Applied Fluid Mechanics

Chapter 3

Pressure Measurement

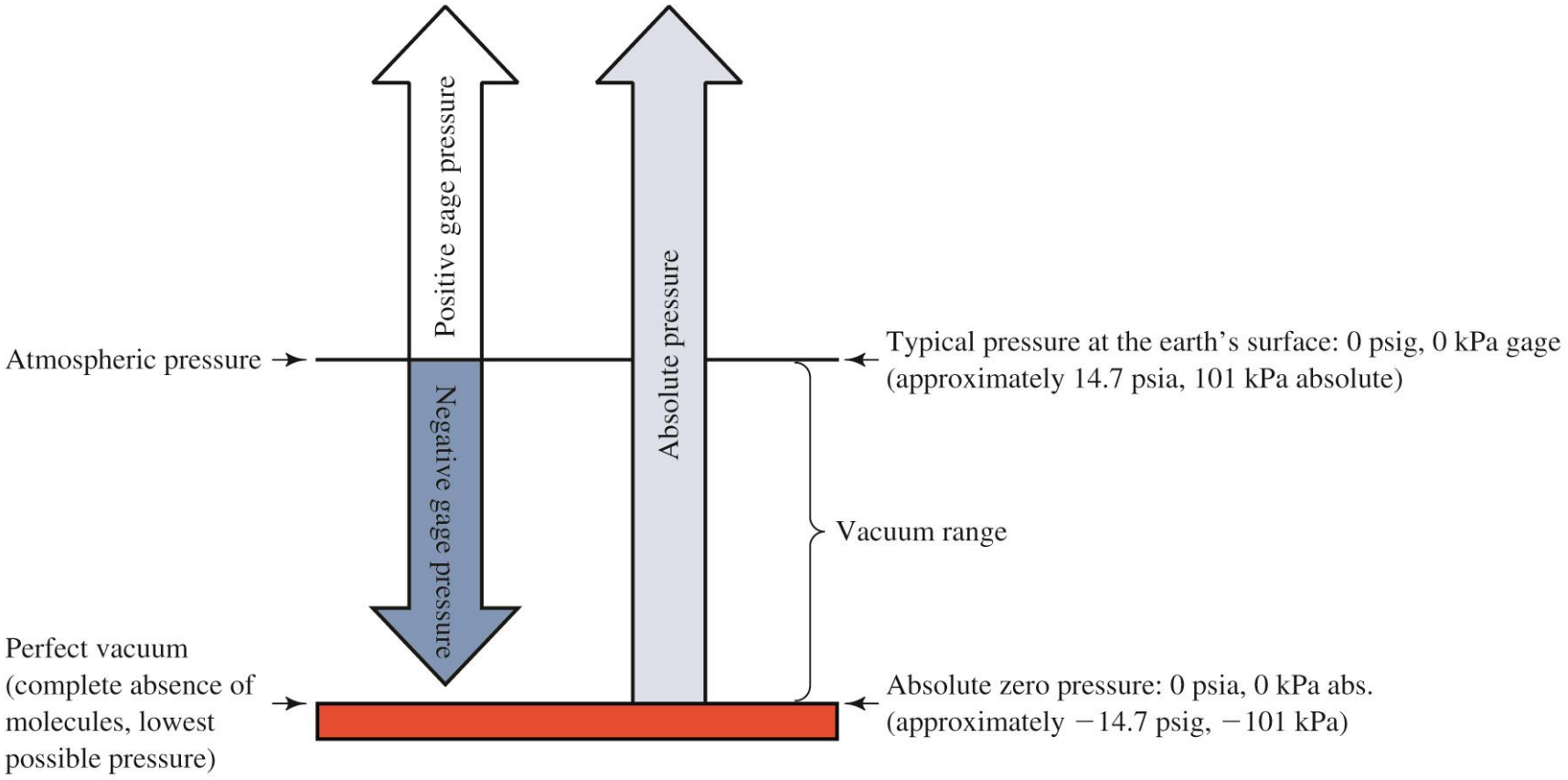
Amjad El-Qanni, PhD
Spring 2022/2023

Pressure measurement is important whether in a laboratory, building system, or industrial process.

- Pressure results from a force acting over an area.
- Units can be N/m^2, called a Pascal, or lb/in^2 called PSI
- Pressure can be reported relative to the surrounding atmosphere (gage) to compared to a perfect vacuum (absolute).

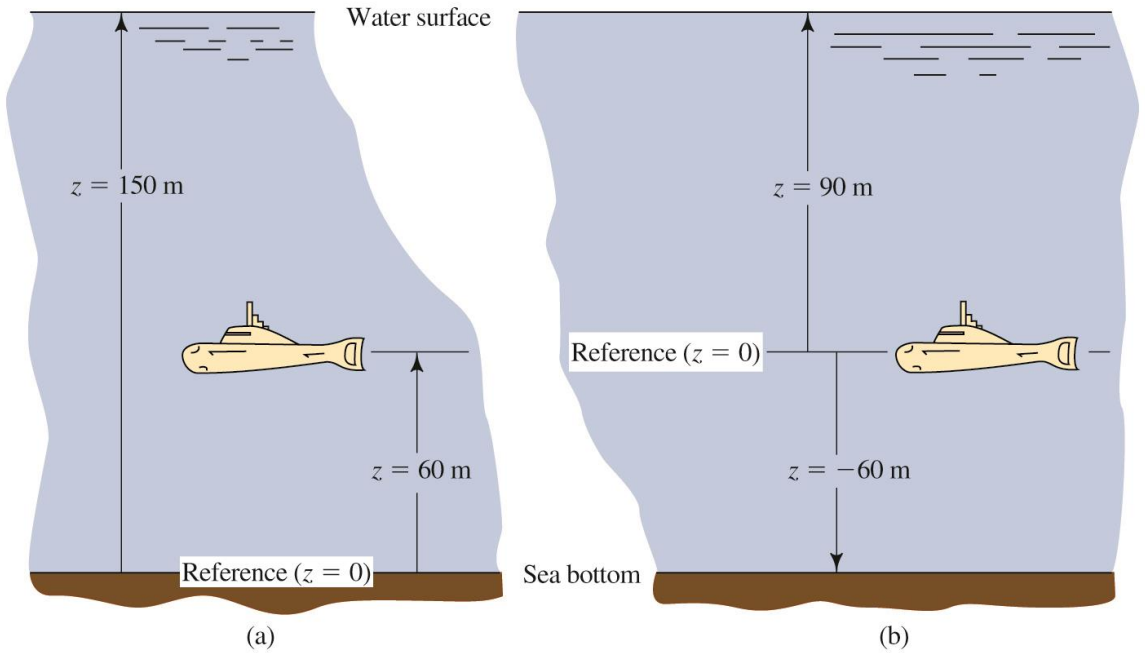
Understand the two ways to report pressures, either compared to the surrounding atmospheric, or compared to a perfect vacuum.

$$p_{\text{abs}} = p_{\text{gage}} + p_{\text{atm}}$$



Relationship Between Pressure and Elevation

The pressure in a fluid increases with depth.



