Thermodynamics I

Lecture 3

Introduction and Basic Concepts (Ch-1)

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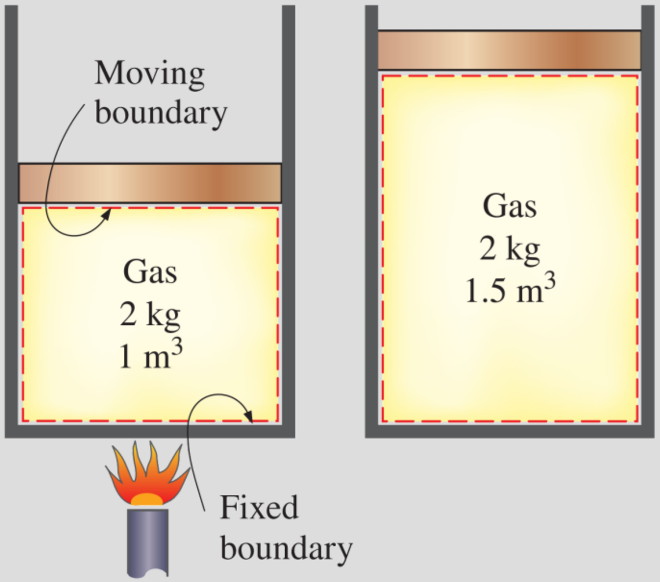
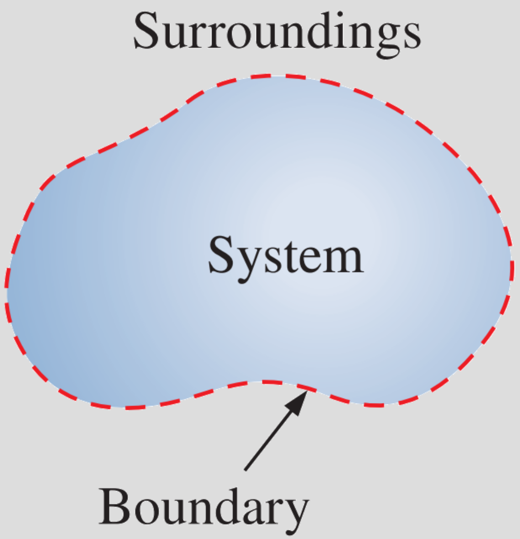
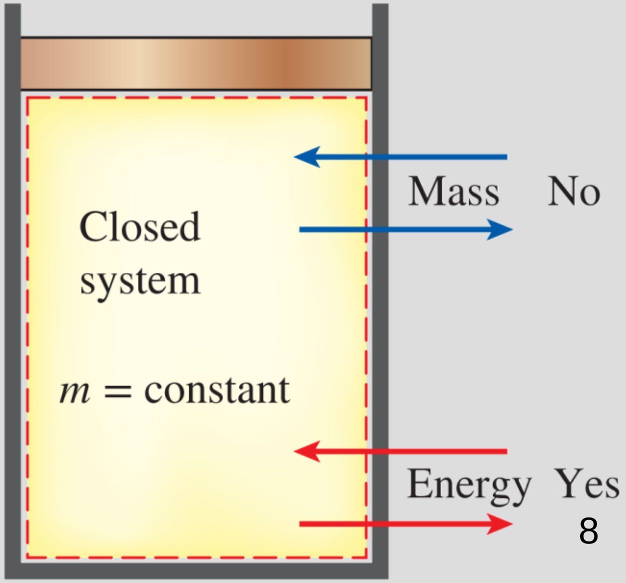
SYSTEMS AND CONTROL VOLUMES

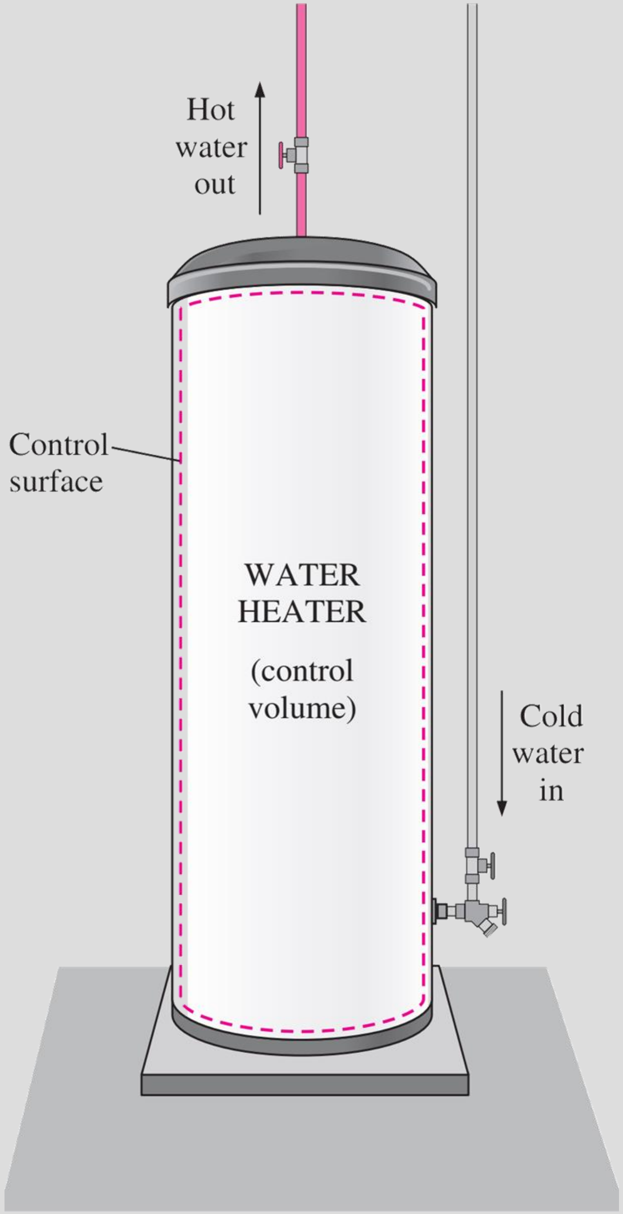
- **System**: A quantity of matter or a region in space chosen for study.
- **Surroundings**: The mass or region outside the system
- **Boundary**: The real or imaginary surface that separates the system from its surroundings.
- The boundary of a system can be *fixed* or *movable*.
- Systems may be considered to be *closed* or *open*.
- **Closed system (Control mass):** A fixed amount of mass, and no mass can cross its boundary.



