1. Definitions

Pressure: Force per Area
- Units of N/m², lb/in² (i.e., psi), etc.
- Force usually caused by a fluid (gas or liquid)
  - Gravity
  - Change in temperature (constant volume)
  - Pump
- Measurement devices
  - Pressure gauge (dial or tire gauge)
  - Pressure transducer (electronic)
  - Manometer or barometer

Atmospheric Pressure
Definition: The local pressure of the atmosphere or the pressure of the surrounding air
- Can be thought of as the pressure at the base of a column of air (\( \rho \text{air}gh \))
- Decreases with increase in elevation
- Ambient pressure is the same as atmospheric pressure (used interchangeably)
- Atmospheric or Ambient Pressure is not necessarily 1 atm! (only true at sea level)
  - In Provo, \( P_{\text{amb}} \approx 12.6 \text{ psia} \)

2. Gauge vs. Absolute Pressure

- **Absolute pressure**: the pressure relative to a perfect vacuum (no molecules present)
- **Gauge pressure**: the pressure relative to the ambient or atmospheric pressure at the measurement point

\[
\begin{align*}
    P_{\text{gauge}} &= P_{\text{absolute}} - P_{\text{ambient}} \\
    P_{\text{gauge}} &= P_{\text{vessel}} - P_{\text{outside air}}
\end{align*}
\]

- psig = lb/in² gauge pressure
- psia = lb/in² absolute pressure

Comments on Homework

- Temperature conversion
  \( T (^{\circ}R) = T (K) \times 1.8 \)
  \( T (^{\circ}C) = T (K) - 273.15 \)
  \( T (^{\circ}F) = T (^{\circ}R) - 460 \)
- However, difference in temperature is:
  \( \Delta T (^{\circ}C) = \Delta T (K) \)
  \( \Delta T (^{\circ}F) = \Delta T (^{\circ}R) \)
  \( \Delta T (^{\circ}R) = 1.8 \times \Delta T (^{\circ}C) \)
Because of elevation, $P_{\text{ambient}} = 11 \text{ psia}$

What is the gauge pressure of the spherical container?

- How can the gauge pressure change when the absolute pressure remains the same?
- What does a tire pressure gauge read when the bike tire is totally flat?
- What is the absolute pressure inside of a flat tire?
- In a pressurized gas bottle, what does the gauge read when it is empty?

This type of pressure gauge only measures a pressure difference! (usually)

• Always use absolute pressure when:
  – Using pressure in a formula like ideal gas equation ($PV = nRT$)
  – Taking ratios of pressures
• You can use gauge pressure when:
  – Taking differences in pressure
  ($\Delta P_{\text{gauge}} = \Delta P_{\text{absolute}}$)

3. Pressure Head

- Weight of the fluid produces a force
  – pressure is highest at the bottom of the column
  – Why?
- Force/Area provides the pressure
- The pressure at the bottom does not depend on the diameter of the column (height only)
  – Why?
- Any pressure can be expressed as an equivalent height of a liquid
  – called a Pressure Head, $P_r$
  – units of length, like "mm Hg" or "inches of H$_2$O"

$P = P_0 + \rho gh$

• We walk around with a column of air pressing down on our head
• Weight of air per area is the atmospheric pressure
• Kind of like the pole throw in Celtic games
Pressure Head Example

- Use Eq. 3.4-2 to calculate $P_h$ for a column of Hg (SG = 13.6) that is equivalent to 1 atm.

$$P = \rho_{\text{fluid}} g P_h$$  ($P_h$ = head of fluid, units of height)

- Repeat the above calculation for H$_2$O.

This is why we can have units such as mm Hg or ft H$_2$O for a pressure, even though this is not strictly a force per unit area!

Table in front of book

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 atm</td>
<td>101.325 kPa</td>
</tr>
<tr>
<td>1 atm</td>
<td>101,325 N/m$^2$</td>
</tr>
</tbody>
</table>

Note that a length of a liquid is a pressure head, and refers to $\rho g h$ or $\rho g P_h$ (where $P_h$ is the pressure head).

4. Pressure Measurement - Manometers

- Principle: Any two points at the same height in a static continuous fluid must be at the same pressure.
- Otherwise, the column height would move!
- Where does this apply?

4. Pressure Measurement - Manometers

- Procedure
  - Draw a horizontal line at the level where the same type of fluid exists in both arms of the tube (i.e., points a and b in Fig. 3.4-6)
  - Add up the pressures on the left ($P_1 + \rho_1 g d_1$)
  - Add up the pressures on the right ($P_2 + \rho_2 g d_2 + \rho g h$)
  - Set the two equal and rearrange to solve for the unknown pressure (or $P_1 - P_2$)

Note: forces must be used if the area isn’t constant.

Manometer Practice Problems

- See Eqns. 3.4-5, 6, & 7
  - These are specific equations
  - Better to learn general concept and derive equation for each scenario
Problem 3-53 (4th Ed.)

• Two mercury manometers, one open-end and the other sealed-end, are attached to an air duct. The reading on the open-end manometer is 25 mm and that on the sealed-end manometer is 800 mm. Determine the absolute pressure in the duct, the gauge pressure in the duct, and the atmospheric pressure, all in mm Hg.

Shortcut with Head Form

\[ \rho_a g h_a + \rho_b g h_b + \cdots = \rho_r g h_r + \rho_a g h_a + \cdots \]

• Now convert to the equivalent height of water by dividing by \( g \) and \( \rho_{\text{water}} \)

\[ SG_a h_a + SG_b h_b + \cdots = SG_r h_r + SG_a h_a + \cdots \]

and all terms have units of \( h_{\text{Hg}} \)

• Proof: Given \( P_1 \) as a height of Hg, divide by \( \rho_{\text{water}} g \) and see what the units become

\[ P_1 = \rho_{\text{Hg}} g h_{\text{Hg}} = \rho_{\text{Hg}} g h_{\text{Hg}}, \text{ so} \]

\[ h_{\text{Hg}} = \frac{\rho_{\text{Hg}} g h_{\text{Hg}}}{\rho_{\text{Hg}} g} = SG_{\text{Hg}} h_{\text{Hg}} \]

Concrete is pumped 100 ft in the air.
What pressure is need in the pump (neglecting velocity and friction)?
1. A manometer containing mercury is used to measure the gas pressure in a pipe. What is the gauge pressure of the gas in mm Hg?

A. 10
B. 30
C. 50
D. 80

2. The unknown fluid is exchanged with a fluid of specific gravity (SG) = 1.1. Therefore the value of h ________

A. increases
B. decreases
C. remains the same
D. need more information

3. Which statements are true?

1) An open-end manometer provides a direct reading of the gauge pressure of a fluid.
2) A sealed-end manometer provides a direct reading of the absolute pressure of a fluid, provided that the fluid pressure in the sealed end may be neglected.
3) The reading of a differential manometer does not depend on the density of fluid in the pipeline but only on that of the manometer fluid.

A. 1 & 3
B. 3
C. 1 & 2
D. 2
E. 1, 2, & 3

4. A fluid sits in an open tank at sea level. The pressure at the top of the fluid is ___________ the pressure at the bottom of the tank.

A. greater than
B. less than
C. equal to
D. not enough information