Relationship between pressure and elevation

$$\Delta p = \gamma h$$

$\Delta p =$ Change in pressure

$\gamma =$ Specific weight of liquid

$h =$ Change in elevation

Example Problem 3.5

Calculate the change in water pressure from the surface to a depth of 5 m.

Use Equation (3–3), $\Delta p = \gamma h$, and let $\gamma = 9.81\ \text{kN/m}^3$ for water and $h = 5\ \text{m}$. Then we have

$$\Delta p = (9.81\ \text{kN/m}^3)\ (5.0\ \text{m}) = 49.05\ \text{kN/m}^2 = 49.05\ \text{kPa}$$

If the surface of the water is exposed to the atmosphere, the pressure there is 0 Pa(gage). Descending in the water (decreasing elevation) produces an increase in pressure. Therefore, at 5 m the pressure is 49.05 kPa(gage).

Forces acting in the vertical direction

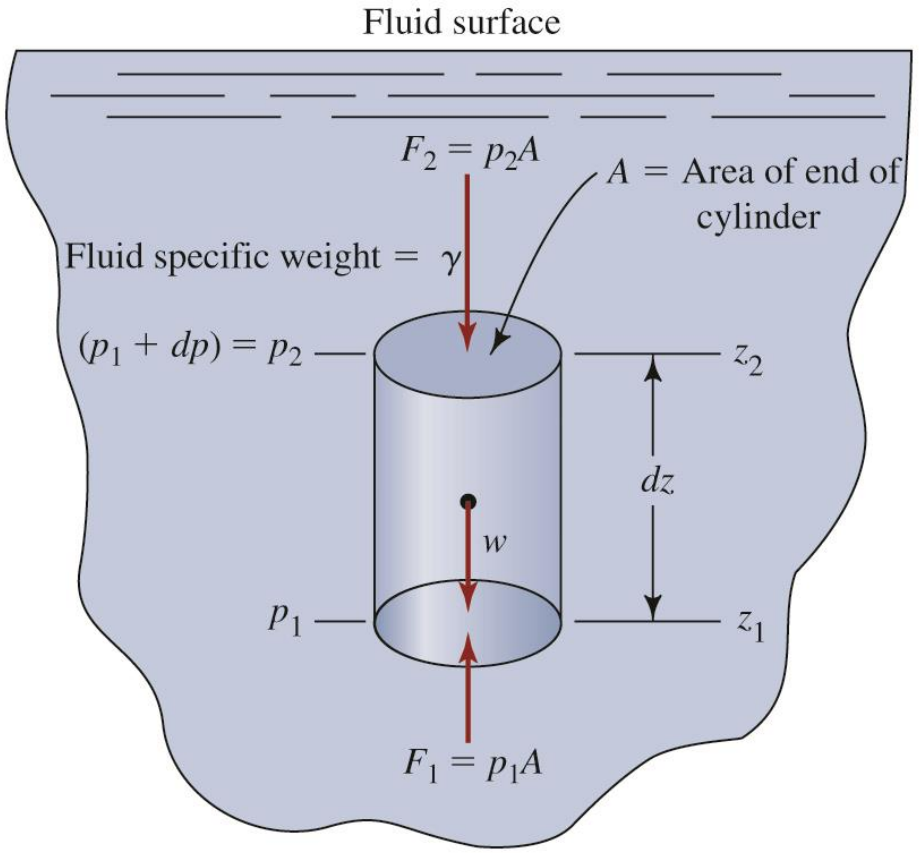
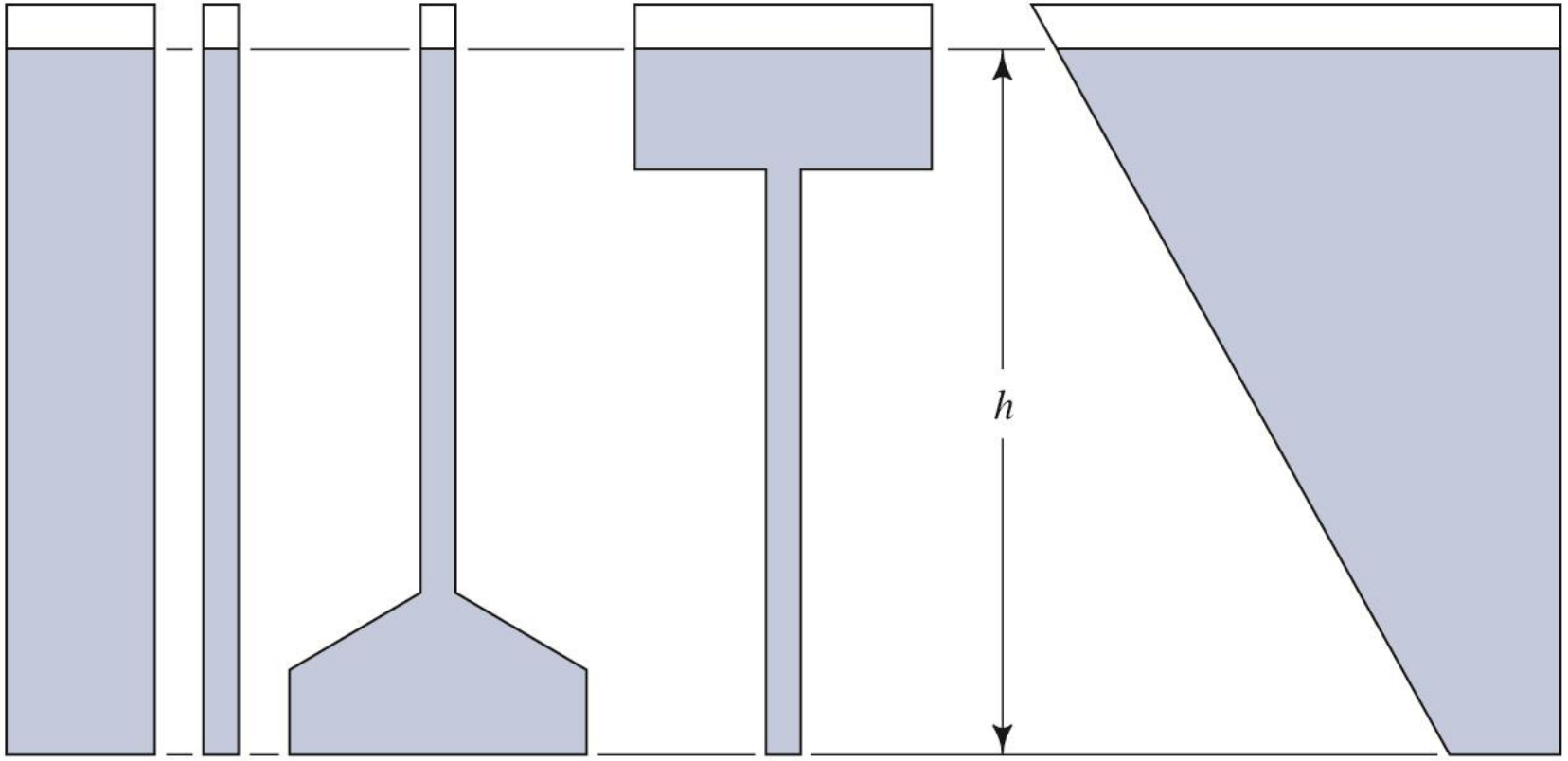
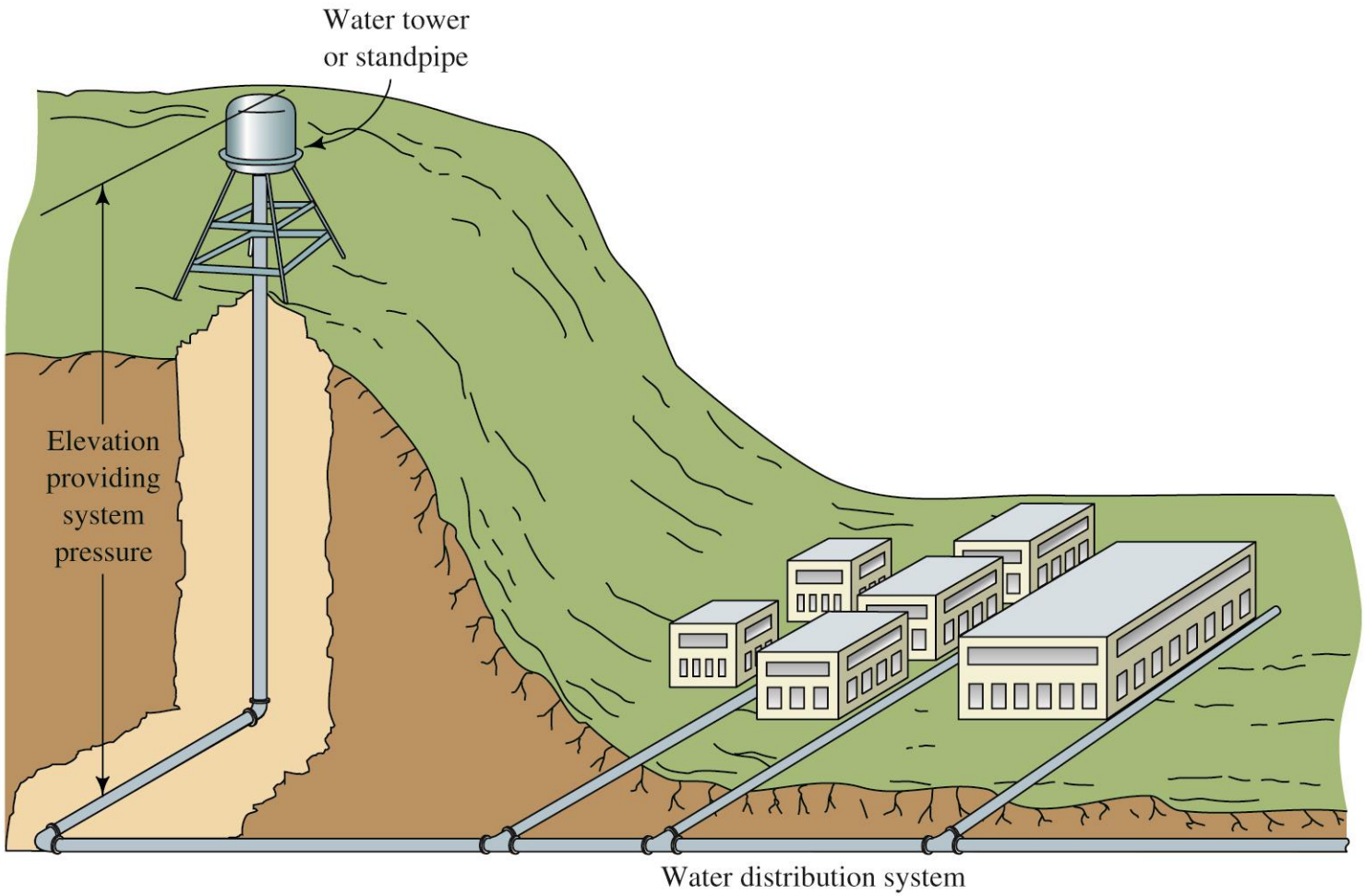


Illustration of Pascal's Paradox



Pressure is the same at the bottom of all containers if the same fluid is in all containers.

