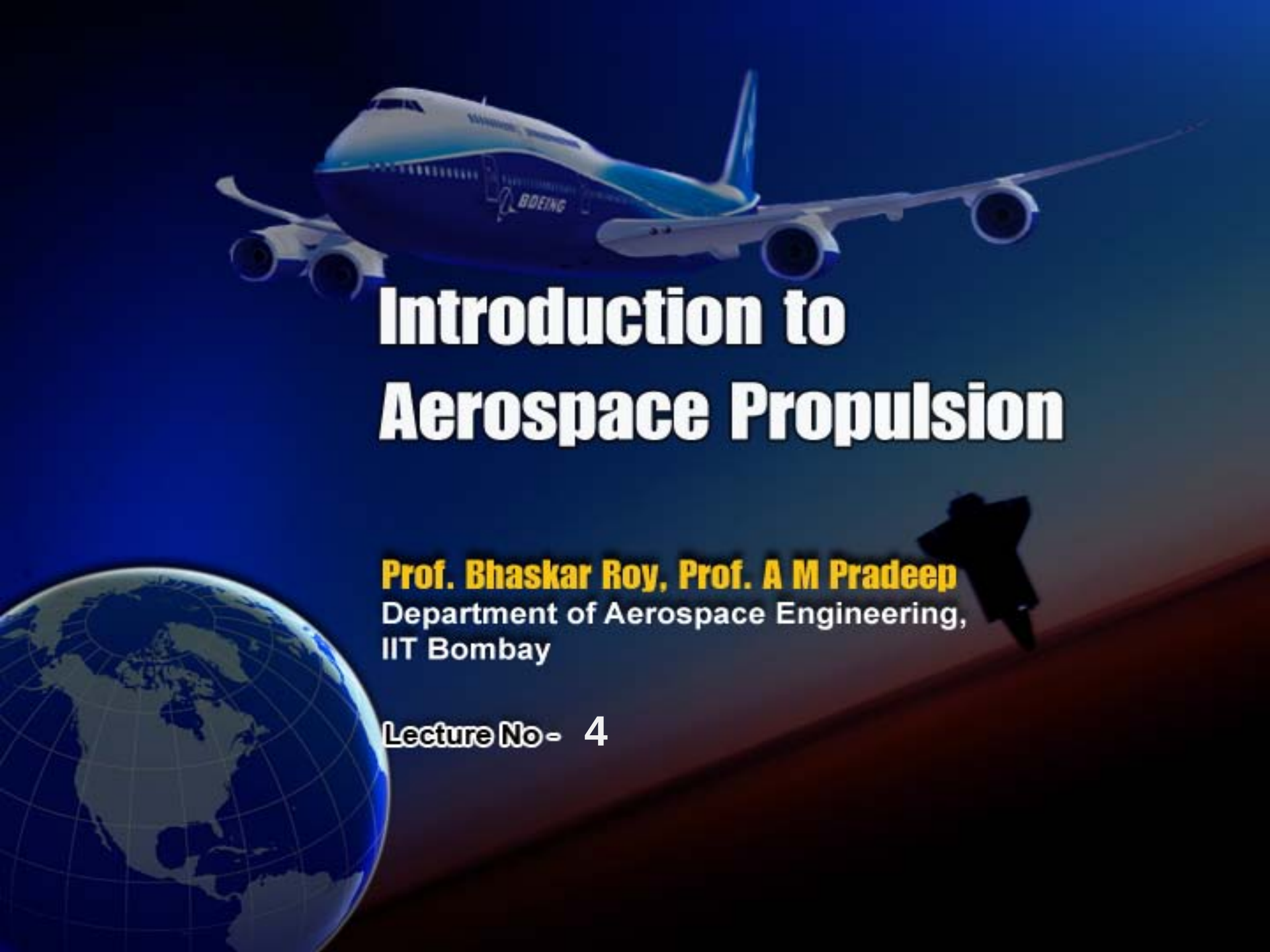

Introduction to Aerospace Propulsion

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Lecture No - 4

In this lecture ...

- Introduction to basic thermodynamics
- Understand the scope and method of thermodynamics
- Define basic terms/concepts
  - System, surroundings, boundary and universe
  - Types of systems
  - Property of a system
  - State of a system
  - Equilibrium
  - State postulate
  - Process, path and cycle

Basic Thermodynamics

- Defined as the “science of energy”
- Originates from Greek words *therme* (heat) and *dynamis* (power)
- Conversion of heat into power
- Thermodynamics encompasses all aspects of energy and energy conversions.
- Thermodynamics provides an understanding of the nature and degree of energy transformations.
- Thermodynamic laws are fundamental laws of nature.

