3.1 Note that students' answers will differ depending on their assumptions.

(a) Number of lanes = 10

Lane width = 2.5 m

Length of lap = 50 m

Depth = 2 m

$$m = V\rho = \frac{10 \mid 2.5\text{ m} \mid 50\text{ m} \mid 2\text{ m} \mid 1000\text{ kg}}{\mid \mid \mid \mid \text{m}^3} = 100\times 2.5\times 5\times 2\times 1000\text{ kg}$$

$$= 2.5\times 10\times 100\times 1000\text{ kg} = \underline{\underline{2.5\times 10^6\text{ kg}}}$$

(b) Assuming 8 oz poured in 3 sec,

$$\dot{m} = \frac{8\text{ oz} \mid 1000\text{ g}}{3\text{ s} \mid 35.3\text{ oz}} \simeq \frac{1000}{3\times 4.5} = \frac{1000}{13.5} \simeq \frac{1000}{10} = \underline{\underline{100\ \frac{\text{g}}{\text{s}}}}$$

(c) Assuming each boxer weighs 250 lb each,

$$W_{\text{max}} = \frac{12 \mid 250\text{ lb}_\text{m} \mid \text{stone}}{\mid \mid 14\text{ lb}_\text{m}} = \frac{3000}{14} = \underline{\underline{200\text{ stones}}}$$

(d) Assuming barrels are standard 55-gallon drums, with an inside diameter of 22.5 in. and height of 33.5 in., we can find the number of barrels by dividing the volume of the pipeline (gallons) by the volume of one barrel (gallons/barrel):

$$\text{Number of barrels} = \frac{V_{\text{pipeline}}}{V_{\text{barrel}}} = \frac{\pi/4 \mid (4\text{ ft})^2 \mid 800\text{ mi} \mid 5280\text{ ft} \mid 1728\text{ in.}^3}{\pi/4 \mid (22.5\text{ in.})^2 \mid 33.5\text{ in.} \mid \text{mi} \mid \text{ft}^3}$$

$$\simeq (1/6)^2 \times 20\times 5280\times 1728 \simeq 1/2\times 5280\times 1728 \simeq 2640\times 1728 \simeq 2500\times 2000 = \underline{\underline{5{,}000{,}000}}$$

(e) Assuming my body can be modeled as a rectangular prism of dimensions 6 ft × 5/3 ft × 1 ft,

$$V_{\text{rp}} = \frac{6\text{ ft} \mid 5\text{ ft} \mid 1\text{ ft} \mid 28317\text{ cm}^3}{\mid 3 \mid \mid \text{ft}^3} = 10\times 28317 = \underline{\underline{283{,}170\text{ cm}^3}}$$

Assuming my body can be modeled as a cylinder 1 ft in radius and 6 ft tall,

$$V_{\text{cyl}} = \frac{\pi \mid (1\text{ ft})^2 \mid 6\text{ ft} \mid 28317\text{ cm}^3}{\mid \mid \mid \text{ft}^3}$$

$$\simeq 3\times 6\times 28317 = 18\times 28317 \simeq 20\times 30{,}000 = \underline{\underline{600{,}000\text{ cm}^3}}$$

(f) If the block sinks very slowly, then its density is only slightly higher than that of water, meaning its specific gravity is slightly larger than 1.00. A possible SG value for this block is 1.05.

3.2 **(a)** (i) $$\frac{995\ \text{kg}}{\text{m}^3}\left|\frac{1\ \text{lb}_\text{m}}{0.45359\ \text{kg}}\right|\frac{0.028317\ \text{m}^3}{1\ \text{ft}^3}=\underline{\underline{62.12\ \text{lb}_\text{m}/\text{ft}^3}}$$

(ii) $$\frac{995\ \text{kg/m}^3}{}\left|\frac{62.43\ \text{lb}_\text{m}/\text{ft}^3}{1000\ \text{kg/m}^3}\right.=\underline{\underline{62.12\ \text{lb}_\text{m}/\text{ft}^3}}$$

(b) $\rho=\rho_{\text{H}_2\text{O}}\times SG=62.43\ \text{lb}_\text{m}/\text{ft}^3\times 5.7=\underline{\underline{360\ \text{lb}_\text{m}/\text{ft}^3}}$

(c) Student response

3.3 **(a)**
$$\frac{50\ \text{L}\ \left|\ 0.70\times10^{3}\ \text{kg}\ \right|\ 1\ \text{m}^3}{\qquad\ \left|\ \text{m}^3\ \right|\ 10^3\ \text{L}} = \underline{\underline{35\ \text{kg}}}$$

(b)
$$\frac{1150\ \text{kg}}{\text{min}}\ \left|\ \frac{\text{m}^3}{0.7\times1000\ \text{kg}}\ \right|\ \frac{1000\ \text{L}}{1\ \text{m}^3}\ \left|\ \frac{1\ \text{min}}{60\ \text{sec}} = \underline{\underline{27\ \text{L/sec}}}\right.$$

