Fundamentals of Thermodynamics

Presentation Outline

- Overview
- Subject Content
- References
- Fundamental Concepts

Overview

Subject : Fundamentals of Thermodynamics
Subject Code : ME 1202
No. of Credits : 02 (GPA)

Academic Component	No. of Hours
Theory	25
Practice / Laboratory Work	10
Total	**35**

Subject Content

- Fundamental Concepts
- First Law of Thermodynamics
- Closed Systems
- Open Systems
- Second Law of Thermodynamics
- Air Standard Cycles

References

- ***Engineering Thermodynamics – Work and Heat Transfer*** by G F C Rogers & Y R Mayhew, ELBS with Longman Group UK Ltd., ISBN 0 582 24454 4

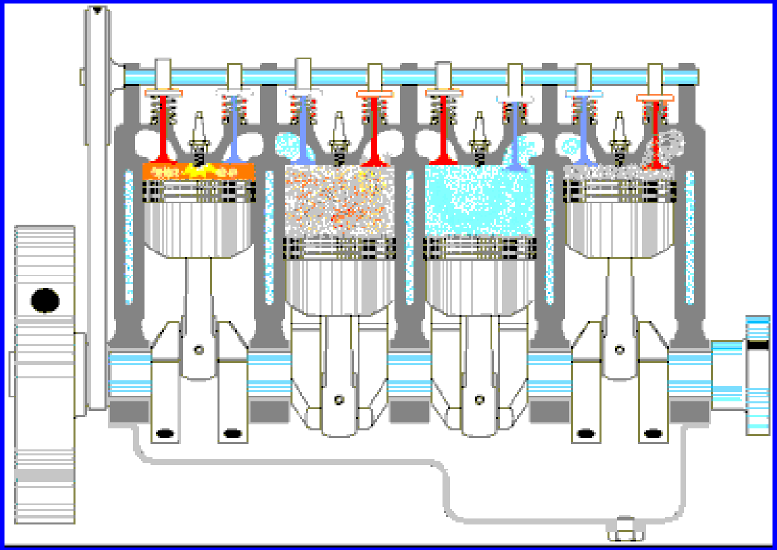
- ***Applied Thermodynamics for Engineering Technologists*** by T D Eastop & A McConkey, Pearson Education Ltd., ISBN 978 81 7758 238 3

Fundamental Concepts

What is Thermodynamics?

- It is the Science of energy transformations and relationships among physical quantities, or properties of substances which are affected by energy transformations.
- Thermodynamics is the science that deals with the relationship of heat and mechanical energy and conversion of one into the other.

Applications of Thermodynamics

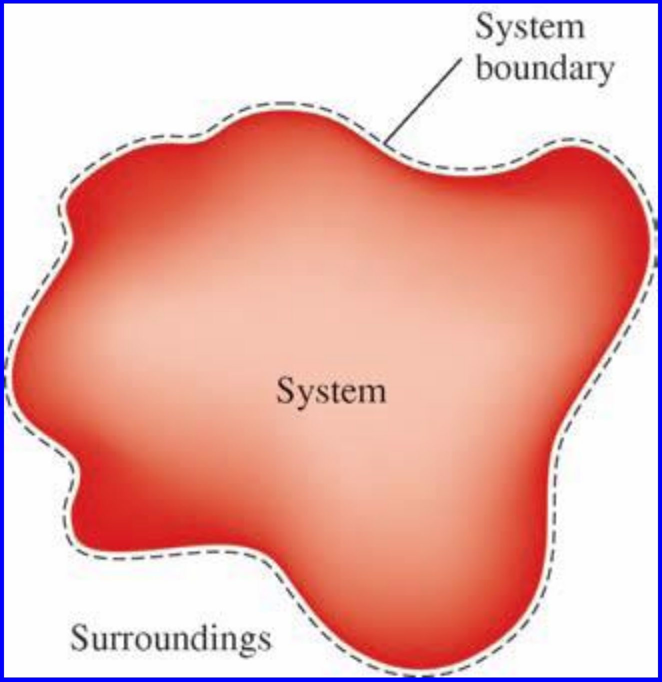


Key Definitions

- **System (S)**
  - Specified region in space to be investigated
  - Constant or variable mass
  - Boundary is fixed or deformable
  - At rest or in motion with respect to a coordinate system

Key Definitions contd..

