Lecture 1

Fundamental Concepts

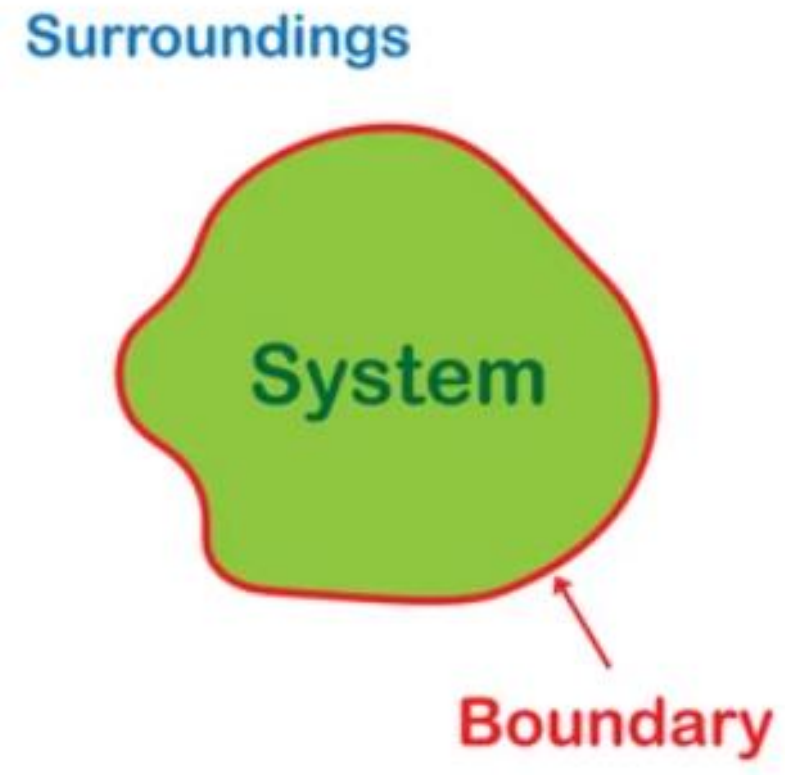
- Thermodynamic state and system, boundary, surrounding, universe, Thermodynamic systems – closed, open, isolated, adiabatic, homogeneous and heterogeneous, macroscopic and microscopic, properties of system – intensive and extensive, thermodynamic equilibrium, quasi – static process, reversible and irreversible processes, definition of properties like pressure, volume, temperature, enthalpy, internal energy.

INTRODUCTION

- The study of thermodynamics is concerned with the ways energy is stored within a body and how energy transformations, which involve heat and work, may take place.
- One of the most fundamental laws of nature is the conservation of energy principle.
- It simply states that during an energy interaction, energy can change from one form to another but the total amount of energy remains constant. That is, energy cannot be created or destroyed.

Thermodynamic System

- **Thermodynamic system** is a definite quantity of matter most often contained within some closed surface
- **A system** is defined as a quantity of matter or a region in space chosen for study
- **Surroundings**- collectively all matter external to a system
- **Boundary**- is the real or imaginary surface that separates the system from its surroundings. It can be either fixed or movable