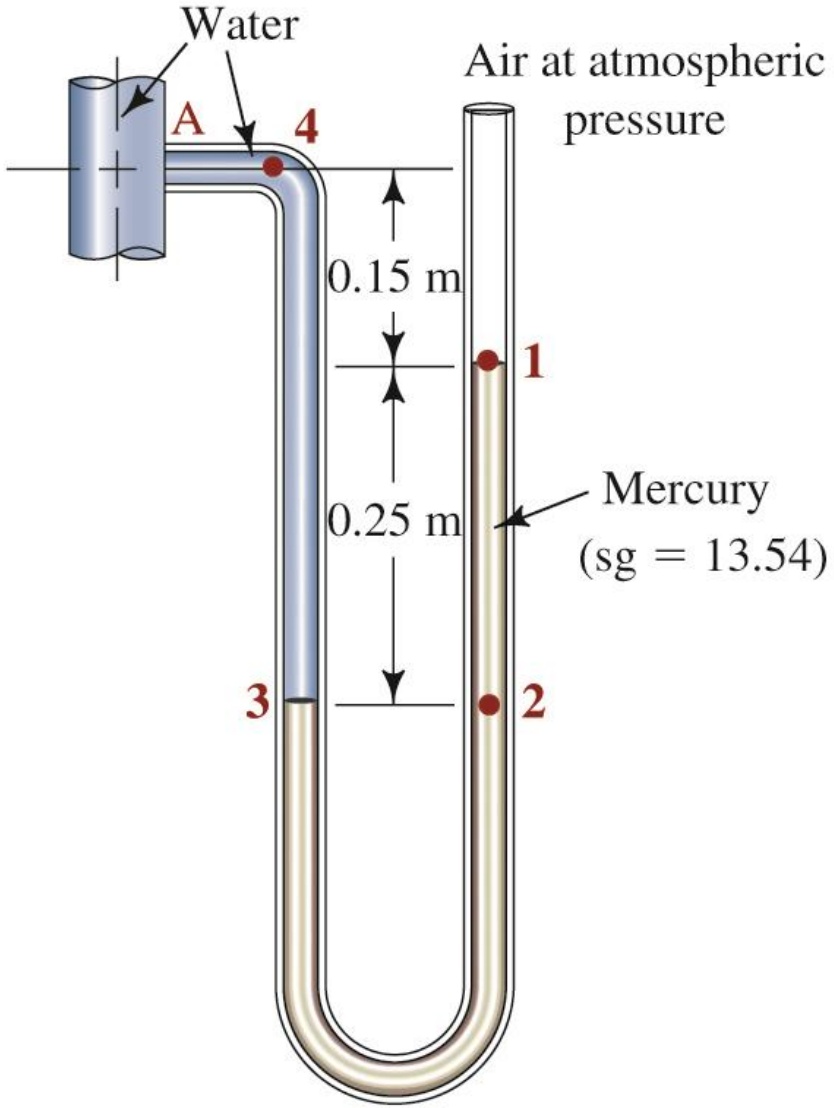
Use of a water tower or a standpipe to maintain water system pressure



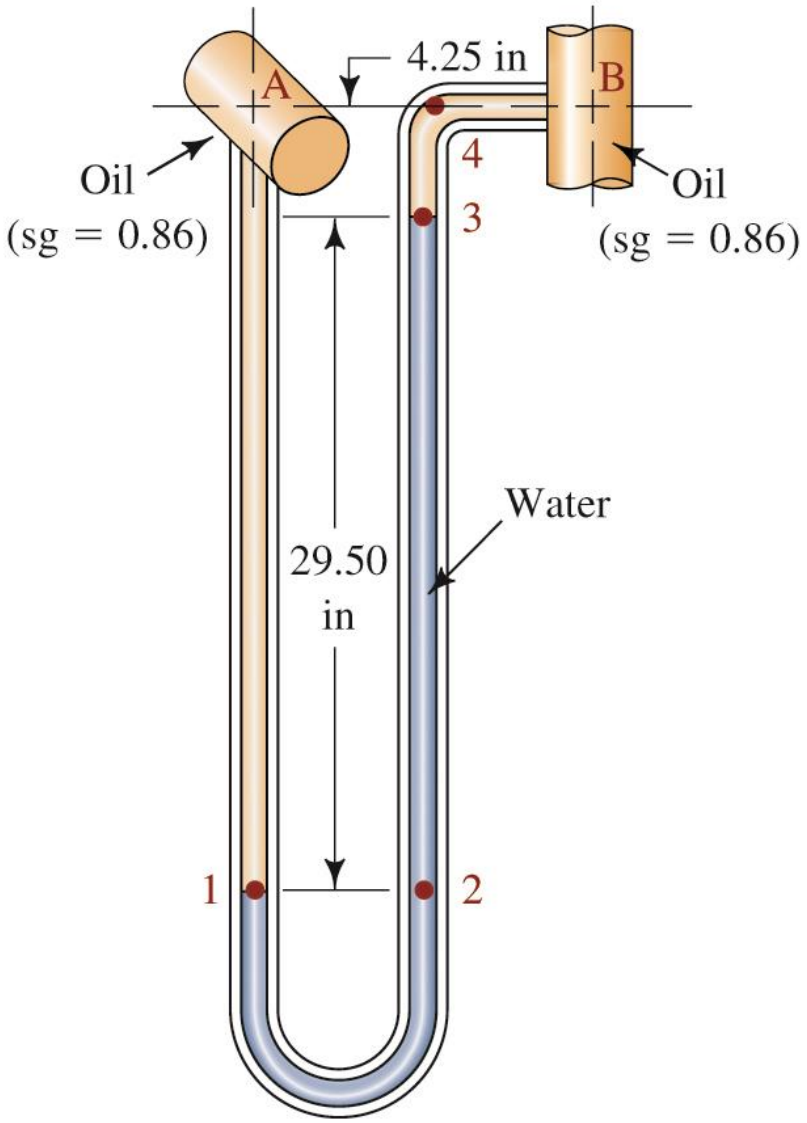
U-tube manometer with both sides open so fluid is balanced and reads zero gage pressure.

Source: Dwyer Instruments, Inc.