- **System Boundary (B) -** Imaginary closed surface which helps to identify the system.
- **Surroundings ($S^{/}$) -** The region outside the system excluding the boundary.



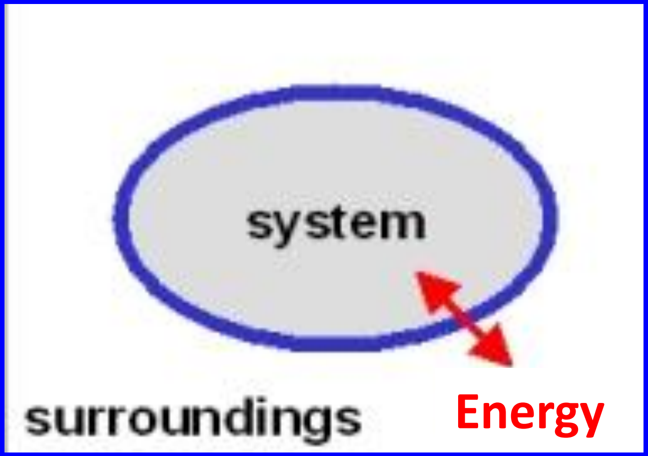
Types of Thermodynamic Systems

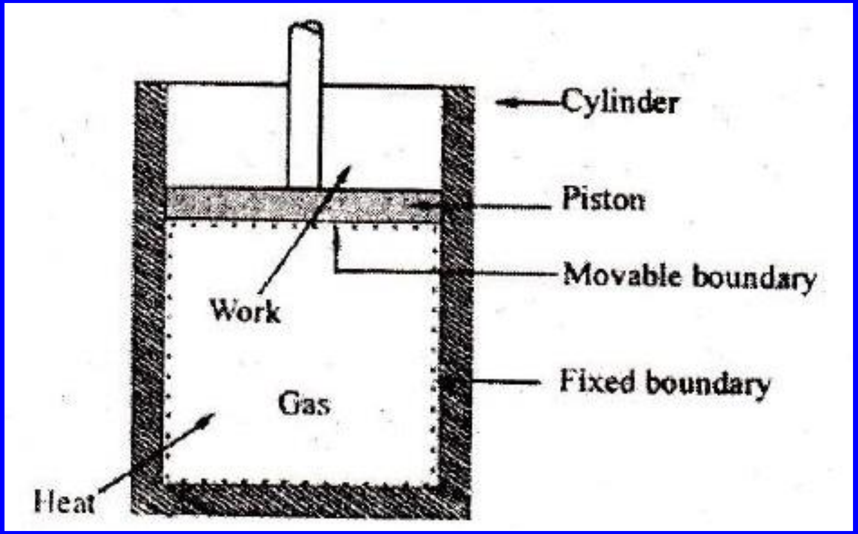
- Thermodynamic systems are categorized based on their ability to transfer energy and mass.

- Basic types include
  - Closed Systems
  - Open Systems
  - Isolated Systems

Closed Systems

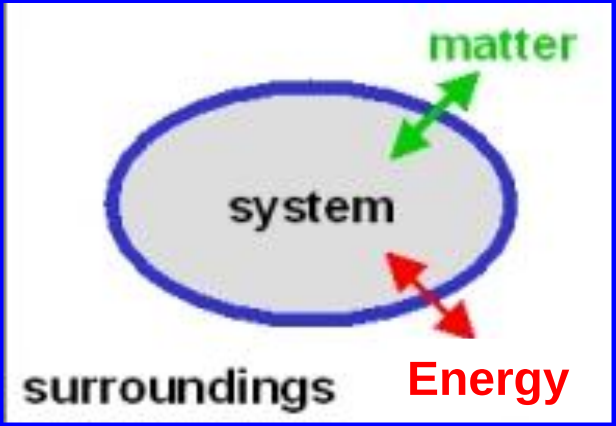
- Fixed non-changing/constant mass of fluid within the system, i.e., no mass transfer across the system boundary but can have energy exchange with the surroundings. Example: piston-cylinder assembly