(c)
$$\frac{10\ \text{gal}}{2\ \text{min}}\ \left|\ \frac{1\ \text{ft}^3}{7.481\ \text{gal}}\ \right|\ \frac{0.70\times62.43\ \text{lb}_\text{m}}{1\ \text{ft}^3} \cong \underline{\underline{29\ \text{lb}_\text{m}/\text{min}}}$$

(d)

Assuming that 1 cm^3 was mixed with V_g (cm^3) gasoline

V_g cm^3 gasoline $\Rightarrow 0.70V_\text{g}$ g gasoline

1 cm^3 kerosene $\Rightarrow 0.82$ g kerosene

$$SG = \frac{0.70V_\text{g} + 0.82\ \text{g blend}}{V_\text{g} + 1\ \text{cm}^3\ \text{blend}} = 0.78 \Rightarrow V_\text{g} = \frac{0.82 - 0.78}{0.78 - 0.70} = 0.50\ \text{cm}^3$$

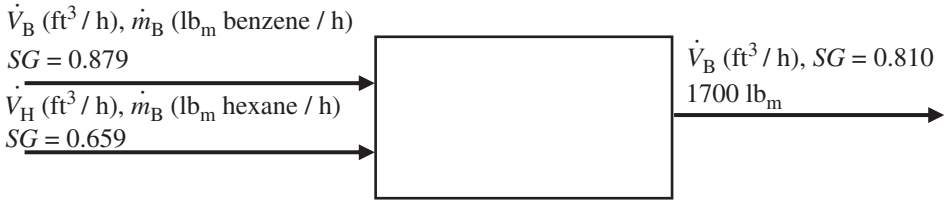
$$\underline{\text{Volumetric ratio}} = \frac{V_\text{gasoline}}{V_\text{kerosene}} = \frac{0.50\ \text{cm}^3}{1\text{cm}^3} = 0.50\ \text{cm}^3\ \text{gasoline/ cm}^3\ \text{kerosene}$$

3.4

$$P_{\text{France}} = \frac{50.0\text{ kg} \left| \frac{\text{L}}{0.71\text{ kg}} \right| \frac{€1.54}{\text{L}} \left| \frac{\$1.42}{€} \right.}{} = \underline{\underline{\$154}}$$

$$P_{\text{US}} = \frac{50.0\text{ kg} \left| \frac{\text{L}}{0.71\text{ kg}} \right| \frac{\text{m}^3}{1000\text{ L}} \left| \frac{264.17\text{ gal}}{\text{m}^3} \right| \frac{\$3.81}{\text{gal}}}{} = \underline{\underline{\$70.9}}$$

3.5



Assumptions:

- No buildup of mass in unit.
- ρ_B and ρ_H at inlet steam conditions are equal to their tabulated values (which are strictly valid at 20°C and 1 atm).
- Volumes of benzene and hexane are additive.
- Densitometer gives correct reading.

$$\dot{V} = \frac{700 \text{ lb}_m}{\text{h}} \left| \frac{\text{ft}^3}{0.810 \times 62.43 \text{ lb}_m} \right. = 33.62 \text{ ft}^3/\text{h}$$

$$\dot{m}_B = \frac{\dot{V}_B \left(\text{ft}^3\right)}{\left(\text{h}\right)} \left| \frac{0.879 \times 62.43 \text{ lb}_m}{\text{ft}^3} \right. = 54.88 \dot{V}_B \left(\text{kg/h}\right)$$

$$\dot{m}_H = \left(\dot{V}_H\right)\left(0.659 \times 62.43\right) = 41.14 \dot{V}_H \left(\text{kg/h}\right)$$

$$\dot{V}_B + \dot{V}_H = 33.62 \text{ ft}^3 / \text{h}$$

$$\dot{m}_B + \dot{m}_H = 54.88 \dot{V}_B + 41.14 \dot{V}_H = 1700 \text{ lb}_m$$

$$\Rightarrow \quad \dot{V}_B = \underline{\underline{23.06 \text{ ft}^3 / \text{h}}} \Rightarrow \dot{m}_B = \underline{\underline{1265.6 \text{ lb}_m / \text{h benzene}}}$$

$$\dot{V}_H = \underline{\underline{10.56 \text{ ft}^3 / \text{h}}} \Rightarrow \dot{m}_H = \underline{\underline{434.4 \text{ lb}_m / \text{h hexane}}}$$

