# IoT 4211: Sensor Technology

## Pressure Measurement

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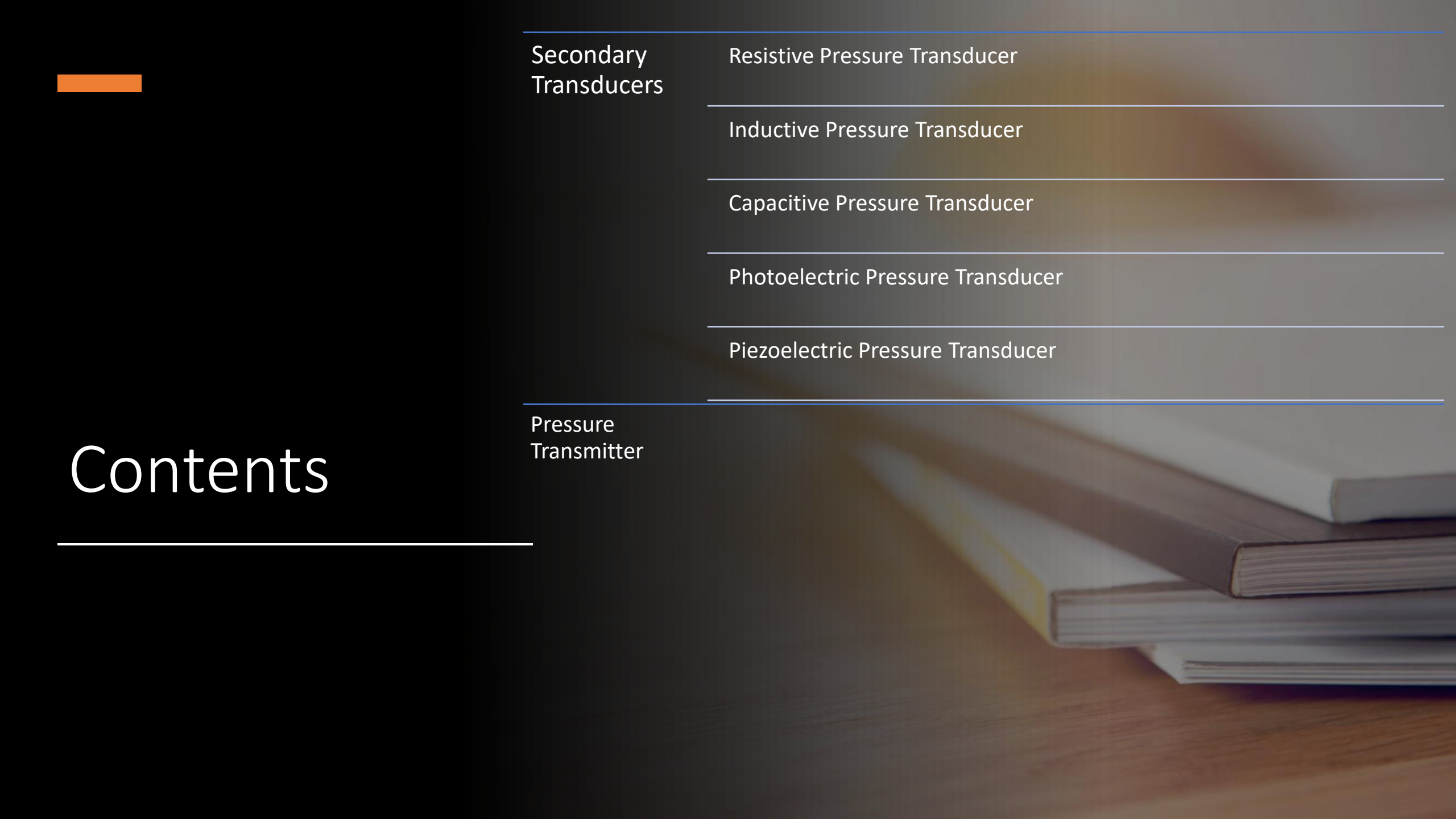
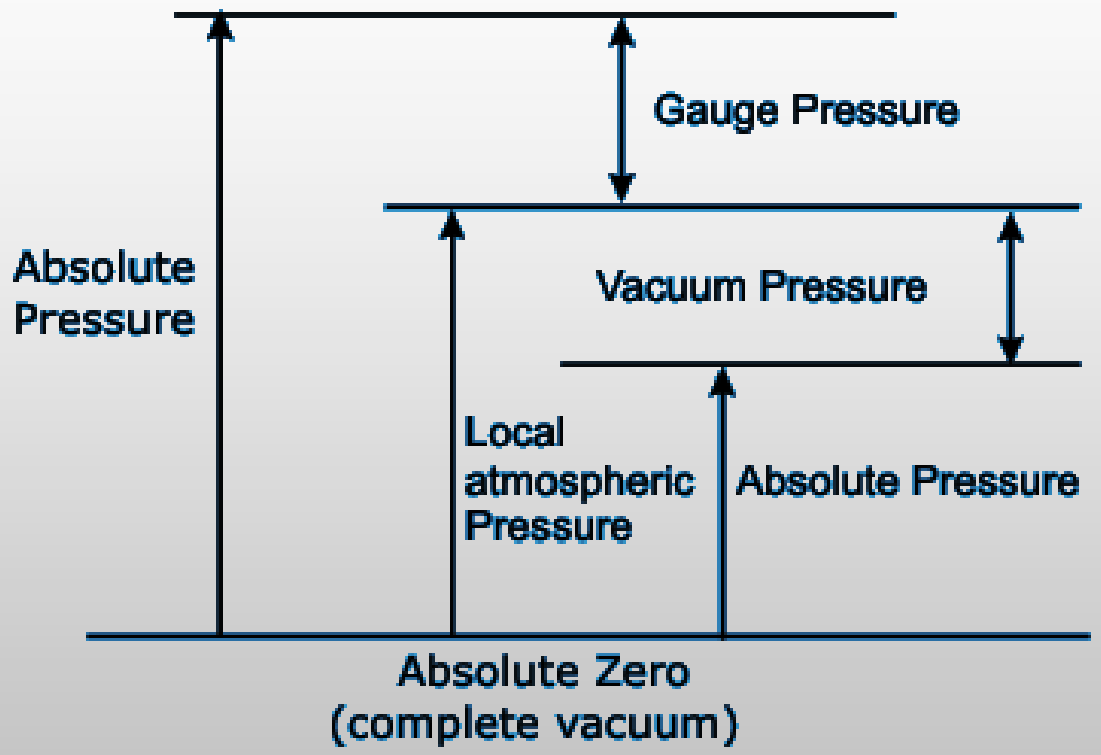


