Any pressure reading can be expressed as a length or head, \( h = p/\rho g \). What is standard sea-level pressure expressed in (a) ft of ethylene glycol, (b) in Hg, (c) m of water and, (d) mm of Methanol? Assume all fluids are at 20°C.

\[
\text{Standard sea level press}, \quad p_0 = 1 \text{ atm} \\
= 101325 \text{ N/m}^2 \\
= 2116.2 \text{ lb/ft}^2
\]

(a) \[ h = \frac{p}{\gamma_{\text{EG}}} = \frac{2116.2 \text{ lb/ft}^2}{6.9813 \text{ lb/ft}^3} = 303 \text{ ft.} \]

(b) \[ p_{\text{Hg}} = 13550 \text{ kPa/m}^3 = 13550 \times 0.00141 \text{ slugs/ft}^3 = 96.3 \text{ slugs/ft}^3 \]
\[ h = \frac{2116.2}{96.3 \times 32.2} = 2.5 \text{ ft} \times 12 = 24.98 \text{ in.} \]

(c) \[ p_{\text{H}_2O} = 998 \text{ kPa/m}^3 \quad \rho_g = 9790 \text{ N/m}^3 \]
\[ h = \frac{101325}{9790} = 10.35 \text{ m} \]

(d) \[ \rho_{\text{MHz}} = 791 \text{ kPa/m}^3 \Rightarrow (\rho g)_m = 7752 \text{ N/m}^3 \]
\[ h = \frac{101325}{7752} = 13.07 \text{ m} = 13070 \text{ mm} \]
#2. (10)

In the figure, pressure gage $A$ reads 1.5 kPa (gage). The fluids are at $20^\circ$C. Determine the elevation $z$, in meters, of the liquid levels in the open piezometer tube $B$ and $C$.

\[ \gamma_a = 11.81 \text{ N/m}^3 \]
\[ \gamma_g = 6.67 \times 10^3 \text{ N/m}^3 \]
\[ \gamma_{glyc} = 1241 \times 10^3 \text{ N/m}^3 \]

Fundamental eq:
\[ p = \gamma h + p_0 \]

On line $D$:
\[ 1.5 \times 10^3 + 11.81 \times 2 + 6.67 \times 10 \times 0.75 \]
\[ = 6526.12 \]
\[ = 6670 \times 21 \]
\[ z_1 = \frac{6526.12}{6670} \]
\[ A_{\text{above}} = 0.98 \text{ m OS/2.73 m} \]

On line $E$:
\[ 2 = 1500 + 23.62 + 6.67 \times 10^3 \times 1.5 \times 0.5 \times 12 \times 10^2 \]
\[ = 12400 \]
\[ = 1.48 \text{ m OS/1.93 m} \]
The closed tank in the figure is at 20°C. If the pressure at point A is 95 kPa absolute, what is the absolute pressure at point B in kPa? What percentage error do you make by neglecting the specific weight of the air?

\[
\begin{align*}
\text{At } 20^\circ C: \gamma_a &= 11.81 \text{ N/m}^2 \\
\gamma_{H_2O} &= 9.790 \text{ N/m}^2
\end{align*}
\]

\[
\begin{align*}
\text{Area} &\quad 4 \text{ m} \quad 2 \text{ m} \\
\text{Height} &\quad 2 \text{ m} \quad 4 \text{ m}
\end{align*}
\]

(a) \[9.5 \times 10^3 + 4 \gamma_{air} - 2 \gamma_{H_2O} - 2 \gamma_{air} = P_B\]

\[
P_B = 95000 + 2 \gamma_{air} - 2 \gamma_{H_2O}
\]

\[
= 95000 + 2 (11.81 - 9.790)
\]

\[
= 95000 + 2 (11.81 - 9.790)
\]

\[
= 95000 - 19556.4 = 75444 \text{ Pa}
\]

(b) Neglect air \( \Rightarrow \gamma_{air} = 0 \)

\[
P_B = 95000 - 2 \times 9.790 = 75420 \text{ Pa}
\]

\[
\text{Error} = \frac{75420 - 75444}{75444} \times 100
\]

\[
= 0.32 \%
\]
#4. (10)
In the figure all fluids are at 20°C. Determine the pressure difference (Pa) between points A and B.

\[ \gamma_B = 881 \times 9.8 = 8634 \text{ N/m}^2 \]
\[ \gamma_{air} = 11.8 \text{ N/m}^2 \]
\[ \gamma_{H_2O} = 9790 \text{ N/m}^2 \]
\[ \gamma_{K} = 8044 \text{ N/m}^2 \]

\[ p_A + \gamma_B \times 0.2 - 0.08 \times \gamma_M - \gamma_K \times 0.32 + 0.4 \times \gamma_{H_2O} - 0.14 \times \gamma_{H_2O} - \gamma_{air} \times 0.09 = p_B \]

\[ \Rightarrow p_A + 0.2 \gamma_B - 0.08 \gamma_M - \gamma_K \times 0.32 + 0.4 \times \gamma_{H_2O} - 0.09 \gamma_{air} = p_B \]

\[ p_A + 0.2 \times 8634 - 0.08 \times 13300 - 0.32 \times 8044 + 0.4 \times 9790 - 0.09 \times 11.8 = p_B \]

\[ p_A + 1727 - 10640 = 8574.08 + 3955.4 - 1.062 = p_B \]

\[ p_A - 8943 = p_B \]

\[ \Rightarrow p_A - p_B = 8943 \text{ Pa} \]
For the inverted manometer in the figure, all fluids are at 20°C. If $p_B - p_A = 97$ kPa. What must the height $H$ be in cm?