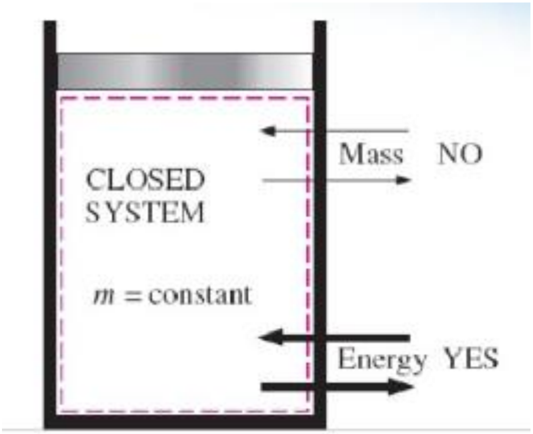


Thermodynamic System

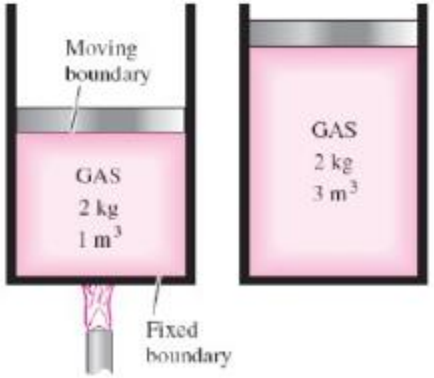
Three Classes of Systems

- **Closed System**-there is no interchange of matter between system and surroundings.
- A closed system (also known as a control mass) consists of a fixed amount of mass, and no mass can cross its boundary

Mass cannot cross the boundaries of a closed system, but energy can.



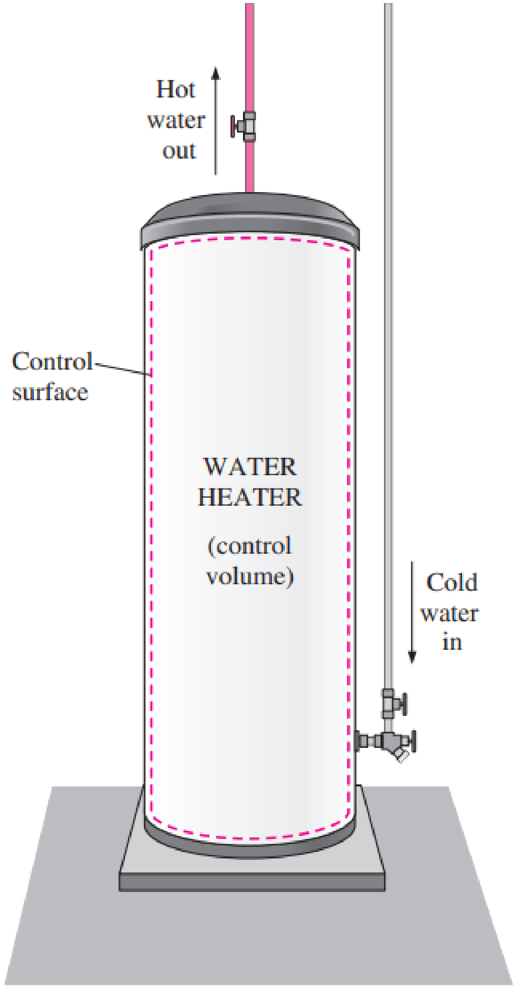
Closed system with moving boundaries



Thermodynamic System

- **Open System**-there is interchange of matter between system and surroundings.
- An open system, or a control volume, as it is often called, is a properly region in space. It usually encloses a device that involves mass flow such as a compressor, turbine, or nozzle

An open system (a control volume) with one inlet and one exit.



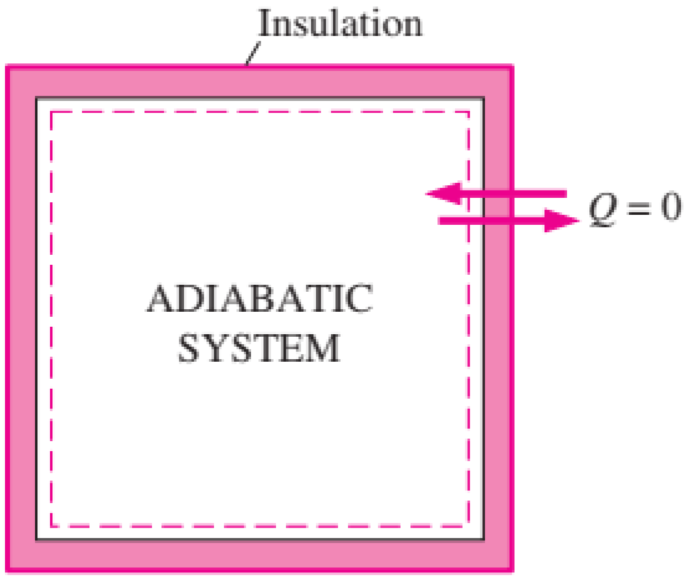
Thermodynamic System

- An **isolated system** is a thermodynamic system that cannot exchange either energy or matter outside the boundaries of the system. There are two ways in which this may occur:

1. The system may be so distant from another system that it cannot interact with them.
2. The system may be enclosed such that neither energy nor mass may enter or exit.

