pi)(D \text{ in})^2}{\text{in}^2 4} = 392.7 D^2 \text{ lb}$$

$D(\text{in})$	$D^2(\text{in}^2)$	$F(\text{lb})$
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



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

$D(\text{in})$	$D^2(\text{in}^2)$	$p(\text{psi})$
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



$$1.55 \quad (\text{Variable Answers}) \text{ Example: } w = 160 \text{ lb} (4.448 \text{ N/lb}) = 712 \text{ N}$$

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

$$p = 2.27 \times 10^6 \text{ Pa} (1 \text{ psi}/6895 \text{ Pa}) = 329 \text{ psi}$$

$$1.56 \quad (\text{Variable Answers}) \text{ using } p = 2.27 \text{ MPa}$$

$$F = pA = (2.27 \times 10^6 \text{ N/m}^2)(\pi(0.250 \text{ m})^2/4) = 111 \times 10^3 \text{ N} = 111 \text{ kN}$$

$$F = 111 \text{ kN} (1 \text{ lb}/4.448 \text{ N}) = 25050 \text{ lb}$$

Bulk modulus

$$1.57 \quad \Delta p = -E(\Delta V/V) = -130000 \text{ psi}(-0.01) = \mathbf{1300 \text{ psi}}$$
$$\Delta p = -896 \text{ MPa}(-0.01) = \mathbf{8.96 \text{ MPa}}$$

$$1.58 \quad \Delta p = -E(\Delta V/V) = -3.59 \times 10^6 \text{ psi}(-0.01) = \mathbf{35900 \text{ psi}}$$
$$\Delta p = -24750 \text{ MPa}(-0.01) = \mathbf{247.5 \text{ MPa}}$$

$$1.59 \quad \Delta p = -E(\Delta V/V) = -189000 \text{ psi}(-0.01) = \mathbf{1890 \text{ psi}}$$
$$\Delta p = -1303 \text{ MPa}(-0.01) = \mathbf{13.03 \text{ MPa}}$$

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

Assume area of cylinder does not change.

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

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

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

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

$$1.63 \quad \text{Stiffness} = \text{Force/Change in Length} = F/\Delta L$$

$$\text{Bulk Modulus} = E = \frac{-p}{\Delta V/V} = \frac{-pV}{\Delta V}$$

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

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

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

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

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

$$1.66 \quad \text{Use large diameter cylinders and short strokes.}$$

Force and mass

$$1.67 \quad m = \frac{w}{g} = \frac{610 \text{ N}}{9.81 \text{ m/s}^2} \times \frac{1 \text{ kg} \cdot \text{m/s}^2}{\text{N}} = \mathbf{62.2 \text{ kg}}$$