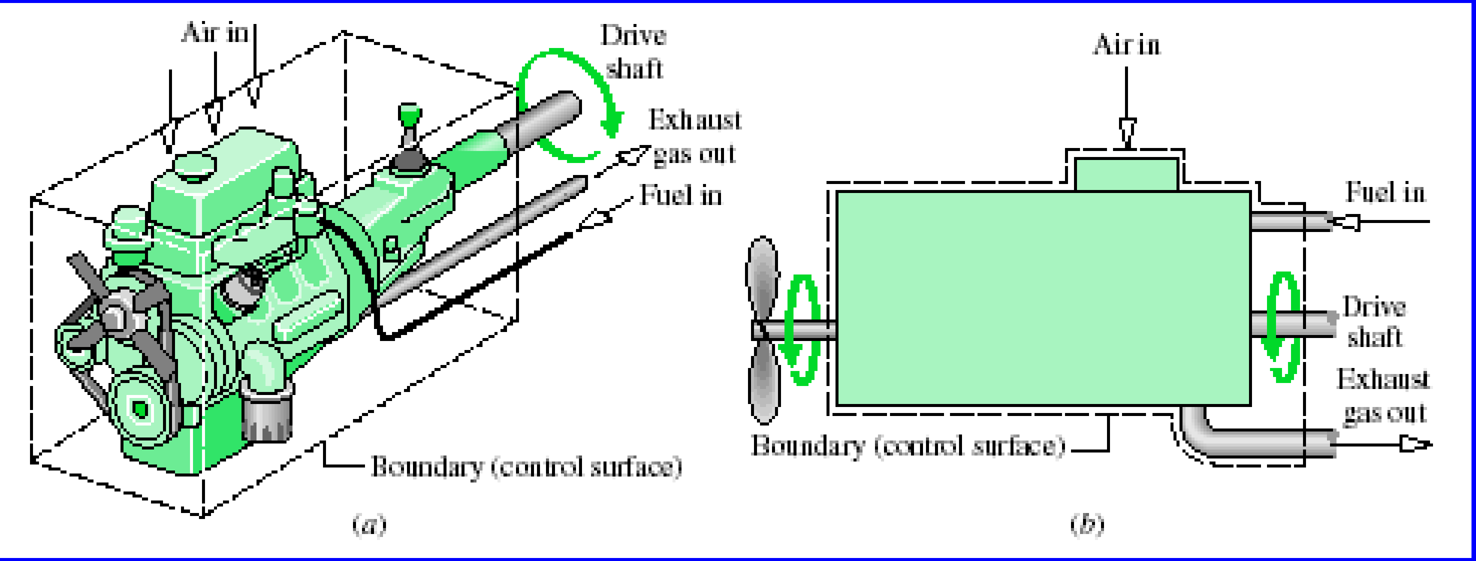




Open Systems

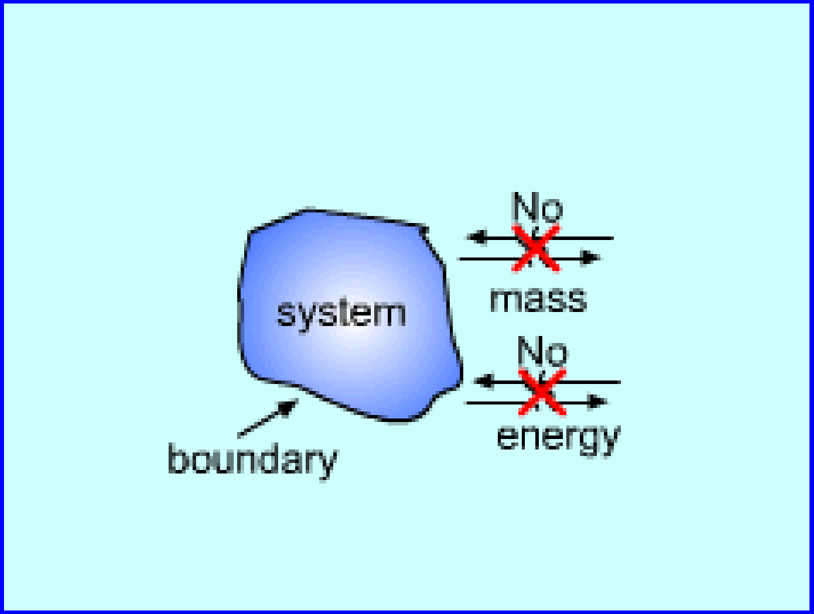
- Fixed volume in space, both mass and energy transfer permitted across the system boundary. Example: Automobile engine





Isolated Systems

- A system that does not interact at all with the surroundings. Hence no energy and mass transfer across system boundary.



