

ENVE 2061 BASIC FLUID MECHANICS

Pressure Measurement:

Atmospheric Pressure

Absolute and Gage Pressure

Manometers, Pressure Gauges

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ATMOSPHERIC PRESSURE

- Atmosphere of earth is a thick layer
- 1500 km
- Mixed gases → Mainly, Nitrogen (N_2) and oxygen (O_2)

Each of gasses possess a certain mass.

Total weight of the atmospheric column exerts a pressure on every surface.

At sea level, under normal conditions → $1.014 \times 10^3 \text{ N/m}^2$ or 1 bar

Pressure unit = 1 N/m^2 known as 1 **pascal**

ABSOLUTE AND GAGE PRESSURE

Gage pressure: Pressure measurement using atmospheric pressure as a base (reference)

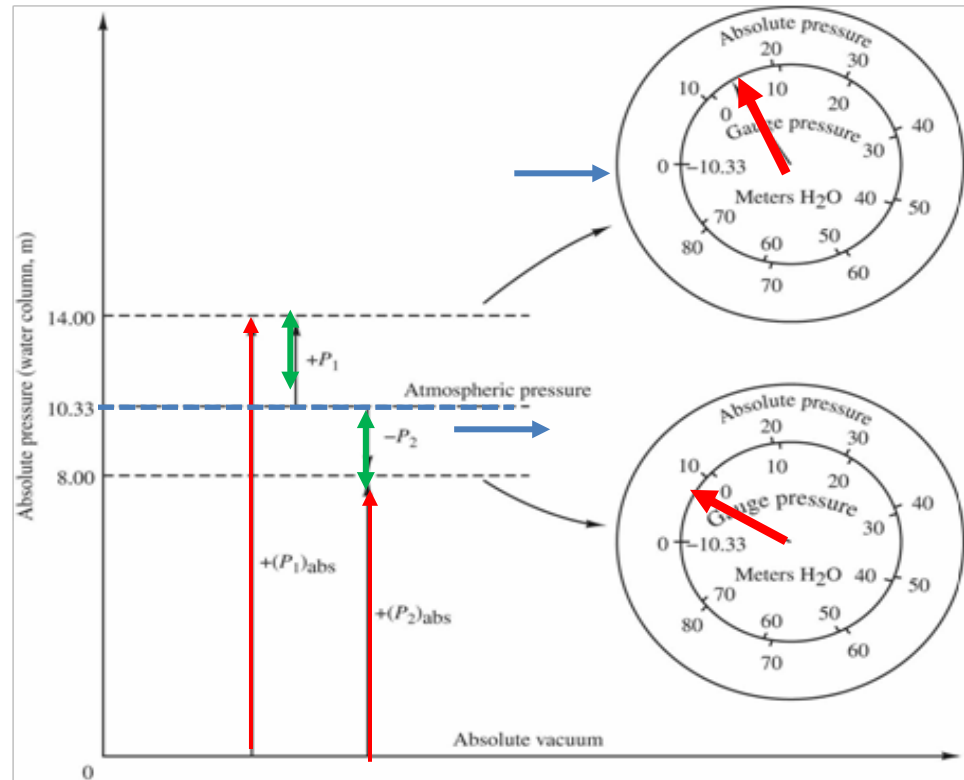
$$P_{abs} = P_{gage} + P_{atm}$$

P_{abs} = Absolute pressure

P_{gage} = Gage Pressure

P_{atm} : 10.33 m H₂O column

Absolute pressure : Pressure measured relative to the perfect vacuum ($P=0$) is called absolute pressure



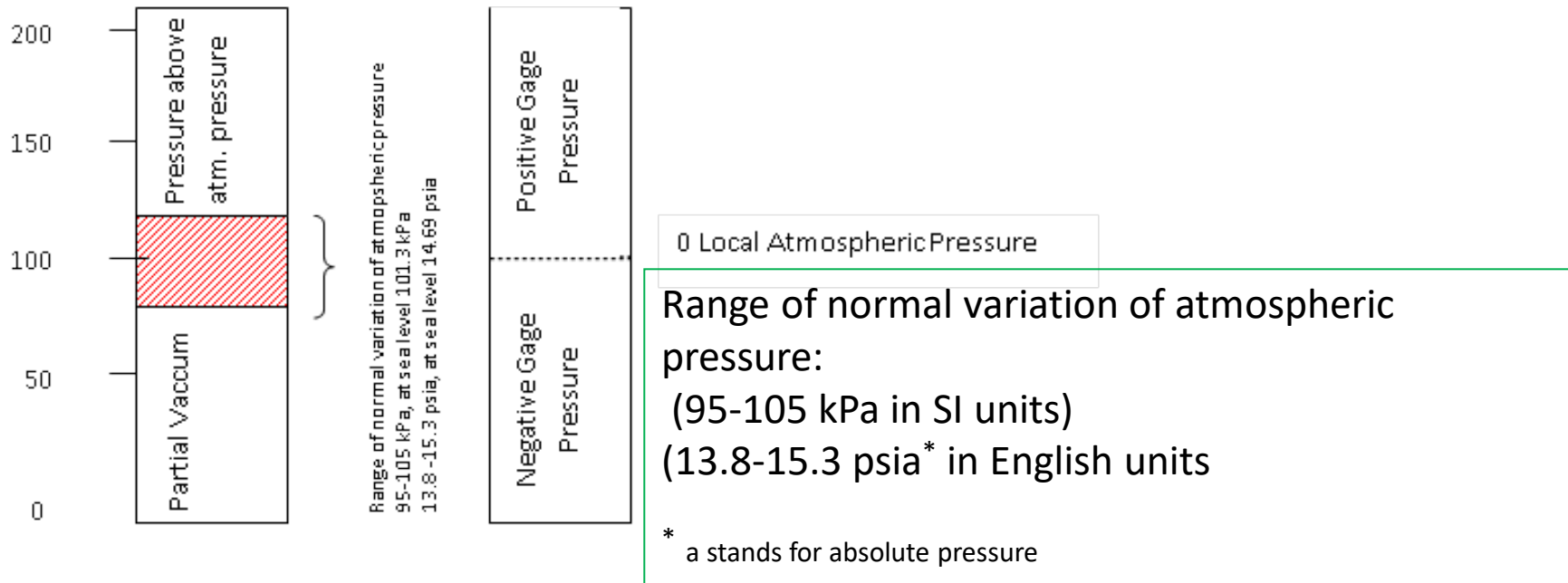
Gage pressure for $P_1 \rightarrow = 14.00 - 10.33 = + 3.67 \text{ m H}_2\text{O}$