Thermodynamic System

- An adiabatic system is considered a closed system. Energy is not transferred as heat but it can still change if it is transferred to or from the system as work. This is why (change in) U=w because q is zero.



Thermodynamic System

- **Homogeneous system-** Is a system with same chemical composition and uniform physical structure throughout its mass, and it exist in a single phase
- **Heterogeneous system-** Is a system consisting of different chemical composition exist in more than one phase

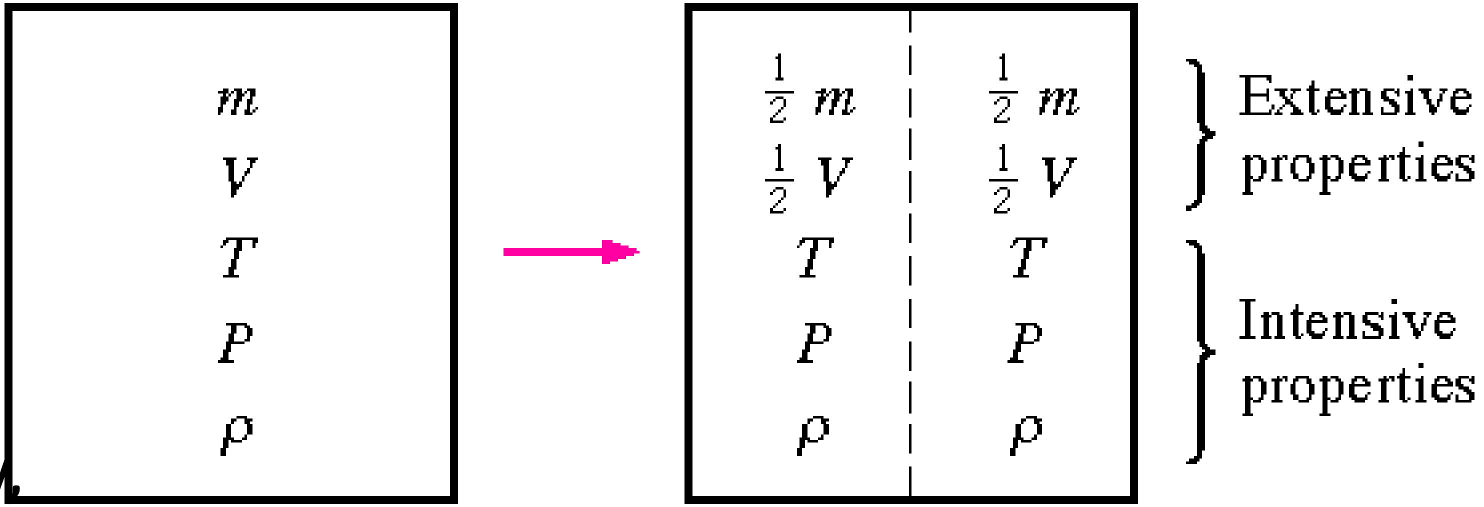
Thermodynamic System

- **Microscopic system-** Is a roughly of atomic dimensions, or smaller (no visible), while
- **Macroscopic** is large enough to be visible in the ordinary sense. However the exact definition depends on the number of particles in the system

Properties of system

- Properties of a system is a measurable characteristic of a system that is in equilibrium.
- Properties may be intensive or extensive.