- 1.68 $m = \frac{w}{g} = \frac{1.35 \times 10^3 \text{ N}}{9.81 \text{ m/s}^2} \times \frac{1 \text{ kg} \cdot \text{m/s}^2}{\text{N}} = \mathbf{138 \text{ kg}}$
- 1.69 $w = mg = 825 \text{ kg} \times 9.81 \text{ m/s}^2 = 8093 \text{ kg} \cdot \text{m/s}^2 = \mathbf{8093 \text{ N}}$
- 1.70 $w = mg = 450 \text{ g} \times \frac{1 \text{ kg}}{10^3 \text{ g}} \times 9.81 \text{ m/s}^2 = 4.41 \text{ kg} \cdot \text{m/s}^2 = \mathbf{4.41 \text{ N}}$
- 1.71 $m = \frac{w}{g} = \frac{7.8 \text{ lb}}{32.2 \text{ ft/s}^2} = 0.242 \frac{\text{lb} \cdot \text{s}^2}{\text{ft}} = \mathbf{0.242 \text{ slugs}}$
- 1.72 $m = \frac{w}{g} = \frac{42.0 \text{ lb}}{32.2 \text{ ft/s}^2} = \mathbf{1.304 \text{ slugs}}$
- 1.73 $w = mg = 1.58 \text{ slugs} \times 32.2 \text{ ft/s}^2 \times \frac{1 \text{ lb} \cdot \text{s}^2/\text{ft}}{\text{slug}} = \mathbf{50.9 \text{ lb}}$
- 1.74 $w = mg = 0.258 \text{ slugs} \times 32.2 \text{ ft/s}^2 \times \frac{1 \text{ lb} \cdot \text{s}^2/\text{ft}}{\text{slug}} = \mathbf{8.31 \text{ lb}}$
- 1.75 $m = \frac{w}{g} = \frac{160 \text{ lb}}{32.2 \text{ ft/s}^2} = \mathbf{4.97 \text{ slugs}}$
 $w = 160 \text{ lb} \times 4.448 \text{ N/lb} = \mathbf{712 \text{ N}}$
 $m = 4.97 \text{ slugs} \times 14.59 \text{ kg/slug} = \mathbf{72.5 \text{ kg}}$
- 1.76 $m = \frac{w}{g} = \frac{1.00 \text{ lb}}{32.2 \text{ ft/s}^2} = \mathbf{0.0311 \text{ slugs}}$
 $m = 0.0311 \text{ slugs} \times 14.59 \text{ kg/slug} = \mathbf{0.453 \text{ kg}}$
 $w = 1.00 \text{ lb} \times 4.448 \text{ N/lb} = \mathbf{4.448 \text{ N}}$
- 1.77 $F = w = mg = 1000 \text{ kg} \times 9.81 \text{ m/s}^2 = 9810 \text{ kg} \cdot \text{m/s}^2 = \mathbf{9810 \text{ N}}$
- 1.78 $F = 9810 \text{ N} \times 1.0 \text{ lb}/4.448 \text{ N} = \mathbf{2205 \text{ lb}}$
- 1.79 (Variable Answers) See problem 1.75 for method.

Density, specific weight, and specific gravity

- 1.80 $\gamma_B = (\text{sg})_B \gamma_w = (0.876)(9.81 \text{ kN/m}^3) = \mathbf{8.59 \text{ kN/m}^3}$
 $\rho_B = (\text{sg})_B \rho_w = (0.876)(1000 \text{ kg/m}^3) = \mathbf{876 \text{ kg/m}^3}$
- 1.81 $\rho = \frac{\gamma}{g} = \frac{12.02 \text{ N}}{\text{m}^3} \times \frac{\text{s}^2}{9.81 \text{ m}} \times \frac{1 \text{ kg} \cdot \text{m/s}^2}{\text{N}} = \mathbf{1.225 \text{ kg/m}^3}$

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

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

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

$$1.84 \quad \gamma = \frac{w}{V}; V = \frac{w}{\gamma} = \frac{2.25 \text{ kN}}{130.4 \text{ kN/m}^3} = \mathbf{0.0173 \text{ m}^3}$$

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

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

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

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

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

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

$$m = \frac{w}{g} = \frac{6.17 \text{ kN}}{9.81 \text{ m/s}^2} \times \frac{10^3 \text{ N}}{\text{kN}} \times \frac{1 \text{ kg} \cdot \text{m/s}^2}{\text{N}} = \mathbf{629 \text{ kg}}$$

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

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

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

$$1.89 \quad V = \frac{w}{\gamma} = \frac{22.0 \text{ N}}{(0.826)(9.81 \text{ kN/m}^3)} \times \frac{1 \text{ kN}}{10^3 \text{ N}} = \mathbf{2.72 \times 10^{-3} \text{ m}^3}$$

