Thermodynamics I

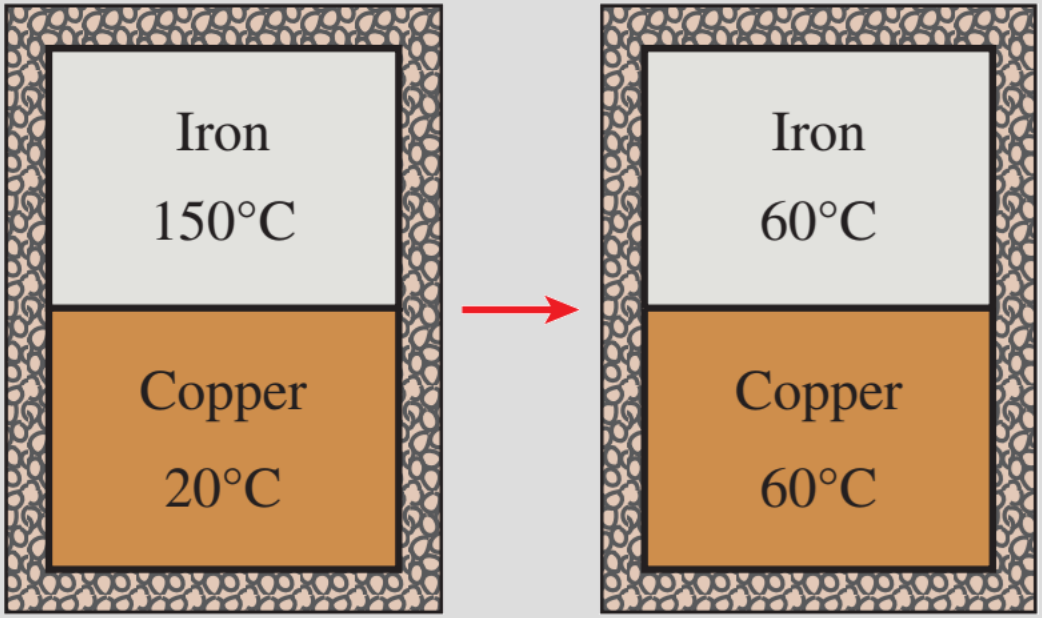
Lecture 4

Introduction and Basic Concepts (Ch-1)

Dr. Ahmed Rasheed

TEMPERATURE AND THE ZEROTH LAW OF THERMODYNAMICS

- **The zeroth law of thermodynamics**: If two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.
- By replacing the third body with a thermometer, the zeroth law can be restated as *two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact*.



Two bodies reaching thermal equilibrium after being brought into contact in an isolated enclosure.

TEMPERATURE SCALES

- All temperature scales are based on some easily reproducible states such as the freezing and boiling points of water: the *ice point* and the *steam point.*
- **Ice point**: A mixture of ice and water that is in equilibrium with air saturated with vapor at 1 atm pressure (0°C or 32°F).
- **Steam point**: A mixture of liquid water and water vapor (with no air) in equilibrium at 1 atm pressure (100°C or 212°F).
- **Celsius scale**: in SI unit system
- **Fahrenheit scale**: in English unit system
- **Thermodynamic temperature scale**: A temperature scale that is independent of the properties of any substance.

Kelvin scale (SI) **Rankine scale** (E)