Basic Thermodynamics

Examples:

- If we would like to
  - heat water in a kettle.
  - burn some fuel in the combustion chamber of an aero engine to propel an aircraft.
  - cool our room on a hot humid day.
  - heat up our room on a cold winter night.
- What is the smallest amount of electricity/fuel needed for the above ?

Basic Thermodynamics

- On the other hand when we burn,
  - some coal/gas in a power plant to generate electricity.
  - Petrol/Diesel in a car engine.
- What is the largest energy we can get out of these efforts?

- Thermodynamics allows us to answer some of these questions.

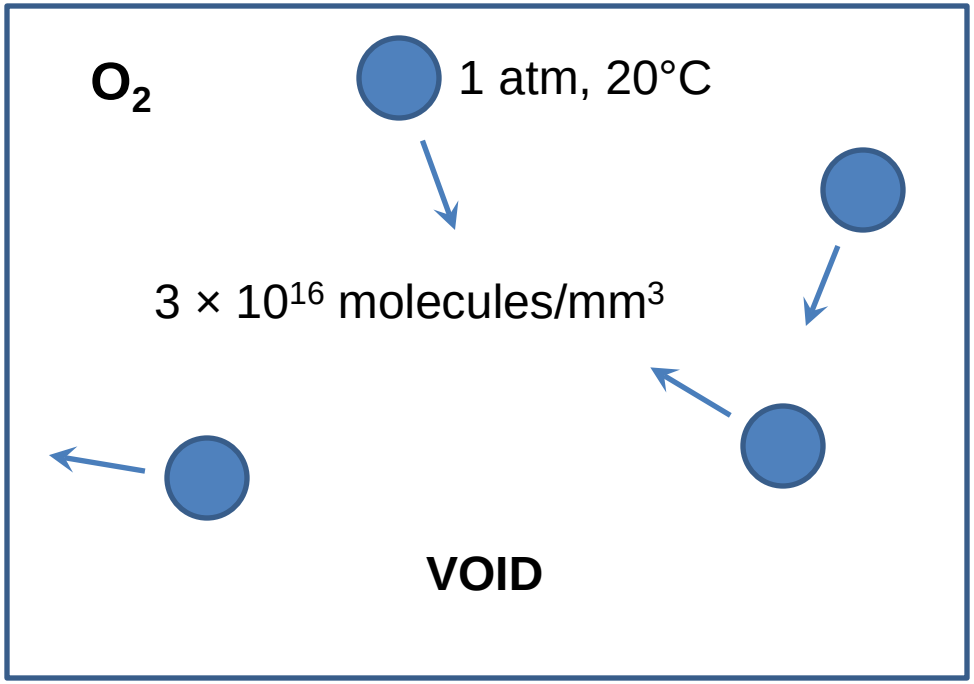
Basic Thermodynamics

- Macroscopic approach: Classical thermodynamics
  - Does not require knowledge of behavior of individual molecules
  - Easier and direct approach for engineering applications
  - Will be followed in this course
- Microscopic approach: Statistical thermodynamics
  - Based on behavior of group of molecules
  - Complicated, Kinetic theory of gases

Basic Thermodynamics

- Continuum:
  - Matter is made up of atoms that are widely spaced in the gas phase.
  - We disregard the atomic nature of a substance and view it as a continuous, homogeneous matter with no holes, that is, a continuum.
  - The continuum idealization allows us to treat properties as point functions and to assume the properties vary continually in space with no jump discontinuities.

