CHAPTER ONE

THE NATURE OF FLUIDS AND THE STUDY OF FLUID MECHANICS

Conversion factors

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

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

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

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

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

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

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

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

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

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 $\upsilon = \dfrac{s}{t} = \dfrac{0.50\text{ km}}{10.6\text{ s}} \times \dfrac{10^3\text{ m}}{\text{km}} = \mathbf{47.2\ m/s}$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The definition of pressure

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

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

1.45 $$p = \frac{F}{A} = \frac{12.0\text{ kN}}{\pi(75\text{ mm})^2/4} \times \frac{10^3\text{ N}}{\text{kN}} \times \frac{(10^3\text{ mm})^2}{\text{m}^2} = 2.72\times10^6\ \frac{\text{N}}{\text{m}^2} = \mathbf{2.72\ MPa}$$

1.46 $$p = \frac{F}{A} = \frac{38.8\times10^3\text{ N}}{\pi(40\text{ mm})^2/4} \times \frac{(10^3\text{ mm})^2}{\text{m}^2} = 30.9\times10^6\ \frac{\text{N}}{\text{m}^2} = \mathbf{30.9\ MPa}$$

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

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

1.49 $$F = pA = \frac{20.5\times10^6\text{ N}}{\text{m}^2} \times \frac{\pi(50\text{ mm})^2}{4} \times \frac{1\text{ m}^2}{(10^3\text{ mm})^2} = \mathbf{40.25\ kN}$$

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

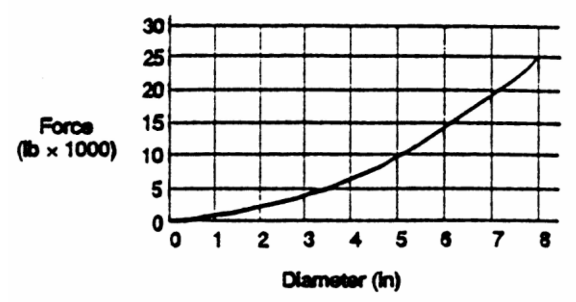
1.51 $$p = \frac{F}{A} = \frac{F}{\pi D^2/4} = \frac{4F}{\pi D^2}:\ \text{Then } D = \sqrt{\frac{4F}{\pi p}}$$

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

1.52 $$D = \sqrt{\frac{4F}{\pi p}} = \sqrt{\frac{4(30\times10^3\text{ N})}{\pi(15.0\times10^6\text{ N/m}^2)}} = 50.5\times10^{-3}\text{ m} = \mathbf{50.5\ mm}$$

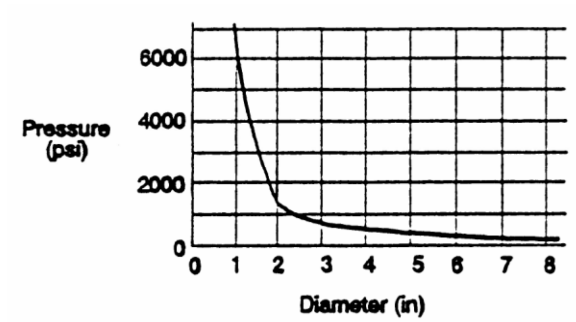
1.53 $F = pA = \dfrac{p[\pi D^2]}{4} = \dfrac{500\text{ lb}(\pi)(D\text{ in})^2}{\text{in}^2\ 4}$ = **392.7 D^2 lb**

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 $\Delta V/V = -0.01$; $\Delta V = 0.01V = 0.01$ AL
Assume area of cylinder does not change.
$\Delta V = A(\Delta L) = 0.01$ AL
Then $\Delta L = 0.01\text{ L} = 0.01(12.00\text{ in}) = \mathbf{0.120\ in}$

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

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

1.63 Stiffness = Force/Change in Length = $F/\Delta L$

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

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

1.66 Use large diameter cylinders and short strokes.

Force and mass

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

1.68 $m = \frac{w}{g} = \frac{1.35 \times 10^3 \text{ N}}{9.81 \text{ m/s}^2} \times \frac{1 \text{ kg} \cdot \text{m/s}^2}{\text{N}}$ = **138 kg**

1.69 $w = mg$ = 825 kg × 9.81 m/s^2 = 8093 kg·m/s^2 = **8093 N**

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

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

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

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

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

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

w = 160 lb × 4.448 N/lb = **712 N**
m = 4.97 slugs × 14.59 kg/slug = **72.5 kg**

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

m = 0.0311 slugs × 14.59 kg/slug = **0.453 kg**
w = 1.00 lb × 4.448 N/lb = **4.448 N**

1.77 $F = w = mg$ = 1000 kg × 9.81 m/s^2 = 9810 kg·m/s^2 = **9810 N**

1.78 F = 9810 N × 1.0 lb/4.448 N = **2205 lb**

1.79 (Variable Answers) See problem 1.75 for method.