# Static and Dynamic Pressure

- Static Pressure
  - Due to weight of the molecules “pressing down”
- Dynamic Pressure
  - Relative movement when a body is moving through air

# ABSOLUTE, GAUGE AND VACUUM PRESSURE



# Pressure Measuring Terms

**Absolute Pressure**

Measured above total vacuum or zero absolute. Zero absolute represents total lack of pressure.

**Atmospheric Pressure**

The pressure exerted by the earth's atmosphere. Atmospheric pressure at sea level is 14.696 psia. The value of atmospheric pressure decreases with increasing altitude.

**Barometric Pressure**

Same as atmospheric pressure.

**Gauge Pressure**

The pressure above atmospheric pressure. Represents positive difference between measured pressure and existing atmospheric pressure. Can be converted to absolute by adding actual atmospheric pressure value.

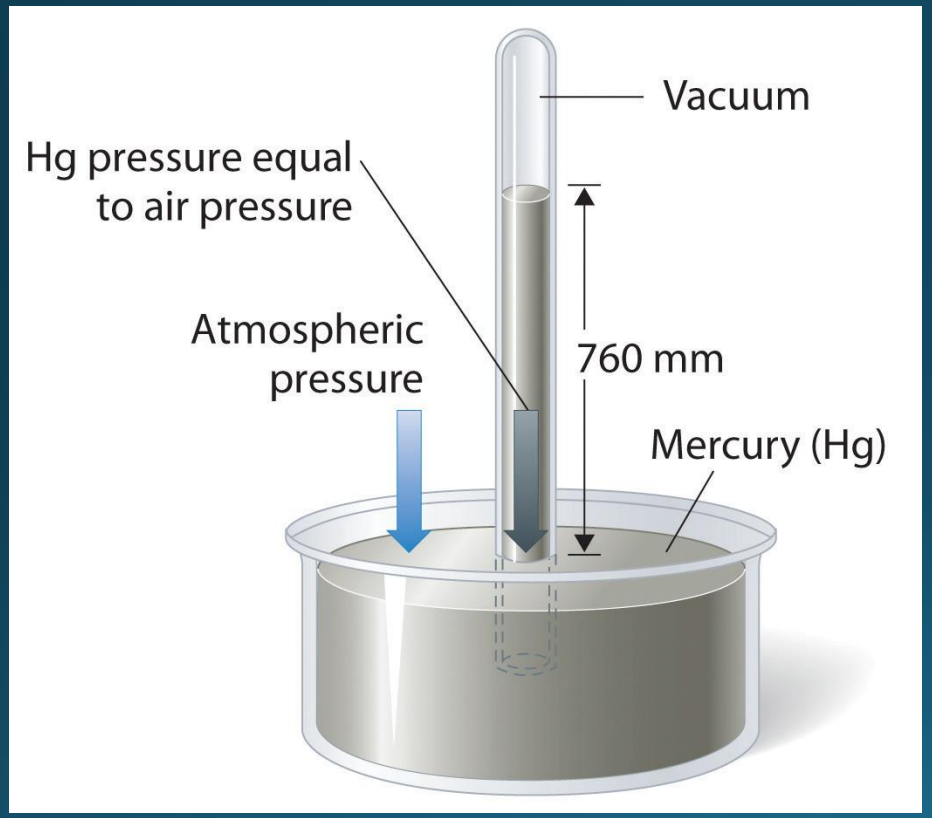
**Differential Pressure**

The difference in magnitude between some pressure value and some reference pressure. In a sense, absolute pressure could be considered as a differential pressure with total vacuum or zero absolute as the reference. Likewise, gauge pressure (defined above) could be considered as Differential Pressure with atmospheric pressure as the reference.

# Pressure Units

| Unit abbreviation | Name of unit | Pa = N/m² | bar | kp/m² = mm WS | m WS | kp/cm² = at | p/cm² |
|---|---|---|---|---|---|---|---|
| 1 Pa = 1 N/m² | Pascal | 1 | 0.00001 | 0.10197 | 0.0001 | 0.00001 | 0.0102 |
| 1 bar | bar | 100000 | 1 | 10197.2 | 10.1972 | 1.01972 | 1019.72 |
| 1 kp/m² ≙ 1 mm WC | millimeter hydrostatic head | 9.80665 | - | 1 | 0.001 | 0.0001 | 0.1 |
| 1 m WC | meter hydrostatic head | 9806.65 | 0.09807 | 100 | 1 | 0.1 | 100 |
| 1 kp/cm² = 1 a | technical atmosphere | 98066.5 | 0.98067 | 10000 | 10 | 1 | 1000 |
| 1 p/cm² | | 98.0665 | 0.00098 | 10 | 0.01 | 0.0001 | 1 |
| 1 atm | physical atmosphere | 101325 | 1.01325 | 10332.3 | 10.3323 | 1.03323 | 1033.23 |
| 1 Torr = 1 mm Hg | millimeter column of mercury | 133.322 | 0.00133 | 13.5951 | 0.013595 | 0.00136 | 1.35951 |
| 1 lbf/in² | pound-force per square inch | 6894.76 | 0.06895 | 703.07 | 0.70307 | 0.07031 | 70.307 |
| 1 lbf/ft² | pound-force per square foot | 47.8803 | 0.00048 | 4.88243 | 0.00488 | 0.00048 | 0.48824 |
| 1 in Hg | inch column of mercury | 3386.39 | 0.03386 | 345.316 | 0.34532 | 0.03453 | 34.5316 |