$$T(\text{K}) = T(^\circ\text{C}) + 273.15$$

$$T(\text{R}) = T(^\circ\text{F}) + 459.67$$

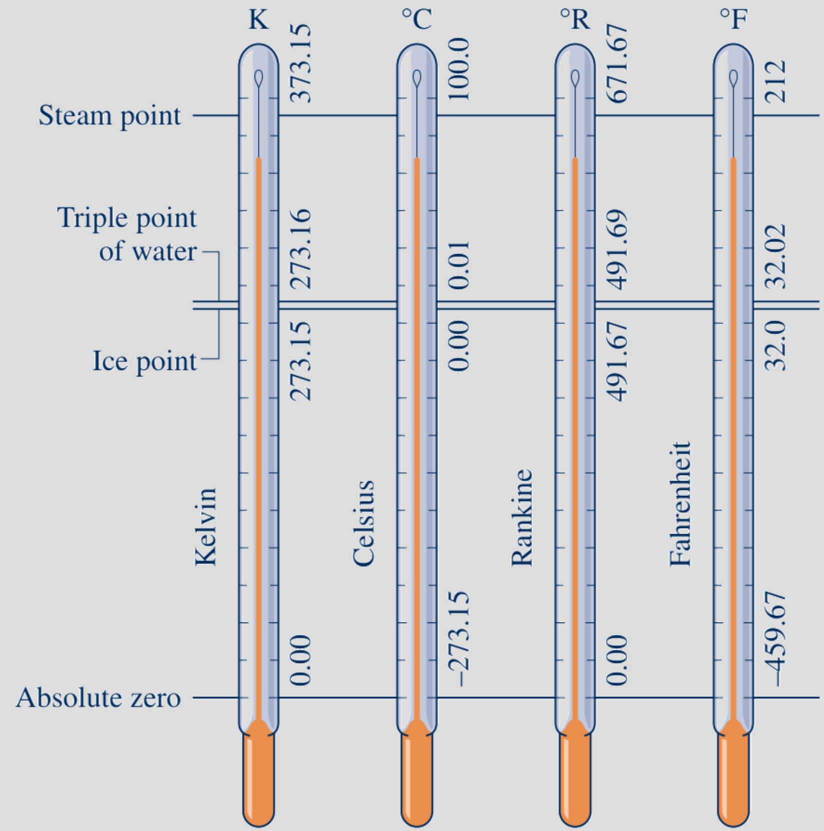
$$T(\text{R}) = 1.8T(\text{K})$$

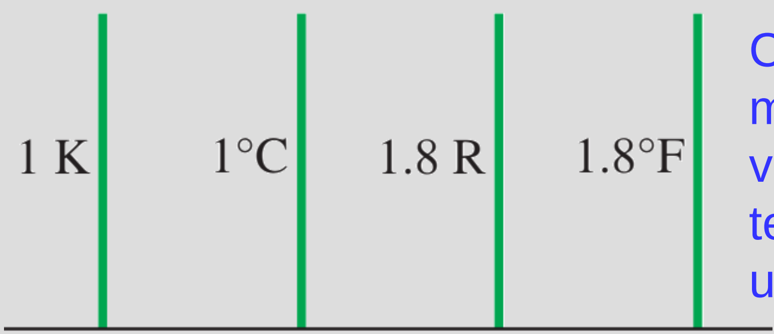
$$T(^\circ\text{F}) = 1.8T(^\circ\text{C}) + 32$$

$$\Delta T(\text{K}) = \Delta T(^\circ\text{C})$$

$$\Delta T(\text{R}) = \Delta T(^\circ\text{F})$$

Comparison of temperature scales.



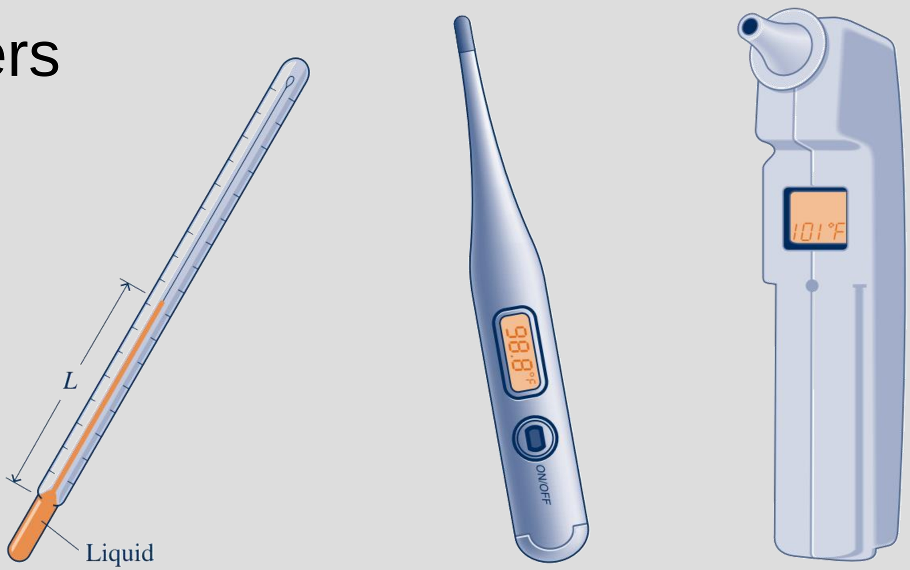


Comparison of magnitudes of various temperature units.

- The reference temperature in the original Kelvin scale was the ***ice point***, 273.15 K, which is the temperature at which water freezes (or ice melts).
- The reference point was changed to a much more precisely reproducible point, the ***triple point*** of water (the state at which all three phases of water coexist in equilibrium), which is assigned the value 273.16 K.