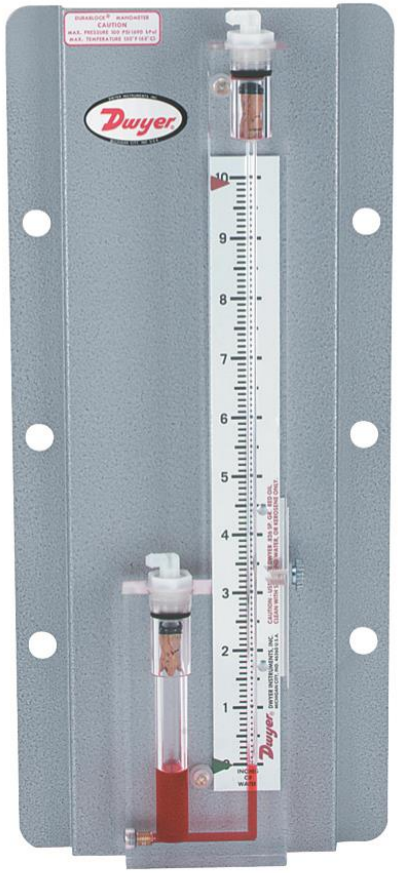
This manometer is used to measure the pressure inside the water pipe that runs vertically to the left of the manometer.



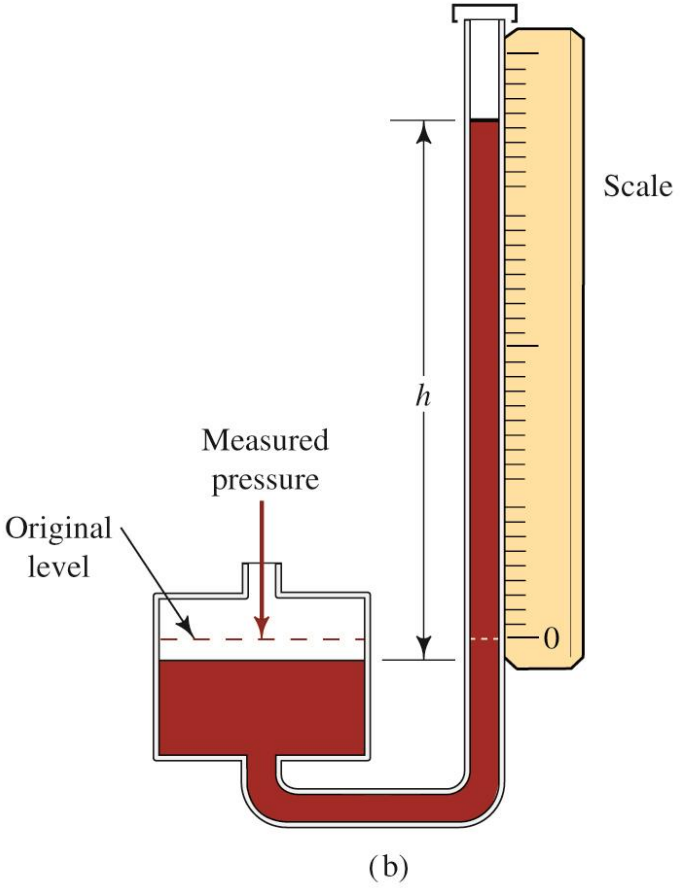
This differential manometer is used to determine the difference in pressure between the oil in pipe “A” and the oil in pipe “B.”



Commercially available well-type manometer

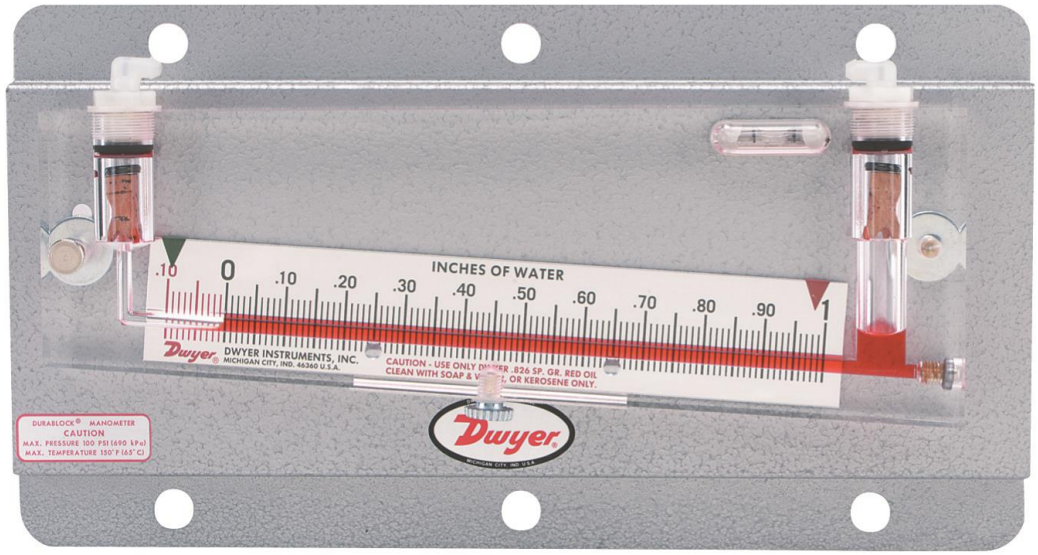


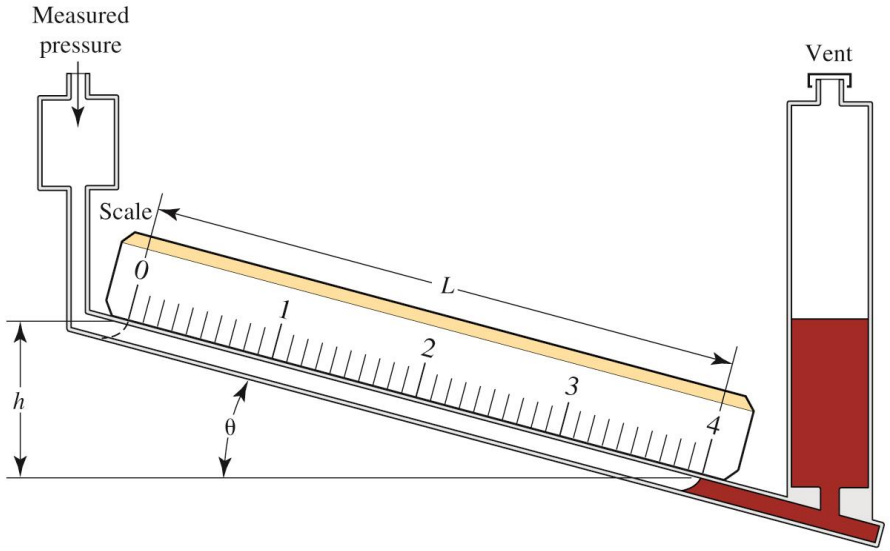
(a)