Basic Thermodynamics

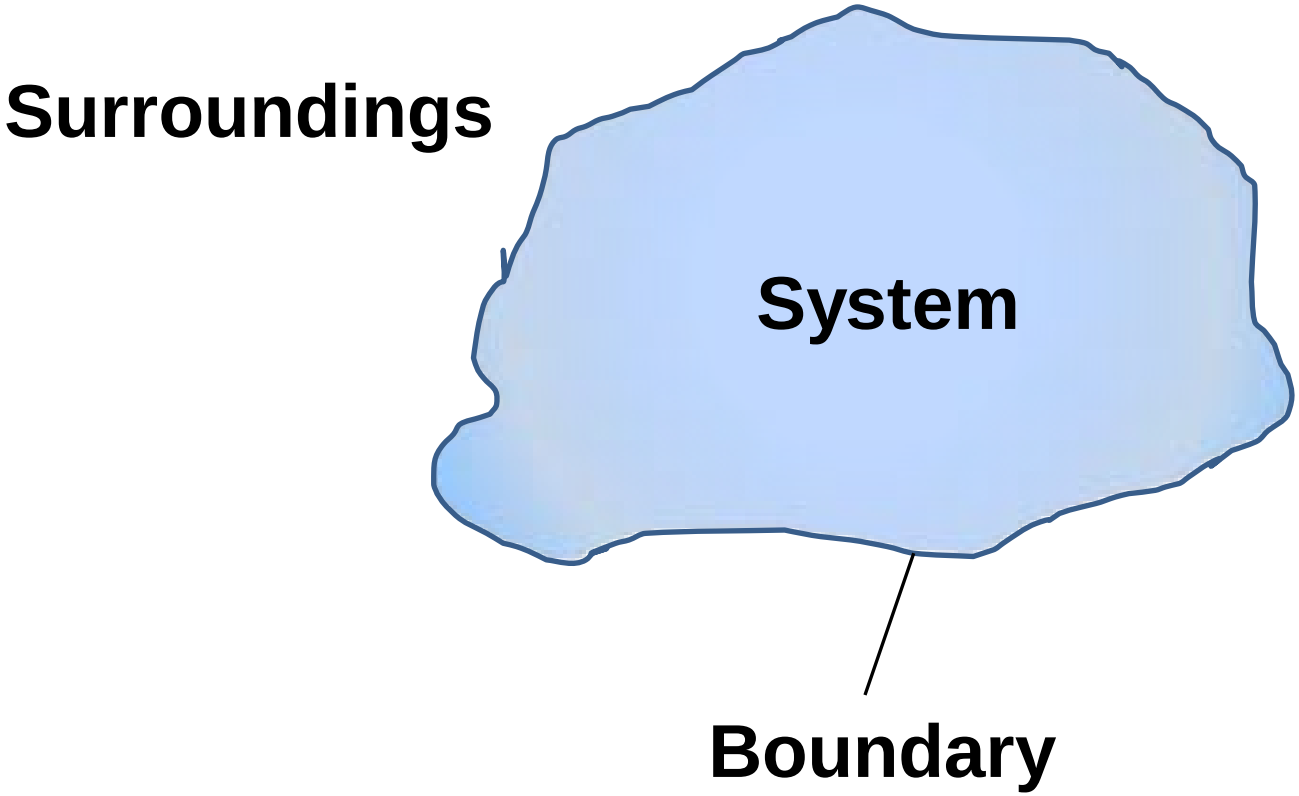


Despite the large gaps between molecules, a substance can be treated as a continuum because of the very large number of molecules

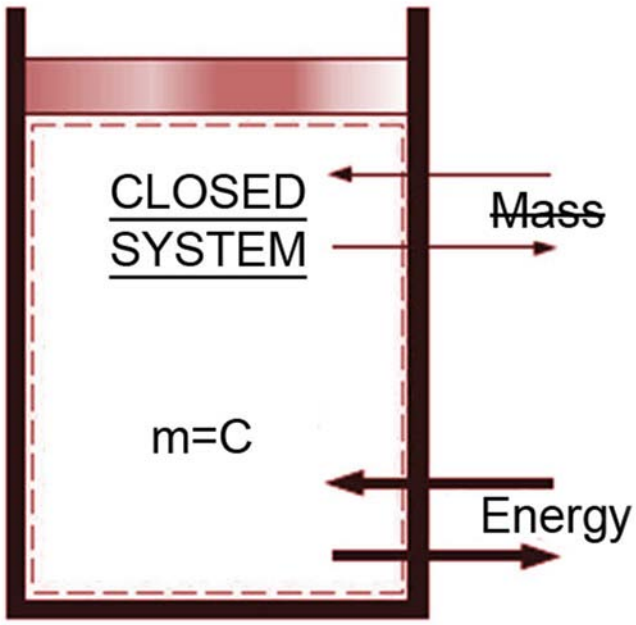
System and Control Volumes

- System: a quantity of matter in space chosen for study
  - It is a macroscopically identifiable collection of matter on which we focus our attention
- Surroundings: mass or region that surrounds a system
  - Surroundings pertain to that part of the universe that is close enough to have some perceptible effect on the system
- Boundary: real or imaginary surface that separates a system from its surroundings
  - May be fixed or movable
- Universe: system and its surroundings