- Intensive – Are independent of the amount of mass:
  e.g: Temperature, Pressure, and Density,
- Extensive – varies directly with the mass:
  e.g: mass, volume, energy, enthalpy



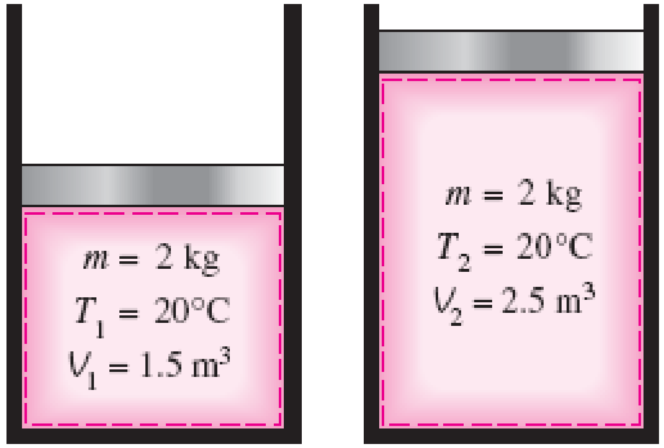
Properties of system

- **Specific properties** – The ratio of any extensive property of a system to that of the mass of the system is called an average specific value of that property (also known as intensives property)

Specific Volume	$V/m = v$	m^3/kg
Total Energy	$E/m = e$	J/kg
Internal Energy	$U/m = u$	J/kg

Thermodynamic equilibrium

- Thermodynamic equilibrium - system that maintains thermal, mechanical, phase and chemical equilibriums.
- State – a set of properties that describes the conditions of a system. Eg. mass m, Temperature T, volume V

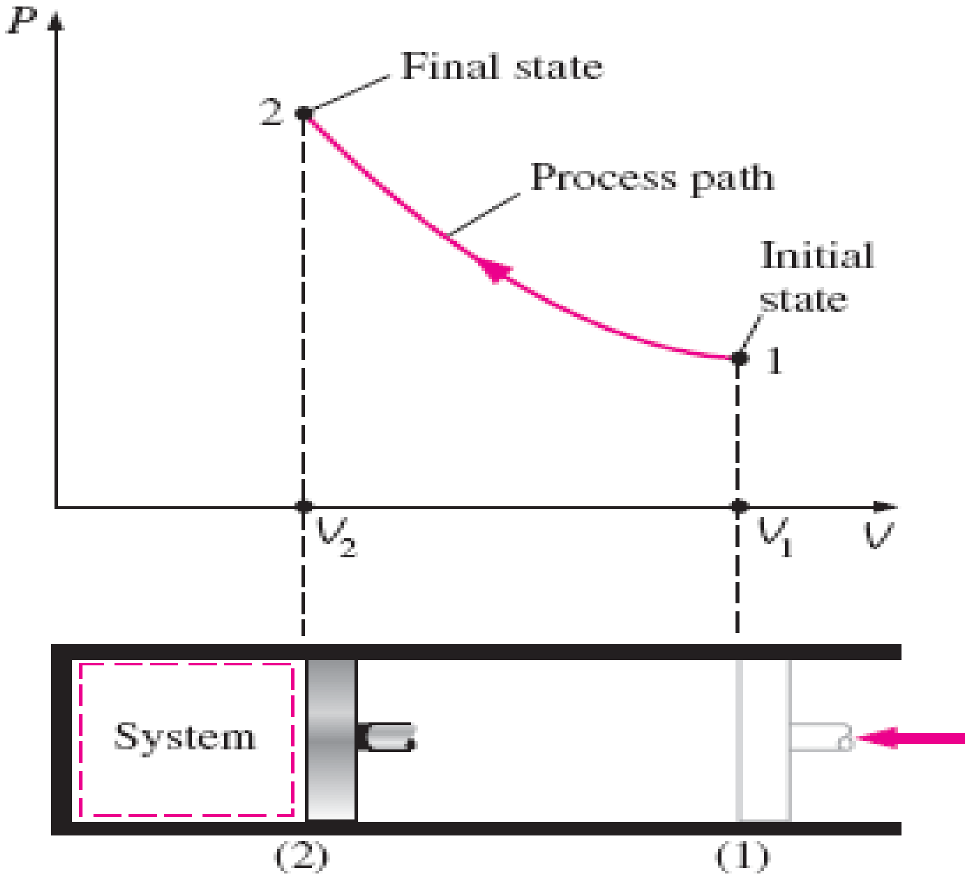


(a) State 1 (b) State 2

Equilibrium and process

- Process – change from one equilibrium state to another

Process	Property held constant
isobaric	pressure
isothermal	temperature
isochoric	volume
isentropic	entropy