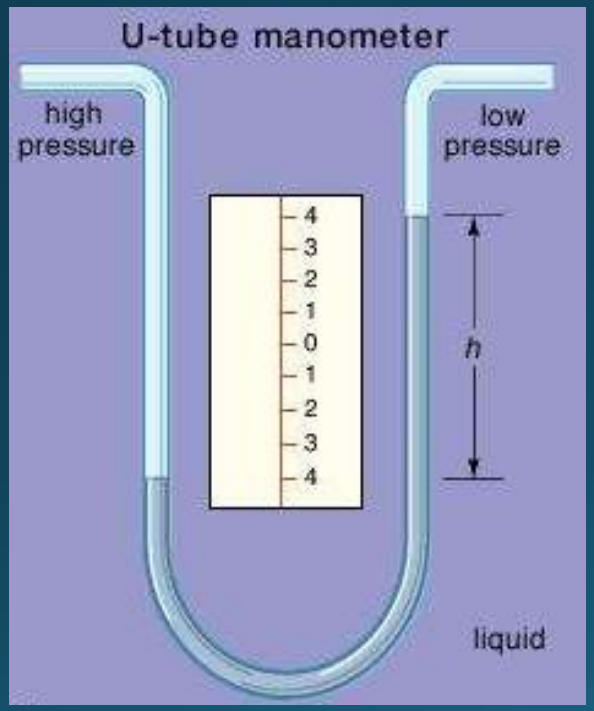
# Mercury Barometer




Atmospheric Pressure Measurement

- Pressure applied by the mercury at the bottom of the column is equal to **atmospheric pressure**.
- Pressure is expressed in height (760 mm Hg), also known as **pressure head**.