3.6 2 lb 13 ounces is 2.8125 pounds, and 1 lb 12 ounces is 1.75 pounds. The mass of juice can be calculated by difference to be:

$$m_{\text{juice}} = 2.8125 - 1.75 = 1.0625 \text{ lb} \left(\frac{1000 \text{ g}}{2.2 \text{ lb}} \right) = 482.95 \text{ g}$$

$$V_{\text{juice}} = 1.75 \text{ cup} \left(\frac{236.6 \text{ cm}^3}{\text{cup}} \right) = 414.05 \text{ cm}^3$$

$$\rho_{\text{juice}} = \frac{482.95 \text{ g}}{414.05 \text{ cm}^3} = 1.17 \text{ g/cm}^3 \text{ so } \underline{\underline{\text{SG} = 1.17}}$$

Assumptions:

- All of the juice is squeezed from the pulp.
- Your measuring device measures juice volume accurately, and your scale weighs the oranges and pulp/peel accurately.

3.7 The total square footage available for capturing rain is: $1967(0.56)\ \text{ft}^2 = 1101.52\ \text{ft}^2$

The average rainfall in Tucson, given in the problem statement, was around 14 inches. So, the volume of water that could have been collected would be:

$$V = \text{Area} \times \text{Depth} = 1101.52\ \text{ft}^2 \left(\frac{14\ \text{in} \mid \text{ft}}{12\ \text{in}} \right) = 1285\ \text{ft}^3$$

We can convert this to volume in m^3:

$$V = 1285\ \text{ft}^3 \left(\frac{0.028317\ \text{m}^3}{\text{ft}^3} \right) = \underline{\underline{36.387\ \text{m}^3}}$$

or to gallons:

$$V = 36.387\ \text{m}^3 \left(\frac{264.17\ \text{gal}}{\text{m}^3} \right) = \underline{\underline{9612\ \text{gal}}}$$

The mass can be found by using the density of water and we get, for kg:

$$m = \rho \times V = \frac{36.357\ \text{m}^3 \mid 1000\ \text{kg}}{\text{m}^3} = \underline{\underline{36{,}357\ \text{kg}}}$$

$$w = mg = \frac{36{,}357\ \text{kg} \mid \text{lb}_\text{m} \mid 32.174\ \text{ft} \mid \text{lb}_\text{f}}{0.453593\ \text{kg} \mid \text{sec}^2 \mid 32.174\ \text{lb}_\text{m}\text{ft/sec}^2} = \underline{\underline{80{,}153\ \text{lb}_\text{f}}}$$

3.8 **(a)** $$V = \frac{195.5 \text{ kg } H_2SO_4 \mid 1 \text{ kg solution} \mid \text{L}}{0.35 \text{ kg } H_2SO_4 \mid 1.2563 \times 1.000 \text{ kg}} = \underline{\underline{445 \text{ L}}}$$

(b) $$V_{\text{ideal}} = \frac{195.5 \text{ kg } H_2SO_4 \mid \text{L}}{1.8255 \times 1.00 \text{ kg}}$$

$$+ \frac{195.5 \text{ kg } H_2SO_4 \mid 0.65 \text{ kg } H_2O \mid \text{L}}{0.35 \text{ kg } H_2SO_4 \mid 1.000 \text{ kg}} = 470 \text{ L}$$

$$\underline{\% \text{ error}} = \frac{470 - 445}{445} \times 100\% = \underline{\underline{5.6\%}}$$

3.9 Top layer is 15-miles long, 1.25 inches thick, has 5 lanes at 12 ft per lane. We can think of this top layer as a large rectangular slab as a rectangular prism, where volume (V) = $l \times w \times h$

$$l = \frac{15 \text{ miles} \left| \frac{3.2808 \text{ ft}}{0.0006214 \text{ miles}} \right.}{} = 79{,}000 \text{ ft}$$

$$w = \frac{5 \text{ lanes} \left| \frac{12 \text{ ft}}{1 \text{ lane}} \right.}{} = 60 \text{ ft}$$

$$h = \frac{1.25 \text{ in} \left| \frac{1 \text{ ft}}{12 \text{ in}} \right.}{} = 0.104 \text{ ft}$$

$$V_{\text{HMA}} = 79{,}000 \text{ ft} \times 60 \text{ ft} \times 0.104 \text{ ft} = 4.94 \times 10^5 \text{ ft}^3$$

Upper layer is composed of 95 wt% aggregate (SG = 2.7) and 5 wt% Asphalt Binder (SG = 1.03)

