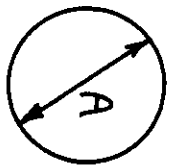
1.4
Meteorite Density

Mass $M = \frac{\pi D^3}{6}\rho$



$$\rho = \frac{6M}{\pi D^3} = \frac{6\times10^6\times1000}{\pi\times60^3}$$

$$\rho = 8,842\ \frac{kg}{m^3}$$

$$s = \frac{8,842}{1,000} = 8.84$$

Specific gravities of some elements are

Fe	7.86	Co	8.9	Ag	10.5
Ni	8.9	Pb	11.3	Au	19.3
				U	18.5

Most likely candidate is iron, the deviation being due to the "ball park" figures in the attack.

Kinetic Energy

$$\frac{1}{2}Mu^2 = \frac{1}{2}10^9\times(15000)^2 = 1.125\times10^{17}\ \underline{J}$$

$$\text{TNT equivalent} = \frac{1.125\times10^{17}}{5\times10^9} = 2.25\times10^7 \text{ tonnes}$$

1.5
Reynolds Number

Cross-sectional area

$$A = \frac{\pi D^2}{4} = \frac{\pi\left(\frac{1.05}{12}\right)^2}{4} = 0.00601\ ft^2$$

Volumetric flow rate

$$Q = \frac{35}{7.48\times60} = 0.0780\ \frac{ft^3}{s}$$

Mean velocity

$$u_m = \frac{Q}{A} = \frac{0.0780}{0.00601} = 12.98\ \frac{ft}{s}$$

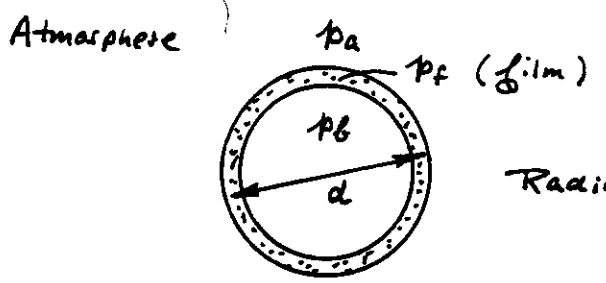
Reynolds number

$$Re = \frac{\rho u_m D}{\mu} = \frac{62.3\times12.98\times1.05/12}{1.2\times0.000672}$$

$$\left.\frac{lbm}{ft^3}\ \frac{ft}{s}\ ft\quad \frac{cP}{cP\ lbm/ft\,s}\right\}\ \text{All units cancel}$$

$$\doteq \underline{\underline{87,740}}\quad \text{(dimensionless)}$$

1.6 Pressure in Bubble



Radius $a = \frac{d}{2}$

From notes, the increase in pressure as we go inwards across a convex surface is

$$p_f - p_a = \frac{2\sigma}{a}$$
$$p_b - p_f = \frac{2\sigma}{a}$$

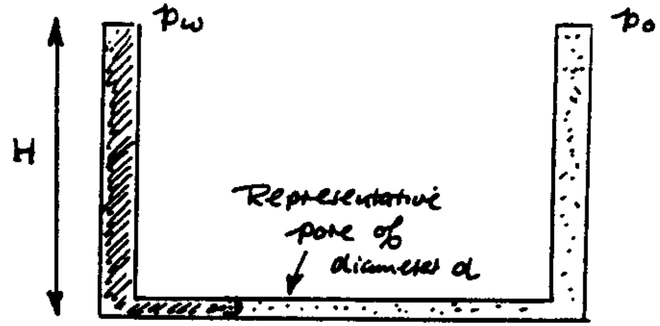
Two surfaces are involved

Hence, by addition,

$$p_b - p_a = \frac{4\sigma}{a} = \frac{8\sigma}{d}$$

$$p_b = p_a + \frac{8\sigma}{d}$$

1.7 Reservoir Water-Flooding



$$p_o + \rho_o g H + \underbrace{\frac{4\sigma}{d}}_{\text{Increase in pressure from oil into water}} = p_w + \rho_w g H$$

Hence required water inlet pressure is

$$p_w = p_o - \underbrace{(\rho_w - \rho_o)}_{\text{Positive}} g H + \frac{4\sigma}{d}$$

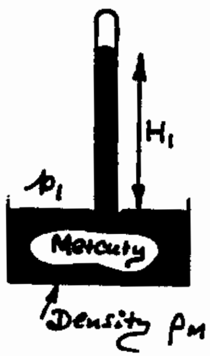
1.8-1

Barometer Reading

28 (7)/45

② • House $z_2 = 950$ ft $p_2 = ?$
$H_2 = ?$

① • Weather Station $z_1 = 700$ ft $p_1 = 0.966$ bar
$H_1 = ?$



At the weather station

The atmospheric pressure p_1 is balanced by a column of mercury of height H_1:

$$p_1 = \rho_M g H_1$$

Hence

$$H_1 = \frac{p_1}{\rho_M g} = \frac{0.966 \times 10^5 \times 3.281 \times 12}{13.57 \times 1000 \times 9.81}$$

$$\frac{kg}{m^2}\frac{m}{s^2} \quad \frac{m^3}{kg}\frac{s^2}{m}\frac{in}{m} = in$$

$$= \underline{28.57 \text{ in mercury}}$$

(Note: $g = 9.81\ m/s^2$, 3.281 ft $= 1$ m, $\rho_W = 1000 \frac{kg}{m^3}$, 1 bar $= 10^5$ pascal $= 10^5 \frac{kg\frac{m}{s^2}}{m^2}$)