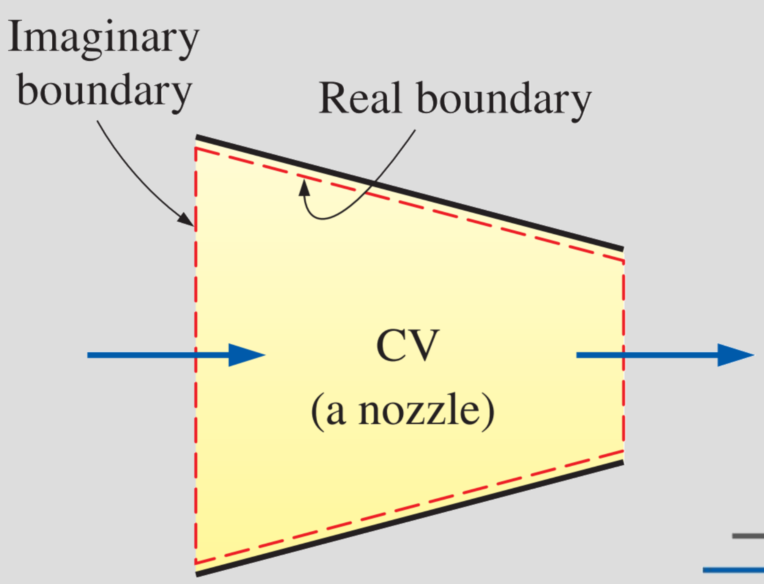


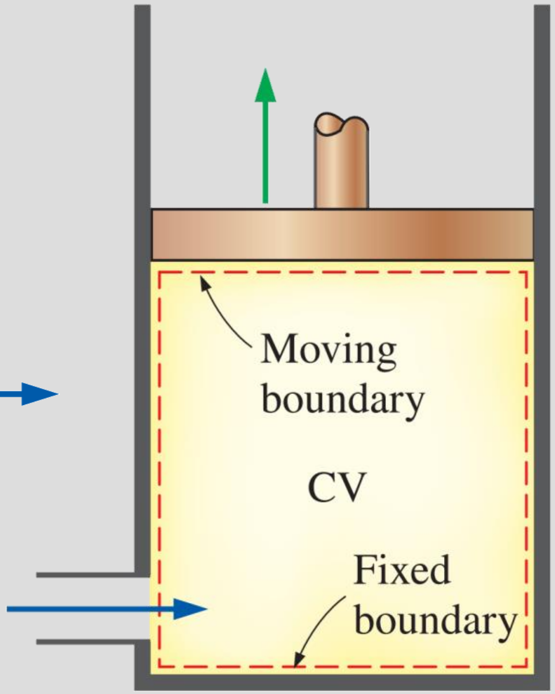


- **Open system (control volume)**: A properly selected region in space.
- It usually encloses a device that involves mass flow such as a compressor, turbine, or nozzle.
- Both mass and energy can cross the boundary of a control volume.
- **Control surface**: The boundaries of a control volume. It can be real or imaginary.