Basis = 1 g HMA

$$V_{\text{HMA}} = \frac{0.95 \text{ g aggregate} \left| \frac{\text{ml}}{2.7 \left| \frac{\text{ml}}{1 \text{ g}} \right.} \right.}{} + \frac{0.05 \text{ g binder} \left| \frac{\text{ml}}{1.03 \left| \frac{\text{ml}}{1 \text{ g}} \right.} \right.}{} = 0.4004 \text{ ml}$$

$$\rho_{\text{average HMA}} = \frac{1 \text{ g} \left| \frac{2.20462 \text{ lb}_\text{m}}{1000 \text{ g}} \right| \frac{10^6 \text{ ml}}{35.3145 \text{ ft}^3} \right.}{0.4004 \text{ ml}} = 155.9 \text{ lb}_\text{m}/\text{ft}^3$$

$$\text{Mass}_{\text{HMA}} = V_{\text{HMA}} \times \rho_{\text{HMA}}$$

$$= \frac{4.94 \times 10^5 \text{ ft}^3 \text{ HMA} \left| \frac{155.9 \text{ lb}_\text{m}}{\text{ft}^3} \right| \frac{\text{ton}}{2000 \text{ lb}_\text{m}} \right.}{} = \underline{\underline{3.85 \times 10^4 \text{ tons HMA}}}$$

Using the volume calculation above,

$$\text{Volume}_{\text{asphalt binder}} = \frac{4.94 \times 10^5 \text{ ft}^3 \text{ HMA} \left| \frac{0.0485 \text{ ml binder}}{0.4004 \text{ ml HMA}} \right.}{} = \underline{\underline{5.98 \times 10^4 \text{ ft}^3 \text{binder}}}$$

3.10 Buoyant force $\left(\text{up}\right) = \left(\text{down}\right)$ Weight of block

$\Downarrow$

Mass of oil displaced + Mass of water displaced = Mass of block

$\rho_{\text{oil}} \left(0.542\right)V + \rho_{H_2O} \left(1 - 0.542\right)V = \rho_c \, V$

From Table B.1: $\rho_c = 2.26 \text{ g/cm}^3$, $\rho_w = 1.00 \text{ g/cm}^3 \Rightarrow \rho_{\text{oil}} = 3.325 \text{ g/cm}^3$

$m_{\text{oil}} = \rho_{\text{oil}} \times V = 3.325 \text{ g/cm}^3 \times 35.3 \text{ cm}^3 = 117.4 \text{ g}$

$m_{\text{oil + flask}} = 117.4 \text{ g} + 124.8 \text{ g} = \underline{\underline{242 \text{ g}}}$

3.11 Buoyant force $\left(\text{up}\right)$=Weight of block $\left(\text{down}\right)$

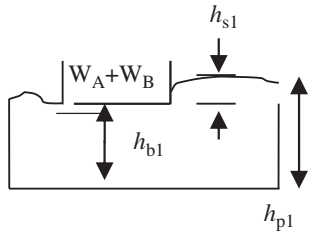
$\Rightarrow W_{\text{displaced liquid}} = W_{\text{block}} \Rightarrow (\rho Vg)_{\text{disp. Liq}} = (\rho Vg)_{\text{block}}$

Expt. 1: $\rho_{\text{w}}\left(1.5A\right)g = \rho_{\text{B}}\left(2A\right)g \Rightarrow \rho_{\text{B}} = \rho_{\text{w}} \times \dfrac{1.5}{2}$

$\xRightarrow{\rho_{\text{w}}=1.00\ \text{g/cm}^3} \rho_{\text{B}} = 0.75\ \text{g/cm}^3 \Rightarrow \underline{\underline{\left(SG\right)_{\text{B}} = 0.75}}$

Expt. 2: $\rho_{\text{soln}}\left(A\right)g = \rho_{\text{B}}\left(2A\right)g \Rightarrow \rho_{\text{soln}} = 2\rho_{\text{B}} = 1.5\ \text{g/cm}^3 \Rightarrow \underline{\underline{\left(SG\right)_{\text{soln}} = 1.5}}$

3.12



Before object is jettisoned

Let ρ_w = density of water. Note: $\rho_A > \rho_w$ (object sinks)

Volume displaced: $V_{d1} = A_b h_{s1} = A_b \left(h_{p1} - h_{b1} \right)$ (1)

Archimedes $\Rightarrow$ $\underbrace{\rho_w V_{d1} g}_{\text{weight of displaced water}} = W_A + W_B$

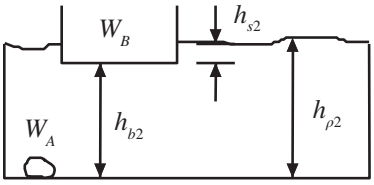
Subst. (1) for V_{d1}, solve for $(h_{p1} - h_{b1})$

$$h_{p1} - h_{b1} = \frac{W_A + W_B}{p_w g A_b} \tag{2}$$

Volume of pond water: $V_w = A_p h_{p1} - V_{d1} \overset{(1)}{\Rightarrow} V_w = A_p h_{p1} - A_b \left(h_{p1} - h_{b1} \right)$

$$\overset{\text{subst. (2) for } h_{p1} - h_{b1}}{\Longrightarrow} V_w = A_p h_{p1} - \frac{W_A + W_B}{\rho_w g} \Rightarrow h_{p1} = \frac{V_w}{A_p} + \frac{W_A + W_B}{\rho_w g A_p} \tag{3}$$

$$\overset{\text{subst. (3) for } h_{p1} \text{ in (2), solve for } h_{b1}}{\Longrightarrow} h_{b1} = \frac{V_w}{A_p} + \frac{\left(W_A + W_B \right)}{\rho_w g} \left[\frac{1}{A_p} - \frac{1}{A_b} \right] \tag{4}$$