System Properties

- Macroscopic characteristics of a system to which a numerical value can be assigned at a given time without knowledge of the history of the system, e.g., mass, volume, pressure

- There are two types of properties:
  - Extensive Properties
  - Intensive Properties

System Properties contd..

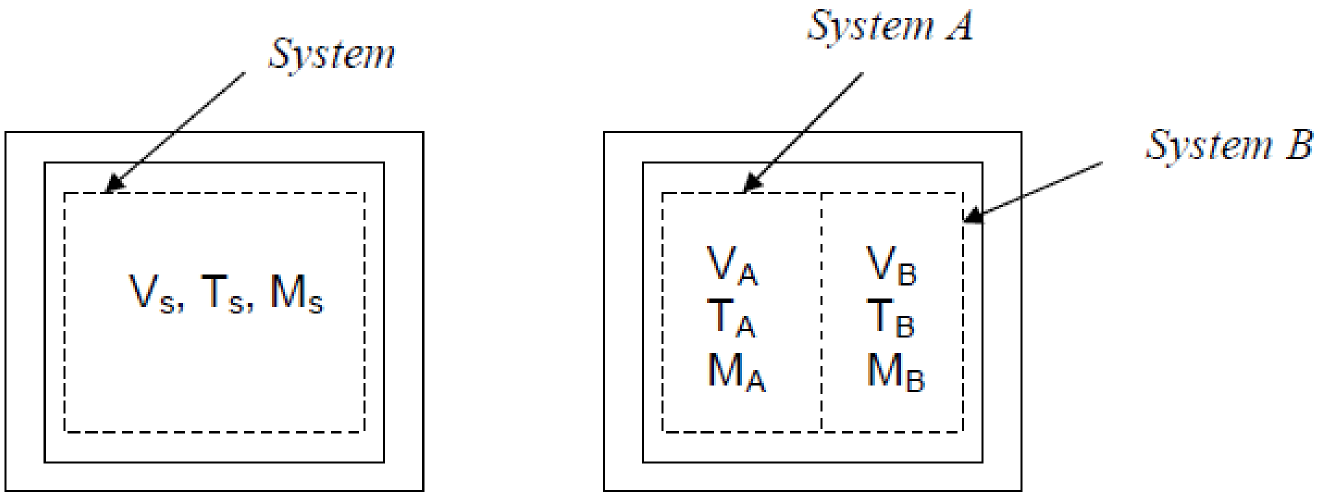
- **Extensive Property**

  The property value for the system is the sum of the property values of the parts into which the system is divided (depends on the system size) e.g., mass, volume, energy

- **Intensive Property**

  The property is independent of system size (Value may vary throughout the system), e.g., pressure, temperature

System Properties contd..



$V_S = V_A + V_B$ extensive

$M_S = M_A + M_B$ extensive

$T_S \neq T_A + T_B$ intensive

Key Definitions contd..

- **System state**
  - Condition of the system is expressed in terms of its thermodynamic properties.
  - Two properties are sufficient for describing simple systems.
  - A system is at steady-state if none of the system properties change with time

Key Definitions contd..