(b)

Inclined well-type manometer

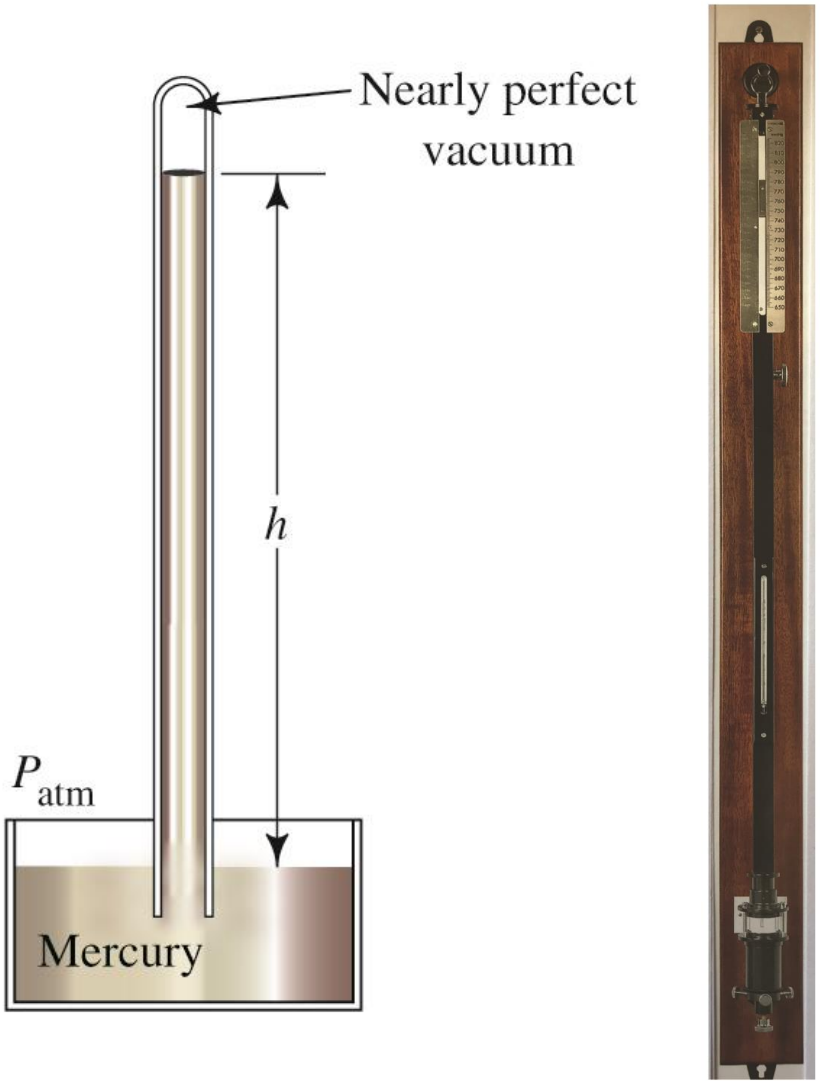




Source: Dwyer Instruments, Inc.

Pearson

A barometer is effectively a manometer, but with one end at vacuum and other open to atmosphere. Therefore, it measures the atmospheric pressure relative to perfect vacuum.



Source: Russell Scientific Instruments, Ltd

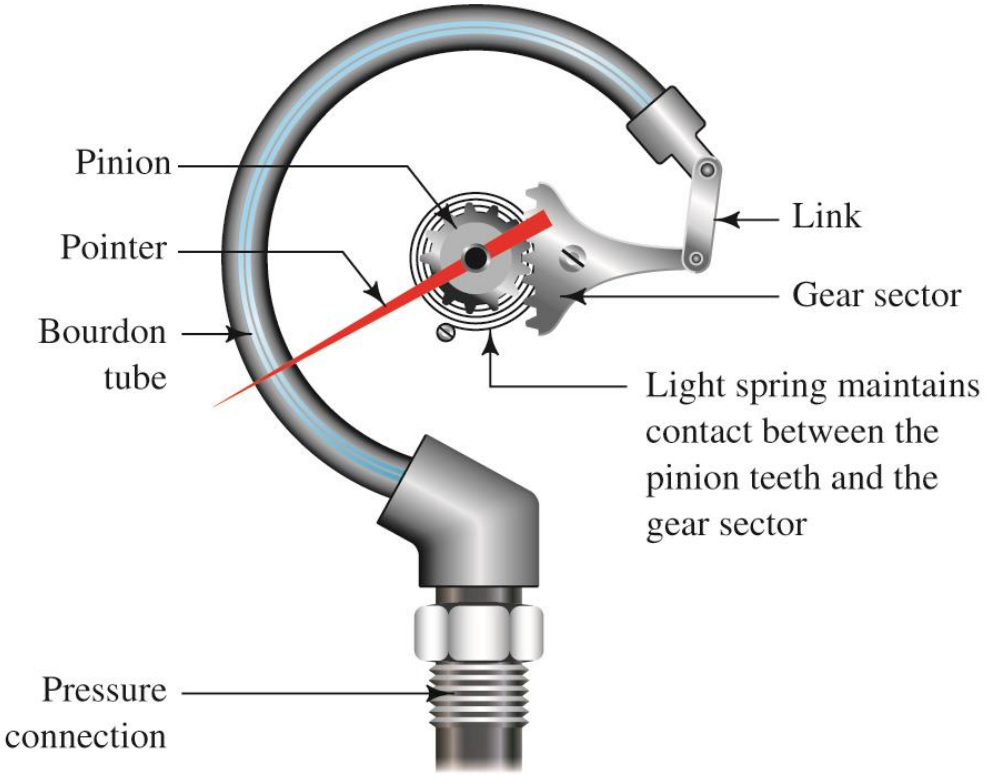
Manometer and barometer calculations

$$\Delta p = \gamma h$$

- Be sure to track units appropriately for pressures, specific weights, and elevations. Show explicit cancellation of units to demonstrate consistency.
- Pressure increases moving down through a fluid, and decreases moving up.
- Be clear about reference pressure.
  - If reference is atmospheric, then report as gage pressure.
  - If reference is a vacuum, then report as absolute pressure.
  - If differential, then report as a pressure difference, taking care with positive and negative values.