Gage pressure for $P_2 \rightarrow = - 10.33 + 8.00 = - 2.33 \text{ m H}_2\text{O}$

$(P_1)_{abs} = 3.67 + 10.33 = 14 \text{ m H}_2\text{O}$

$(P_2)_{abs} = - 2.33 + 10.33 = 8.0 \text{ m H}_2\text{O}$

ABSOLUTE AND GAGE PRESSURE

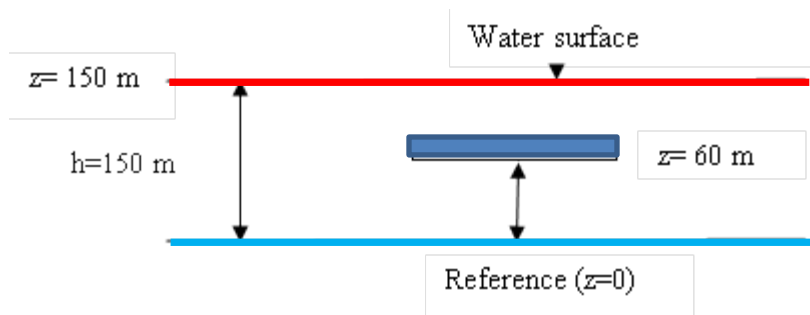


Summary:

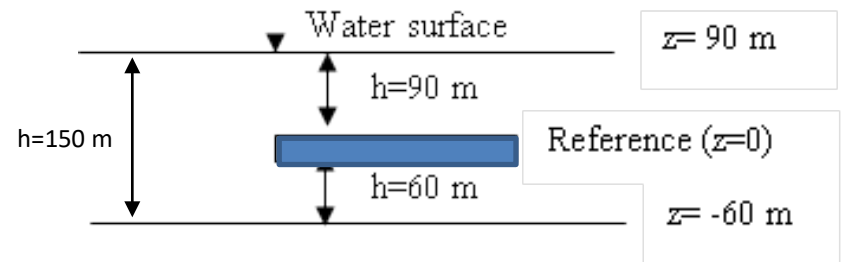
1. A **perfect vacuum** is the lowest possible pressure. Therefore, an absolute pressure is always positive.
2. A gage pressure above atmospheric is positive
3. A gage pressure below atmospheric pressure is negative, and sometimes called **vacuum**.
4. The actual magnitude of the atmospheric pressure varies with location and climatic conditions. **How ?**

ELEVATION

- **Elevation (z):** Vertical distance from some reference level to a point of interest
- **h :** a change in elevation between two points



Elevation of object in Case
1: 60 m



Elevation of object in Case
2: 0 m

RELATIONSHIP BETWEEN PRESSURE AND ELEVATION

The change in pressure in a homogenous liquid at rest due to a change in elevation.

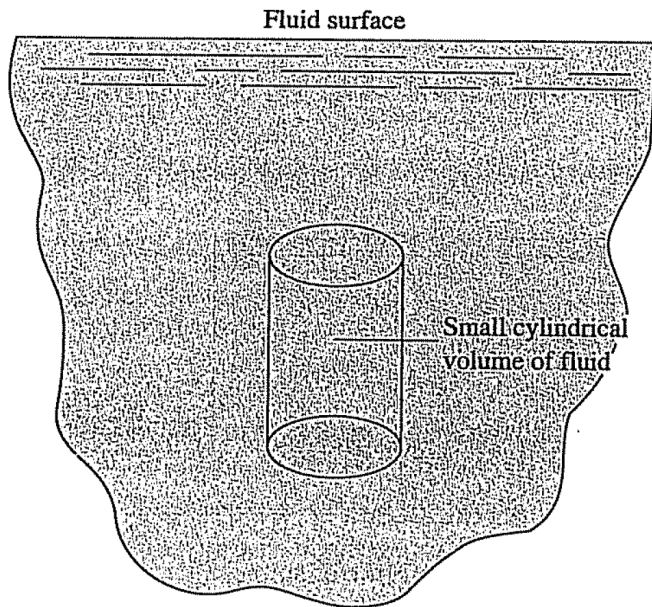
$$\Delta P = \gamma \times h \longrightarrow \text{change in elevation.}$$

Pressure change Specific weight of liquid

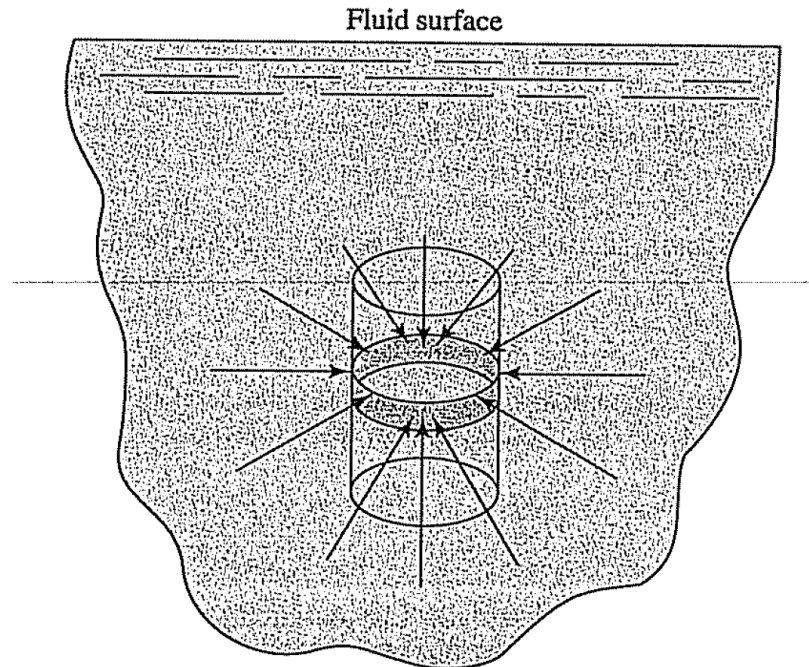
The diagram illustrates the components of the equation $\Delta P = \gamma \times h$. An arrow points from ΔP to the text 'Pressure change'. Another arrow points from γ to the text 'Specific weight of liquid'. A third arrow points from h to the text 'change in elevation'.