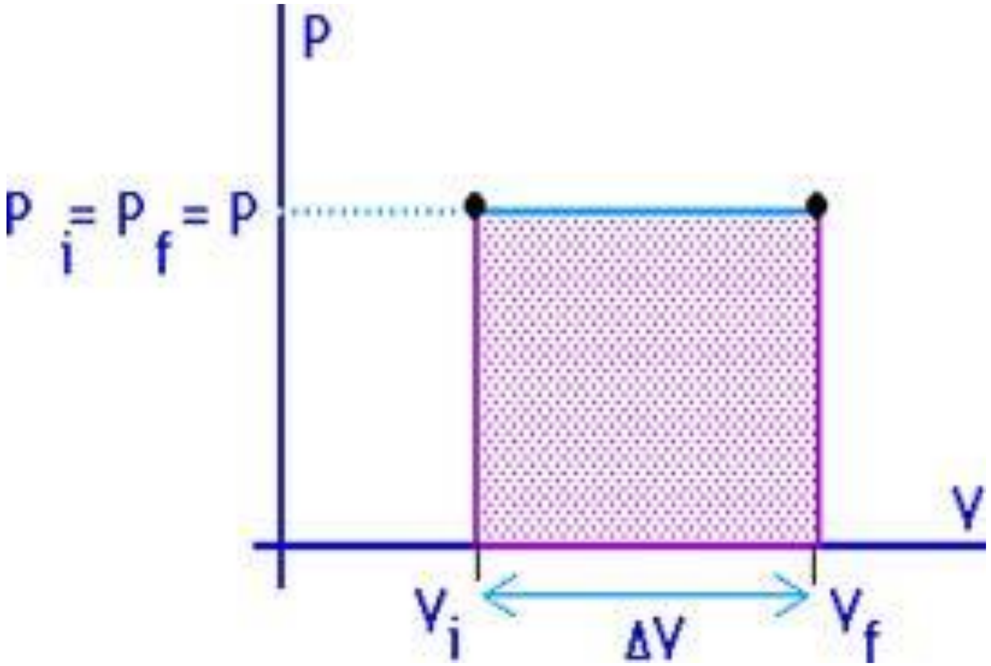


Equilibrium and process

- **Quasi processes**:-When a process moves so slowly that all parts of the system change at the same rate and are in equilibrium with all other parts of the system, the process is called quasi-static or a quasi-equilibrium process.
- A **quasi-equilibrium** process is an idealized process and does not occur in nature.
  - Serve as a standard to be compared to.

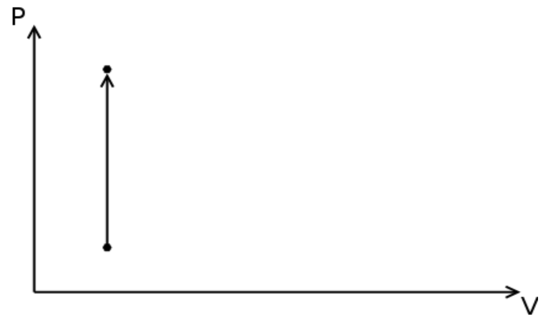
Equilibrium and process

- The prefix iso- is often used to designate a process for which a particular property remains constant.
- **Isobaric process**: A process during which the pressure *P* remains constant.
- **Pressure** is Constant (**ΔP = 0**)

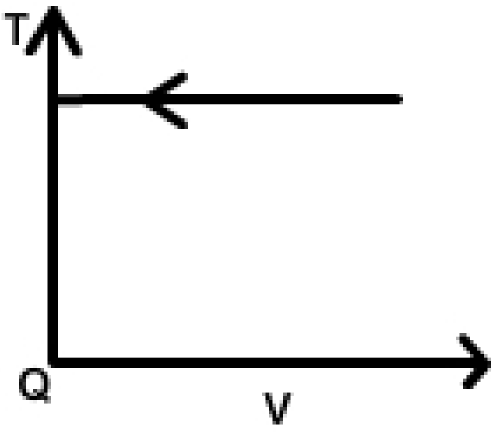


Equilibrium and process

- **Isochoric (or isometric) process**: A process during which the specific volume *v* remains constant



- **Isothermal process**: A process during which the temperature *T* remains constant.