Density, specific weight, and specific gravity

1.80 $\gamma_B = (sg)_B \gamma_w$ = (0.876)(9.81 kN/m^3) = **8.59 kN/m³**
$\rho_B = (sg)_B \rho_w$ = (0.876)(1000 kg/m^3) = **876 kg/m³**

1.81 $\rho = \frac{\gamma}{g} = \frac{12.02 \text{ N}}{\text{m}^3} \times \frac{\text{s}^2}{9.81 \text{ m}} \times \frac{1 \text{ kg} \cdot \text{m/s}^2}{\text{N}}$ = **1.225 kg/m³**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1.94 $w_{castor\ oil} = \gamma_{co}\cdot V_{co} = (9.42\text{ kN/m}^3)(0.02\text{ m}^3) = 0.1884\text{ kN}$

$$V_m = \frac{w}{\gamma_m} = \frac{0.1884\text{ kN}}{(13.54)(9.81\text{ kN/m}^3)} = \mathbf{1.42\times10^{-3}\text{ m}^3}$$

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

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

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

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

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

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

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

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

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 $$w = \gamma V = \rho g V = \frac{1.32\text{ lb}\cdot\text{s}^2}{\text{ft}^4}\times\frac{32.2\text{ ft}}{\text{s}^2}\times25.0\text{ gal}\times\frac{1\text{ ft}^3}{7.48\text{ gal}} = \mathbf{142\text{ lb}}$$

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

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

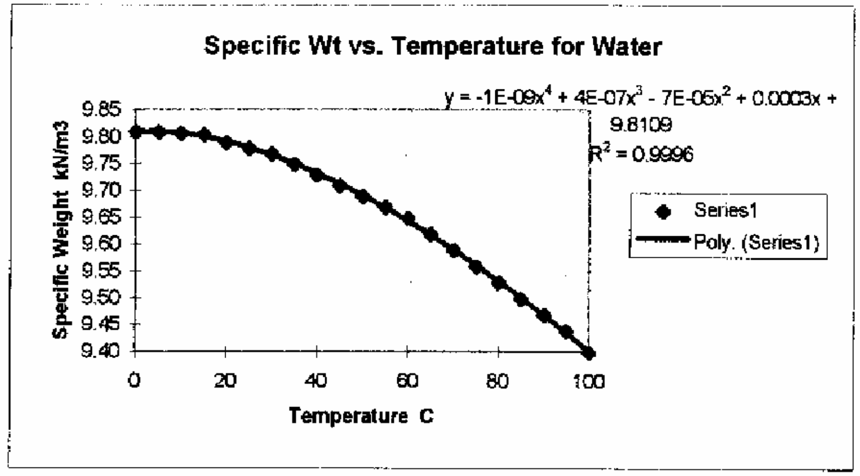
1.110 $w_{co} = \gamma_{co} V = (59.69\text{ lb/ft}^3)(5\text{ gal})(1\text{ ft}^3/7.48\text{ gal}) = \mathbf{39.90\ lb}$

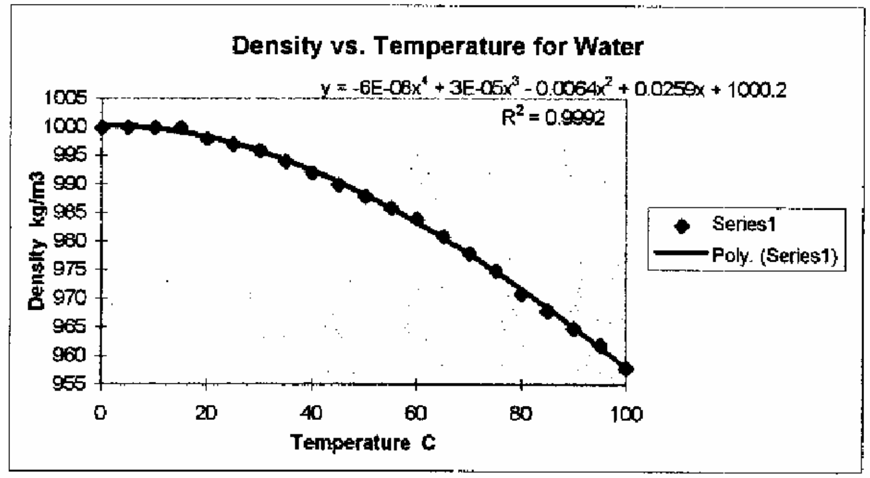
$V_m = \frac{w}{\gamma_m} = \frac{39.90\text{ lb ft}^3}{13.54(62.4\text{ lb})} \times \frac{7.48\text{ gal}}{\text{ft}^3} = \mathbf{0.353\ gal}$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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⊕s/m^2 or Pa⊕s

2.6 lb⊕s/ft^2

2.7 1 poise = 1 dyne⊕s/cm^2 = 1 g/(cm⊕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⊕s

2.19 $1.5 \cdot 10^{-3}$ Pa⊕s

2.20 $2.0 \cdot 10^{-5}$ Pa⊕s