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

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

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

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

- 1.92 $w_o = 35.4 \text{ N} - 2.25 \text{ N} = 33.15 \text{ N}$
 $V_o = Ad = (\pi D^2/4)(d) = \pi(.150 \text{ m})^2(.20 \text{ m})/4 = 3.53 \times 10^{-3} \text{ m}^3$
 $\gamma_o = \frac{w}{V} = \frac{33.15 \text{ N}}{3.53 \times 10^{-3} \text{ m}^3} = 9.38 \times 10^3 \text{ N/m}^3 = \mathbf{9.38 \text{ kN/m}^3}$
 $\text{sg} = \frac{\gamma_o}{\gamma_w} = \frac{9.38 \text{ kN/m}^3}{9.81 \text{ kN/m}^3} = \mathbf{0.956}$
- 1.93 $V = Ad = (\pi D^2/4)(d) = \pi(10 \text{ m})^2(6.75 \text{ m})/4 = 530.1 \text{ m}^3$
 $w = \gamma V = (0.68)(9.81 \text{ kN/m}^3)(530.1 \text{ m}^3) = 3.536 \times 10^3 \text{ kN} = \mathbf{3.536 \text{ MN}}$
 $m = \rho V = (0.68)(1000 \text{ kg/m}^3)(530.1 \text{ m}^3) = 360.5 \times 10^3 \text{ kg} = \mathbf{360.5 \text{ Mg}}$
- 1.94 $w_{\text{castor oil}} = \gamma_{co} \cdot V_{co} = (9.42 \text{ kN/m}^3)(0.02 \text{ m}^3) = 0.1884 \text{ kN}$
 $V_m = \frac{w}{\gamma_m} = \frac{0.1884 \text{ kN}}{(13.54)(9.81 \text{ kN/m}^3)} = \mathbf{1.42 \times 10^{-3} \text{ m}^3}$
- 1.95 $w = \gamma V = (2.32)(9.81 \text{ kN/m}^3)(1.42 \times 10^{-4} \text{ m}^3) = 3.23 \times 10^{-3} \text{ kN} = \mathbf{3.23 \text{ N}}$
- 1.96 $\gamma = (\text{sg})(\gamma_w) = 0.876(62.4 \text{ lb/ft}^3) = \mathbf{54.7 \text{ lb/ft}^3}$
 $\rho = (\text{sg})(\rho_w) = 0.876(1.94 \text{ slugs/ft}^3) = \mathbf{1.70 \text{ slugs/ft}^3}$
- 1.97 $\rho = \frac{\gamma}{g} = \frac{0.0765 \text{ lb/ft}^3}{32.2 \text{ ft/s}^2} \times \frac{1 \text{ slug}}{1 \text{ lb} \cdot \text{s}^2/\text{ft}} = \mathbf{2.38 \times 10^{-3} \text{ slugs/ft}^3}$
- 1.98 $\gamma = \rho g = 0.00381 \text{ slug/ft}^3 (32.2 \text{ ft/s}^2) \frac{1 \text{ lb} \cdot \text{s}^2/\text{ft}}{\text{slug}} = \mathbf{0.1227 \text{ lb/ft}^3}$
- 1.99 $\text{sg} = \gamma_o/(\gamma_w @ 4^\circ\text{C}) = 56.4 \text{ lb/ft}^3/62.4 \text{ lb/ft}^3 = \mathbf{0.904 \text{ at } 40^\circ\text{F}}$
 $\text{sg} = \gamma_o/(\gamma_w @ 4^\circ\text{C}) = 54.0 \text{ lb/ft}^3/62.4 \text{ lb/ft}^3 = \mathbf{0.865 \text{ at } 120^\circ\text{F}}$
- 1.100 $V = w/\gamma = 500 \text{ lb}/834 \text{ lb/ft}^3 = \mathbf{0.600 \text{ ft}^3}$
- 1.101 $\gamma = \frac{w}{V} = \frac{7.50 \text{ lb}}{1 \text{ gal}} \times \frac{7.48 \text{ gal}}{\text{ft}^3} = \mathbf{56.1 \text{ lb/ft}^3}$
 $\rho = \frac{\gamma}{g} = \frac{56.1 \text{ lb/ft}^3}{32.2 \text{ ft/s}^2} = 1.74 \frac{\text{lb} \cdot \text{s}^2}{\text{ft}^4} = \mathbf{1.74 \text{ slugs/ft}^3}$
 $\text{sg} = \frac{\gamma_o}{\gamma_w @ 4^\circ\text{C}} = \frac{5.61 \text{ lb/ft}^3}{62.4 \text{ lb/ft}^3} = \mathbf{0.899}$
- 1.102 $w = \gamma V = (1.258) \frac{(62.4 \text{ lb})}{\text{ft}^3} (50 \text{ gal}) \frac{(1 \text{ ft}^3)}{7.48 \text{ gal}} = \mathbf{525 \text{ lb}}$
- 1.103 $w = \gamma V = \rho g V = \frac{1.32 \text{ lb} \cdot \text{s}^2}{\text{ft}^4} \times \frac{32.2 \text{ ft}}{\text{s}^2} \times 25.0 \text{ gal} \times \frac{1 \text{ ft}^3}{7.48 \text{ gal}} = \mathbf{142 \text{ lb}}$