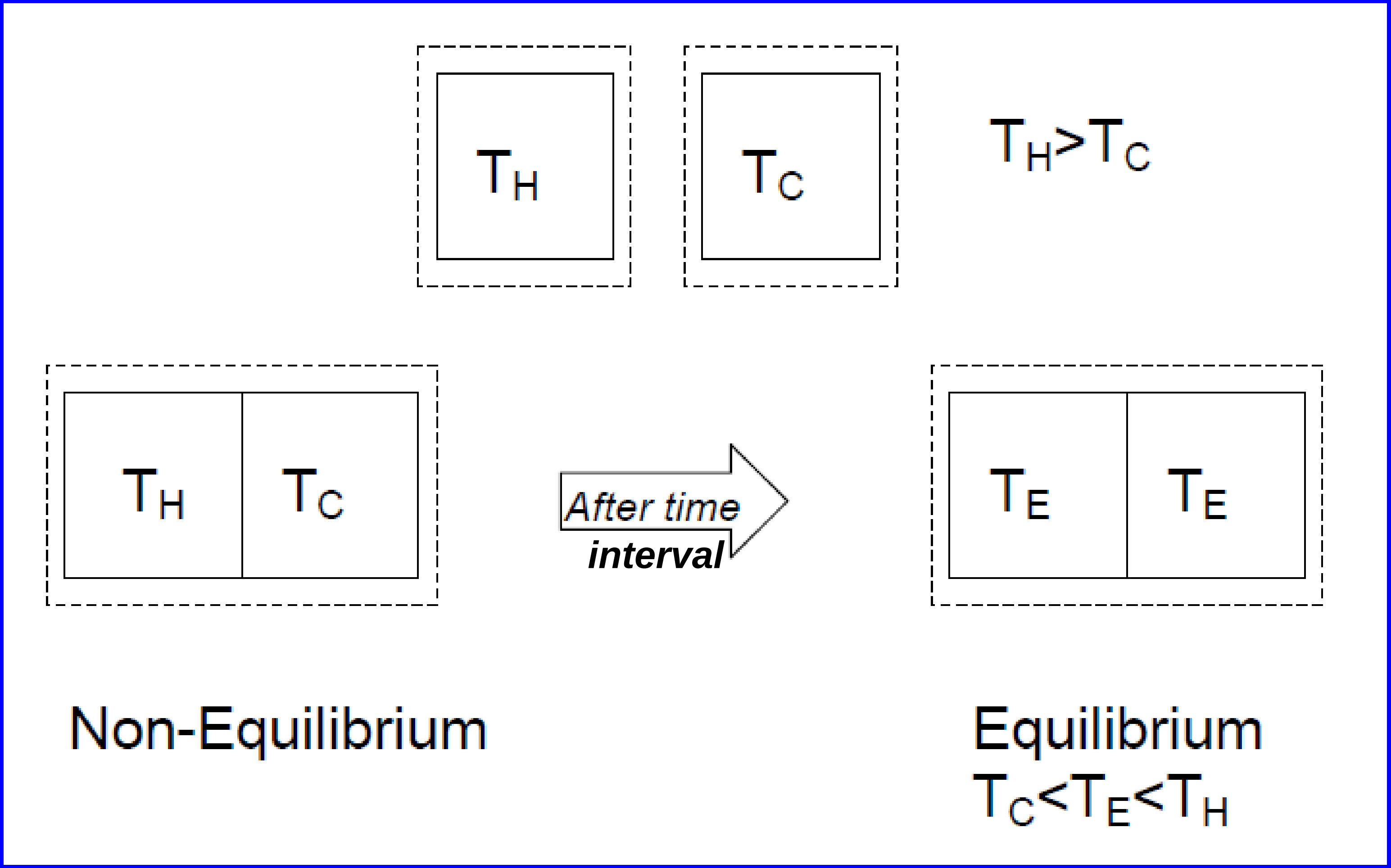
- Thermodynamics deals with *equilibrium states.*
- The word ***equilibrium*** implies a state of balance.
- In an equilibrium state there are no unbalanced potentials (or driving forces) within the system.
- A system in equilibrium experiences no changes when it is isolated from its surroundings.

Key Definitions contd..

- A system is not in thermodynamic equilibrium unless the conditions of all the relevant types of equilibrium are satisfied.
- For e.g., a system is in thermal equilibrium if the temperature is the same throughout the entire system.
- That is, the system involves no temperature differential, which is the driving force for heat flow.

Key Definitions contd..