\[ p_A - H \times \gamma_{H_2O} - 0.18 \times 0.827 \times 1000 \times 9.8 + (0.18 + H + 0.35)(133000) = p_B \]

\[ \Rightarrow p_B - p_A = -H \gamma_{H_2O} - 1459 + 23940 + 133000H + 46520 \]

\[ = (133000 - 9700)H + 69031 \]

\[ 97000 = 123210H + 69031 \]

\[ \Rightarrow H = \frac{97000 - 69031}{123210} = 0.827 \text{ m} \]

\[ \approx 82.7 \text{ cm} \]
Water flows upward in a pipe slanted at 30°, as shown. The mercury manometer reads \( h = 12 \) cm. Both fluids are at 20°C. What is the pressure difference \( p_1 - p_2 \) in the pipe?

\[
h_1 = 8 + \tan 30° = 1.155 \text{ m}.
\]

\[
p_1 + h \gamma_{H_2O} - h \gamma_{Hg} - 1.155 \times \gamma_{H_2O} = p_2.
\]

\[
= p_1 - p_2 = h \gamma_{Hg} + 1.155 \times \gamma_{H_2O} - h \gamma_{H_2O}
\]

\[
= 0.12 \times 133000 + 1.155 \times 9790 - 0.12 \times 97
\]

\[
= 26043 \text{ Pa} = 26.1 \text{ kPa}
\]
Both the tank and the tube are open to the atmosphere. If $L = 2.13 \text{ m}$, what is the angle of tilt $\theta$ of the tube?

![Diagram showing oil and water levels and angle $\theta$.]

Equating pressures at datum line:

\[
\text{Patm} + 0.8 \times 9790 \times 0.5 + 9790 \times 0.5 = \text{Patm} + 9790 \times 2.13
\]

\[
8811 = 20852.7 \sin \theta
\]

\[
\theta = \sin^{-1} \left( \frac{8811}{20852.7} \right) = 24.494^\circ
\]

\[\approx 25^\circ\]
The deepest known point in the ocean is 11,034 m in the Mariana Trench in the Pacific. At this depth the specific weight of seawater is approximately 10,520 N/m³. At the surface, \( \gamma = 10,050 \) N/m³. Estimate the absolute pressure at this depth, in atm.

\[
\frac{dP}{dz} = -\gamma(z)
\]

\[
\gamma(z) = 10520 + \frac{d\gamma}{dz}(z) = 10520 + \frac{10050 - 10520}{z_2 - z_1} \cdot z
\]

\[
= 10520 - \frac{470}{11034} \cdot z
\]

\[
= 10520 - 0.0426 \cdot z
\]

So

\[
\int_{P_1}^{P_2} dP = \int_{z_1}^{z_2} (0.0426 \cdot z - 10520) \, dz
\]

\[
P_2 - P_1 = (0.0426 \cdot \frac{z^2}{2} - 10520 \cdot z) \bigg|_{z_1}^{z_2} = \gamma h
\]

\[
P_{atm} - P_{seabed} = \frac{0.0426 \cdot (11034)^2 - 10520 \cdot (11034)}{8}
\]

\[
= 2593257 - 1.16078 \times 10^8
\]

\[
= -1.135 \times 10^8 \text{ N/m}^2
\]

\[
P_{seabed} = P_{atm} + 1.135 \times 10^8 \text{ N/m}^2.
\]

\[
= (1 + 1.121) = 11.81 \text{ atm}
\]

\( \approx 113.6 \text{ MPa} \)
The two-fluid differential manometer shown below can measure the very small pressure difference \( P_A - P_B \) accurately. Density \( \rho_2 \) is only slightly larger than that of the upper fluid \( \rho_1 \). Derive an expression for the proportionality between \( h \) and \( P_A - P_B \) if the reservoirs are very large.

\[
\begin{align*}
\rho_1 + \gamma_1 h_1 &= \gamma_2 h - \gamma_1 (h_1 - h) = P_B \\
\rho_A - P_B &= \gamma_2 h + \gamma_1 (h_1 - h) - \gamma_1 h_1 \\
&= \gamma_2 h - \gamma_1 h \\
&= h (\gamma_2 - \gamma_1) \\
\rho_A - P_B &= gh (\rho_2 - \rho_1)
\end{align*}
\]