Basic Concepts & Terminology

Dr. Md. Zahurul Haq, *Ph.D., CEA, FBSME, FIEB*

Professor
Department of Mechanical Engineering
Bangladesh University of Engineering & Technology (BUET)
Dhaka-1000, Bangladesh

http://zahurul.buet.ac.bd/

ME 203: Engineering Thermodynamics
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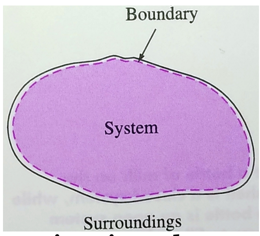
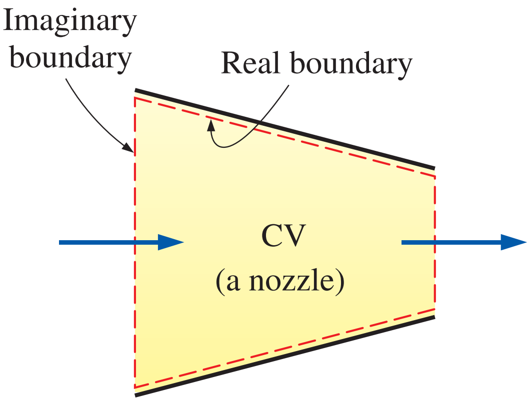
Thermodynamic System

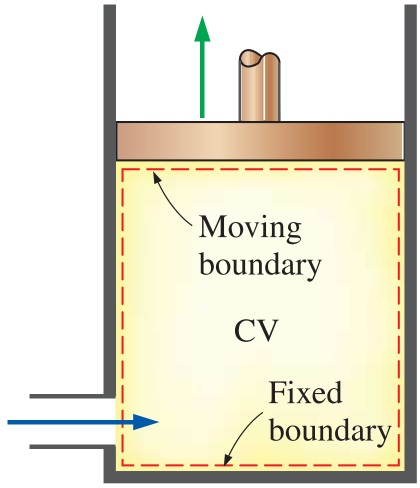


T006

- A thermodynamic system is simply any object or quantity of matter or region of space that has been selected for thermodynamic study. Everything that is not part of the system is referred to as the surroundings or environment.
- Boundary or control surface (CS) separates the system from its surroundings which
  - may be real or imaginary, at rest or in motion
  - may change its shape and size
  - neither contains matter nor occupies volume
  - has zero thickness and a property value at a point on the boundary is shared by both the system and its surroundings.



(*a*) A control volume (CV) with real and imaginary boundaries



(*b*) A control volume (CV) with fixed and moving boundaries as well as real and imaginary boundaries

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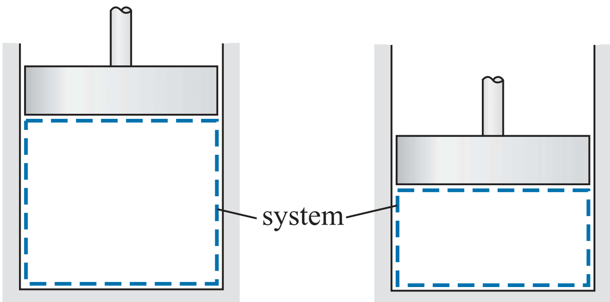
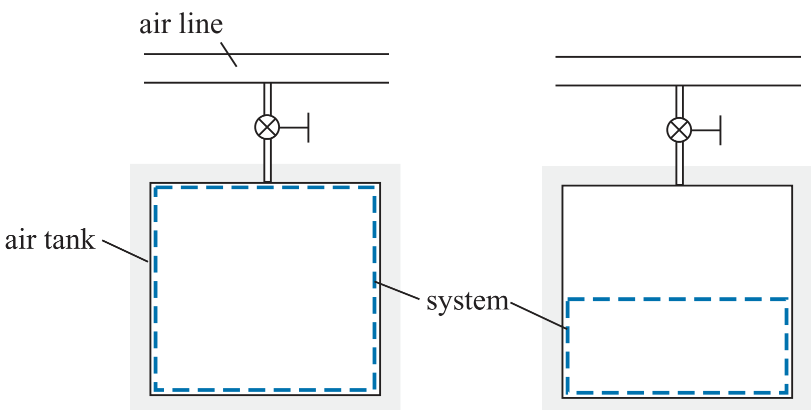


T061

A system defined to contain all of the air in a piston-cylinder device.