System and Control Volumes



System and Control Volumes



- System
  - Closed system: no mass transfer, energy transfer possible
  - Open system: also called control volume, mass and energy transfer possible
  - Isolated system: neither energy nor mass transfer possible

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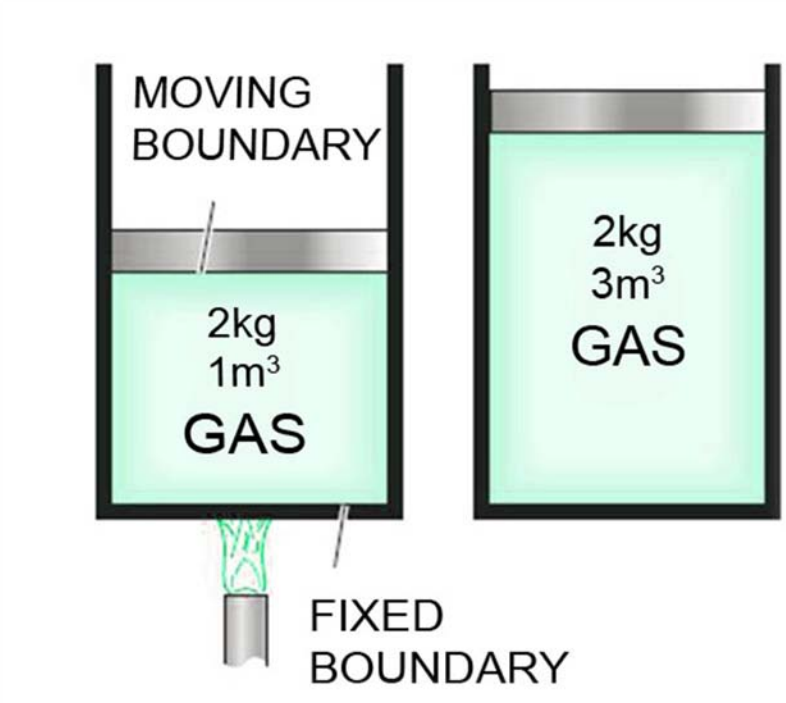
System and Control Volumes

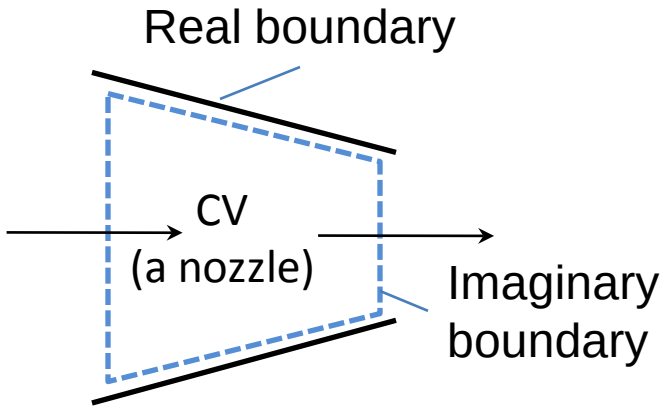
- We must choose the system for each and every problem we work on, so as to obtain best possible information on how it behaves.
- In some cases the choice of the system will be obvious and in some cases not so obvious.
- The boundaries may be real physical surfaces or they may be imaginary for the convenience of analysis.
- The boundaries may be at rest or in motion.