After object is jettisoned

Let V_A = volume of jettisoned object = $\dfrac{W_A}{\rho_A g}$ (5)

Volume displaced by boat: $V_{d2} = A_b (h_{p2} - h_{b2})$ (6)

Archimedes $\Rightarrow \rho_w V_{d2} g = W_B$

Subst. for V_{d2}, solve for $(h_{p2} - h_{b2})$

$$h_{p2} - h_{b2} = \frac{W_B}{\rho_w g A_b} \tag{7}$$

Volume of pond water: $V_w = A_p h_{p2} - V_{d2} - V_A \overset{(5),\,(6)\ \&\ (7)}{\Longrightarrow} V_w = A_p h_{p2} - \dfrac{W_B}{\rho_w g} - \dfrac{W_A}{\rho_A g}$

$$\overset{\text{solve for } h_{p2}}{\Rightarrow} h_{p2} = \frac{V_w}{A_p} + \frac{W_B}{\rho_w g A_p} + \frac{W_A}{\rho_A g A_p} \tag{8}$$

$$\overset{\text{subst. } (8) \text{ for } h_{p2} \text{ in } (7), \text{ solve for } h_{b2}}{\Rightarrow} h_{b2} = \frac{V_w}{A_p} + \frac{W_B}{\rho_w g A_p} + \frac{W_A}{\rho_A g A_p} - \frac{W_B}{\rho_w g A_b} \tag{9}$$

(a) Change in pond level

$$h_{p2} - h_{p1} \overset{(8)-(3)}{=} \frac{W_A}{A_p g}\left[\frac{1}{\rho_A} - \frac{1}{\rho_W}\right] = \frac{W_A\left(\rho_w - \rho_A\right)}{\rho_A \rho_w g A_p} < 0 \quad (\text{since } \rho_w < \rho_A)$$

$\Rightarrow$ the pond level falls

(b) Change in boat level

$$h_{b2} - h_{b1} \overset{(9)-(4)}{=} \frac{W_A}{g}\left[\frac{1}{\rho_A A_p} - \frac{1}{\rho_W A_p} + \frac{1}{\rho_W A_b}\right] \overset{(5)}{=} \overset{>0}{\left(\frac{V_A}{A_p}\right)}\left[1 + \overbrace{\left(\frac{\rho_A}{\rho_W}\left(\frac{A_p}{A_b} - 1\right)\right)}^{>0}\right] > 0$$

$\Rightarrow$ the boat rises

3.13 **(a)** We assume the tunnel to be a rectangular shape:

$$A_{\text{tunnel}} = A_{\text{top}} + A_{\text{left}} + A_{\text{right}} = wl + hl + hl = wl + 2hl = 8 \times 148 + 2 \times 12 \times 148 = 4736 \text{ ft}^2$$

$$\text{Number of cans} = \frac{A_{\text{tunnel}}}{A_{\text{can}}} = \frac{4736}{25} = 189.44 \approx \underline{\underline{190 \text{ cans}}}$$

(**b**) Top hazards (could list any of the following three):

(1) Eye irritation (wear safety glasses to avoid getting in your eyes)

(2) Skin irritation (wash with soap and water if you get spray paint on your hands)

(3) Flammable vapor (don't smoke while spray painting or have open flames)

(4) Inhalation (don't spray paint in an enclosed area without ventilation)

3.14 **(a)** $$\rho_{bulk} = \frac{2.93 \text{ kg } CaCO_3}{\text{L } CaCO_3} \left| \frac{0.70 \text{ L } CaCO_3}{\text{L total}} \right. = \underline{\underline{2.05 \text{ kg/L}}}$$

(b) $$W_{bag} = \rho_{bulk} V g = \frac{2.05 \text{ kg}}{\text{L}} \left| \frac{50 \text{ L}}{} \right| \frac{9.807 \text{ m/s}^2}{} \left| \frac{1 \text{ N}}{1 \text{ kg} \cdot \text{m/s}^2} \right. = \underline{\underline{1.00 \times 10^3 \text{ N}}}$$

Neglected the weight of the bag itself and of the air in the filled bag.

(c) The limestone would fall short of filling three bags, because

– The powder would pack tighter than the original particles.

– You could never recover 100% of what you fed to the mill.