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

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

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

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

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

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

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

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

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

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

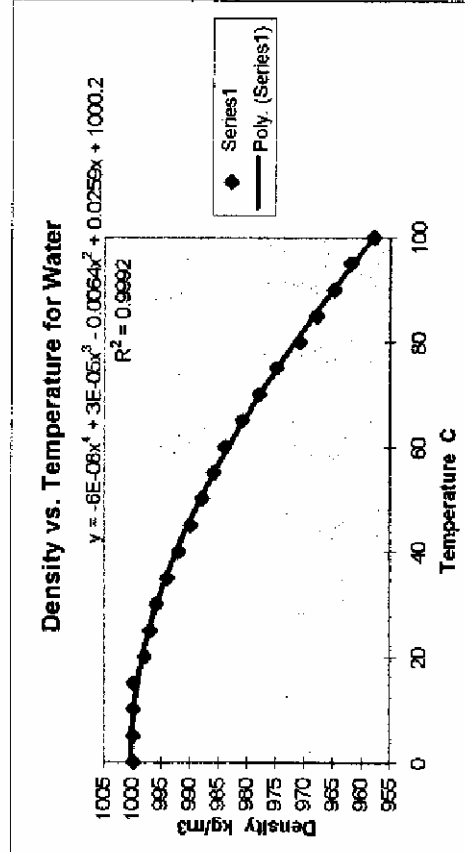
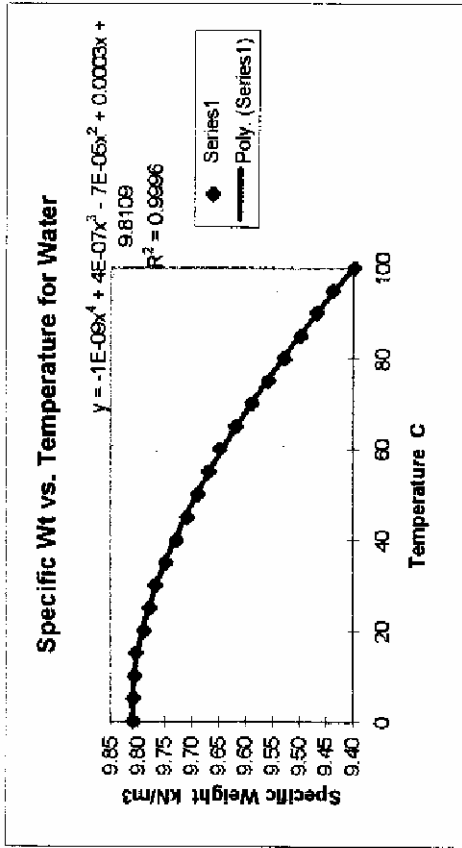
$$1.110 \quad w_{co} = \gamma_{co} V = (59.69 \text{ lb/ft}^3)(5 \text{ gal})(1 \text{ ft}^3/7.48 \text{ gal}) = \mathbf{39.90 \text{ lb}}$$

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

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

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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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 $\text{N}\cdot\text{s}/\text{m}^2$ or $\text{Pa}\cdot\text{s}$
- 2.6 $\text{lb}\cdot\text{s}/\text{ft}^2$
- 2.7 $1 \text{ poise} = 1 \text{ dyne}\cdot\text{s}/\text{cm}^2 = 1 \text{ g}/(\text{cm}\cdot\text{s})$
- 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 $1 \text{ stoke} = 1 \text{ cm}^2/\text{s}$
- 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 $6.5 \cdot 10^{-4} \text{ Pa}\cdot\text{s}$
- 2.19 $1.5 \cdot 10^{-3} \text{ Pa}\cdot\text{s}$
- 2.20 $2.0 \cdot 10^{-5} \text{ Pa}\cdot\text{s}$