Problem 1.1

Data:

$\gamma = 7000\ N/m^3$, $\rho = ?$ $V = ?$ $S = ?$

$T = 15°C$

Sol:

a) $\gamma = \rho g \Rightarrow \rho = \frac{\gamma}{g} = \frac{7000}{9.81} = 713.55\ kg/m^3$

b) $V = \frac{1}{\rho} = \frac{1}{713.55} = 1.4 \times 10^{-3}\ m^3/kg$

c) $S = \frac{\gamma_{gasoline}}{\gamma_{water}} = \frac{7000}{9.798 \times 10^3} = 0.7144$

Prob. 1.2

Data:

$\gamma_{gas} = 16\ N/m^3$ $\rho = ?$, $V = ?$, $S = ?$

$\gamma_{air} = 12\ N/m^3$

Sol:

a) $\gamma = \rho g \Rightarrow \rho = \frac{\gamma}{g} = \frac{16}{9.81} = 1.63\ kg/m^3$

b) $V = \frac{1}{\rho} = \frac{1}{1.63} = 0.613\ m^3/kg$

c) $S = \frac{\gamma_{gas}}{\gamma_{air}} = \frac{16}{12} = 1.33$

Prob. 1.3

Data:

$S_{fluid} = 1.26$ $\rho = ?$ $\gamma = ?$

Sol:

$$S = \frac{\rho_{fluid}}{\rho_{water}} \Rightarrow \rho_{fluid} = 1.26 \times 1000 = 1260\ kg/m^3$$

$$\gamma = \rho g = 1260 \times 9.81 = 12360.6\ N/m^3$$

Prob 1.4

Data:

$\gamma = 8KN/m^3 = 8 \times 10^3 N/m^3$ $\rho = ?$

Sol:

$$\gamma = \rho g$$

$$\rho = \frac{\gamma}{g} = \frac{8 \times 10^3}{9.81} = 815.49\ kg/m^3$$

Prob 1.5

Data:

$v = 0.72\ m^3/kg$ $\gamma = ?$ in N/m^3

Sol:

$$\gamma = \rho g$$

$$= \frac{1}{v} g = \frac{1}{0.72} \times 9.81 = 13.625\ N/m^3$$

Prob 1.7

Data:

$P_2 = 100M\ N/m^2$

$T = 20°C$

$P_1 = 100KN/m^2 = 0.1MN/m^2$

% dec. in specific volume $= \frac{V_1 - V_2}{V_1} \times 100 = ?$

Sol:

$$(E_v)_{avg} = \frac{\Delta P}{\Delta V/V}$$

$$\frac{V_1 - V_2}{V_1} \times 100 = \frac{P_2 - P_1}{(E_v)_{avg}} \times 100$$

$$= \frac{100 - 0.1}{2430} \times 100 = 4.11\%$$

From table 1.1

$P_1 = 0.1MN/m^2 \qquad E_v = 2130\ MN/m^2$

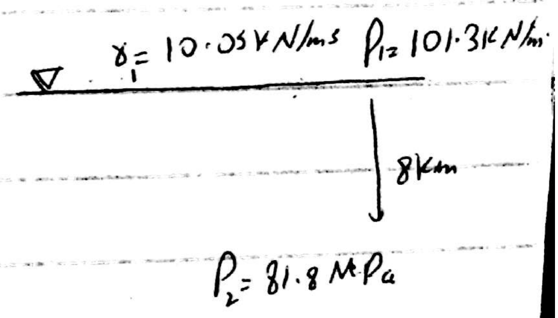
$P_2 = 100\ MN/m^2 \qquad E_v = 2730MN/m^2$

$$(E_v)_{avg} = \frac{2730 + 2130}{2} = 2430\ MN/m^2$$

Prob 1.8

Data:

$(E_v)_{avg} = 2.34 \times 10^9 N/m^2$



a) $V_1 - V_2$

b) $V_2 = ?$

c) $\gamma_2 = ?$

Sol:

a) $(E_v)_{avg} = \dfrac{\Delta P}{\Delta V/V} = \dfrac{P_2 - P_1}{(V_1 - V_2)/V_1}$

$\because \gamma = \rho g$

$\gamma_1 = \dfrac{1}{V_1} g$

$V_1 = \dfrac{9.81}{10.05 \times 10^3}$

$V_1 = 9.76 \times 10^{-4} \, m^3/kg$

$$V_1 - V_2 = \frac{(P_2 - P_1)\, V_1}{(E_v)_{avg}}$$

$$= \frac{(81.8 \times 10^6 - 101300) \times 9.76 \times 10^{-4}}{2.34 \times 10^9}$$