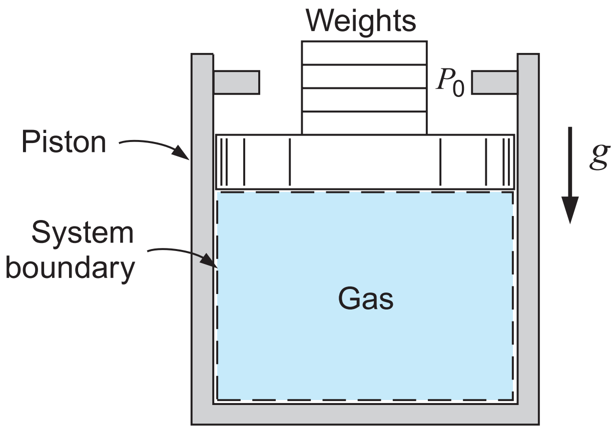


T062

A system defined to contain all of the air that is initially in a tank that is being filled.

Control Mass (CM) or Closed System

T007

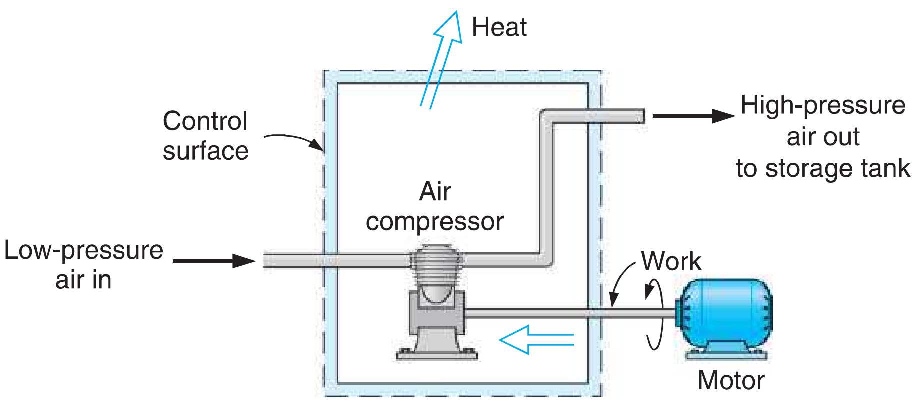


In Control Mass (CM) or Closed system:

- CS is closed to mass flow, so that no mass can escape from or enter into the system.
- Heat/work may cross the CS.

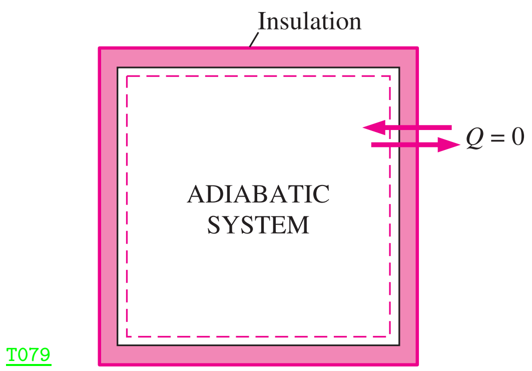
Control Volume (CV) or Open System

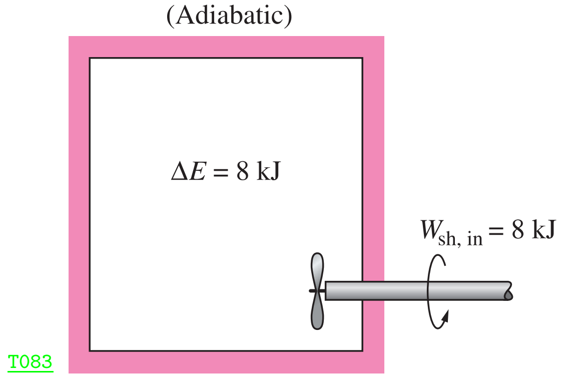
T1601



When there is flow of mass through CS, the system is called a Control Volume (CV) or Open system.