3.15 **(a)** $$W_b = m_b g = \frac{122.5 \text{ kg} \mid 9.807 \text{ m/sec}^2 \mid 1 \text{ N}}{\mid \mid 1 \text{ kg}\cdot\text{m/sec}^2} = \underline{\underline{1202 \text{ N}}}$$

$$V_b = \frac{W_b - W_I}{\rho_w g} = \frac{(1202 \text{ N} - 44.0 \text{ N}) \mid 1 \text{ kg}\cdot\text{m/sec}^2}{0.996 \text{ kg/L} \times 9.807 \text{m/sec}^2 \mid 1 \text{ N}} = \underline{\underline{119 \text{ L}}}$$

$$\rho_b = \frac{m_b}{V_b} = \frac{122.5 \text{ kg}}{119 \text{ L}} = \underline{\underline{1.03 \text{ kg/L}}}$$

(b) $m_f + m_{nf} = m_b$ (1)

$x_f = \dfrac{m_f}{m_b} \Rightarrow m_f = m_b x_f$ (2)

$(1), (2) \Rightarrow m_{nf} = m_b (1 - x_f)$ (3)

$V_f + V_{nf} + V_{lungs} + V_{other} = V_b$

$$\overset{(2),(3)}{\Rightarrow} m_b \left(\frac{x_f}{\rho_f} + \frac{1 - x_f}{\rho_{nf}} \right) = \frac{m_b}{\rho_b} \Rightarrow x_f \left(\frac{1}{\rho_f} - \frac{1}{\rho_{nf}} \right) = \frac{1}{\rho_b} - \frac{1}{\rho_{nf}} \Rightarrow \underline{\underline{x_f = \frac{1/\rho_b - 1/\rho_{nf}}{1/\rho_f - 1/\rho_{nf}}}}$$

(c) $$x_f = \frac{1/\rho_b - 1/\rho_{nf}}{1/\rho_f - 1/\rho_{nf}} = \frac{1/1.03 - 1/1.1}{1/0.9 - 1/1.1} = \underline{\underline{0.31}}$$

(d) $V_f + V_{nf} + V_{lungs} + V_{other} = V_b$

$$\frac{m_f}{\rho_f} + \frac{m_{nf}}{\rho_{nf}} + V_{lungs} + V_{other} = \frac{m_b}{\rho_b}$$

Note: $m_f = m_b x_f$ and $m_{nf} = m_b (1 - x_f)$

$$m_b \left(\frac{x_f}{\rho_f} + \frac{1 - x_f}{\rho_{nf}} \right) + (V_{lungs} + V_{other}) = m_b \left(\frac{1}{\rho_b} \right)$$

$$\Rightarrow x_f \left(\frac{1}{\rho_f} - \frac{1}{\rho_{nf}} \right) = \frac{1}{\rho_b} - \frac{1}{\rho_{nf}} - \frac{V_{lungs} + V_{other}}{m_b}$$

$$\Rightarrow x_f = \frac{\left(\frac{1}{\rho_b} - \frac{1}{\rho_{nf}} \right) - \left(\frac{V_{lungs} + V_{other}}{m_b} \right)}{\left(\frac{1}{\rho_f} - \frac{1}{\rho_{nf}} \right)} = \frac{\left(\frac{1}{1.03} - \frac{1}{1.1} \right) - \left(\frac{1.2 + 0.1}{122.5} \right)}{\left(\frac{1}{0.9} - \frac{1}{1.1} \right)} = \underline{\underline{0.25}}$$

3.16

(a)

$$P = \rho g h = \frac{1.03 \times 62.4\ \text{lb}_\text{m}}{\text{ft}^3} \left| \frac{32.174\ \text{ft}}{\text{s}^2} \right| \frac{5053\ \text{ft}}{} \left| \frac{\text{lb}_\text{f}}{32.174\ \text{lb}_\text{m}\frac{\text{ft}}{\text{s}^2}} \right| \frac{\text{ft}^2}{12^2\ \text{in}^2} \left| \frac{\text{psi}}{\frac{\text{lb}_\text{f}}{\text{in}^2}} \right| = \underline{\underline{2255\ \text{psig}}}$$

(b)

$$\rho = \frac{P}{gh} = \frac{4400\ \text{lb}_\text{f}}{\text{in}^2} \left| \frac{}{32.174\ \frac{\text{ft}}{\text{s}^2}} \right| \frac{}{5053\ \text{ft}} \left| \frac{32.174\ \text{lb}_\text{m}\frac{\text{ft}}{\text{s}^2}}{\text{lb}_\text{f}} \right| \frac{12^2\ \text{in}^2}{\text{ft}^2} = 125.4\ \frac{\text{lb}_\text{m}}{\text{ft}^3}$$

$$SG = \frac{\rho}{\rho_{H_2O}} = \frac{125.4\ \frac{\text{lb}_\text{m}}{\text{ft}^3}}{62.43\ \frac{\text{lb}_\text{m}}{\text{ft}^3}} = \underline{\underline{2.0}}$$