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

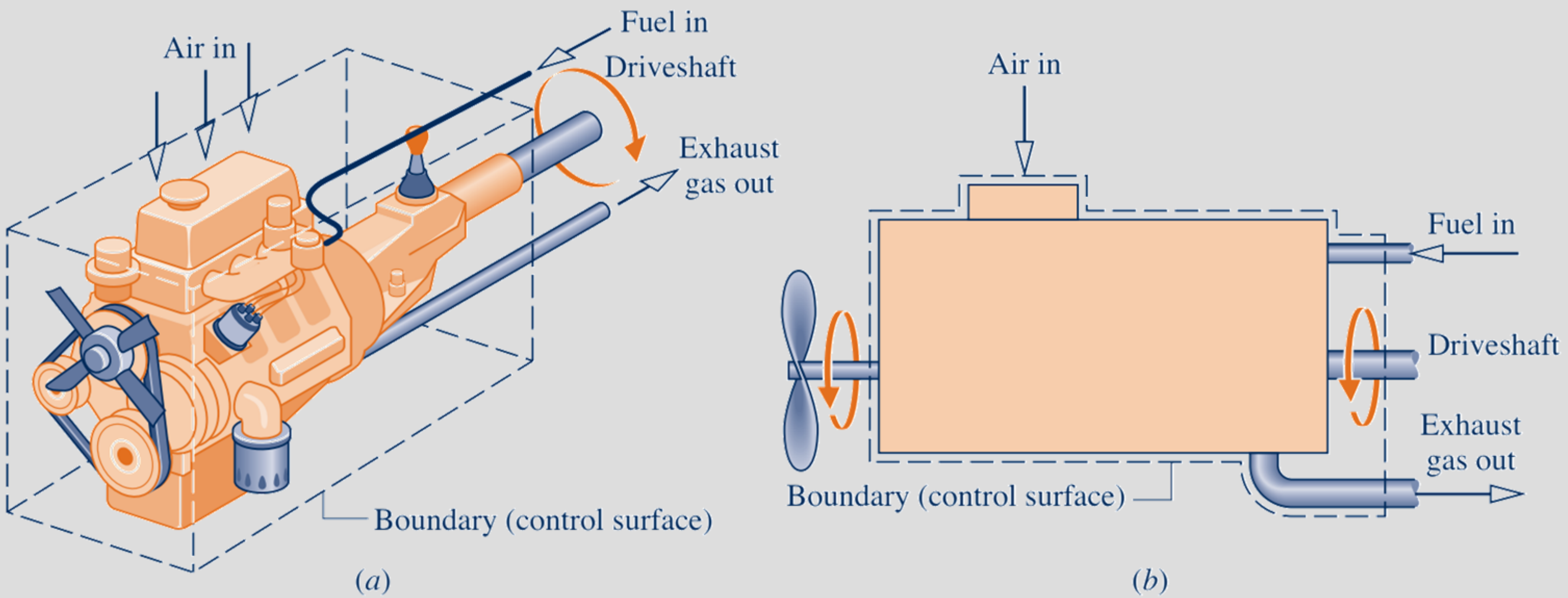




Selecting the System Boundary:

Choice of boundary defining a particular system depends upon the convenience of analysis

(1) What is known about a possible system
(2) Objective of analysis

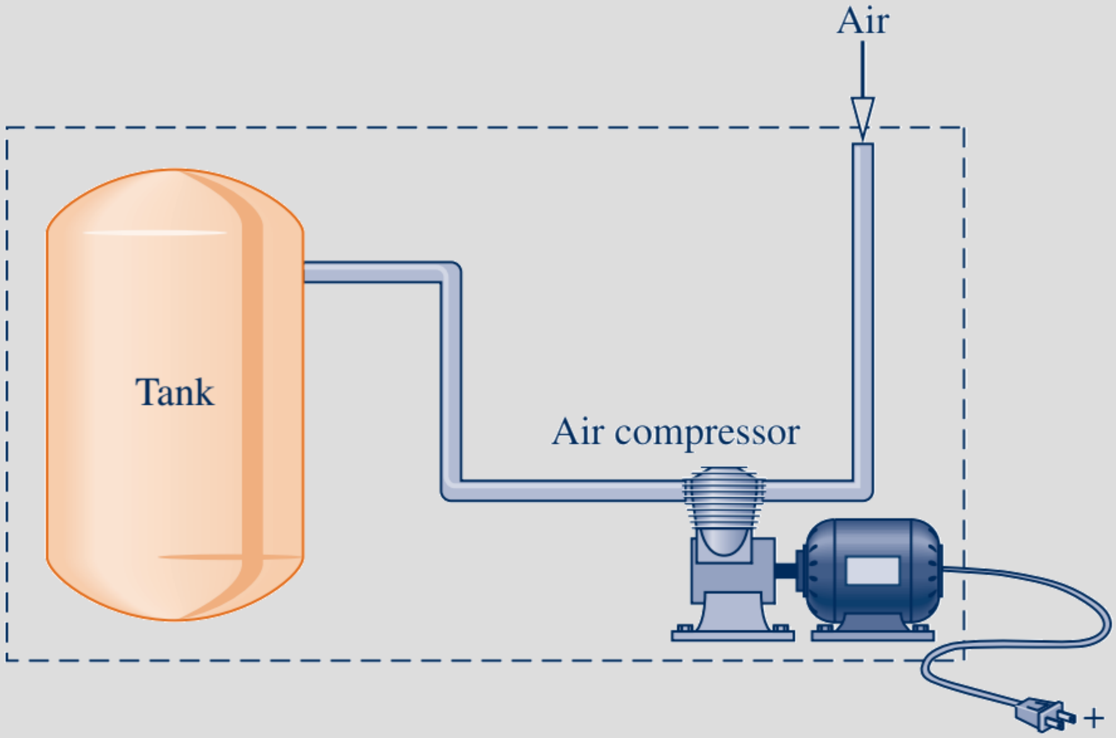


Selecting the System Boundary: Example

The system boundry encloses the compressor, tank and all piping

Known: Elect. Input

Objective of analysis: how long compressor must operate for pressure in the tank to rise to required value