Note: The above equation does not apply to gases because the specific weight changes with pressure.

RELATIONSHIP BETWEEN PRESSURE AND ELEVATION

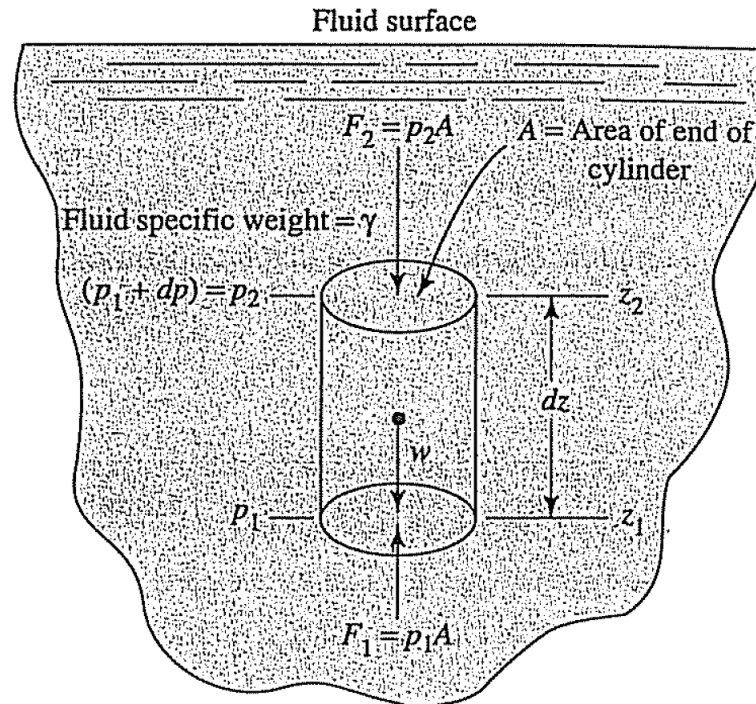


Small volume of fluid in a static fluid body



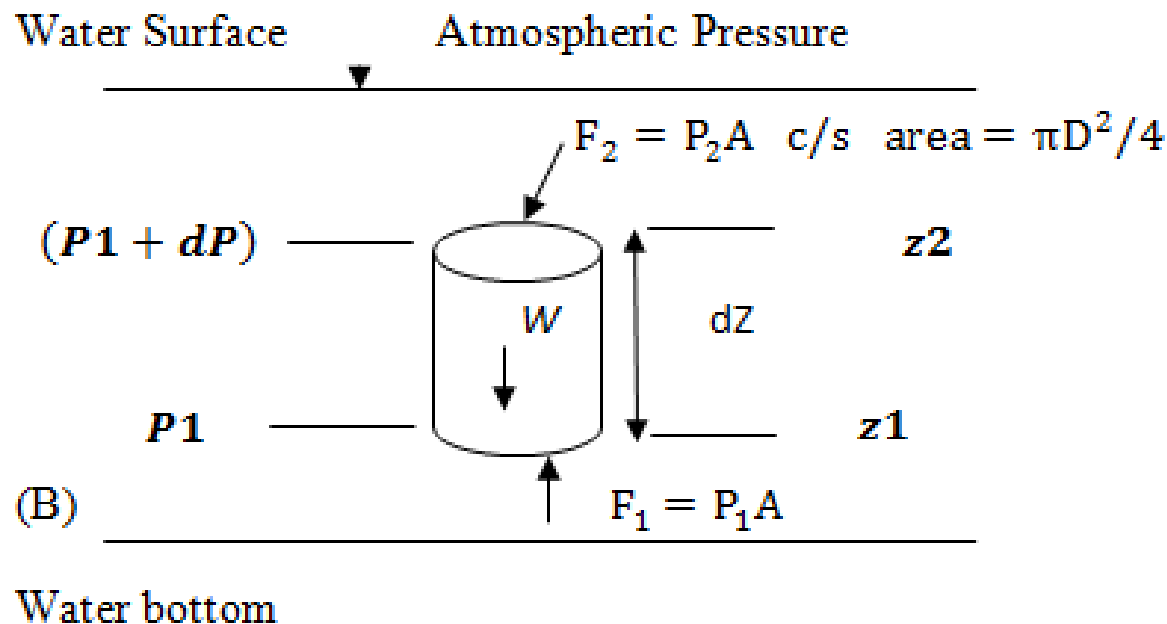
Pressure forces acting on horizontal plane on a thin ring