System and Control Volumes



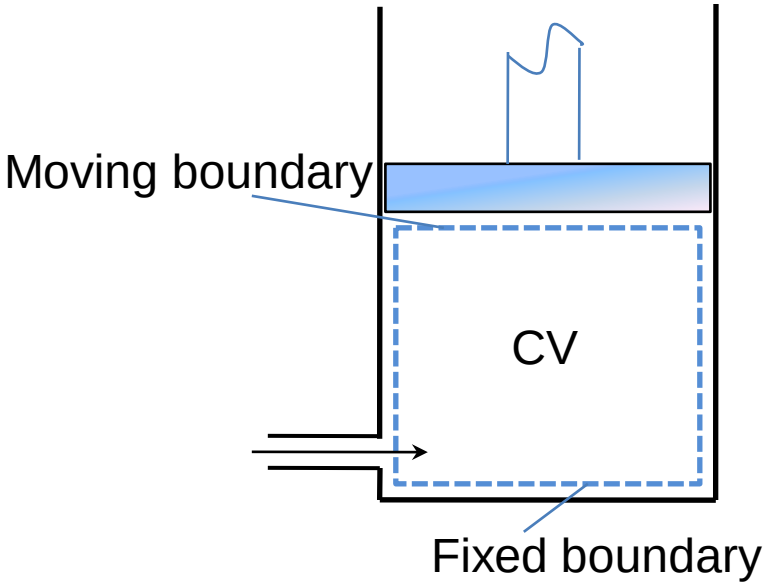
A closed system with a moving boundary

System and Control Volumes



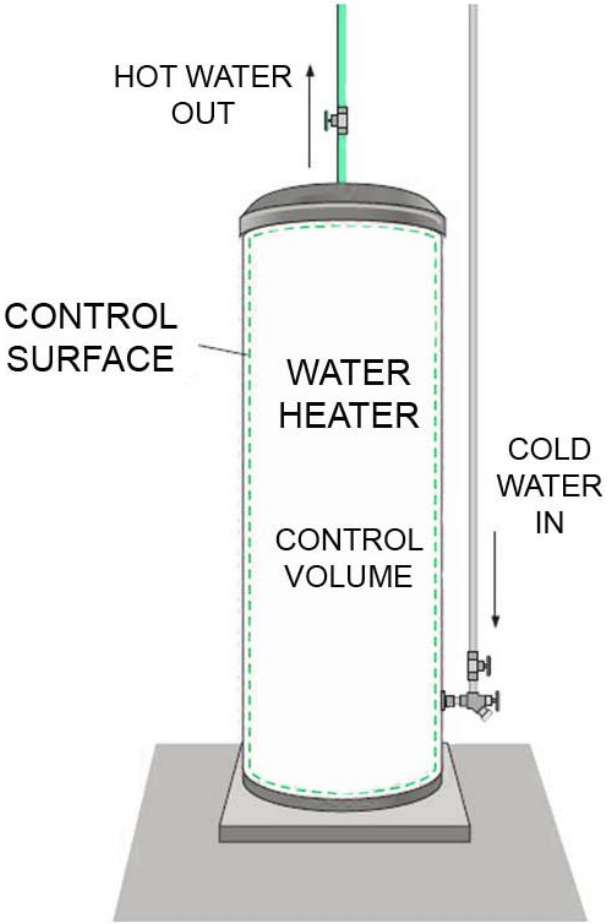
A control volume with real and imaginary boundaries