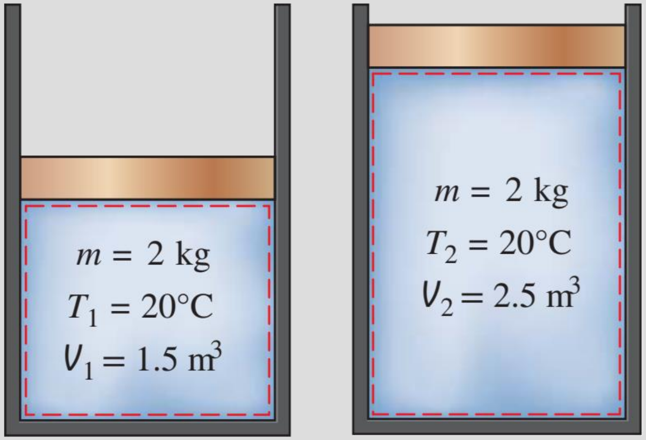


Describing a system requires knowledge of its properties

Property: is a macroscopic characteristic of a system pressure *P,* temperature *T,* volume *V, and* mass *m*

State: refers to the condition of a system as described by its properties

Process: When any of the properties of a system chage, the state changes and system is said to undergone a process

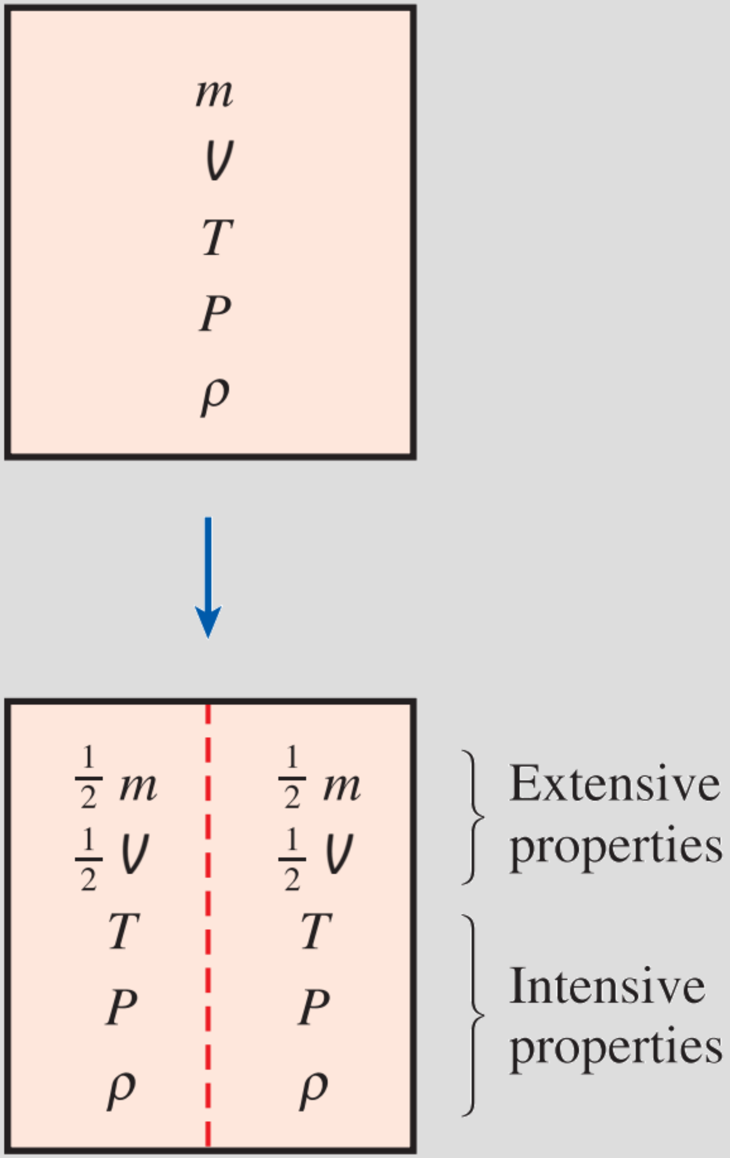


(*a*) State 1 (*b*) State 2

Steady State: if a system exhibits the same value of its properties at two different times

