

## 1.2 Units Conversion

### Viscosity

$$\mu = 10 \text{ Centipoise} = 10 \times 0.01 \times 10^{-1} \frac{\text{kg}}{\text{m s}} = 0.01 \frac{\text{kg}}{\text{m s}}$$

1 poise

$$= 0.01 \times \frac{0.3048}{0.4536} = 6.72 \times 10^{-3} \frac{\text{lbm}}{\text{ft s}}$$

$\frac{\text{kg}}{\text{m s}} \quad \frac{\text{lbm}}{\text{kg}} \quad \frac{\text{m}}{\text{ft}}$

(Useful conversion factors:  $1 \text{ cp} = 0.000672 \text{ lbm/ft s}$   
 $= 2.42 \text{ lbm/ft hr}$ )

### Density

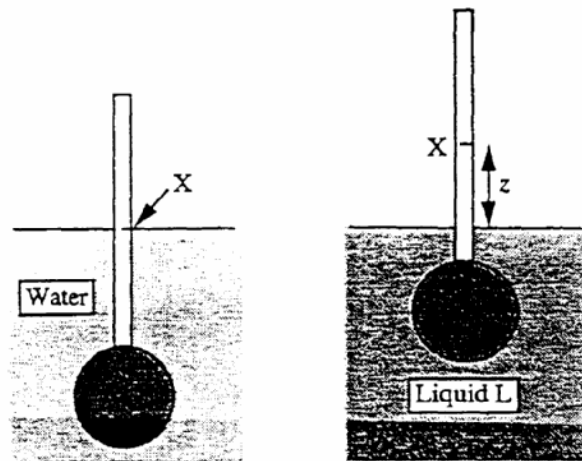
$$\rho = 0.8 \times 1 \times \frac{(100)^3}{1000} = 800 \frac{\text{kg}}{\text{m}^3}$$

$\frac{\text{g}}{\text{cm}^3} \quad \frac{\text{kg}}{\text{g}} \quad \left(\frac{\text{cm}}{\text{m}}\right)^3$

$$= 0.8 \times 62.4 = 49.9 \frac{\text{lbm}}{\text{ft}^3}$$

1.14

## Hydrometer



Since the same weight (that of the hydrometer) is supported by the displaced liquid in both cases:

$$Mg = V \rho_w g = (V - Az) \rho_w s g$$

mass of hydrometer                      ↑  
Density of water

Cancellation of  $\rho_w g$  and solution for  $s$  gives

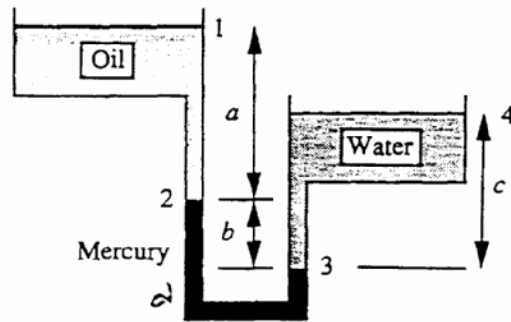
$$s = \frac{1}{1 - \frac{Az}{V}}$$

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1.15

Three-Liquid Manometer



From hydrostatics:

$$p_4 = p_1 + \rho_o a g + \rho_m b g - \rho_w c g = p_1$$

Cancel  $p_1$  and divide by  $\rho_w g$ , with  $s = \frac{\rho}{\rho_w}$

$$s_o a + s_m b = c$$

$$b = \frac{c - s_o a}{s_m} = \frac{48 - 0.8 \times 72}{13.6} = -0.706$$

Thus the diagram is incorrect as drawn,  
and the mercury rises on the right by  
0.706 in.

1.30

Pressures in Oil and Gas Well

Variation of pressure with elevation for an ideal gas:

$$\frac{dp}{dz} = -\rho g = -\frac{Mp}{RT} g$$

Separate variables and integrate:

$$\int_{p_A}^{p_B} \frac{dp}{p} = -\frac{Mg}{RT} \int_h^0 dz$$

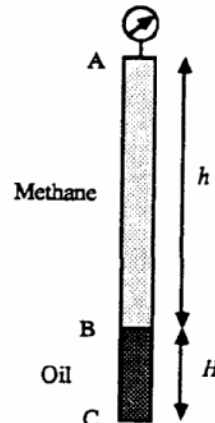


Fig. 1 Well containing oil and methane.

$$\ln \frac{p_B}{p_A} = + \frac{Mg h}{RT} = \frac{16 \times 32.2 \times 10,000}{10.73 \times 560 \times 32.2 \times 144} = 0.185$$

$$[=] \frac{\text{lb}_m}{\text{mole}} \frac{\text{ft}}{\text{s}^2} \frac{\text{ft}}{\text{lb}_f \text{ft}^3} \frac{\text{in}^2 \text{mole}^\circ \text{R}}{\text{lb}_f \text{ft}^3} \text{ OR } \frac{\text{lb}_f \text{ s}^2 \text{ ft}^2}{\text{lb}_m \text{ ft in}^2} \text{ (all units cancel)}$$

$$p_B = p_A e^{0.185} = 1014.7 \times 1.203 = \underline{\underline{1221 \text{ psia}}}$$

Pressure increase in the oil section

$$p_C - p_B = \rho_o g H = \frac{0.75 \times 62.4 \times 32.2 \times 2000}{32.2 \times 144}$$

$$= \underline{\underline{650 \text{ psi}}}$$

1.34

Blake-Kozeny Equation

$$\frac{p_1 - p_2}{L} = 150 \frac{\mu v_0}{D_p^2} \frac{(1-E)^2}{E^3}$$

Check dimension

$$\frac{M}{L^2 T^2} \frac{1}{L} = \frac{M}{L T} \frac{L}{T} \frac{1}{L^2} = \frac{M}{L^2 T^2}$$

Same, hence  $E$  is dimensionless. Also, examination of  $(1-E)$  gives same conclusion assuming "1" is dimensionless.

Numerical value

$$\frac{E^3}{(1-E)^2} = \frac{150 \mu v_0 L}{(p_1 - p_2) D_p^2} = \frac{150 \times \frac{\text{g}}{\text{cm s}} \times 0.22 \times 0.1 \times 6 \times 30.48}{453.6 \times 75 \times 0.1^2 \times 32.2}$$

$$= 0.05509$$

$\frac{\text{ft}}{\text{s}}$      $\frac{\text{cm}}{\text{ft}^2}$   
 $\frac{\text{g}}{\text{lbm}}$      $\frac{\text{lb}_f}{\text{in}^2}$      $\frac{\text{in}^2}{\text{lb}_m \text{ ft}}$      $\frac{\text{lb}_f \text{ ft}}{\text{lb}_f \text{ s}^2}$

Rearrange to  $E = f(E) = [0.05509 \times (1-E)^2]^{1/3}$

Successive substitution

<u>L</u>	<u>E<sub>L</sub></u>	<u>f(E<sub>L</sub>)</u>
1	0.5000	0.2397
2	0.2397	0.3170
3	0.3170	0.3014
4	0.3014	0.2996
5	0.2996	0.3001
6	0.3001	0.3000

E = 0.300