System and Control Volumes



A control volume with fixed and moving boundaries

System and Control Volumes

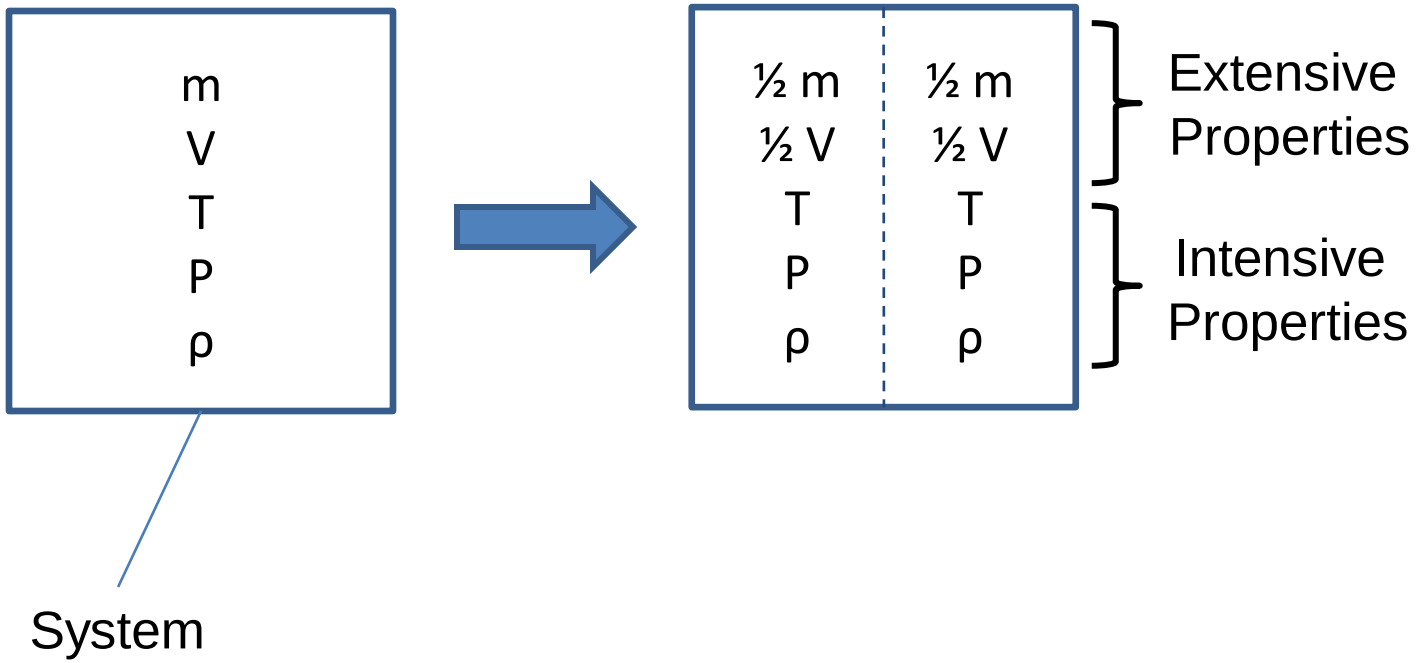


An open system (a control volume) with one inlet and one exit

Property

- Property: Any characteristic of a system
  - Temperature, pressure, density, mass…
- Intensive property: independent of mass
  - Temperature, pressure
- Extensive property: dependent on size or mass of the system
  - Mass, volume, momentum
- Specific properties: extensive properties per unit mass
  - specific volume (v=V/m), specific energy (e=E/m)

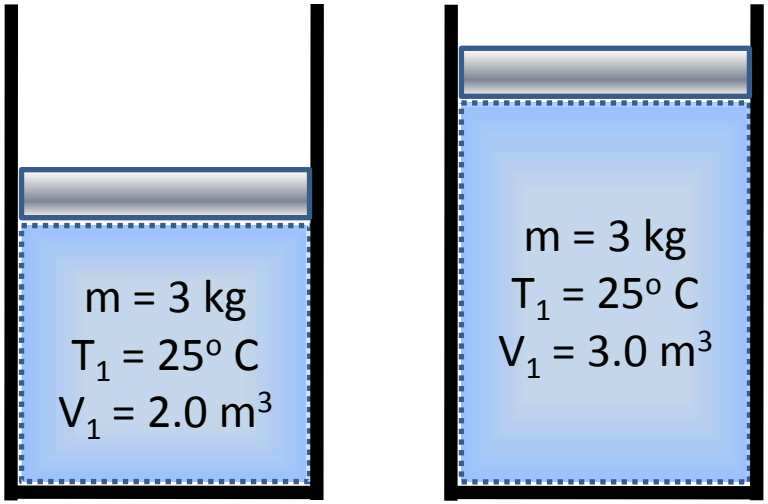
Properties of a system



State of a System

- State: a set of properties that completely defines the condition of a system.
- It gives a complete description of the system.
- At a given state, all the properties of a system have fixed values.
- Any operation in which one or more properties of a system change is called a change of state.

State of a System



(a) State 1 (b) State 2

A system at two different states

Equilibrium

- Thermodynamics deals with equilibrium states.
- The word equilibrium implies a state of balance.
- In an equilibrium state there are no unbalanced potentials (or driving forces) within the system.
- A system in equilibrium experiences no changes when it is isolated from its surroundings.