Example: Thermal Equilibrium



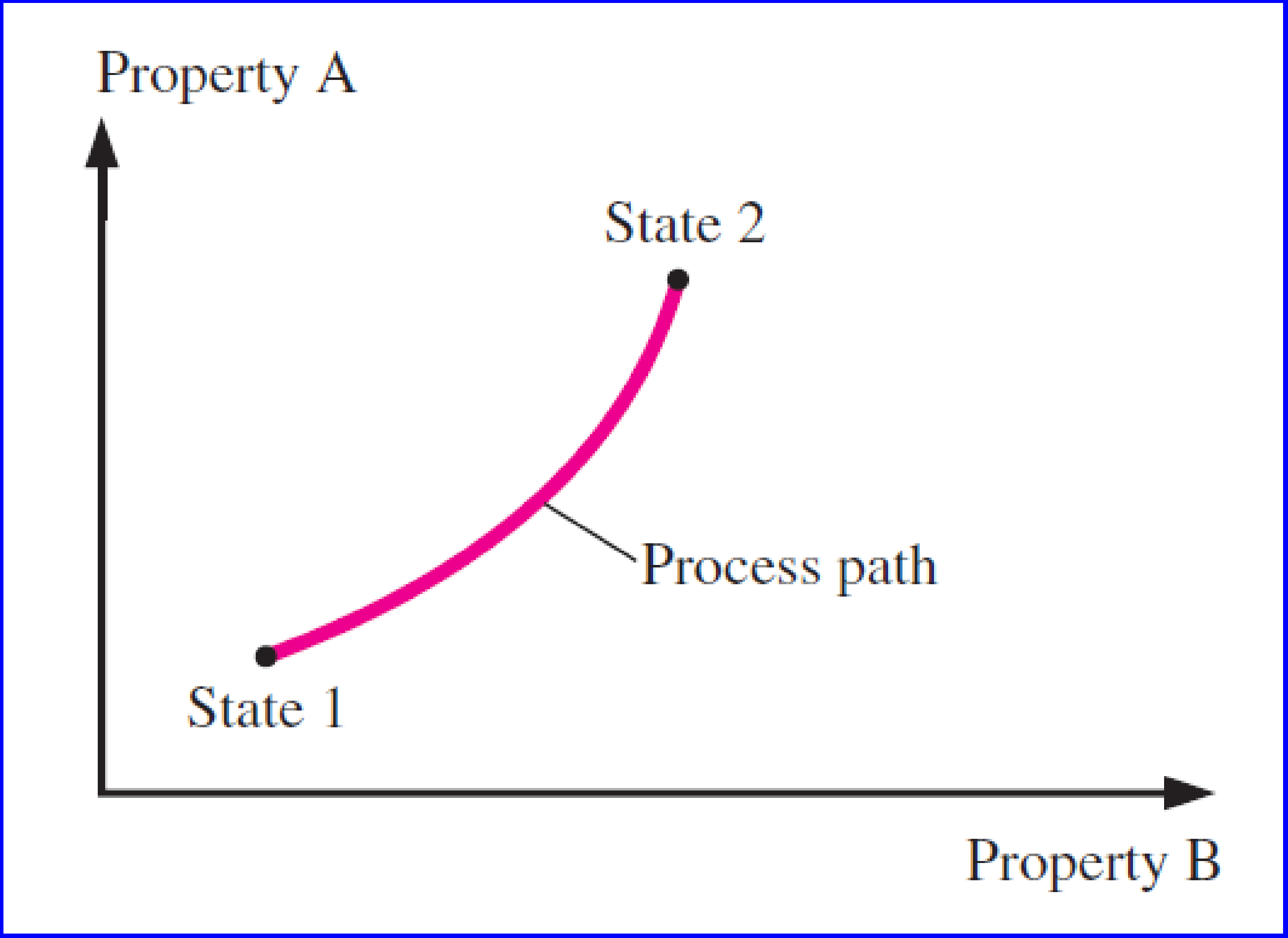
Key Definitions contd..