RELATIONSHIP BETWEEN PRESSURE AND ELEVATION

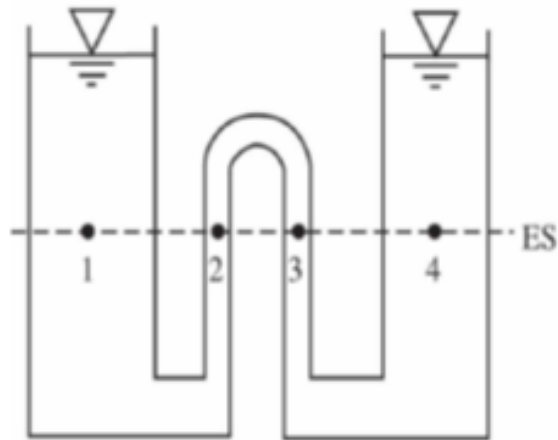


Pressure forces acting in the vertical direction

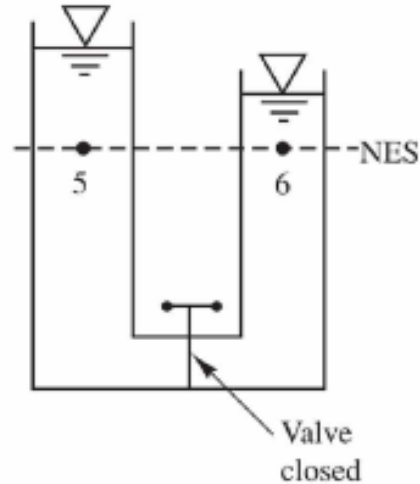
DEVELOPMENT OF THE PRESSURE ELEVATION RELATION



SURFACES OF EQUAL PRESSURES

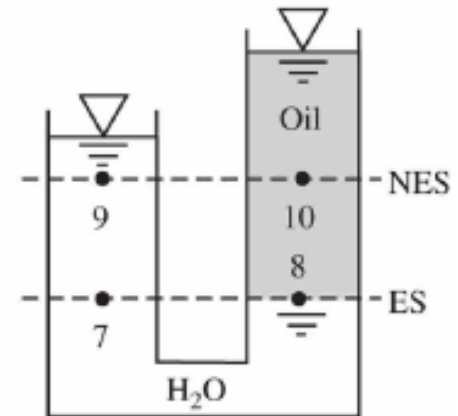


$$P_1 = P_2 = P_3 = P_4$$



$$P_5 \neq P_6$$

Water in the two tanks are not connected and overlying depths to the free surfaces are different



$$P_7 = P_8$$

$$P_9 \neq P_{10}$$

Point 9 and 10 reside in different liquids

Example 11.2: Figure shows a tank of oil with one side open to the atmosphere and other side sealed with air above oil. The oil has a specific gravity of 0.9. Calculate the gage pressures at A, B, C, D, E and air pressure at right hand side of the tank.

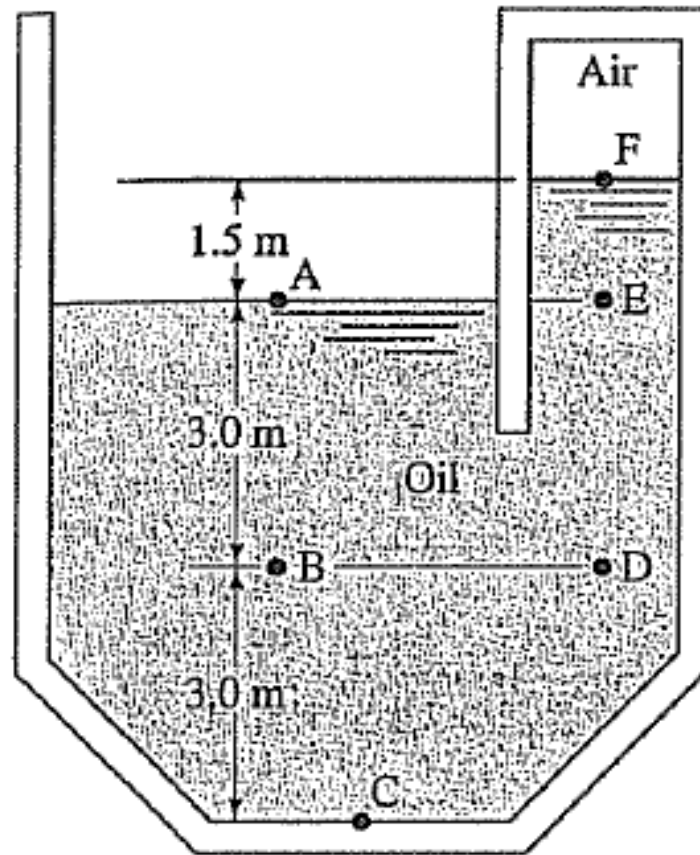


FIGURE 3.3 Tank for Example Problem 3.7.

MANOMETERS

Manometer : is a pressure measurement device uses relationship between **pressure change** and **elevation change** in a **static liquid**. Basically there are two types of manometers.

U-Tube Manometer

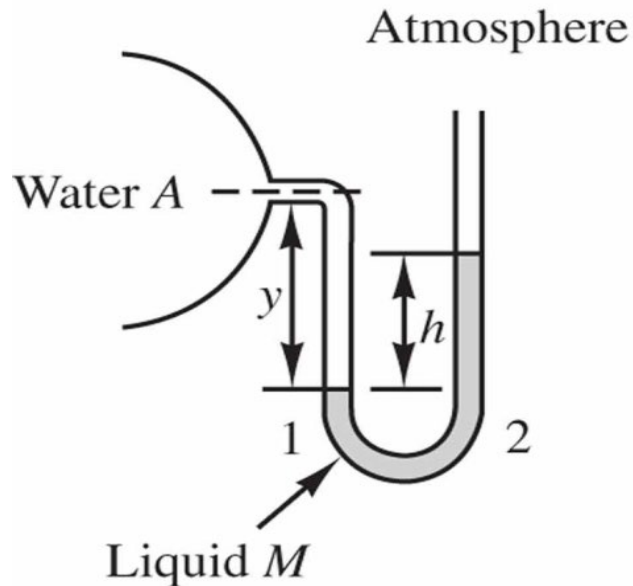


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graph TD; A[U-Tube Manometer] --> B[Open manometer]; A --> C[Differential manometer];
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Open manometer

Differential manometer

U-Tube Manometer



- The liquid used in manometer (**M**) is usually heavier than the fluids to be measured.
- It must form a distinct interface-that is, it must not mix with the adjacent liquids.

The most frequently used manometer liquids are **mercury** (sp. gr. = 13.6), water (sp. gr. = 1.00), **alcohol** (sp. gr. = 0.9), and other commercial manometers oils of various specific gravities.