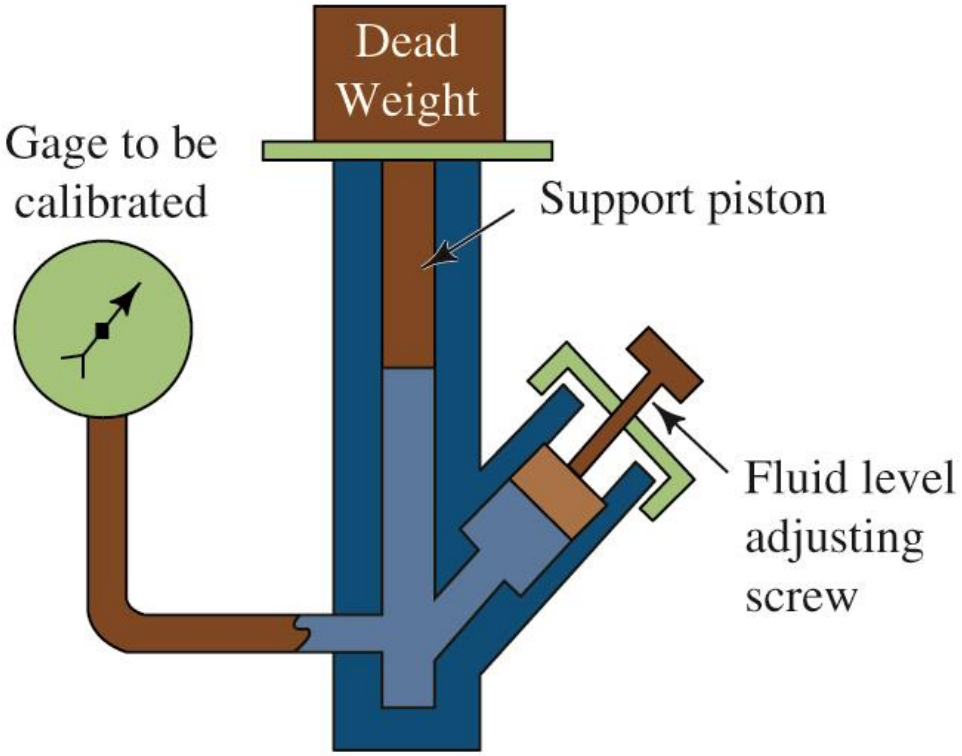
Bourdon tube pressure gage

(a) Front view

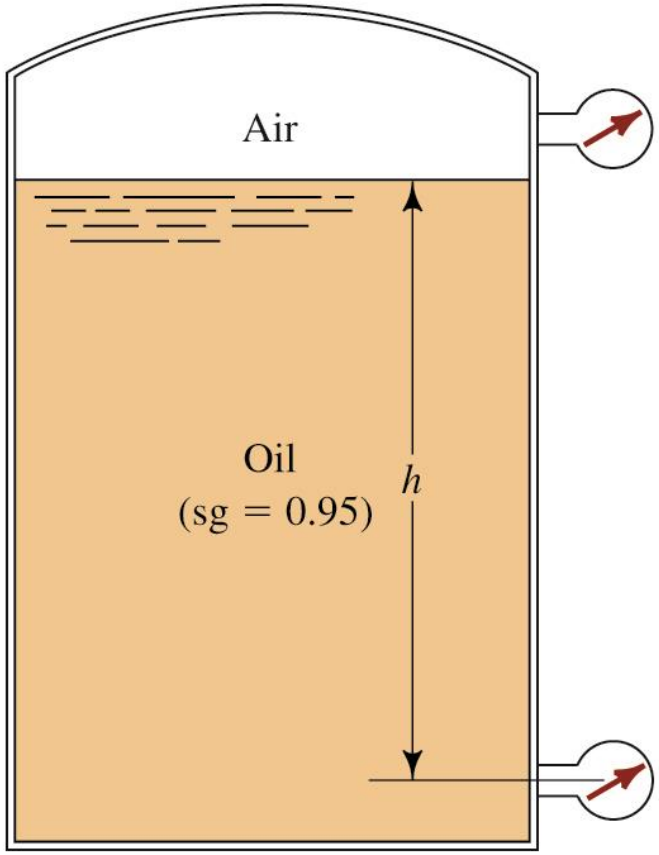


(b) Internal parts showing the Bourdon tube and the indicator mechanism

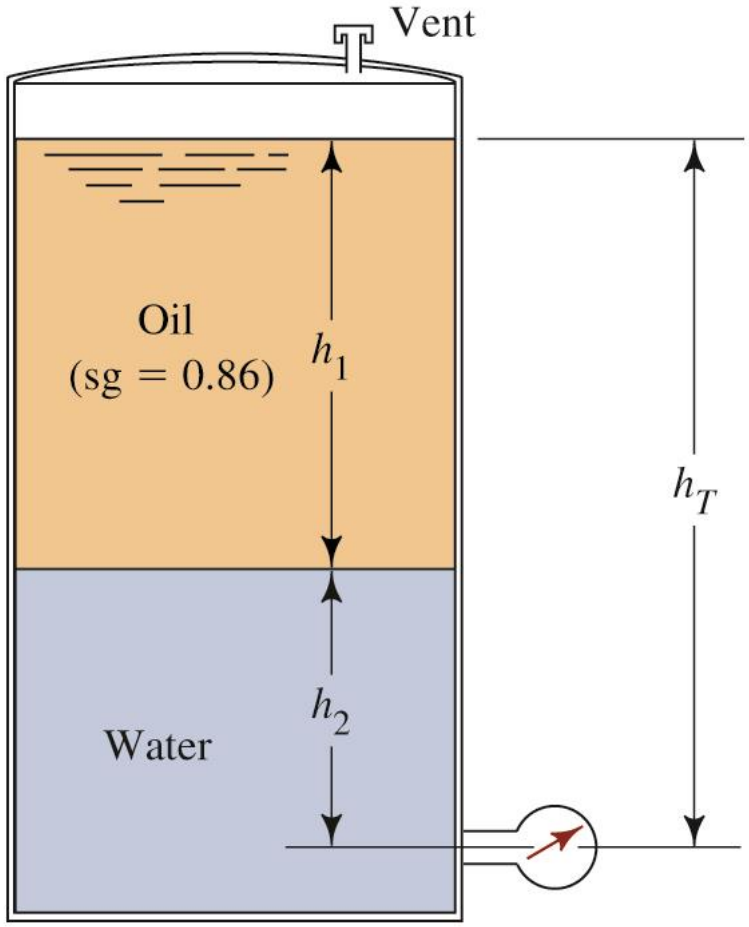
A dead weight tester offers a calibration standard since both force and area are carefully controlled, and friction is negligible.