Temperature Measurement Devices

- Thermometers (Mercury based, Alcohol based)
- Thermocouples
- RTD (Resistance Temperature Detector)
- Thermistors
- Radiation Thermometers
- Optical Pyrometers



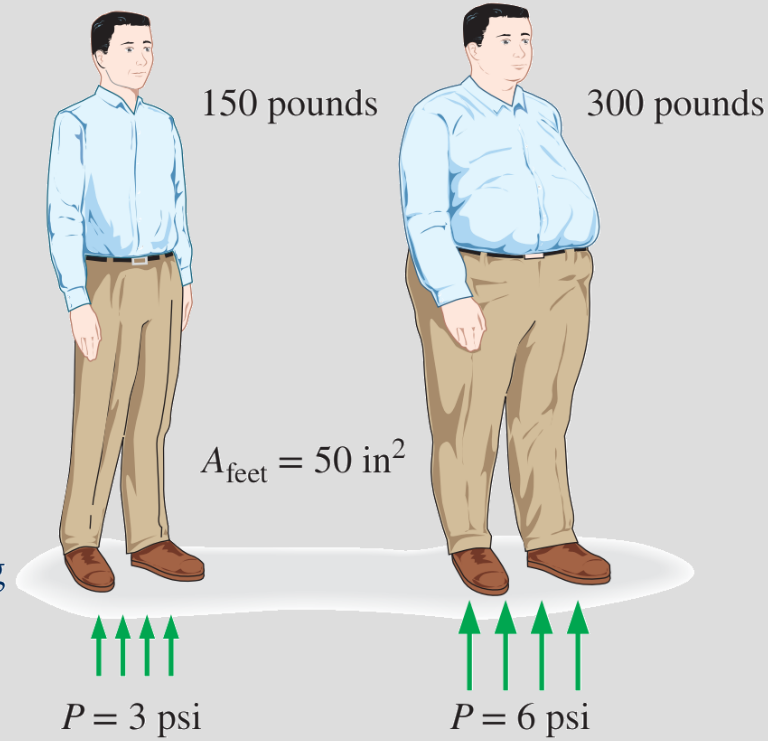
(a) (b) (c)

PRESSURE

Pressure: A normal force exerted by a fluid per unit area

$$1 \text{ pascal} = 1 \text{ N/m}^2$$

$$1 \text{ standard atmosphere (atm)} = \begin{cases} 1.01325 \times 10^5 \text{ N/m}^2 \\ 14.696 \text{ lbf/in.}^2 \\ 760 \text{ mmHg} = 29.92 \text{ inHg} \end{cases}$$



$$P = \sigma_n = \frac{W}{A_{\text{feet}}} = \frac{150 \text{ lbf}}{50 \text{ in}^2} = 3 \text{ psi}$$