PROPERTIES OF A SYSTEM

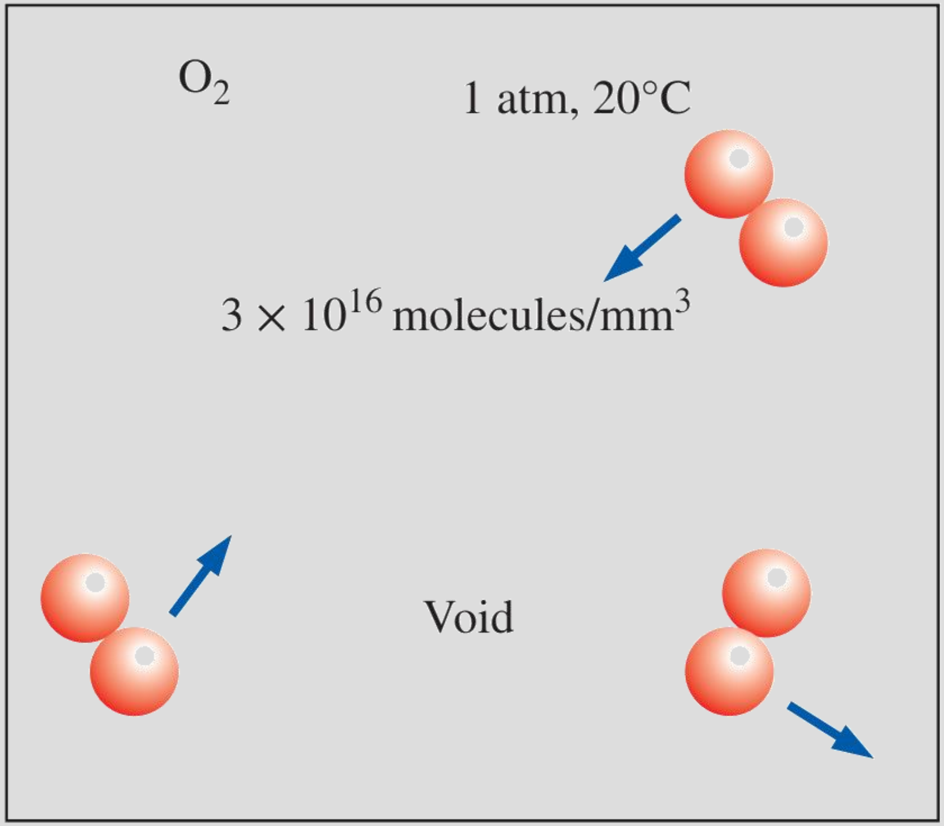
- **Property:** Any characteristic of a system.
- Some familiar properties are pressure *P*, temperature *T*, volume *V*, and mass *m*.
- Properties are considered to be either *intensive* or *extensive*.
- **Intensive properties:** Those that are independent of the mass of a system, such as temperature, pressure, and density.
- **Extensive properties:** Those whose values depend on the size or extent of the system.
- **Specific properties:** Extensive properties per unit mass.



Criterion to differentiate intensive and extensive properties.

Continuum

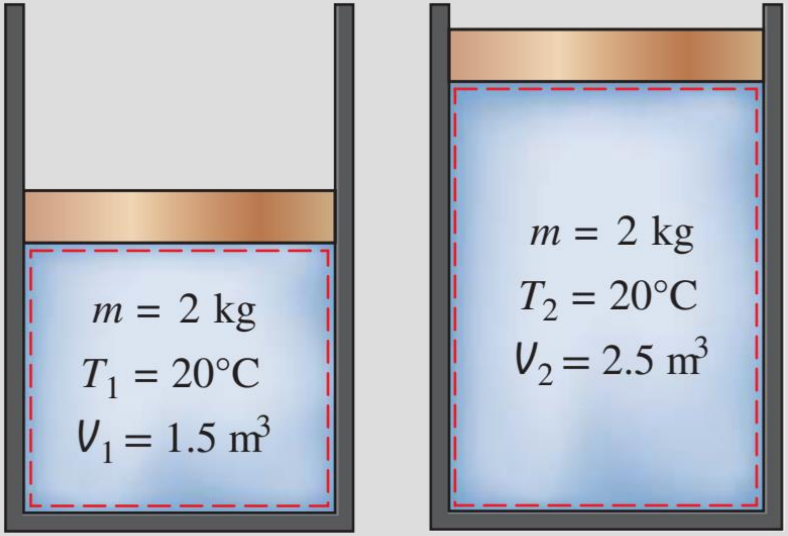
- Matter is made up of atoms that are widely spaced in the gas phase. Yet it is very convenient to disregard the atomic nature of a substance and view it as a continuous, homogeneous matter with no holes, that is, a **continuum**.
- The continuum idealization allows us to treat properties as point functions and to assume the properties vary continually in space with no jump discontinuities.
- This idealization is valid as long as the size of the system we deal with is large relative to the space between the molecules.
- This is the case in practically all problems.
- In this text we will limit our consideration to substances that can be modeled as a continuum.



Despite the large gaps between molecules, a substance can be treated as a continuum because of the very large number of molecules even in an extremely small volume.

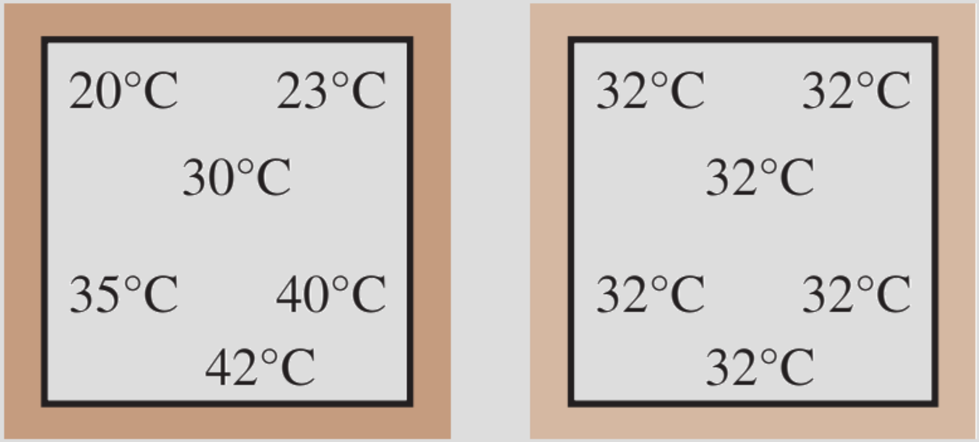
STATE AND EQUILIBRIUM

- Thermodynamics deals with *equilibrium* states.
- **Equilibrium**: A state of balance.
- In an equilibrium state there are no unbalanced potentials (or driving forces) within the system.
- **Thermal equilibrium**: If the temperature is the same throughout the entire system.
- **Mechanical equilibrium:** If there is no change in pressure at any point of the system with time.
- **Phase equilibrium:** If a system involves two phases and when the mass of each phase reaches an equilibrium level and stays there.
- **Chemical equilibrium:** If the chemical composition of a system does not change with time, that is, no chemical reactions occur.