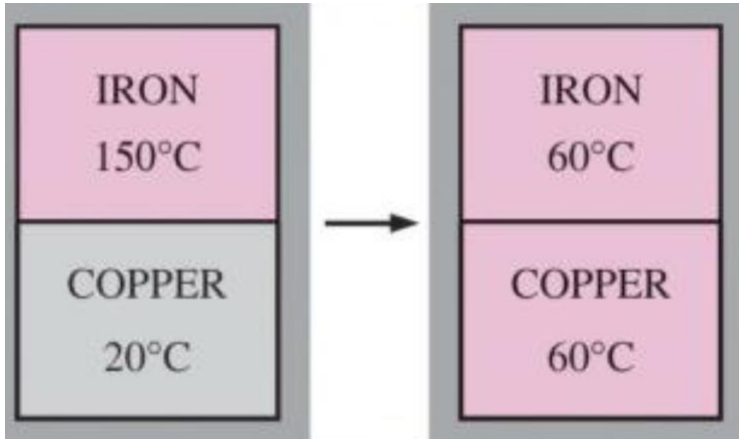


Types of Thermodynamics Processes

- **Cyclic process** - when a system in a given initial state goes through various processes and finally return to its initial state, the system has undergone a cyclic process or cycle.
- **Reversible process** - it is defined as a process that, once having take place it can be reversed. In doing so, it leaves no change in the system or boundary.
- **Irreversible process** - a process that cannot return both the system and surrounding to their original conditions

Temperature properties

- Relative: freezing cold, cold, warm, hot, red-hot
- Reference to know events, solidifying of water, vaporizing of water.
- Thermal equilibrium occurs when no temperature gradient exists, both objects are at same temperature.



Temperature properties

Temperature scale

- Relative or Two Point Scales
- Based on temperature of ice/liquid water and liquid water/water vapor mixtures
- SI system: Celsius scale based on 100 units between points (°C)
- English system: Fahrenheit scale based on 180 units between points with lower point set at 32 units (°F)

Temperature properties

- Thermodynamic temperature scales, absolute scales
- Based on absolute zero temperature
- SI system: Kelvin scale, freezing point of water at 273.15 units (K)
- English system: Rankine scale, freezing point of water at 459.67 units (R)
- Ideal-gas temperature scale

Temperature properties

- Kelvin to Celsius:

$$T(K) = T(°C) + 273.15$$

- Rankine to Fahrenheit:

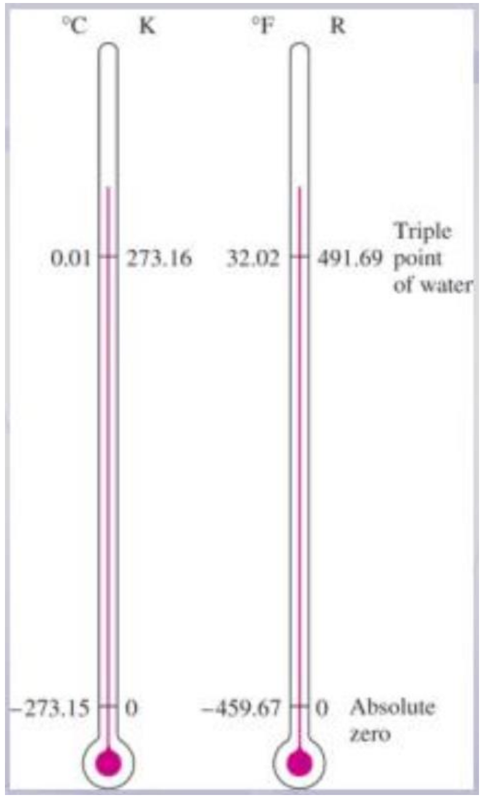
$$T(R) = T(°F) + 459.67$$

- Between the English and SI systems:

$$T(R) = 1.8T(K)$$

$$T(°F) = 1.8T(°C) + 32$$

Note that:
$\Delta T(K) = \Delta T(°C)$
$\Delta T(R) = \Delta T(°F)$

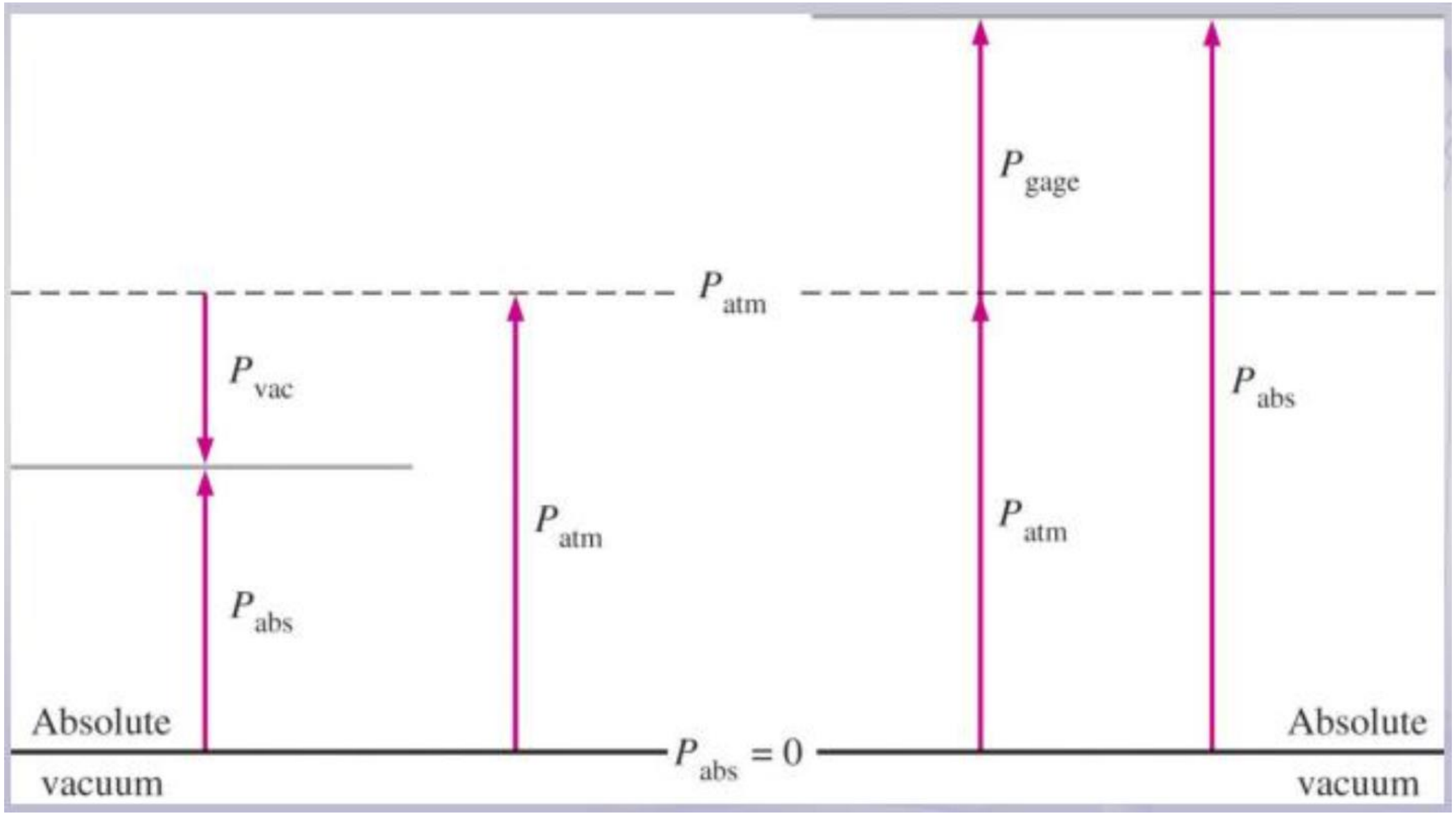


Pressure properties

- Pressure is a normal force exerted by a fluid per unit area
- Units, force/unit area, N/m2, called a pascal (Pa)
  - 1 bar = 105 Pa = 0.1 MPa = 100 kPa
  - 1 atm = 101.325 kPa = 1.01325 bars

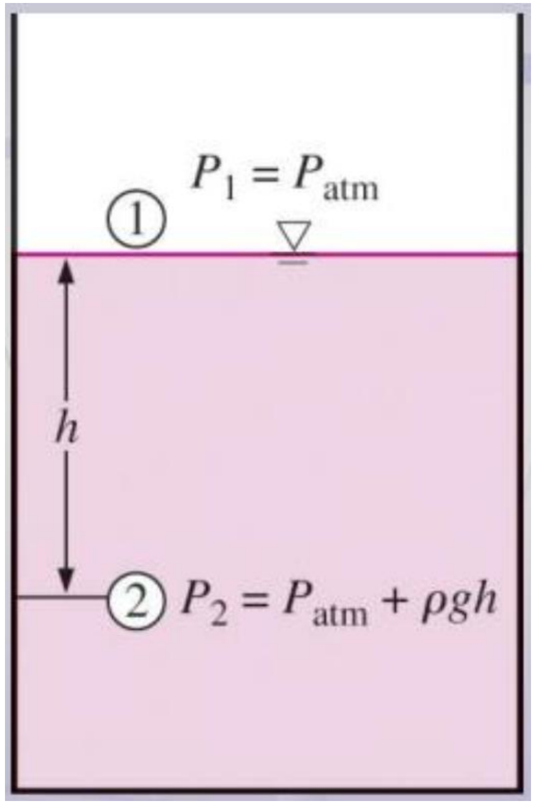
- Absolute pressure: relative to absolute vacuum (absolute zero pressure)
- Gage pressure: relative to atmospheric pressure
  - Pgage = Pabs - Patm
  - Pvac = Patm – Pabs

Pressure properties



Pressure properties

- $\Delta P = P_2 - P_1 = \rho g \Delta Z = \gamma_s \Delta z$
- $P = P_{atm} + \rho g h$ or
- $P_{gage} = \rho g h$



Volume and specific volume properties

- The specific volume (v) of substance is the total volume (V) of that substance divided by the total mass (m) of that substance.

$$v = \frac{V}{m}$$

  - v=specific volume (m^3/kg)
  - V= volume (m^3)
  - m=mass (kg)
- So, $\rho = density(kg/m^3)$

Enthalpy and internal energy properties

- Enthalpy (H) is the heat content of a system, or the amount of energy within a substance, both kinetic and potential.
- Every substance possesses a definite amount of energy which depends upon its chemical nature, temperature, pressure and volume. This is called internal energy (U).

Enthalpy and internal energy properties

- Enthalpy is a measure of the total energy of a thermodynamic system (kJ/kg). It includes the internal energy U, which is the energy required to create a system, and the amount of energy required to make room for it by displacing its environment and establishing its volume V and pressure P.

$$H = U + PV$$

- It is somewhat parallel to the first law of thermodynamics for a constant pressure system $Q = \Delta U + P\Delta V$, since in this case $Q=\Delta H$
- Internal energy and enthalpy are examples of state functions.

EXAMPLE 1

- A 0.6 kg copper piece at 100 ^oC is dropped in an insulated rigid tank which contains 0.75 kg of liquid water at 25 ^oC. Determine the temperature of the system when thermal equilibrium is established. Take specific heats of copper and water to be 0.393 kJ/(kg K) and 4.184 kJ/(kg k), respectively.