Differential Manometer

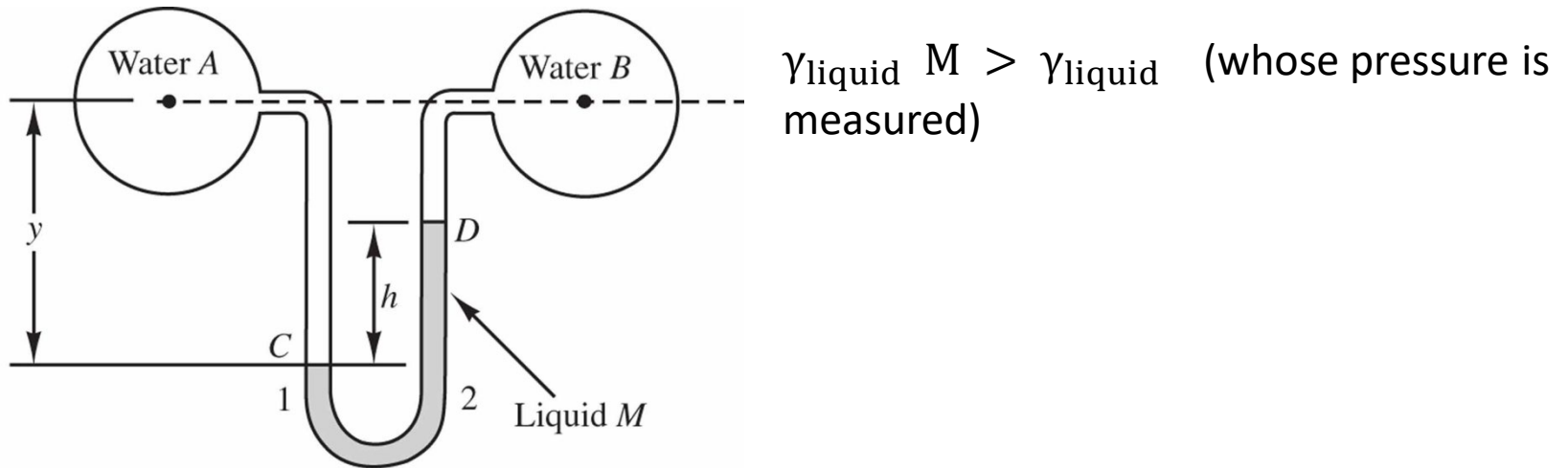
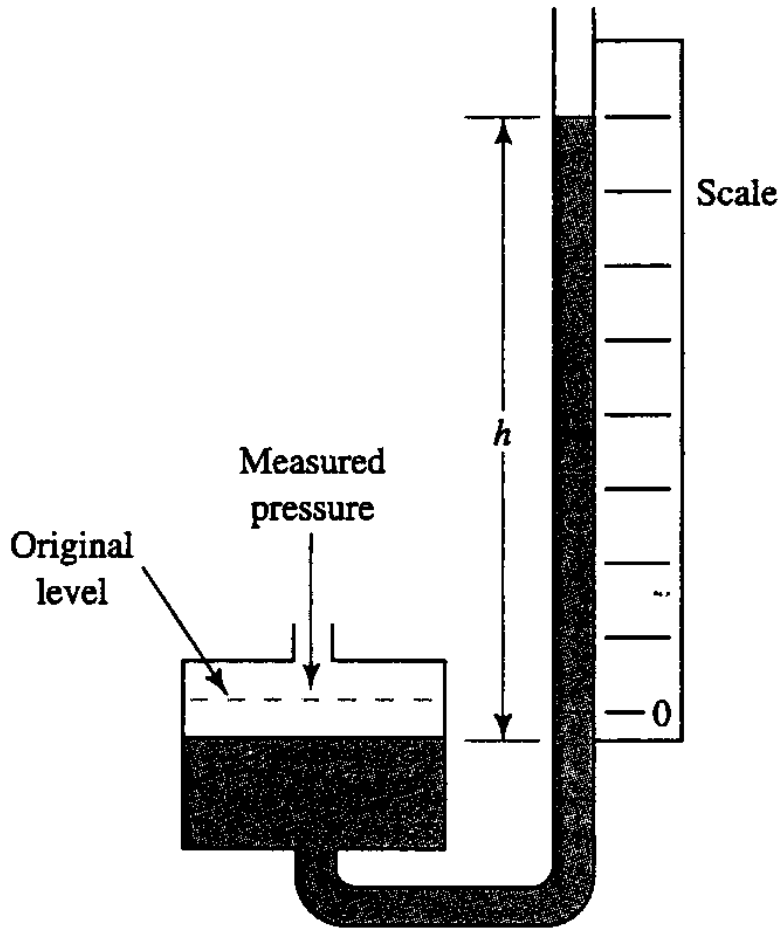


Figure 14.2 differential manometer [Hwang et al., 4th edition]

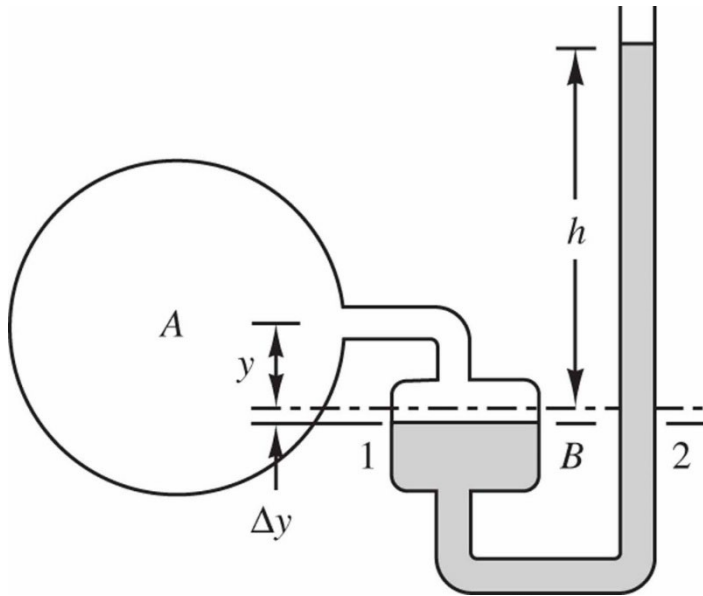
Single – Reading Manometers (Well type manometer)



When a pressure is applied to a well-type manometer, the fluid level drops a small amount while the level in the right leg rises a larger amount in proportion to the ratios of the areas of the well and the tube.

The pressure difference can be indicated only by the height of the liquid column in single leg.