$V_1 - V_2 = 3.407 \times 10^{-5} \; m^3/kg$

b) $V_1 - V_2 = 3.407 \times 10^{-5} \; m^3/kg$

$9.76 \times 10^{-4} - V_2 = 3.407 \times 10^{-5}$

$V_2 = 9.41 \times 10^{-4} \; m^3/kg$

c) $\gamma_2 = \dfrac{1}{V_2} g$

$$= \frac{9.81}{9.41 \times 10^{-4}} = 10425.07 \; N/m^3$$

Prob. 1.9

Data:

a) % change in V in 1.8 $= \dfrac{V_1 - V_2}{V_1} \times 100 = ?$

b) % chang in γ in 1.8 $= \dfrac{\gamma_1 - \gamma_2}{\gamma_1} \times 100 = ?$

Sol:

a) $\dfrac{V_1 - V_2}{V_1} \times 100 = \dfrac{3.407 \times 10^{-5}}{9.76 \times 10^{-4}} \times 100 = 3.49\,\%$

b) $\dfrac{\overset{\gamma_2 - \gamma_1}{\cancel{\gamma_1 - \gamma_2}}}{\gamma_1} \times 100 = \dfrac{\overset{10425.07 - 10050}{\cancel{10050 - 10425.07}}}{10050} \times 100 = 3.73\,\%$

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Prob. 1.10

Data:

$E_V = ?$ in MN/m^2

$T = 50°C$

$P = 30\ MN/m^2$

Sol:

By using table 1.1

Bulk modulus $= E_V = 2410\ MN/m^2$ at $50°C$

Prob. 1.11

Data:

$P = ?$

For reduction of vol. of H_2O 2%

we should put

$$\frac{V_1 - V_2}{V_1} \times 100 = 2$$

$$\frac{V_1 - V_2}{V_1} = 2/100$$

So $$E_V = \frac{P_2 - P_1}{\frac{V_1 - V_2}{V_1}}$$

$$\frac{V_1 - V_2}{V_1} = \frac{P_2 - P_1}{E_V}$$

$$P_2 - P_1 = \Delta P = \frac{V_1 - V_2}{V_1} \times E_V$$

$$= \frac{2}{100} \times (2.18 \times 10^6 N/m^2)$$

$$= 43600\ N/m^2$$

Prob 1.27

Data:

$1 cP = 10^{-3} Ns/m^2$

$\mu = 23 cP = 23 \times 10^{-3} Ns/m^2$

$\gamma = 8.4 KN/m^3 = 8.4 \times 10^3 N/m^3$

$\nu = ?$

Sol:

$\nu = \frac{\mu}{\rho}$

$\gamma = \rho g$

$\rho = \frac{\gamma}{g} = \frac{8.4 \times 10^3}{9.81} = 856.26 kg/m$

$= \frac{23 \times 10^{-3}}{856.26}$

$\nu = 2.6 \times 10^{-5} m^2/s$

Prob 1.28

Data:

a) Water:

$\frac{\mu_{20°C}}{\mu_{90°C}} = \frac{1.002 \times 10^3}{0.315 \times 10^3} = 3.180$

b)

$T = 15°C$

$\frac{\text{crude oil}}{\text{gasoline}}$ $\frac{\mu_{0.925}}{\mu_{0.680}} = \frac{1 \times 10^{-1} Ns/m^2}{3.3 \times 10^{-4}} = 300$

c)

$\frac{\text{change } \mu \text{ of SAE 30 western}}{\text{chang } \mu \text{ of SAE 30 eastern}} = \frac{0.04 - 3}{0.03 - 1.5}$

$= 2.01$

Prob. 1.29:

Data:

$T = 15°C$

$\nu_{gasoline} = ?$

$S = 0.680$

Sol:

From figure 1.3 $\nu_{gasoline} = 4.8 \times 10^{-7}\ m^2/s$

Prob 1.30:

ν_{water} at $4°C = 1.57 \times 10^{-6} m^2/s$

Using Relation

$\nu_{fuel} = 3\nu_{water}$

$= 3 \times 1.57 \times 10^{-6} = 4.71 \times 10^{-6} m^2/s$

This Kinematic viscosity is at temp. $= 198°C$

Prob. 1.32:

Compare $\frac{\mu_{air} \text{ at } 20°C}{\mu_{water} \text{ at } 20°C}$ with $\frac{\nu_{air} \text{ at } 20°C}{\nu_{water} \text{ at } 20°C}$