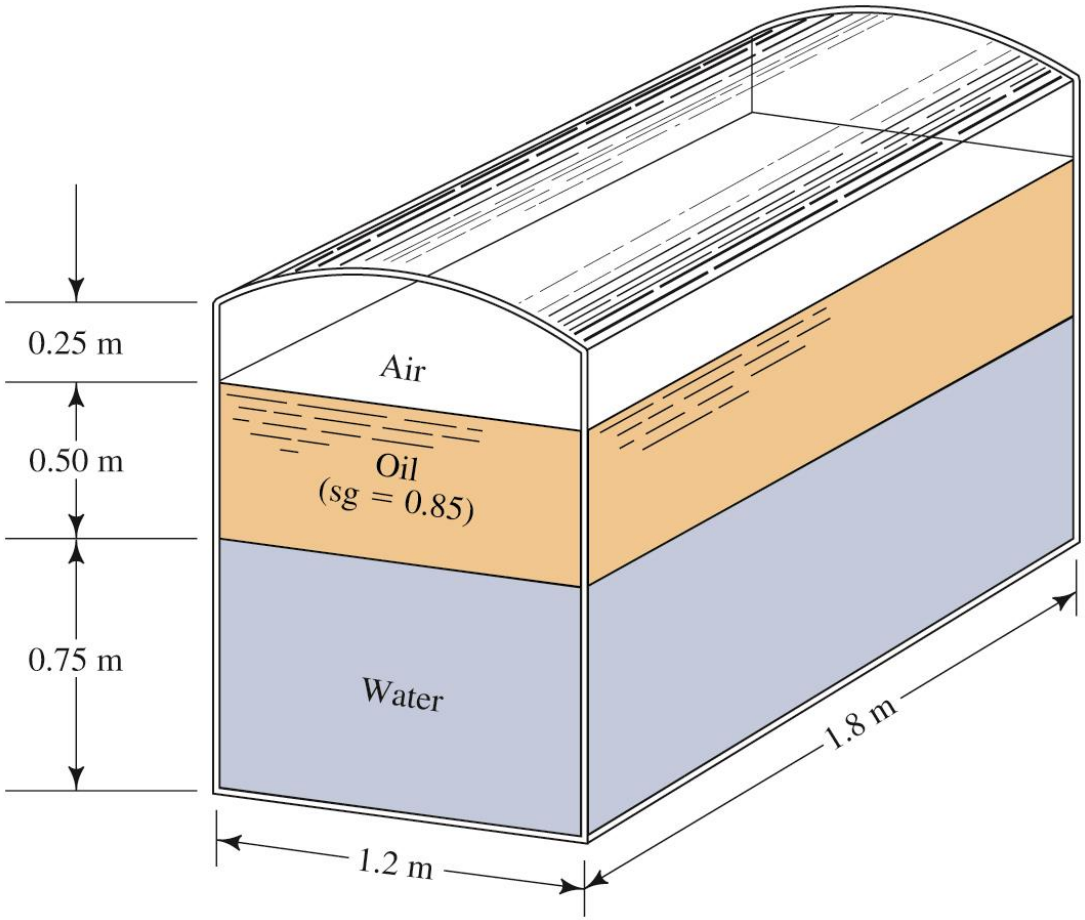
Tank for Problems 3.44–3.47



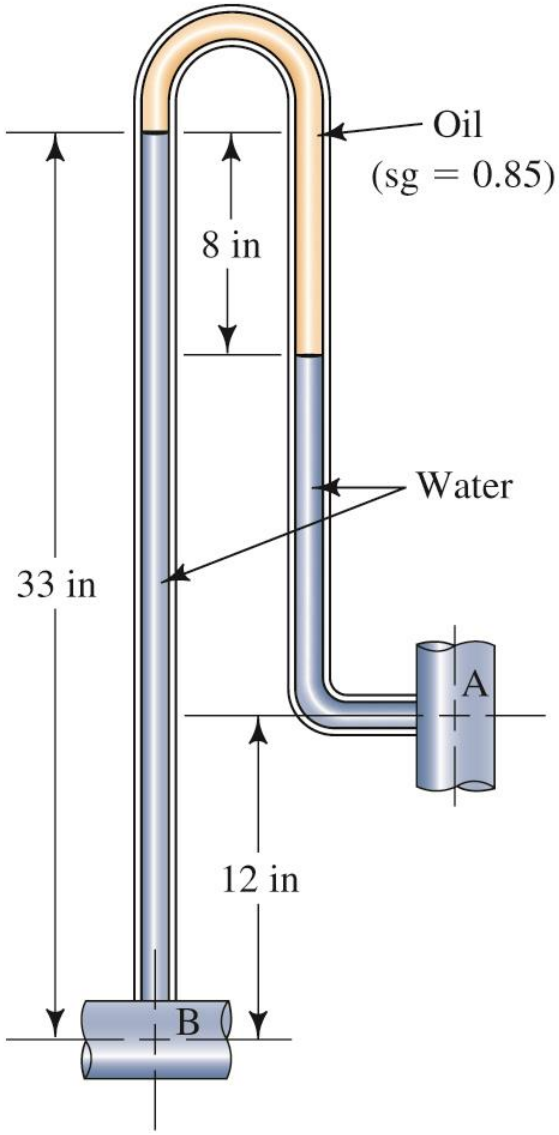
Vented oil storage drum for Problems 3.48–3.50



Closed tank for Problem 3.56



Differential manometer for Problem 3.64



Differential manometer for Problem 3.66