Well-type manometers



$$\underbrace{\Delta y \times A}_{\text{Volume change in reservoir}} = \underbrace{a \times h}_{\text{Volume change in tube}}$$

Volume change in reservoir

Pressure at point 1 = Pressure at point 2

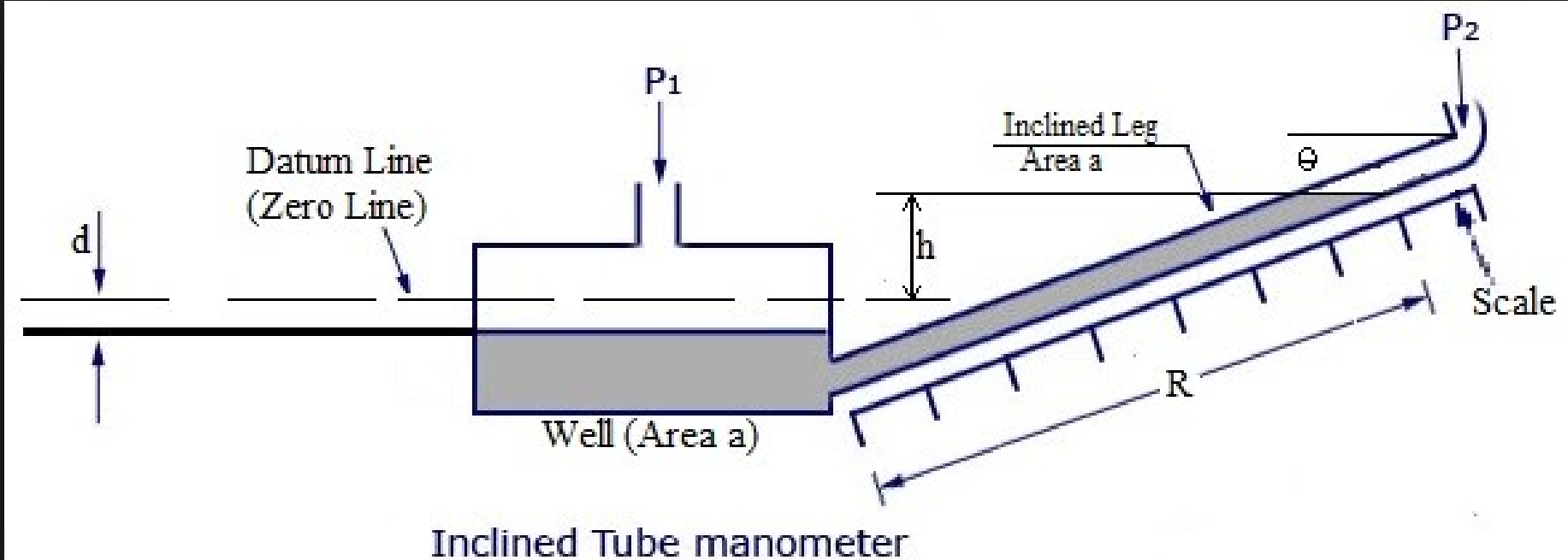
$$P_A + \gamma_A(y + \Delta y) = \gamma_B(h + \Delta y)$$

Because Δy can be made negligible by introducing a large $\frac{A}{a}$

$$\gamma_A y + P_A = \gamma_B h$$

Height of the reading h is a measure of the pressure in the vessel

Inclined Well Type Manometer

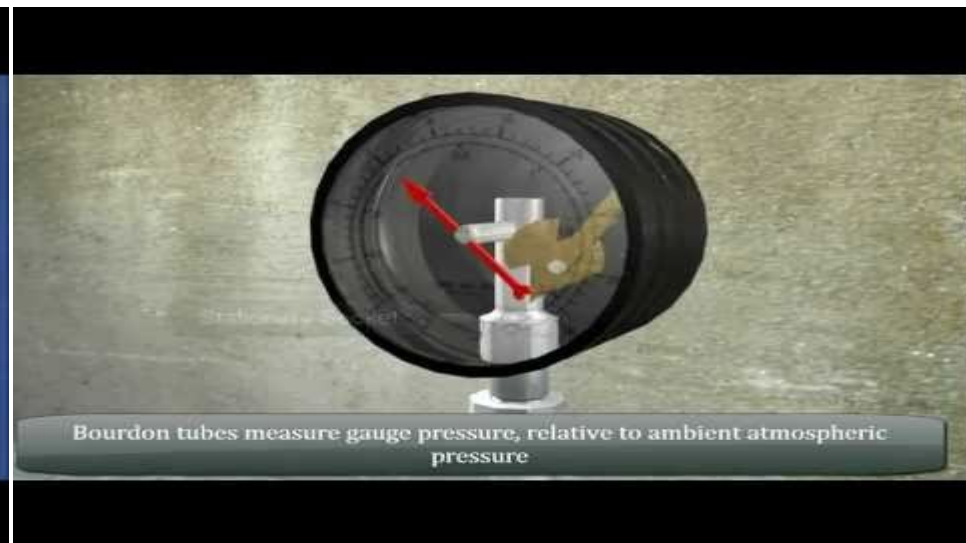


An inclined tube manometer is a modified version of a well type manometer where in the vertical leg is placed in an inclined position so that a very small change in pressure in the well causes a very large change in the measured level of liquid in the inclined leg.