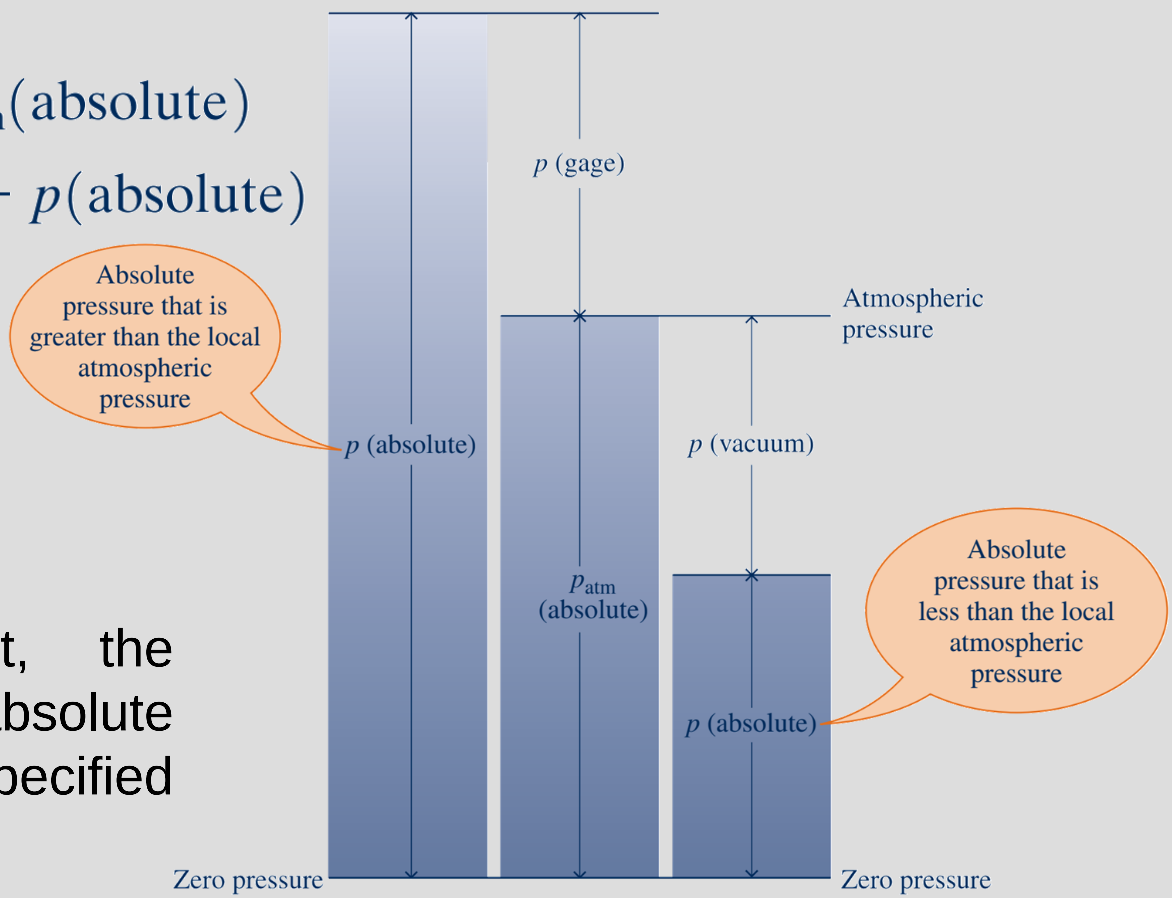
The normal stress (or “pressure”) on the feet of a chubby person is much greater than on the feet of a slim person.

Some basic pressure gages.

- **Absolute pressure**: The actual pressure at a given position. It is measured relative to absolute vacuum (i.e., absolute zero pressure).
- **Gage pressure**: The difference between the absolute pressure and the local atmospheric pressure. Most pressure-measuring devices are calibrated to read zero in the atmosphere, and so they indicate gage pressure.
- **Vacuum pressures**: Pressures below atmospheric pressure.

$$p(\text{gage}) = p(\text{absolute}) - p_{\text{atm}}(\text{absolute})$$

$$p(\text{vacuum}) = p_{\text{atm}}(\text{absolute}) - p(\text{absolute})$$



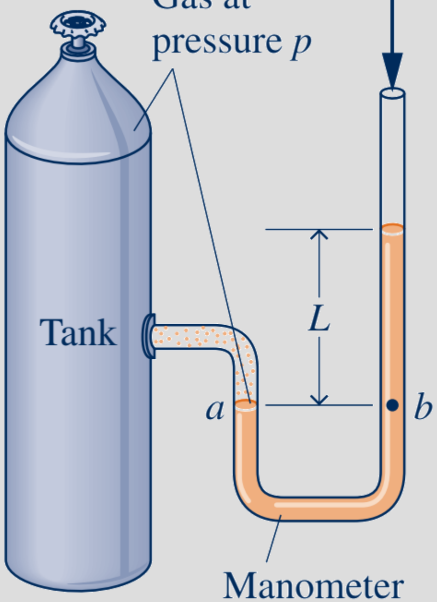
Throughout this text, the pressure P will denote absolute pressure unless specified otherwise.

Pressure Measurement

In terms of the length of a column of liquid

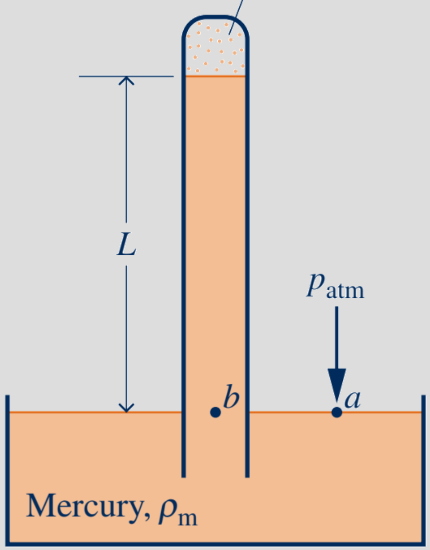
Manometer:

$$p = p_{\text{atm}} + \rho g L$$

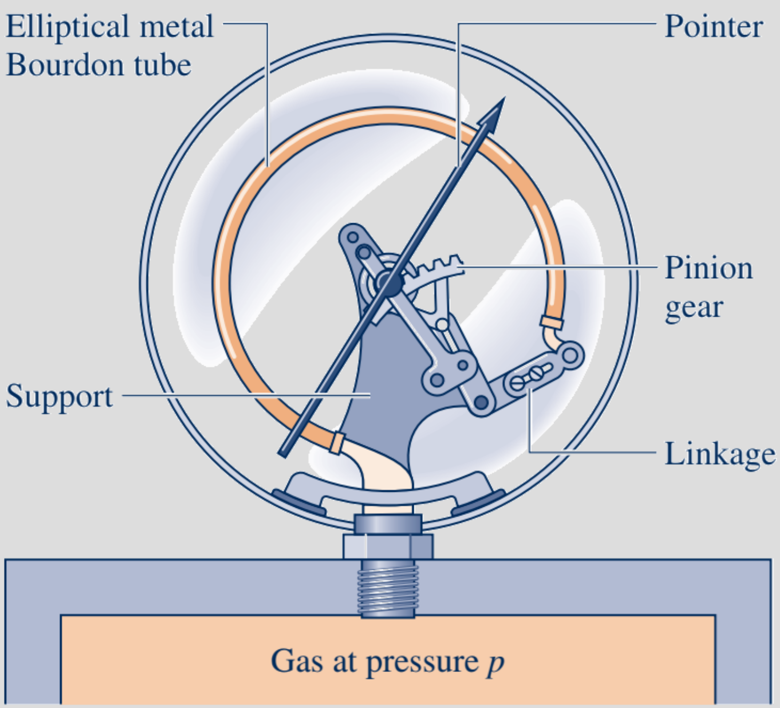


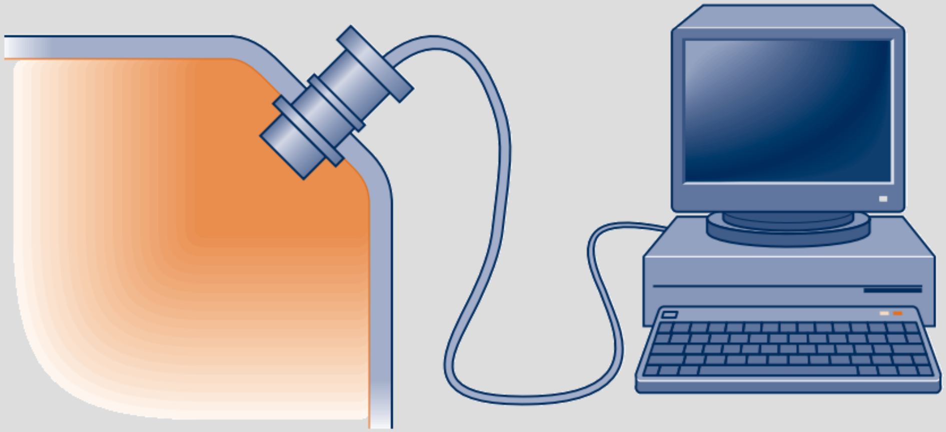
Barometer:

$$p_{\text{atm}} = p_{\text{vapor}} + \rho_{\text{m}} g L$$



Pressure Measurement





Bourden Tube Gauge

Piezoelectric Transducer

Piezoelectric effect: A charge is generated within certain solid materials when deformed i.e. crystals and ceramics e.g. Quartz

PROBLEM-SOLVING TECHNIQUE

- Step 1: Problem Statement
- Step 2: Schematic
- Step 3: Assumptions and Approximations
- Step 4: Physical Laws
- Step 5: Properties
- Step 6: Calculations
- Step 7: Reasoning, Verification, and Discussion

Summary

- Thermodynamics and energy
  - ✓ Application areas of thermodynamics
- Importance of dimensions and units
  - ✓ Some SI and English units, Dimensional homogeneity, Unity conversion ratios
- Systems and control volumes
- Properties of a system
- Density and specific gravity
- State and equilibrium
  - ✓ The state postulate
- Processes and cycles
  - ✓ The steady-flow process
- Temperature and the zeroth law of thermodynamics
  - ✓ Temperature scales
- Pressure
- The manometer and the atmospheric pressure
- Problem solving technique