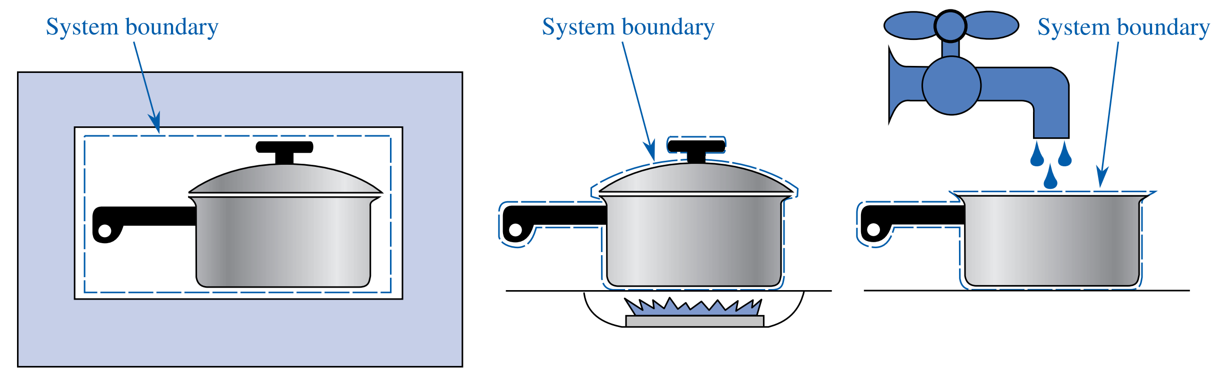
Adiabatic System





In Adiabatic system the boundary is impermeable to heat.

Classification of Thermodynamic Systems



(a) Isolated System: Neither mass nor energy can cross the system boundary.

(b) Closed System: Mass cannot cross the system boundary, but energy can.

(c) Open System: Both mass and energy can cross the system boundary.

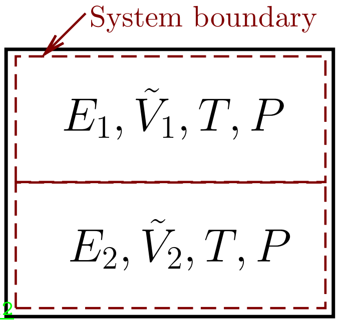
An Isolated system is a special case of CM system that does not interact in any way with its surroundings.

Macroscopic & Microscopic Views of Thermodynamics

- Thermodynamic systems can be studied from two points of view:
  1. Microscopic approach or statistical thermodynamics
  2. Macroscopic approach or classical thermodynamics
- The microscopic approach recognizes that the system consists of matter that is composed of countless and discrete molecules. Statistics and probability theories are applied to deduce the macroscopic behaviour or measurable quantities e.g. pressure, temperature etc.
- In the macroscopic approach, the state of the system is described by a relatively small set of characteristics that are called properties e.g. mass, temperature, pressure and volume.
- Macroscopic approach works well when the system is sufficiently large such that it contains many molecules. However, macroscopic approach would not work well for a system that consists of a rarefied gas (i.e., a vacuum with just a few molecules).

State & Property

- The condition of a system at any instant of time is called its state. State at a given instant determines the properties of the system.
- A property is a quantity whose numerical value depends on the state but not on the history of the system. The origin of properties include those are
  1. directly measurable
  2. defined by laws of thermodynamics
  3. defined by mathematical combinations of other properties.
- Two states are identical if, and only if, the properties of the two states are identical.
- Intensive properties are independent of the size or extent of the system. Extensive properties depend on the size or extent of the system. An extensive property is additive in the sense that its value for the whole system is the sum of the values for its parts.