Process

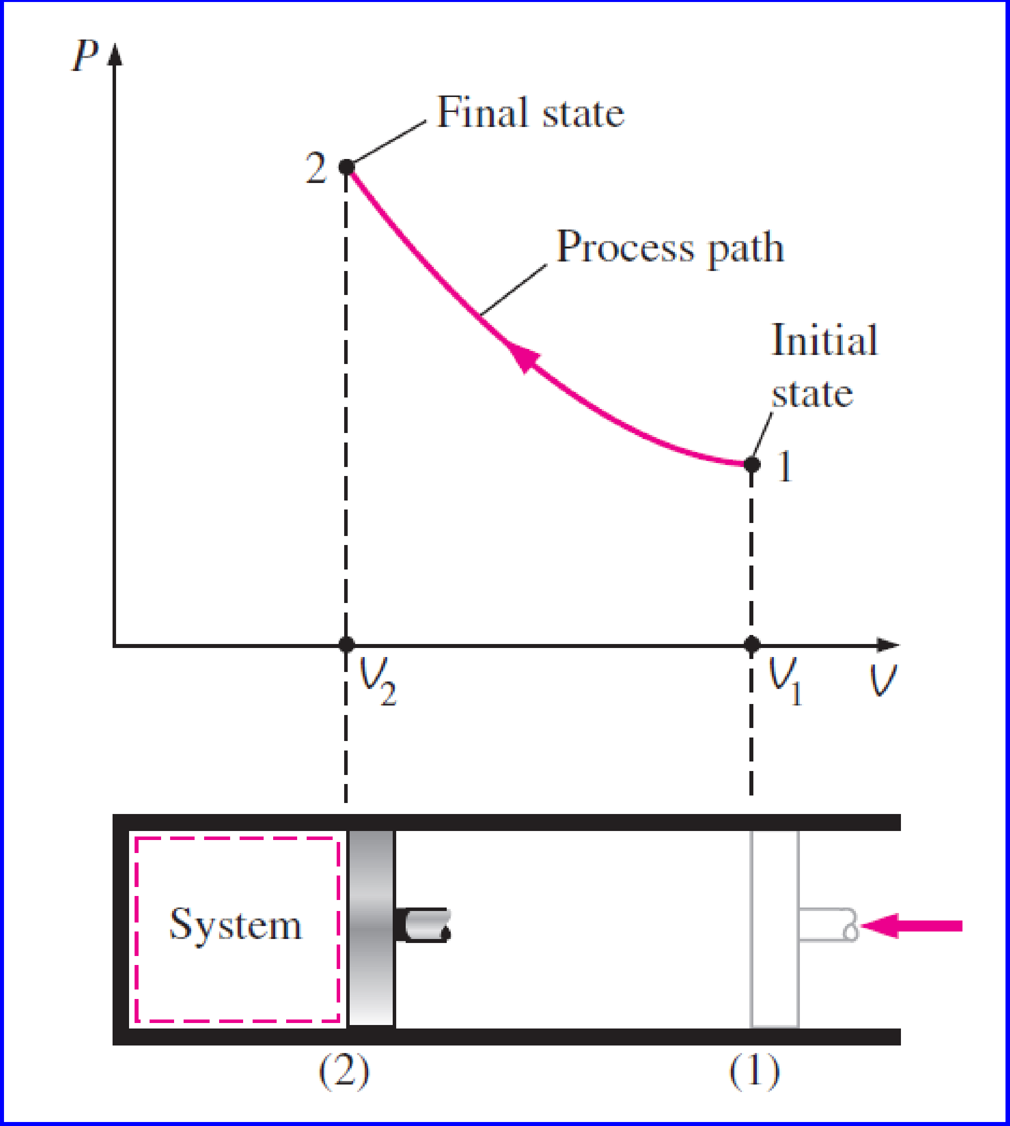
- Any change that a system undergoes from one equilibrium state to another is called a **process,** and the series of states through which a system passes during a process is called the **path of the process.**

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

Key Definitions contd..



Key Definitions contd..



Key Definitions contd..

- **Reversible Process**
  - ➢ Process that brings the system back to its original state without imparting any change to both the system and surroundings.
  - ➢ During a reversible process, each state that the system undergoes is in thermodynamic equilibrium.
  - ➢ When a system is in thermodynamic equilibrium, all the properties within the system are uniform.
  - ➢ Processes that are subjected to friction are always irreversible.

Key Definitions contd..