1.8-2

Correction for elevation increase. Since $z_2 - z_1$ is "small" for air, we can take ρ_A as essentially constant between ① and ②. Now pressure at weather station is

$$0.966 \text{ bar} \times \frac{14.7 \text{ psia}}{1.01 \text{ bar}} \left(\text{see Problem 3}\right) = 14.06 \text{ psia}$$

Hence the appropriate mean pressure between ① and ② for purposes of estimating the density can be taken as 14.06 or (as done here, with a trifling change in the answer) slightly less — say 14.0 psia.

$$\rho_A = \frac{M_A p}{RT} = \frac{28.8 \times 14.0}{10.73 \times (460 + 25)} = 0.0775 \frac{lbm}{ft^3}$$

Average for January

Change in Pressure . $p_2 - p_1 = -\rho_A g (z_2 - z_1)$

Change in Barometer Reading $H_2 - H_1 = \frac{p_2 - p_1}{\rho_M g} = -\frac{\rho_A}{\rho_M}(z_2 - z_1)$

$$H_2 - H_1 = -\frac{0.0775 (950 - 700) \times 12}{13.57 \times 62.4} = -0.27 \text{ in}$$

Hence $H_2 = H_1 - 0.27 = 28.57 - 0.27 = \underline{\underline{28.3 \text{ in Hg}}}$

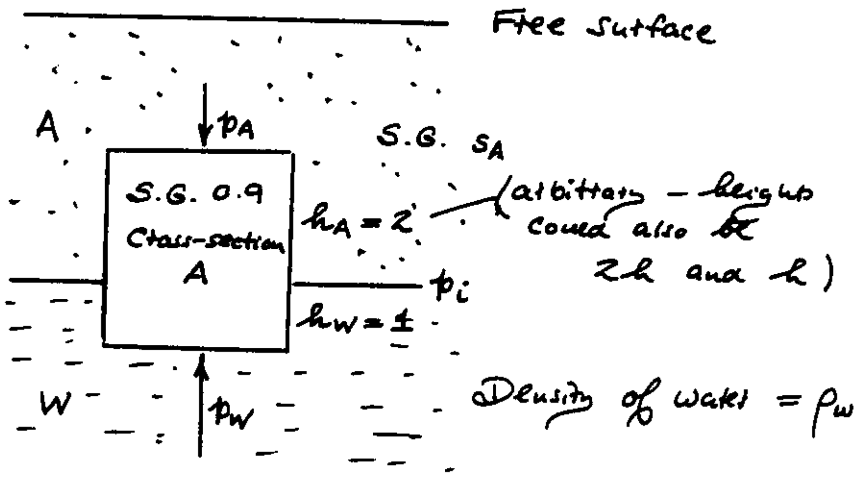
Pressure $p_2 = \rho_M g H_2 = \frac{13.57 \times 62.4 \times 32.2 \times 28.3}{32.2 \times 144 \times 12}$

$$\underline{\underline{p_2 = 13.87 \text{ psia}}}$$

$$\frac{lbm}{ft^3}\frac{ft}{sec^2} \quad in \quad \frac{lbf\ sec^2}{lbm\ ft}\frac{ft^2}{in^2}\frac{ft}{in}$$

1.9

Two-Layer Buoyancy



Method 1

Weight displaced (upwards buoyant force) = Weight of cylinder downwards

$$\rho_w A g (1 + 2 s_A) = 0.9 \rho_w A \, 3g$$

$$\underline{\underline{s_A = 0.85}}$$

Method 2 Force balance on cylinder ↓

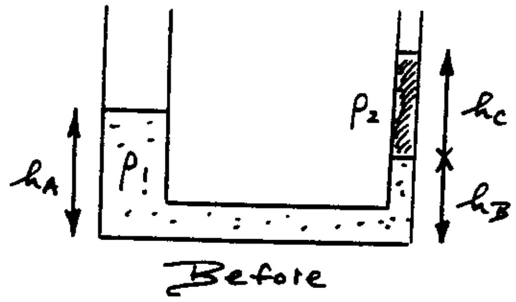
$$p_A A + \underbrace{0.9 \rho_w A \, 3g}_{\text{Weight}} - p_W A = 0$$