T012

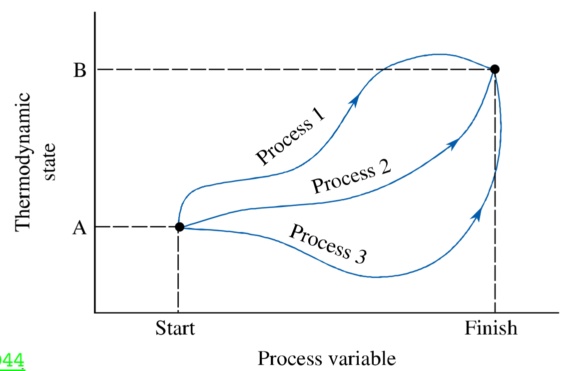
$$\left.\begin{aligned} E_{system} &= E_1 + E_2 \\ \tilde{V}_{system} &= \tilde{V}_1 + \tilde{V}_2 \end{aligned}\right\} \text{Extensive Properties}$$

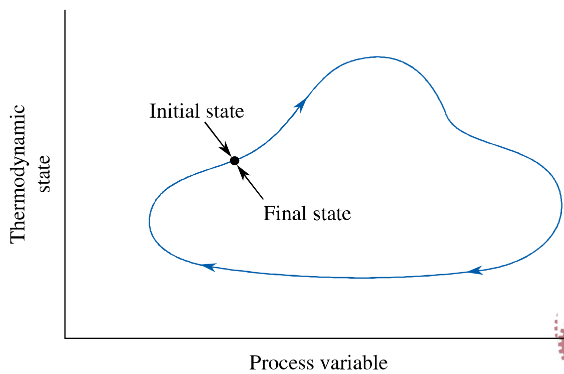
$$\left.\begin{aligned} T_{system} &= T_1 = T_2 \\ P_{system} &= P_1 = P_2 \end{aligned}\right\} \text{Intensive Properties}$$

Property	Extensive	Intensive
Mass	m	ρ
Volume	$\tilde{V}$	v
KE	$\frac{1}{2}mV^2$	$\frac{1}{2}V^2$
PE	mgZ	gZ
Total Energy	E	e
Internal Energy	U	u
Enthalpy	H	h
Entropy	S	s

Process & Cycle

- A thermodynamic process is a change of system from one equilibrium state to another.
- The path of a process refers to the specific series of states through which the system passes.
- A system process is said to go through a thermodynamic cycle when the final state and the initial state of the process are same.





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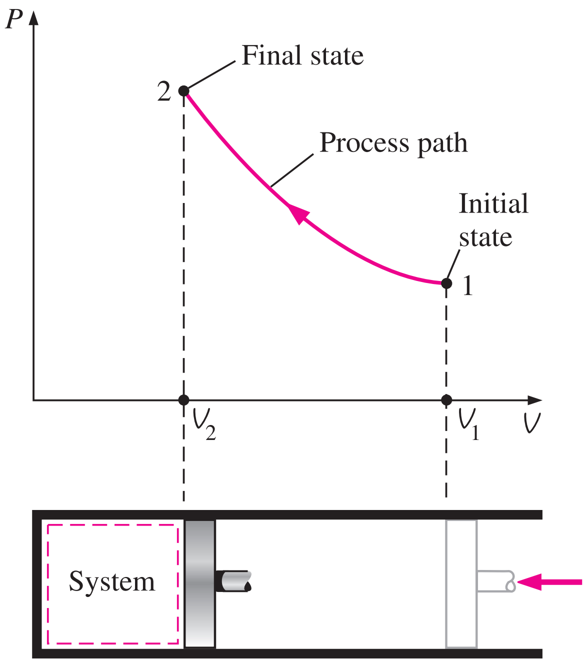
Thermodynamic Equilibrium

- A system in thermodynamic equilibrium satisfies the following stringent requirements:
  1. Mechanical Equilibrium: no unbalance forces acting on any part of the system or the system as a whole.
  2. Thermal Equilibrium: no temperature differences between parts of the system or between the system and the surrounding.
  3. Chemical Equilibrium: no chemical reactions within the system and no motion of any chemical species from one part to another part of the system.
- Once a system is in thermodynamic equilibrium and the surroundings are kept unchanged, no motion will take place and no work will be done.