(*a*) State 1 (*b*) State 2

A system at two different states.



(*a*) Before (*b*) After

A closed system reaching thermal equilibrium.

The State Postulate:

•The number of properties required to fix the state of a system is given by the **state postulate**:

•The state postulate requires that the two properties specified be **independent** to fix the state.

•Two properties are **independent** if one property can be varied while the other one is held constant.

•Temperature and Specific volume are always independent properties.

•Temperature and Pressure are independent properties for only single phase systems

•But Temperature and Pressure are dependent properties for multiple phase system i.e. $T = f(P)$

The state of nitrogen is fixed by two independent properties

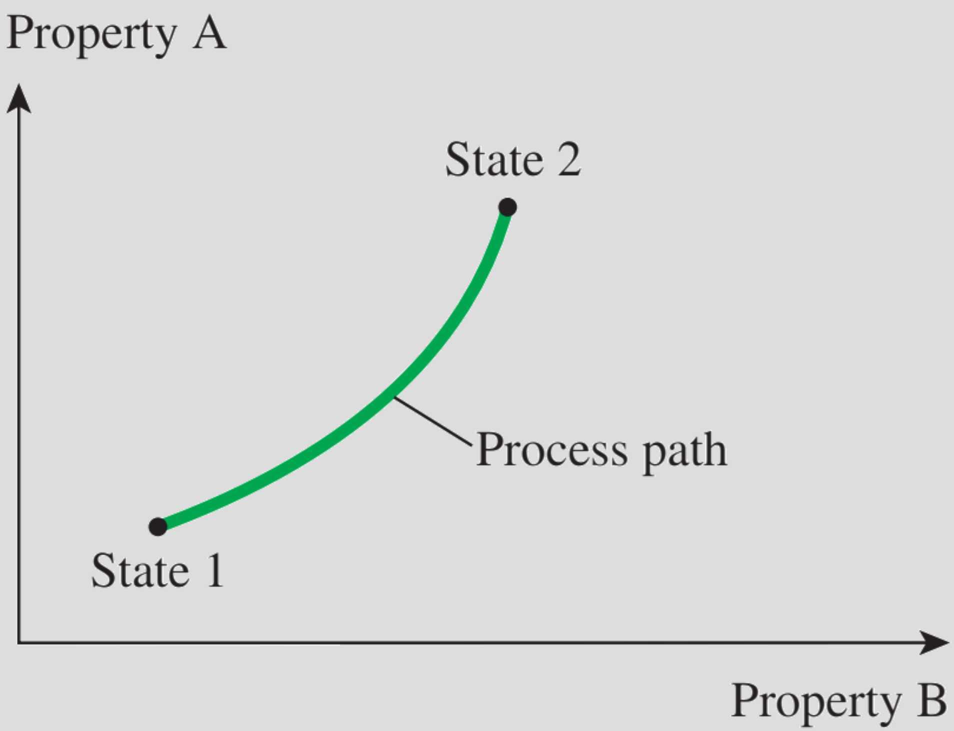
PROCESSES AND CYCLES

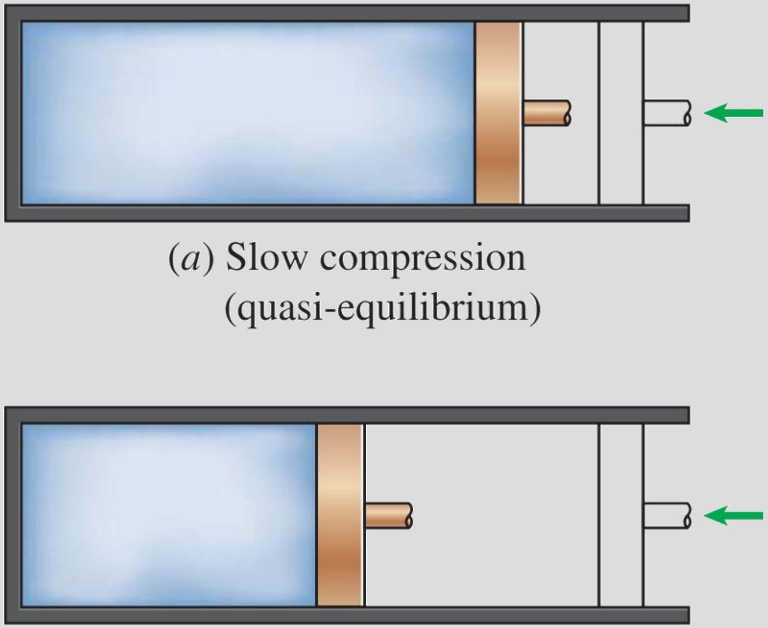
Process: Any change that a system undergoes from one equilibrium state to another.

Path: The series of states through which a system passes during a process.