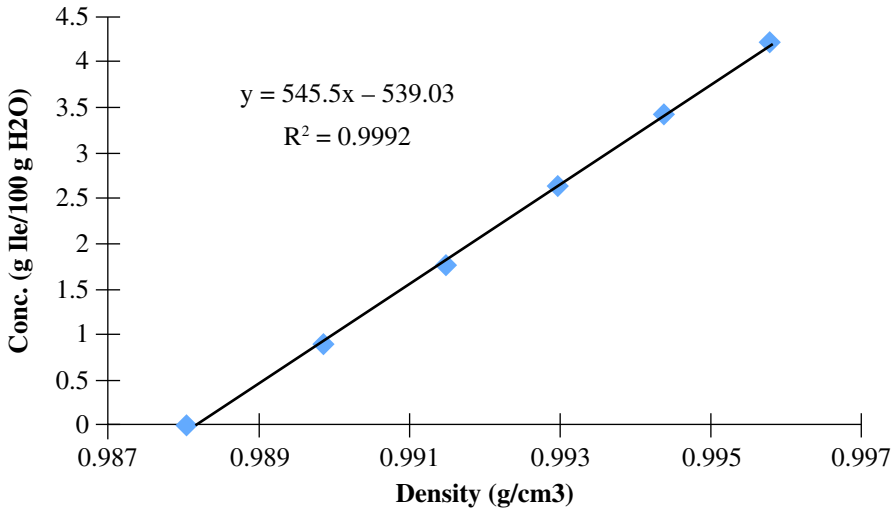
(c)

$$\rho_{\text{mix}} = \frac{m_\text{B} + m_\text{S}}{V_B + V_S} = \frac{1}{\frac{V_B + V_S}{m_\text{B} + m_\text{S}}} = \frac{1}{\frac{V_B m_\text{B}}{(m_\text{B} + m_\text{S})} + \frac{V_S m_\text{S}}{(m_\text{B} + m_\text{S})}}$$

$$\rho_{\text{mix}} = \frac{1}{\frac{x_\text{B}}{\rho_\text{B}} + \frac{1 - x_\text{B}}{\rho_\text{S}}} \Rightarrow \left(\frac{x_\text{B}}{4.37} + \frac{1 - x_\text{B}}{1.03}\right) = 0.5 \Rightarrow x_\text{B} = \underline{\underline{0.63}}$$

(d) If x_B was significantly smaller, the overall specific gravity of the mud would be much lower, which would mean it would not settle at the well head and the oil would escape.

3.17 (a)



From the plot above, $r = 545.5\rho - 539.03$

(b) For $\rho = 0.9940$ g/cm^3, $r = 3.197$ g Ile/100g H_2O

$$\dot{m}_{Ile} = \frac{150\ \text{L}}{\text{h}} \left| \frac{0.994\ \text{g}}{\text{cm}^3} \right| \frac{1000\ \text{cm}^3}{\text{L}} \left| \frac{3.197\ \text{g Ile}}{103.197\ \text{g sol}} \right| \frac{1\ \text{kg}}{1000\ \text{g}} = \underline{\underline{4.6\ \text{kg Ile/h}}}$$

(c) The density of H_2O increases as T decreases, therefore the density was higher than it should have been to use the calibration formula. The valve of r and hence the Ile mass flow rate calculated in part (b) would be <u>too high</u> .

3.18 (a) The problem provides the following data:

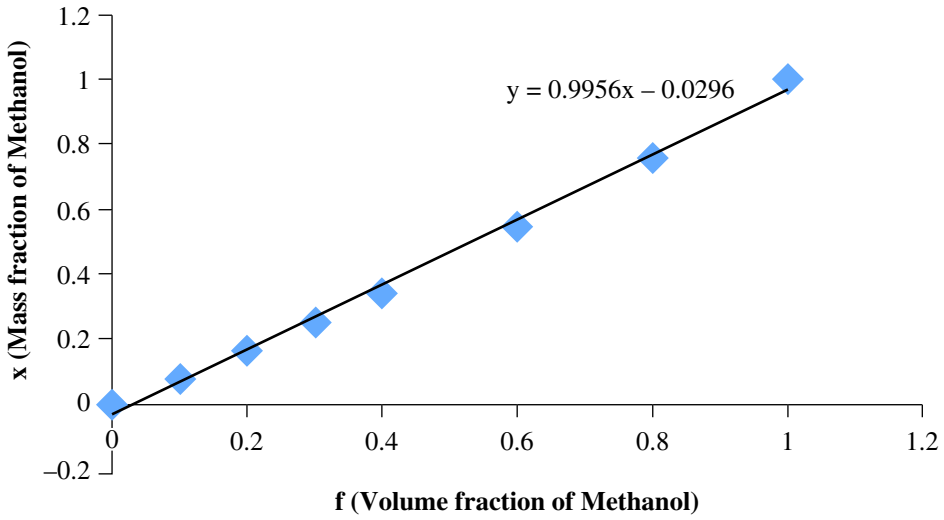
Volume % Methanol	0	10	20	30	40	60	80	100
Volume % Water	100	90	80	70	60	40	20	0
Solubility (g/100mL solvent)	22.72	18.98	11.58	6.415	4.205	1.805	0.85	0.65
Solution Density (g/mL)	1	0.98	0.97	0.95	0.94	0.91	0.88	0.79