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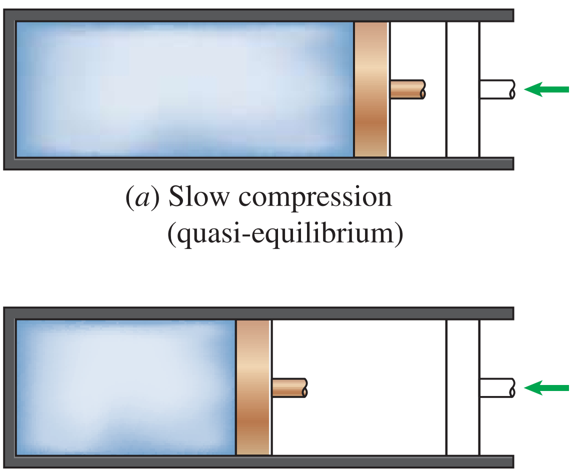


(*a*) Slow compression (quasi-equilibrium)

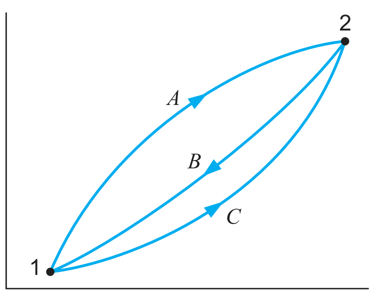
(*b*) Very fast compression (nonquasi-equilibrium)

T076

- A system is said to be in Stable/Equilibrium State when no finite change of state can occur unless there is an interaction between the system and its environment which leaves a finite alteration in the state of the environment.
- During a quasi-static process, the system is infinitesimally near a state of thermodynamic equilibrium at all times. So, the process should be carried out infinitely slow to allow the system to settle to a stable state at the end of each infinitesimal step in the process.
- Theoretical calculations must relate to *stable states*, since it is only for these we have thermodynamic data.

Categories of Thermodynamics Quantities

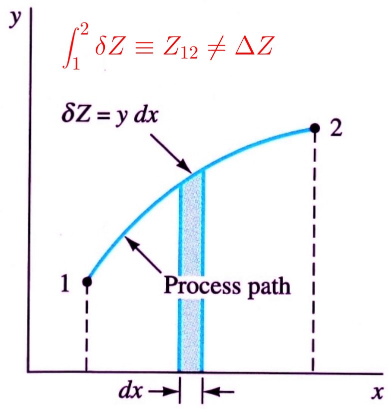
1. State functions: all properties are state functions.
2. Process or Path functions: quantities whose values depend on the path of the process.



T038

$$\int_1^2 dy = y_2 - y_1 = \Delta y \quad \Rightarrow \quad \oint dy = 0$$

State function



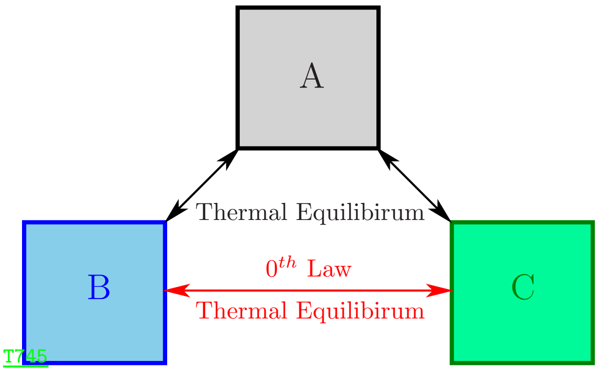
T013

Path function

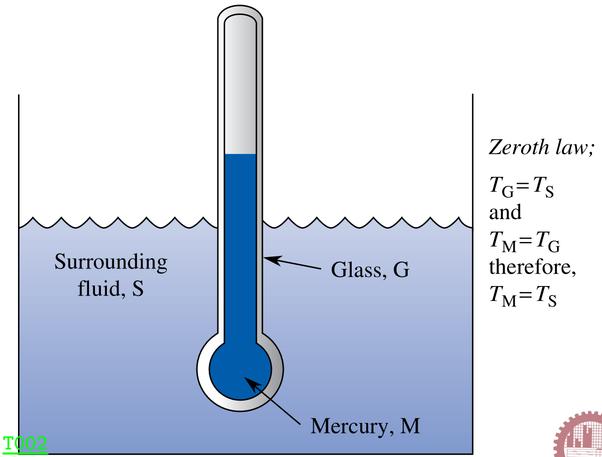
Zero'th Law of Thermodynamics

Zero'th Law of Thermodynamics

Two systems with thermal equilibrium with a third are in thermal equilibrium with each other.