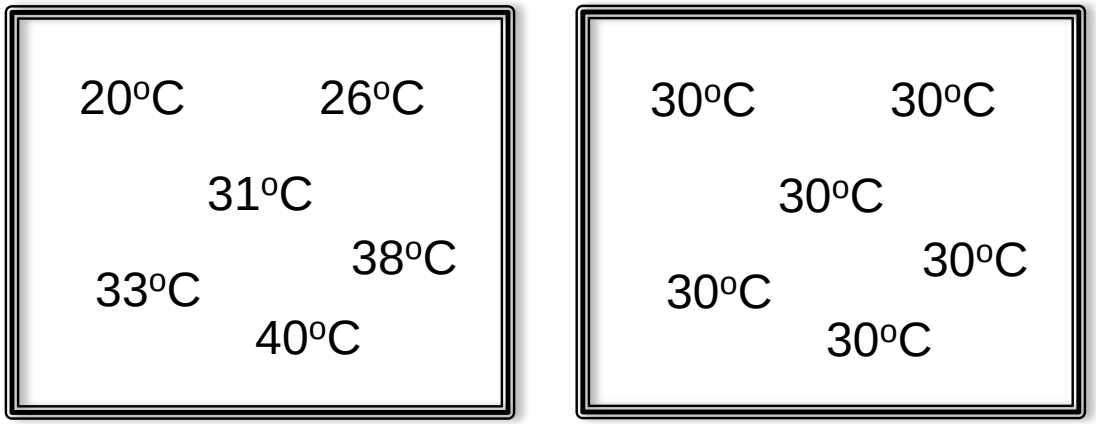
Equilibrium

- There are many types of equilibrium.
- These are mechanical equilibrium, thermal equilibrium, chemical equilibrium and phase equilibrium.
- A system is not in thermodynamic equilibrium unless the conditions of all the relevant types of equilibrium are satisfied.
- A system in thermodynamic equilibrium does not deliver any useful work.

Equilibrium

- Thermal equilibrium: if the temperature is the same throughout the system
- Mechanical equilibrium: if the pressure is the same throughout the system
- Chemical equilibrium: if the chemical composition does not change with time, i.e., no chemical reactions occur
- Phase equilibrium: when the mass of each phase reaches an equilibrium level and stays there

Equilibrium



(a) Before (b) After

A closed system reaching thermal equilibrium

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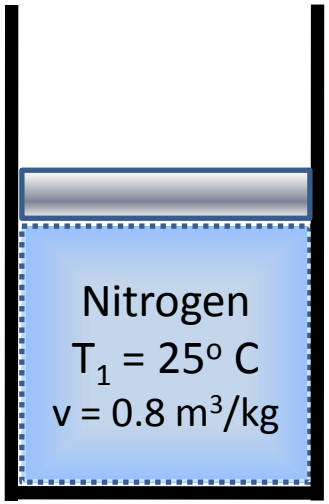
State Postulate

- The state of a system is described by its properties.
- Specifying a certain number of properties is sufficient to fix a state.
- State Postulate: The state of a simple compressible system is completely specified by two independent, intensive properties.
- Simple compressible system: absence of electrical, magnetic, gravitational, surface tension effects

State Postulate



- The state of nitrogen, for example, can be fixed by two independent, intensive properties.
- Temperature and specific volume are independent, intensive properties.
- But temperature and pressure are not independent, though are intensive properties.

Process, path and cycle

- Process: Any change that a system undergoes from one equilibrium state to another.
- Path: The series of states through which a system passes during a process.
- Cycle: If the system returns to its initial state at the end of the process
  - That is, for a cycle the initial and final states are identical.