$$p_i - 2 s_A \rho_w g + 2.7 \rho_w g - (p_i + \rho_w g) = 0$$

$$\underline{\underline{s_A = 0.85}}$$

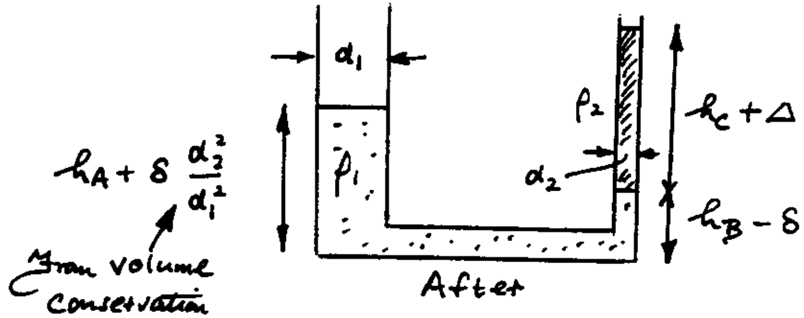
1.10-1

Differential Manometer



$$\rho_1 (h_A - h_B) = \rho_2 h_c \qquad (1)$$

Now add Δ to h_c and let h_B decline by δ



$$\rho_1 \left(h_A + \delta \frac{d_2^2}{d_1^2} - (h_B - \delta) \right) = \rho_2 (h_c + \Delta) \qquad (2)$$

Subtract (1) from (2)

$$\rho_1 \delta \left(\frac{d_2^2}{d_1^2} + 1 \right) = \rho_2 \Delta = \rho_2 \frac{v_2}{\frac{\pi d_2^2}{4}} \qquad (3)$$

Equation (3) gives δ as a function of v_2, and also enables ρ_2 to be found by observing the value of δ.

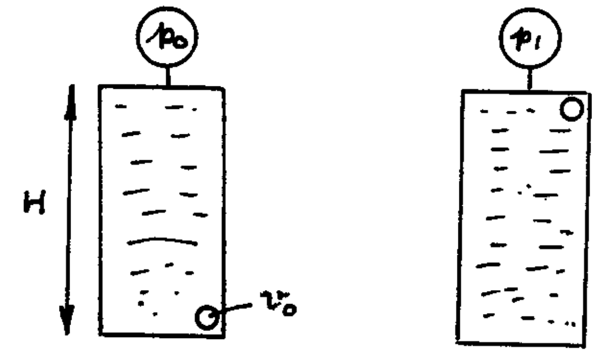
1.10-2

Solution for δ gives:

$$\delta = \frac{\rho_2}{\rho_1}\,\frac{4\,v_2}{\pi\,d_2^2}\left(\frac{d_1^2}{d_1^2+d_2^2}\right)$$

1.11

Ascending Bubble



Since the cylinder and oil volumes don't change, the bubble volume must remain constant at v_0.

But

$$p V_0 = n R T$$

Therefore, since T is constant, p within the bubble does not change. Hence

$$p = \underbrace{p_0 + \rho g H}_{\text{Before}} = \underbrace{p_1}_{\text{After}}$$

Thus $\quad p_1 = p_0 + \rho g H$

1.12
Ship Passing Through Locks

Uphill The ship must increase its elevation by an amount h as it passes from lock 1 to lock 2. Consider the water in lock 1 before and after;

Before **After**

Mass of water in lock
$= \rho AH - M$

Mass of water in lock
$= \rho A(H+h)$

From Archimedes law, the ship displaces a mass M of water

Hence mass of water to be supplied to lock 1 is

$$\rho A(H+h) - (\rho AH - M) = \rho Ah + M$$

Downhill A similar analysis gives the water loss from a lock as

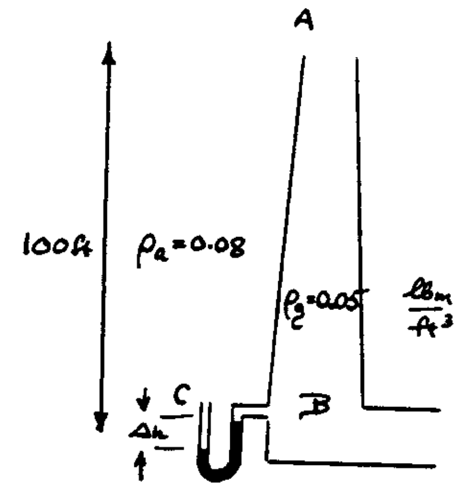
$$\underbrace{\rho AH - M}_{\text{mass at start}} - \underbrace{\rho A(H-h)}_{\substack{\text{mass at end (note that final depth}\\ \text{of water in lock is } H-h)}} = \rho Ah - M$$

Total water supply

(i) Uphill only: $\rho Ah + M$ (depends on M)

(ii) Up and down: $\rho Ah + M + \rho Ah - M = 2\rho Ah$ (independent of M)

1.13
Furnace Stack



Start from point A and consider hydro-static increase of pressure in both cases:

$$p_B = p_A + \rho_g g H$$

$$p_C = p_A + \rho_a g H$$

Hence $p_C = p_B + \underbrace{(\rho_a - \rho_g)}_{\text{positive}} gH$

Hence the water moves **up** in the right-hand leg by Δh given by

$$\rho_w g \, \Delta h = (\rho_a - \rho_g) g H$$

$$\Delta h = \frac{\rho_a - \rho_g}{\rho_w} H = \frac{(0.08 - 0.05) \times 100 \times 12}{62.4} = \underline{\underline{0.58 \text{ in.}}}$$