Pressure Gages



Bourdon tube pressure gages



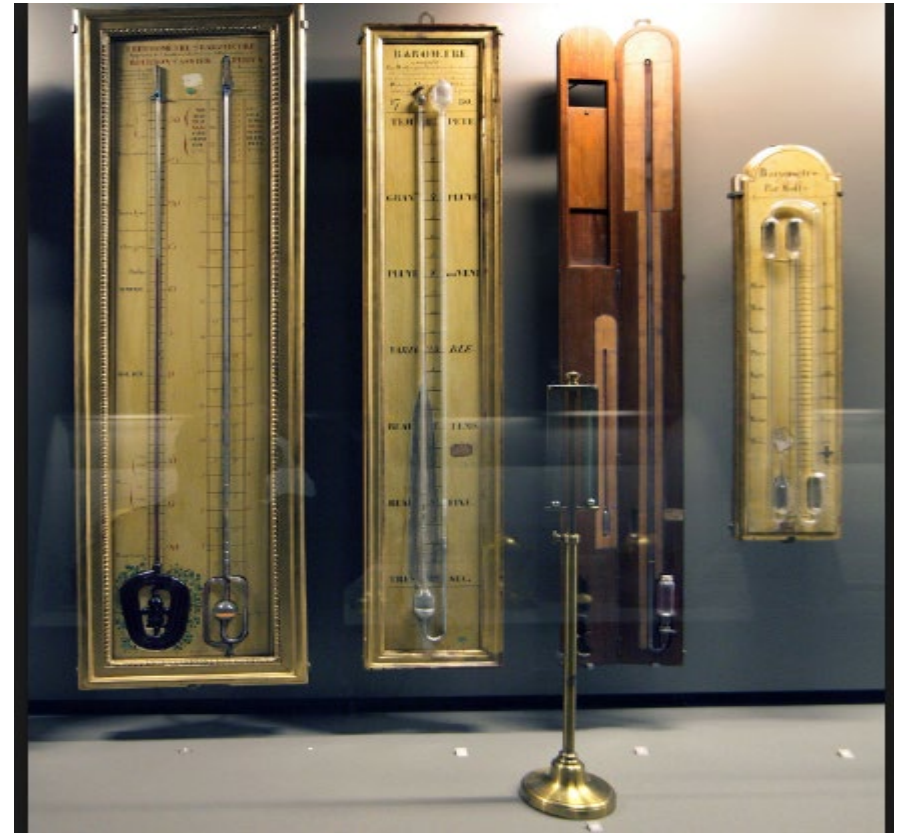
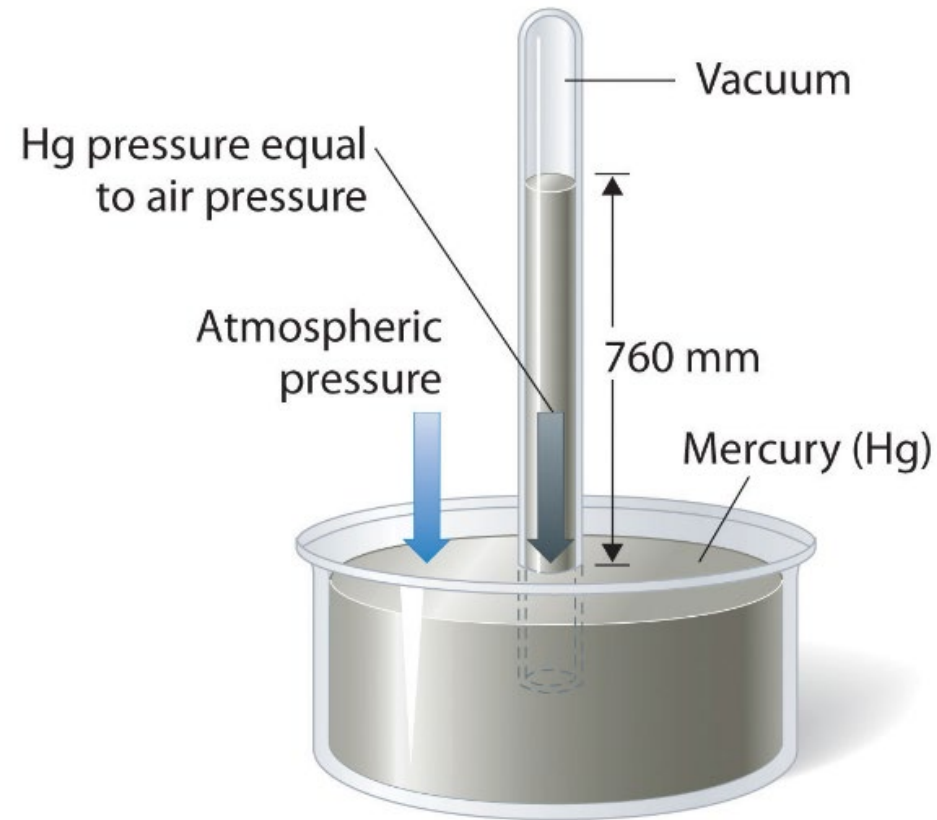
Pressure Transducer

A **pressure transducer**, often called a **pressure transmitter**, is a transducer that converts pressure into an analog electrical signal.

Although there are various types of pressure transducers, one of the most common is the strain-gage base transducer.



Barometer



- A device for measuring the atmospheric pressure

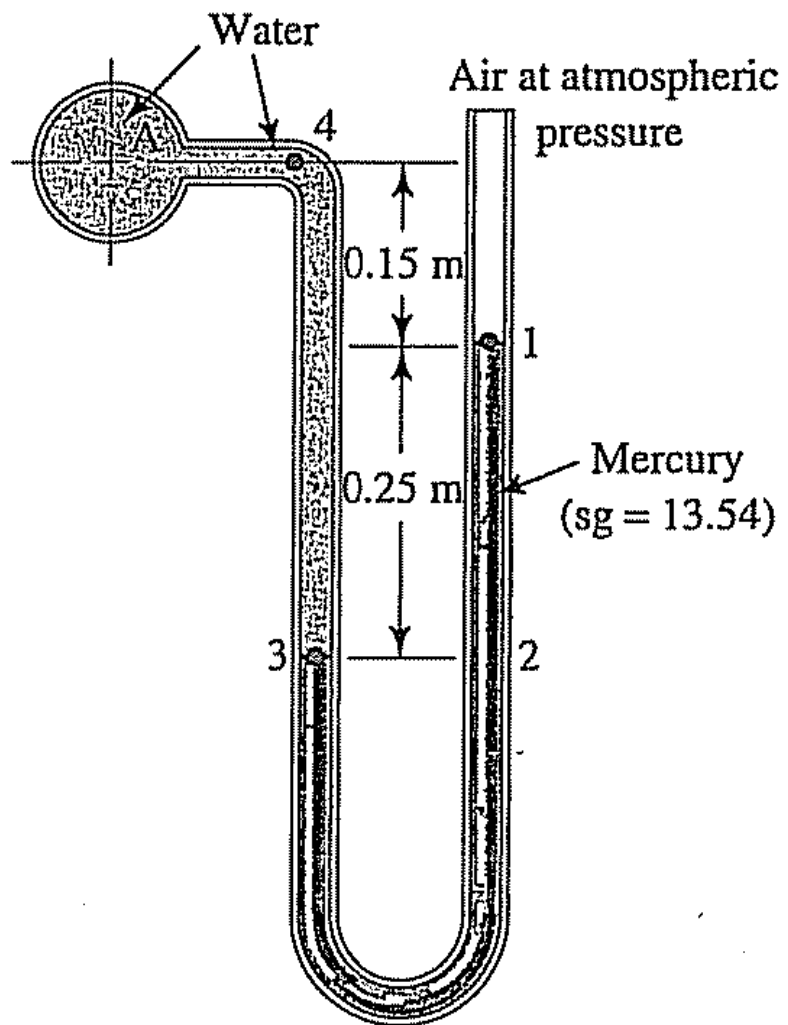


FIGURE 3.10 U-tube manometer.