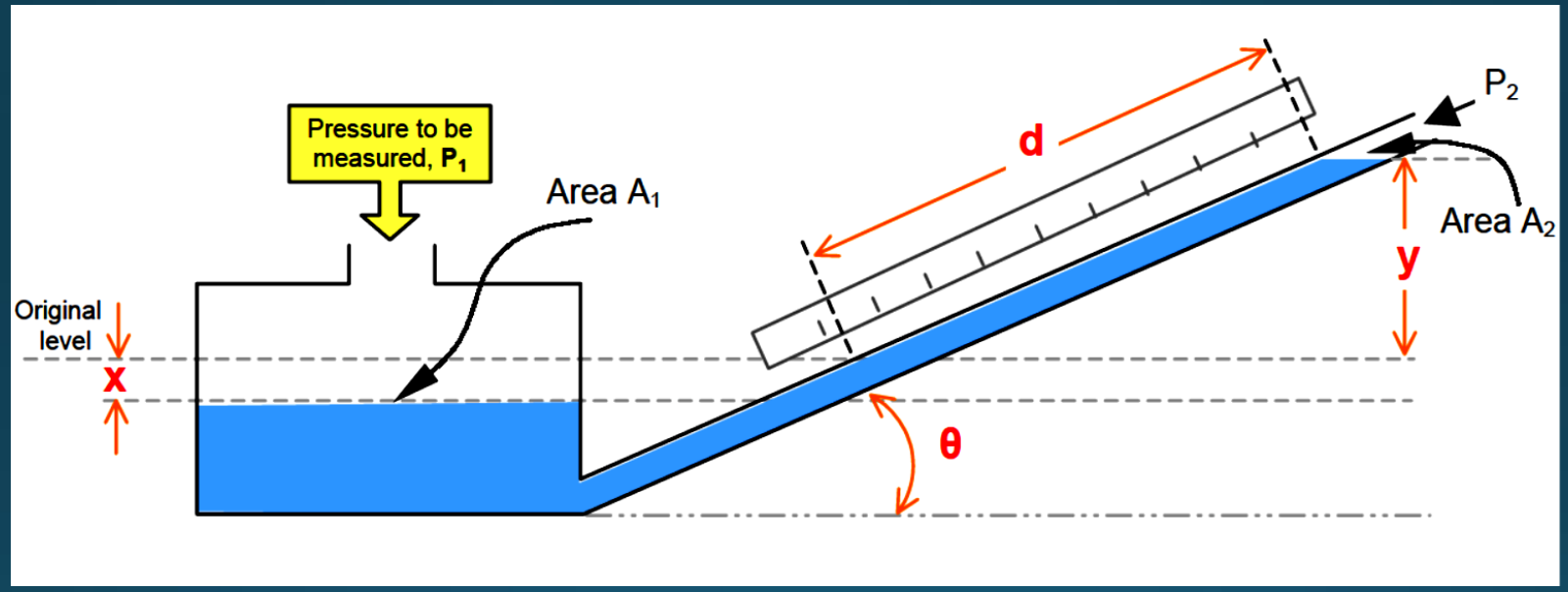
# U-tube Manometer




Differential Pressure Measurement

- Difference of the heights between two columns shows the **differential pressure**.
- **Gauge pressure** can be measured in this was if one column is exposed to atmosphere.

# Inclined Limb Manometer




- One of the limb is inclined.
- Sensitivity of the instrument increases.

# Manometers

Characteristics of Manometer Fluids:

1. It should not wet the wall of the container.
2. It should not absorb gas or chemically react with it.
3. It should be reasonably high density so that the pressure balancing column stays within a desirable limit.
4. It should have low vapor pressure at the operating temperature.
5. It should freely move in the limbs of the manometer.
6. It should not be compressible.

# Manometers

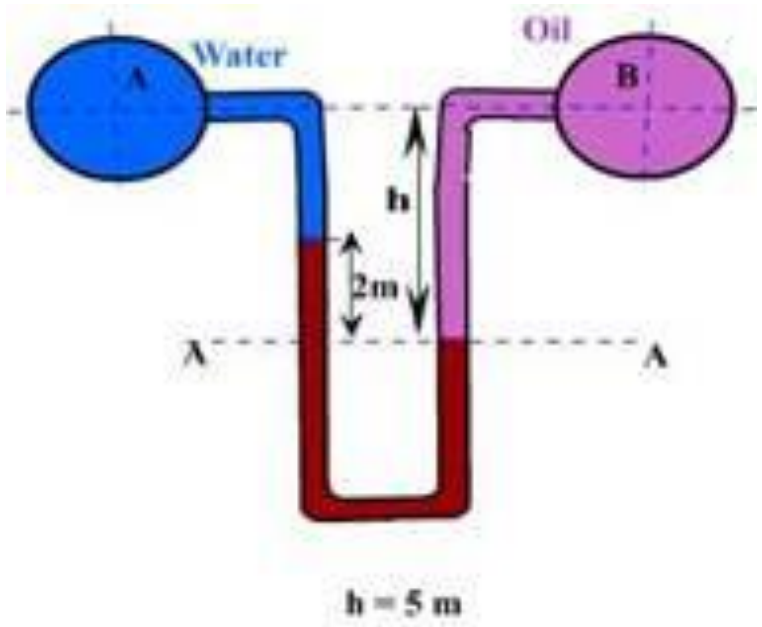
**Advantages:**

1. Manometers are considered as standard of pressure by many standardizing institutions..
2. They are simple and low-cost devices.
3. Suitable sensors such as capacitance or sonar devices can be used to provide better precision in their readouts.

**Disadvantages:**

Higher pressure measurements with manometers are impractical because of the length of liquid columns involved.

**Problem-1:** Two pipes on the same elevation convey water and oil of specific gravity 0.88 respectively. They are connected by a U-tube manometer with the manometric liquid having a specific gravity of 1.25. If the manometric liquid in the limb connecting the water pipe is 2 m higher than the other find the pressure difference in two pipes.