Sol:

$\frac{1.81 \times 10^{-5}}{1.002 \times 10^{-3}} = 0.01806$ $\frac{1.5 \times 10^{-5}}{1.003 \times 10^{-6}} = 14.95$

Diff. $= 14.95 - 0.01806$

$= 14.93$

Prob. 1.33

Data:

$A = 30\,cm \times 50\,cm = 1500\,cm^2 = 0.15\,m^2$

$\mu = 0.8\,Ns/m^2$

$u = 2\,ms^{-1}$

$y = 0.4\,mm = 0.4 \times 10^{-3}\,m$

$F = ?$

Sol:

$$F = \frac{\mu u A}{y}$$

$$F = \frac{2 \times 0.8 \times 0.15}{0.4 \times 10^{-3}} = 600\,N$$

Prob 1.34

Data:

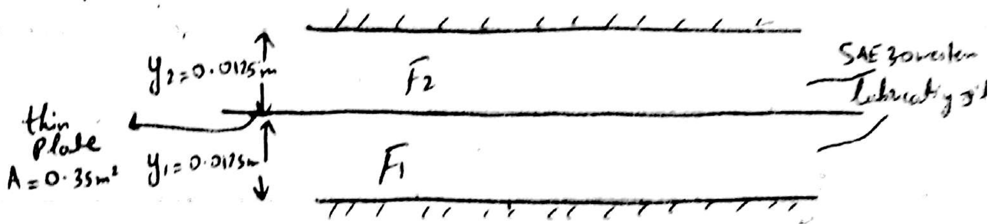
$y = 25\,mm = 0.0125\,m$

$T = 25°C$

a) $F = ?$

$A = 0.35\,m^2$

$u = 0.1\,m/s$



Sol:

$F = F_1 + F_2$

$$F_1 = \frac{\mu u A}{y} = \frac{(0.3)(0.1)(0.35)}{0.0125}$$

From fig 1.2 Pg 11

$= 0.84$

$F_2 = 0.84$

$F = 0.84 + 0.84$

$\boxed{F = 1.68\,N}$

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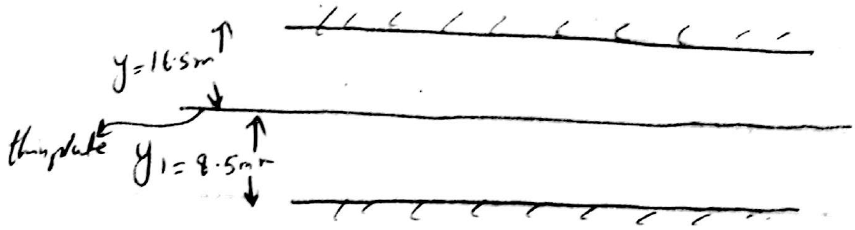
b)

$y = 25\,mm$

$F = ?$



$$F_1 = \frac{(0.3)(0.1)(0.35)}{8.5\times10^{-3}} \qquad F_2 = \frac{(0.3)(0.1)(0.35)}{16.5\times10^{-3}}$$

$F_1 = 1.235\ N$ $\qquad F_2 = 0.636\,N$

$$F = 1.235 + 0.636$$

$$\boxed{F = 1.87\ N}$$

Prob. 1.42

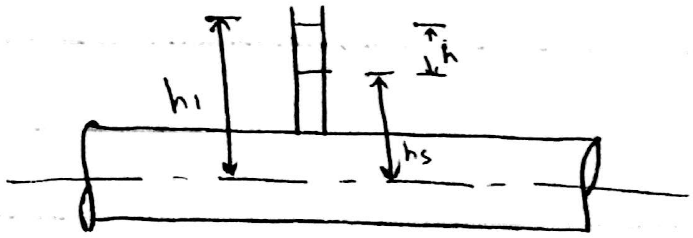
Data: Distilled water

$T = 10°C$

$d = 8\,mm = 8\times10^{-3}\,m$

$h_1 = 25\,mm = 25\times10^{-3}\,m$

$h_s = ?$



Sol:

$h_s = h_1 - h$,

$h_s = 25\times10^{-3} - 3.78\times10^{-3}$

$h_s = 21.22\times10^{-3}\,m$

$h_s = 21.22$ mm of water

$$h = \frac{4\sigma\cos\theta}{\gamma d} \quad , \quad \gamma = \rho g$$

$\gamma = 999.7\times9.8$

$\gamma = 9807.05$

$$h = \frac{4(0.0742)\cos 0}{9.807\times10^{3}\times8\times10^{-3}}$$

$h = 3.78\times10^{-3}\,m$

Prob. 1.43

Data: Tap water

$T = 20°C$

$d = 8mm = 8 \times 10^{-3} m$

$h_1 = 11.25 mm = 11.25 \times 10^{-3} m$

$h_s = ?$

Sol:

$h_s = h_1 - h$ $\quad$ $h = 1.45mm$ (capillarity rise)

$= 11.25 - 1.45$

$h_s = 9.8mm$

Prob. 1.44

Data:

Capillary Rise = ? $\quad$ Fluid = Water $\quad$ $d = 5mm$

$T = 20°C$

Sol:

$$h = \frac{4\sigma\cos\theta}{\gamma d} = \frac{4\sigma\cos\theta}{\rho g d} = \frac{4(0.0728)\cos 0°}{998.2 \times 9.81 \times 5\times10^{-3}}$$

$h = 5.947 \times 10^{-3} m$

$h = 5.95\ mm$

Prob. 1.45

Data

Capillary depression = ? $\rho_{20^\circ} = 13550\ kg/m^3$

$\theta = 140^\circ$ fluid = Mercury

$d = 2.5mm$ $T = 20^\circ$

$\sigma = 0.4641\ N/m$

Sol:

$$h = \frac{4\sigma \cos\theta}{(\rho g)d} = \frac{4(0.4641)\cos 140^\circ}{13550 \times 9.81 \times 2.5\times10^{-3}}$$

$h = -4.27 \times 10^{-3} m$

$h = 4.27\ mm$ fall

Prob. 12.6

Data:

Type = Rotational

$h = 25cm = 0.25m$

Outer diameter of inner cylinder $= d_1 = 9.9\ cm = 0.099\ m \Rightarrow r_1 = 0.0495$

Inner diameter of outer cylinder $= d_2 = 10.1\ cm = 0.101\ m \Rightarrow r_2 = 0.0505$

$T = 7Nm$ on outer cylinder

$$N = \frac{1\ rev}{3.5\ s} = \frac{1\ rev}{\frac{3.5}{60}\ min} = 17.14\ rev/min$$

$\mu = ?$

Sol:

$$\mu = \frac{T}{K_r N}$$

$$K_r = \frac{\pi^2 r_2^3 h}{15 \Delta r}$$

$$K_r = \frac{\pi^2 (0.0505)^3 (0.25)}{15\ (0.0505 - 0.0495)}$$

$K_r = 0.0212\ m^3$

$$\mu = \frac{7}{0.0212 \times 17.14} = 19.26\ Ns/m^2$$

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Prob. 12.7

Data:

Type = Tube type

$D = 1.07 mm = 1.07 \times 10^{-3} m$

$L = 7.75\ cm = 7.75 \times 10^{-2}\ m$

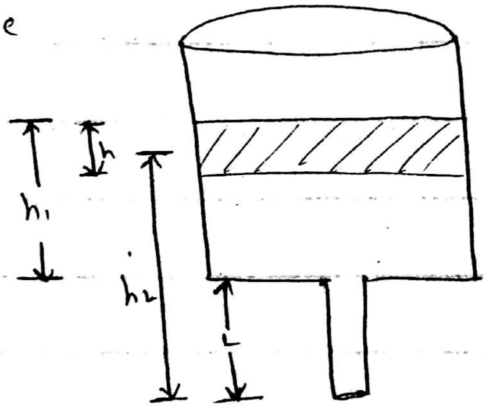
$\nu = ?$

$V_L = 50 cm^3 = 50 \times 10^{-6} m^3$

$t = 126.4 s$

Distance from lq surface to the tube outlet changes from $24 \rightarrow 22.8 cm$

Means



$h_1 + L = 24\ cm$ — (1)

$h_1 + L = 0.24$

$h_1 = 0.24 - 7.75 \times 10^{-2}$

$\boxed{h_1 = 0.1625 m}$

and

$h_L - \frac{h}{2} = 22.8\ cm$ — (2)

$h_L - \frac{h}{2} = 0.228$

$h_1 + L - \frac{h}{2} - \frac{h}{2} = 0.228$

$h_1 + L - h = 0.228$

$0.1625 + 7.75 \times 10^{-2} - 0.228 = h$

$\boxed{h = 0.012 m}$

$h_L = h_1 + L - \frac{h}{2}$

$h_L = 0.1625 + 7.75 \times 10^{-2} - \frac{0.012}{2}$

$\boxed{h_L = 0.234\ m}$

Sol:

$\nu = K_t g t$

$\nu = 1.94 \times 10^{-9} \times 9.81 \times 126.4$

$\nu = 2.4 \times 10^{-6}\ m^2/s$

$K_t = \frac{\pi D^4 h_L}{128 L V_L}$

$= \frac{\pi (1.07 \times 10^{-3})^4 (0.234)}{128 (7.75 \times 10^{-2})(50 \times 10^{-6})}$

$K_t = 1.94 \times 10^{-9} m$

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Prob. 12.8

Data:

Type = Tube type

Water $V_L = 50\ cm^3$

$T_1 = 25°C$

$t_1 = 50.5s$

Oil $V_L = 50cm^3$

$T_2 = 15°C$

$t_2 = 800s$

$S = 0.86$

$\mu_2 = ?$

Sol:

water

$\mu_1 = K_t \gamma_1 t_1$

$K_t = \frac{\mu_1}{\gamma_1 t_1}$

$= \frac{0.890 \times 10^{-3}}{(997 \times 9.81)(50.5)}$

$K_t = 1.8 \times 10^{-9}\ m$

$\mu_2 = K_t \gamma_2 t_2$

$\mu_2 = 1.8 \times 10^{-9}(8411.29)(800)$

$\boxed{\mu_2 = 0.012\ Ns/m^2}$

$S = \frac{\rho_{fluid}}{\rho_{water}}$

$\rho_{fluid} = 0.86 \times 997$

$= 857.42\ kg/m^3$

$\gamma_2 = \rho_{fluid} \times g$

$= 857.42 \times 9.81$

$\gamma_2 = 8411.29\ N/m^3$

12.9

Data:

$\rho = 880\, kg/m^3$ $D = 2mm = 2\times10^{-3} m \Rightarrow r = 10^{-3} m$

$L = 4.5m$ $h_L = 50cm = 0.5m$ $\frac{V}{t} = \frac{30 cm^3}{min} = \frac{30}{60\times10^6} m^3/s$

$= 0.5\times10^{-6} m^3/s$

$\mu = ?$ $\nu = ?$

in poise in strokes

Sol:

$$V = \frac{h_L \gamma D^2}{32 \mu L}$$

$\because \gamma = \rho g = 820 \times 9.81 = 8632.8 N/m^3$

$$AV = \frac{V}{t}$$

a) $$\mu = \frac{(0.5)(8632.8)(2\times10^{-3})^2}{(32)(0.1591)(4.5)}$$

$$V = \frac{0.5\times10^{-6}}{\pi (10^{-3})^2}$$

$\mu = 7.53 \times 10^{-4} Ns/m^2$

$\therefore V = 0.1591 m/s$

$\mu = 7.53 \times10^{-4} \times 10$ poise

$\mu = 7.53\times10^{-3}$ poise

$\because 10$ poise $= 1 Ns/m^2$

b) $$\nu = \frac{\mu}{\rho} = \frac{7.53\times10^{-4}}{880}$$

$= 8.56 \times10^{-7} m^2/s$

$= 8.56 \times10^{-3}$ strokes $\because 10^4$ strokes $= 1 m^2/s$

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12.10

Data:

$T_1 = 10°C$ liquid = Water

Type = type type

$t_1 = 100s$

$T_2 = 38°C$ $t_2 = ?$

Sol:

$\mu_1 = K_t \gamma_1 t_1$ $\mu_2 = K_t \gamma_2 t_2$

$K_t = \frac{\mu_1}{\gamma_1 t_1}$ $t_2 = \frac{\mu_2}{K_t \gamma_2}$

$= \frac{1.307 \times 10^{-3}}{9804 \times 100}$ $= \frac{0.682 \times 10^{-3}}{1.33 \times 10^{-9} \times 9736.8}$

$K_t = 1.33 \times 10^{-9} m$ $\boxed{t_2 = 52.66s}$

Calculations

γ at $10°C = 9.804\ KN/m^3$ and γ_2 at $38°C$ =

μ_1 at $10°C = 1.307 \times 10^{-3}\ Ns/m^2$ and μ_2 at $38°C$ =

$T°C$	$\gamma\ (KN/m^3)$	$\mu\ (\times 10^{-3})\ Ns/m^2$
30°	9.764	0.798
40	9.730	0.653
Difference = 10°C	0.034	0.145
1°C	3.4×10^{-3}	0.0145
1×8°C	0.0272	0.116

At 38°C = 30° + 8° = $9.764 - 0.0272 = 9.7368\ KN/m^3$

$0.798 - 0.116 = 0.682 \times 10^{-3}\ Ns/m^2$