Specific gravities from Table B.1: SG Methanol = 0.792, SG Water = 1

Choosing a basis of 100 mL, we can calculate the mass of water and solvent using $m = \rho V = SG \times \rho_{H_2O} \times V$. We can then find the mass fraction of methanol, *x*.

Mass of Methanol (g)	0	7.92	15.84	23.76	31.68	47.52	63.36	79.2
Mass of Water (g)	100	90	80	70	60	40	20	0
Mass of Solvent (g)	100	97.92	95.84	93.76	91.68	87.52	83.36	79.2
Mass Fraction of Methanol (*x*)	0	0.08	0.17	0.25	0.35	0.54	0.76	1
Volume Fraction of Methanol (*f*)(given)	0	0.10	0.20	0.30	0.40	0.60	0.08	1.0

We can now plot mass fraction of methanol vs. volume fraction of methanol:



$x = 0.9956\,f - 0.0296$

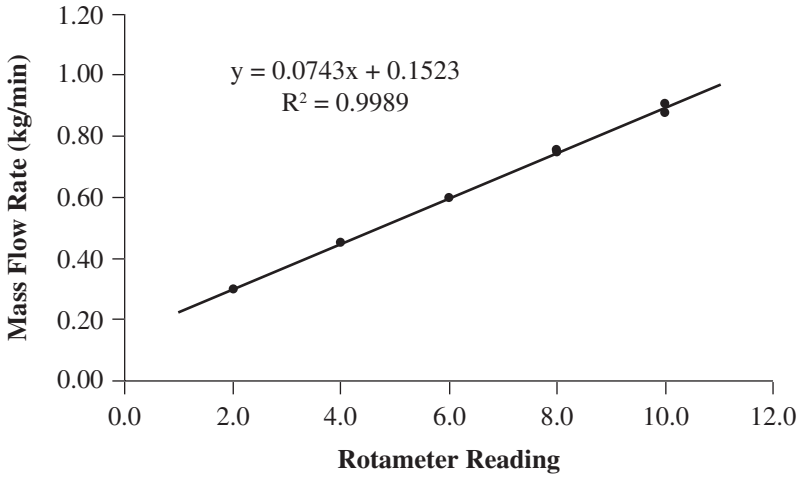
(b) Solvent Composition: Solvent = Methanol + Water

Mass Fraction of Methanol	0	0.08	0.17	0.25	0.35	0.54	0.76	1
Mass Fraction of Water	1	0.92	0.83	0.75	0.65	0.46	0.24	0

Solubility:

Mass of Serine (g)	100	98	97	95	94	91	88	79
Mass of Solution (g)	100	97.92	95.84	93.76	91.68	87.52	83.36	79.2
Solubility (g serine/g solution)	1	1.00	1.01	1.01	1.03	1.04	1.06	1.00

3.19 (a)



From the plot, $R = 5.3 \Rightarrow \dot{m} = 0.0743\ (5.3) + 0.1523 =$ <u>0.55 kg/min</u>

(b)

Rotameter Reading	Collection Time (min)	Collected Volume (cm^3)	Mass Flow Rate (kg/min)	Difference Duplicate (D_i)	Mean D_i
2	1	297	0.297		
2	1	301	0.301	0.004	
4	1	454	0.454		
4	1	448	0.448	0.006	
6	0.5	300	0.600		
6	0.5	298	0.596	0.004	0.0104
8	0.5	371	0.742		
8	0.5	377	0.754	0.012	
10	0.5	440	0.880		
10	0.5	453	0.906	0.026	

$\bar{D}_i = \frac{1}{5}\left(0.004 + 0.006 + 0.004 + 0.012 + 0.026\right) =$ <u>0.0104 kg/min</u>

<u>95% confidence limits</u>: $(0.610 \pm 1.74\bar{D}_i)$ kg/min = <u>0.610 ± 0.018 kg/min</u>

There is roughly a 95% probability that the true flow rate is between 0.592 kg/min and 0.628 kg/min.