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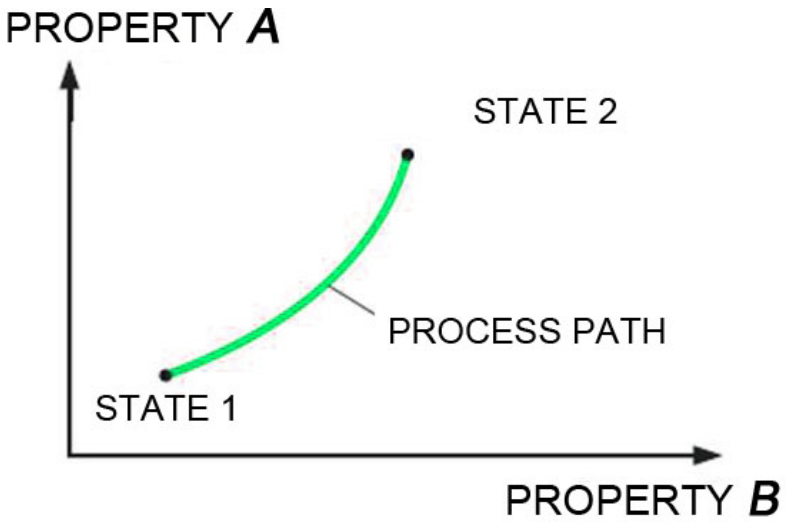
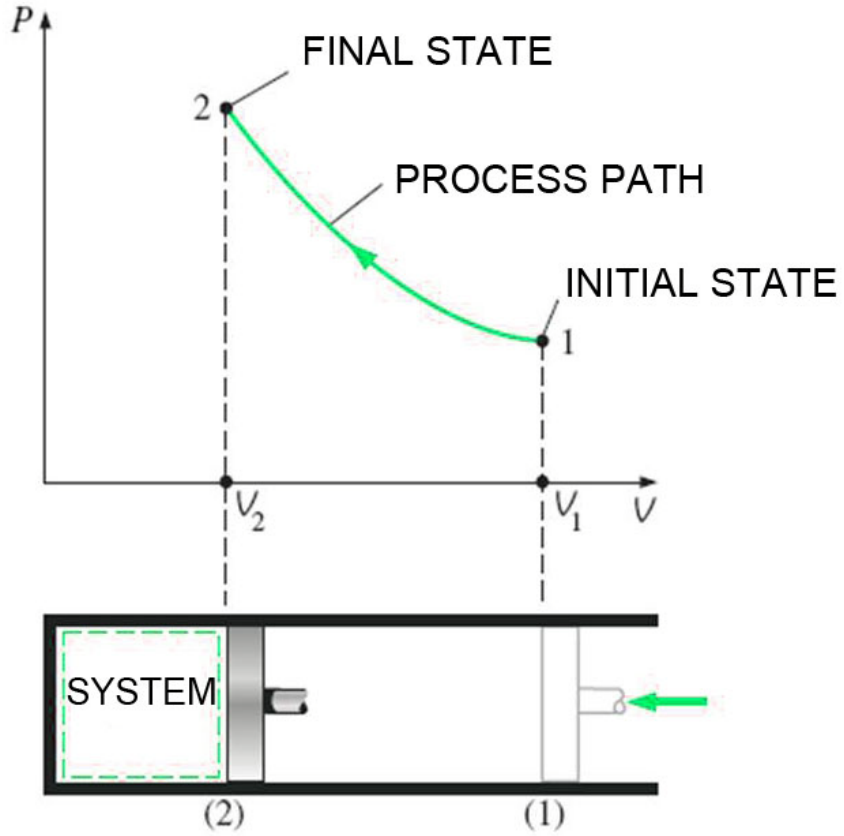
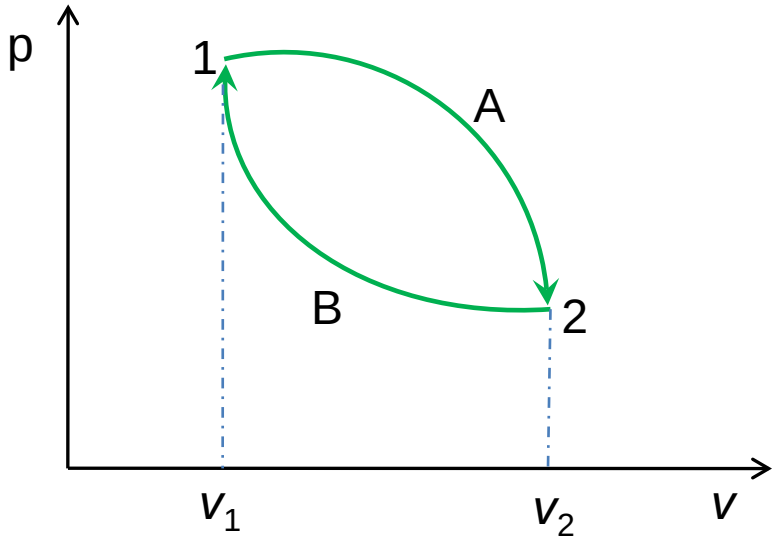
Process, path and cycle





Cycle



Types of processes

- Usually during a process, we allow one of the properties to remain a constant.

- Isothermal process: constant temperature
- Isobaric process: constant pressure
- Isochoric process: constant volume
- Isentropic process: constant entropy (?)
- Isenthalpic process: constant enthalpy (?)

Recap of this lecture

- Basic thermodynamic concepts
  - System, surroundings, boundary and universe
  - Types of systems
  - Property of a system
  - State of a system
  - Equilibrium
  - State postulate
  - Process, path and cycle

In the next lecture ...

- Quasi-static processes
- Concept of energy and its various forms
- Internal energy
- Enthalpy
- Zeroth law of thermodynamics and temperature