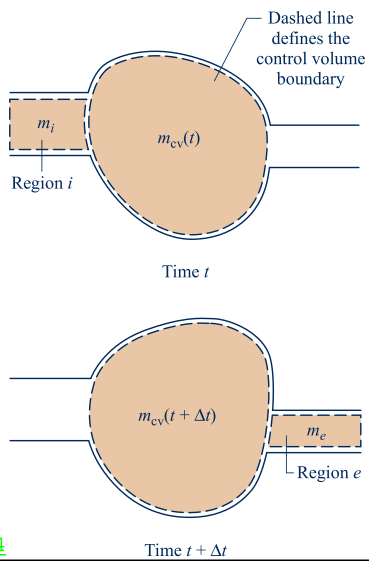


T745

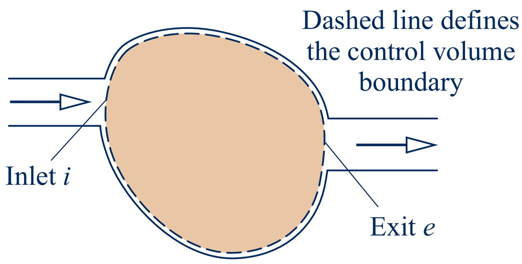


T002

Mass Continuity Equation



T444



T443

$\Rightarrow m_{cv}(t) + m_i = m_{cv}(t + \Delta t) + m_e$

$\Rightarrow m_{cv}(t + \Delta t) - m_{cv}(t) = m_i - m_e$

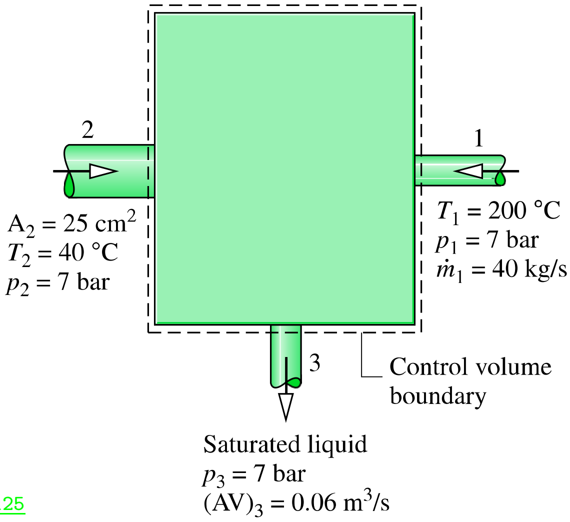
$\Rightarrow \frac{m_{cv}(t+\Delta t) - m_{cv}(t)}{\Delta t} = \frac{m_i - m_e}{\Delta t}$

- if $\Delta t \to 0 : \Rightarrow \frac{dm_{cv}}{dt} = \dot{m}_i - \dot{m}_e$

$$\frac{dm_{cv}}{dt} = \sum_i \dot{m}_i - \sum_e \dot{m}_e$$

$$\dot{m} = \rho A \mathbb{V} = \frac{A\mathbb{V}}{v} \text{ (for 1D flow)}$$

Moran Ex. 4.1: ▷ Feed-water heater at steady-state. Determine $\dot{m}_2$ & V_2. Assume, $v_2 \simeq v_f(T_2)$.



T125

- $\frac{dm_{cv}}{dt} = \sum_i \dot{m}_i - \sum_e \dot{m}_e$

$\Rightarrow dm_{cv}/dt = 0$

$\Rightarrow \sum_i \dot{m}_i = \dot{m}_1 + \dot{m}_2$

$\Rightarrow \sum_e \dot{m}_e = \dot{m}_3$

- $\dot{m} = \rho A \mathbb{V}$

$\Rightarrow \dot{m}_3 = \rho_3 (A\mathbb{V})_3$

$\Rightarrow \rho_2 = \rho(T = T_2, P = P_2) \quad \rho_3 = \rho(x = 0.0, P = P_3)$

$\Longrightarrow \dot{m}_2 = 14.15\ \mathtt{kg/s}, \quad \mathbb{V}_2 = 5.7\ \mathtt{m/s}$ ◁.