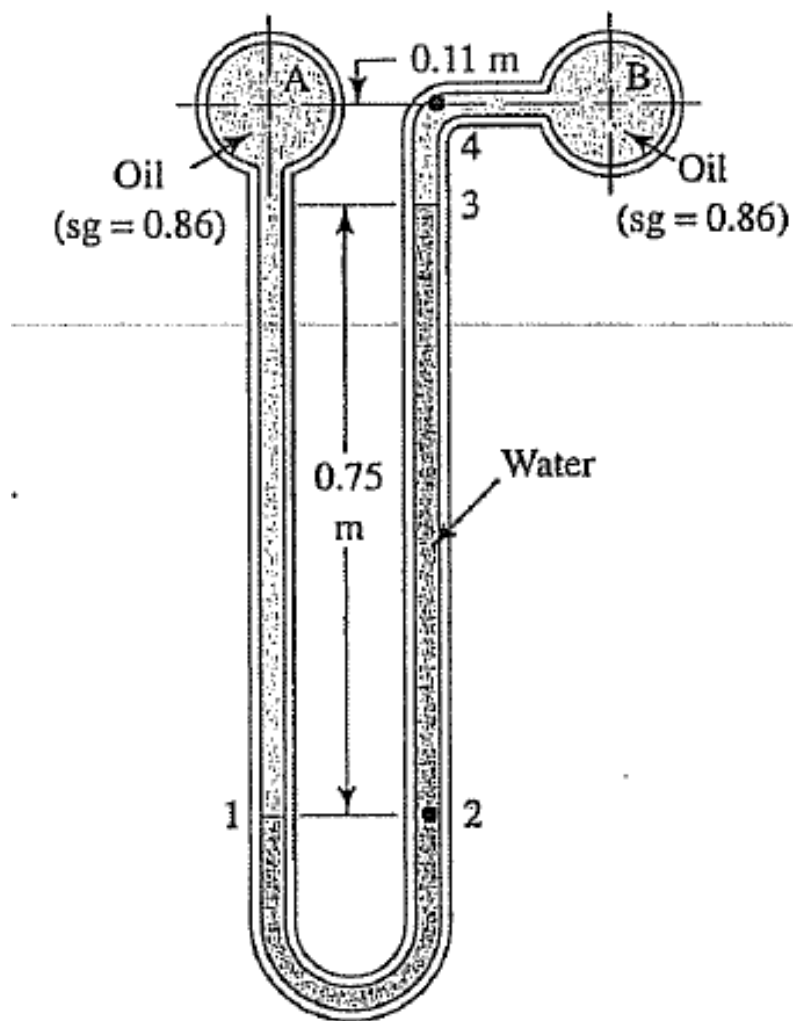


FIGURE 3.11 Differential manometer.

Problem 3.34 & 3.35

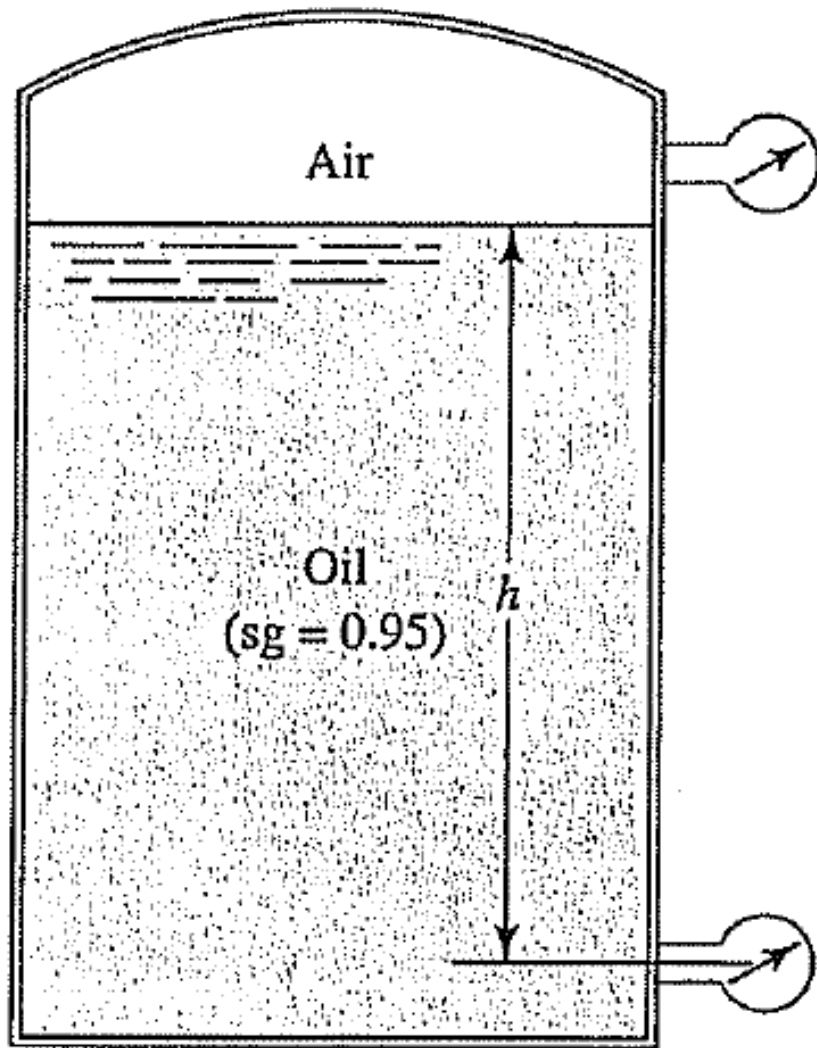


FIGURE 3.22 Problems 3.34–3.37.