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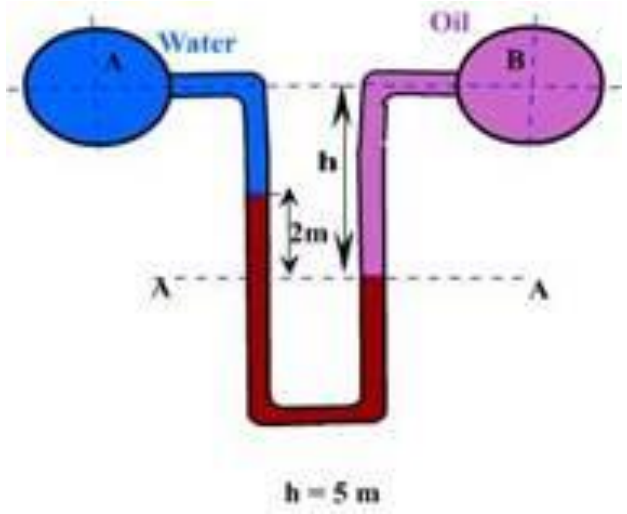
**Solution:**

Given data:




Height difference = 2 m

Specific gravity of oil = 0.88

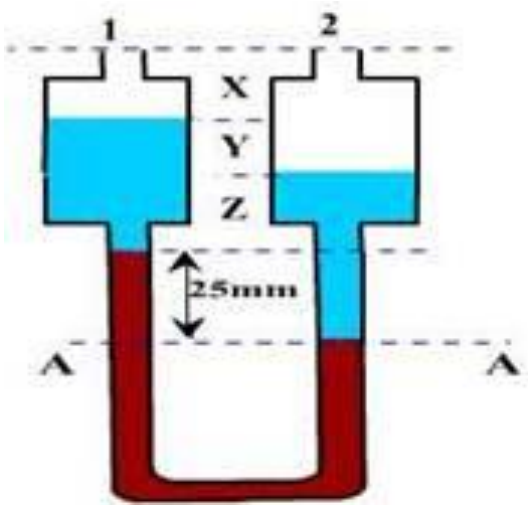
Specific gravity of manometric liquid = 1.25

Equating pressure head at section (A-A)

$$P_A + 2 \times 1.25 \rho_w \, g + (h-2) \rho_w \, g = P_B + h \times 0.88 \rho_w \, g$$

Substituing h = 5 m and density of water 998.2 kg/m$^3$ we have $P_A - P_B = 10791$

**Problem-2:** A two liquid double column enlarged-ends manometer is used to measure pressure difference between two points. The basins are partially filled with liquid of specific gravity 0.75 and the lower portion of U-tube is filled with mercury of specific gravity 13.6. The diameter of the basin is 20 times higher than that of the U-tube. Find the pressure difference if the U-tube reading is 25 mm and the liquid in the pipe has a specific weight of 0.475 $N/m^3$.



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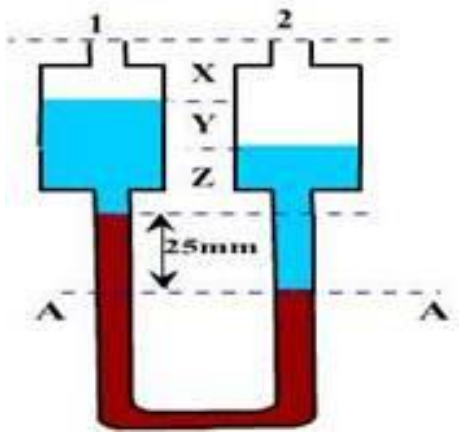
**Solution:** Given data: U-tube reading 25 mm
Specific gravity of liquid in the basin 0.75
Specific gravity of Mercury in the U-tube 13.6

As the volume displaced is constant, we have,

$$Y = 25\frac{a}{A} = 25 \times \frac{1}{20^2}$$

[a, A -- Cross-Section of tube and basin, respectively]




Equating pressure head at (A--A)

$$P_1 + X \quad 0.475 \quad + (Z+Y)\rho_w g \times 0.75 + 25 \times 13.6 \rho_w g$$

$$= P_2 + (X+Y) \; 0.475 \; + (Z+25) \times 0.75 \rho_w g$$

Put the value of Y while X and Z cancel out.
Answer: 3.151 kPa