To describe a process completely, one should specify the initial and final states, as well as the path it follows, and the interactions with the surroundings.

Quasistatic or quasi-equilibrium process: When a process proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times.





(*a*) Slow compression (quasi-equilibrium)

(*b*) Very fast compression (nonquasi-equilibrium)

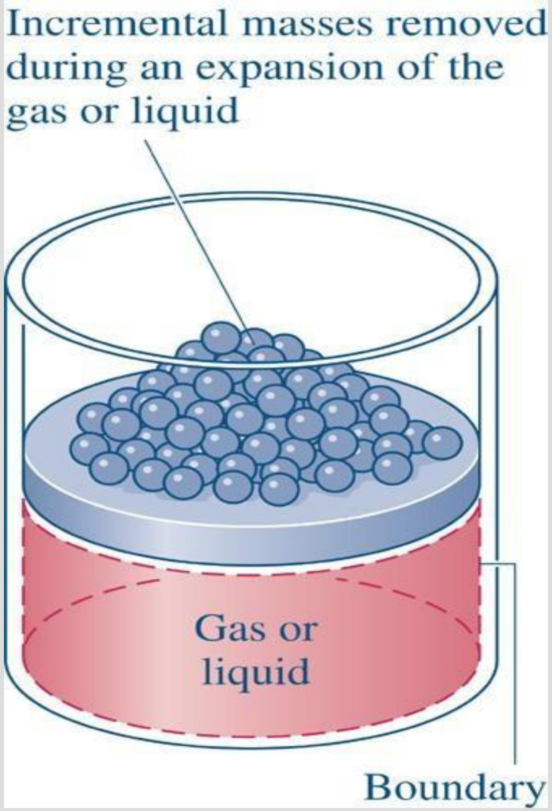
Expansion or Compression Work in Quasiequilibrium Processes: REVERSIBILITY

Departure from thermodynamic equilibrium is infinitesimal

All states in such process are considered equilibrium states

Imagine one of the masses removed – the state will depart only slightly

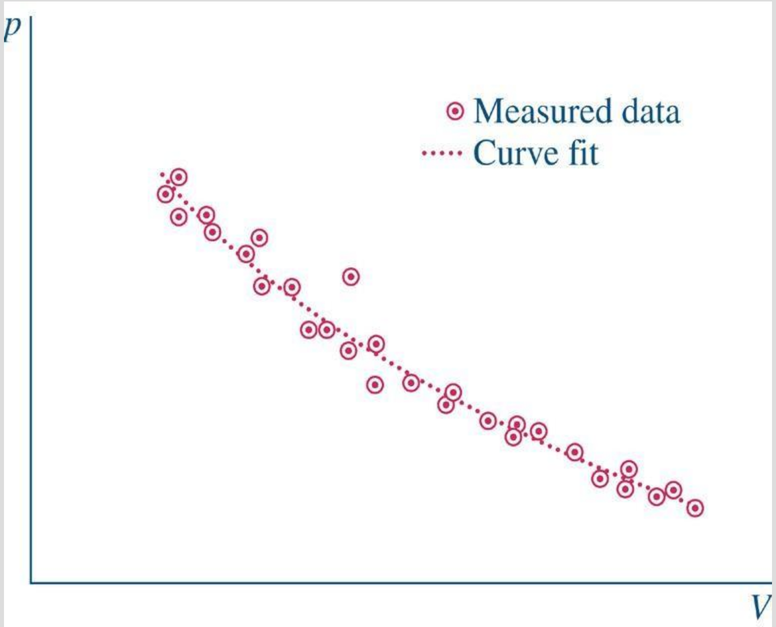
If masses are removed one after another, the gas would pass through a sequence of equilibrium states without ever being far from equilibrium



Expansion or Compression Work in Actual Processes: IRREVERSIBILITY

To perform integral, requires a relationship between P & V

Due to non-equilibrium effects during actual process such relationship is impossible



- The recorded output might provide only approximation
- Scatter might exist in pressure volume data

Still integral will be based on a curve fitted to the data give an estimate of work done

Kinds of Process:

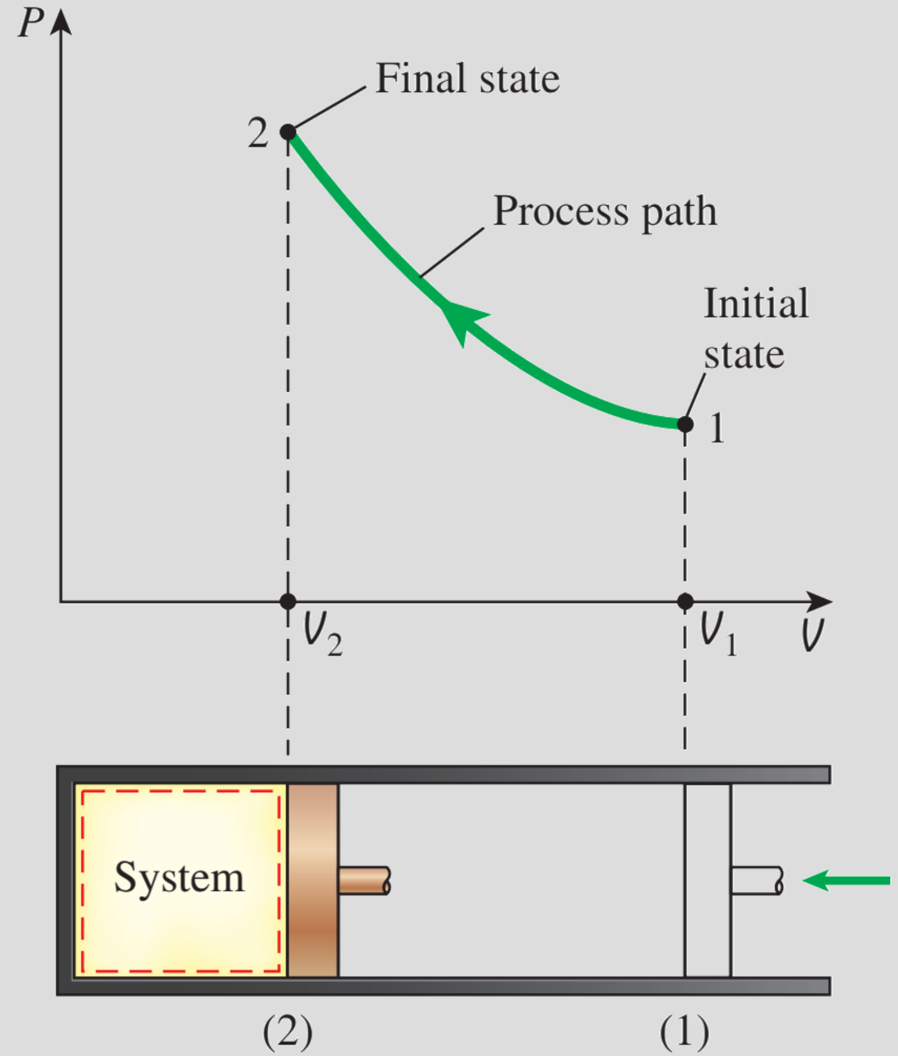
Quasi-equilibrium process is an Idealized Process: Engineers are interested in in quasi-equilibrium processes for two reasons:

•Easier to analyze

•Quasi-equilibrium processes serves as standards to which actual processes can be compared

•Process diagrams plotted by employing thermodynamic properties as coordinates are very useful in visualizing the processes.

•Some common properties that are used as coordinates are temperature *T*, pressure *P*, and volume *V* (or specific volume *v*).



The *P*-*V* diagram of a compression process.

Process:

The prefix ***iso-*** is often used to designate a process for which a particular property remains constant.

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

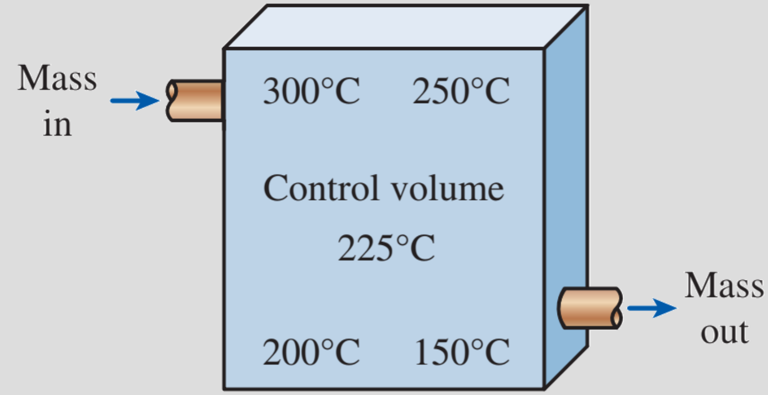
Isobaric process: A process during which the pressure P remains constant.

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

Adiabatic Process: A process in which no heat is transferred to or from the working fluid.

The Steady-Flow Process

- The term *steady* implies *no change with time*. The opposite of steady is *unsteady*, or *transient*.
- A large number of engineering devices operate for long periods of time under the same conditions, and they are classified as *steady-flow devices*.
- **Steady-flow process**: A process during which a fluid flows through a control volume steadily.
- Steady-flow conditions can be closely approximated by devices that are intended for continuous operation such as turbines, pumps, boilers, condensers, and heat exchangers or power plants or refrigeration systems.



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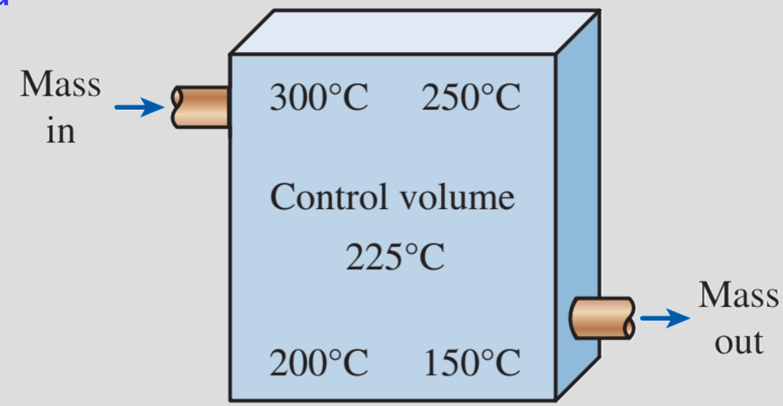
During a steady-flow process, fluid properties within the control volume may change with position but not with time.



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Under steady-flow conditions, the mass and energy contents of a control volume remain constant.