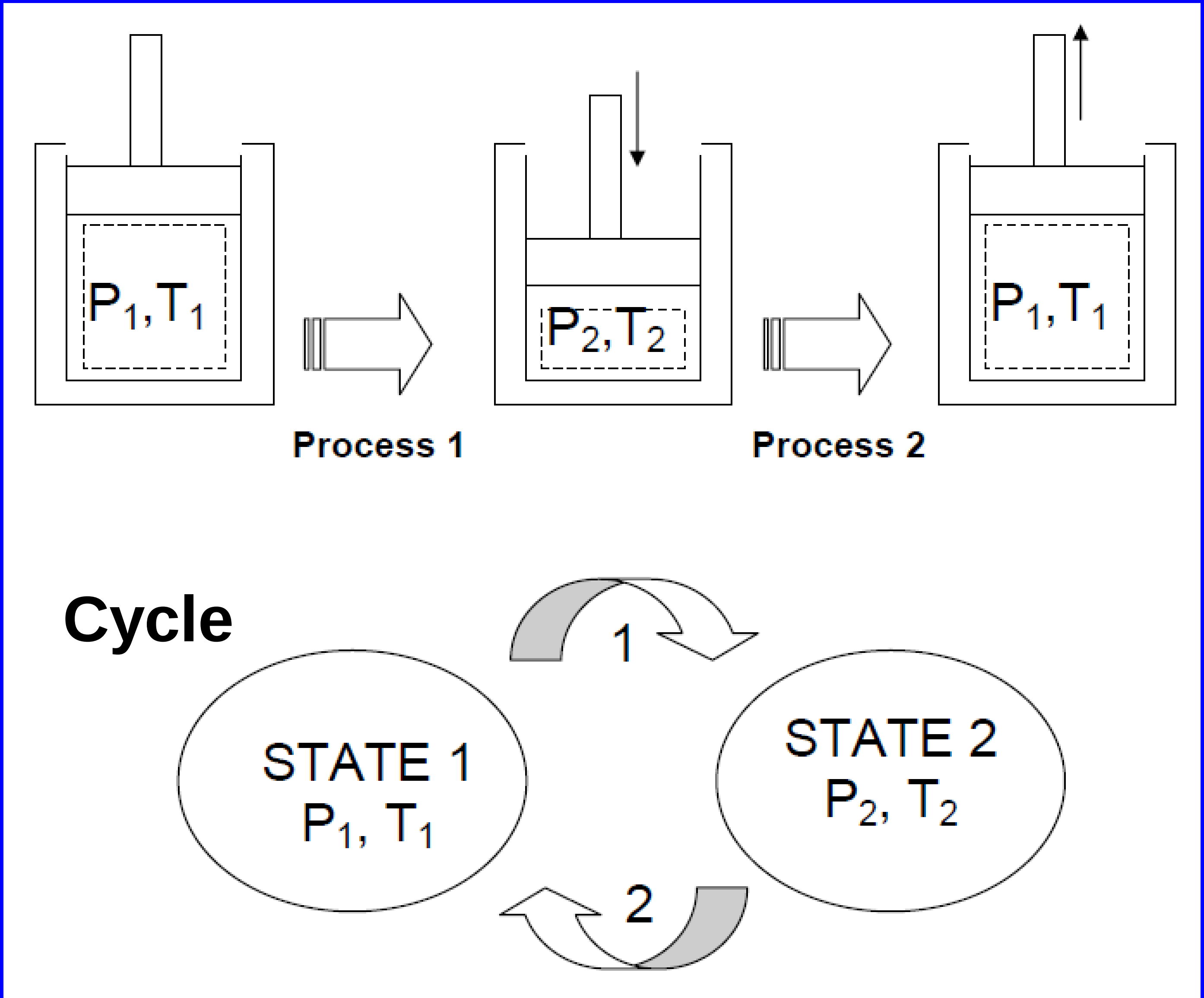
- **Process**

  ➢ A process is the transformation of a system from one state to another state.

- **Cycle**

  ➢ A cycle is a sequence of processes that begins and ends at the same state.

Example showing a cycle consisting of two processes



Key Definitions contd..

- The **Zeroth Law of Thermodynamics** states that if two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.
- If body A is in thermal equilibrium with body B, and body C is in thermal equilibrium with body B, then body A is in thermal equilibrium with body C.
- The concept which arises from the zeroth law is that of temperature.

Energy Transfer as Heat

- Energy transfer in the form of heat takes place from a hot body (High temperature) to a cold body (Low temperature) under natural conditions.
- For heat transfer to occur, the system and its surroundings must be at different temperatures.
- Three modes of heat transfer; Conduction, Convection and Radiation.
- No heat transfer (Adiabatic Process) : When the system is perfectly insulated, or when the temperature difference is zero.

Estimation of Heat Transfer

$$Q = mc(\Delta\theta)$$

- For solids and liquids, c (Specific heat capacity) is a constant.

- For gases c_p (Specific heat capacity at constant pressure) and c_v (Specific heat capacity at constant volume) are defined.

- Experimental data of these are available in standard property tables.

Energy Transfer as Work

- Work is also an energy interaction between a system and its surroundings.
- Work, in classical Mechanics, is defined as a force acting through a distance;

$$W = \int_{s_1}^{s_2} F.ds$$

- The work done per unit time is called **Power.**

Heat and Work

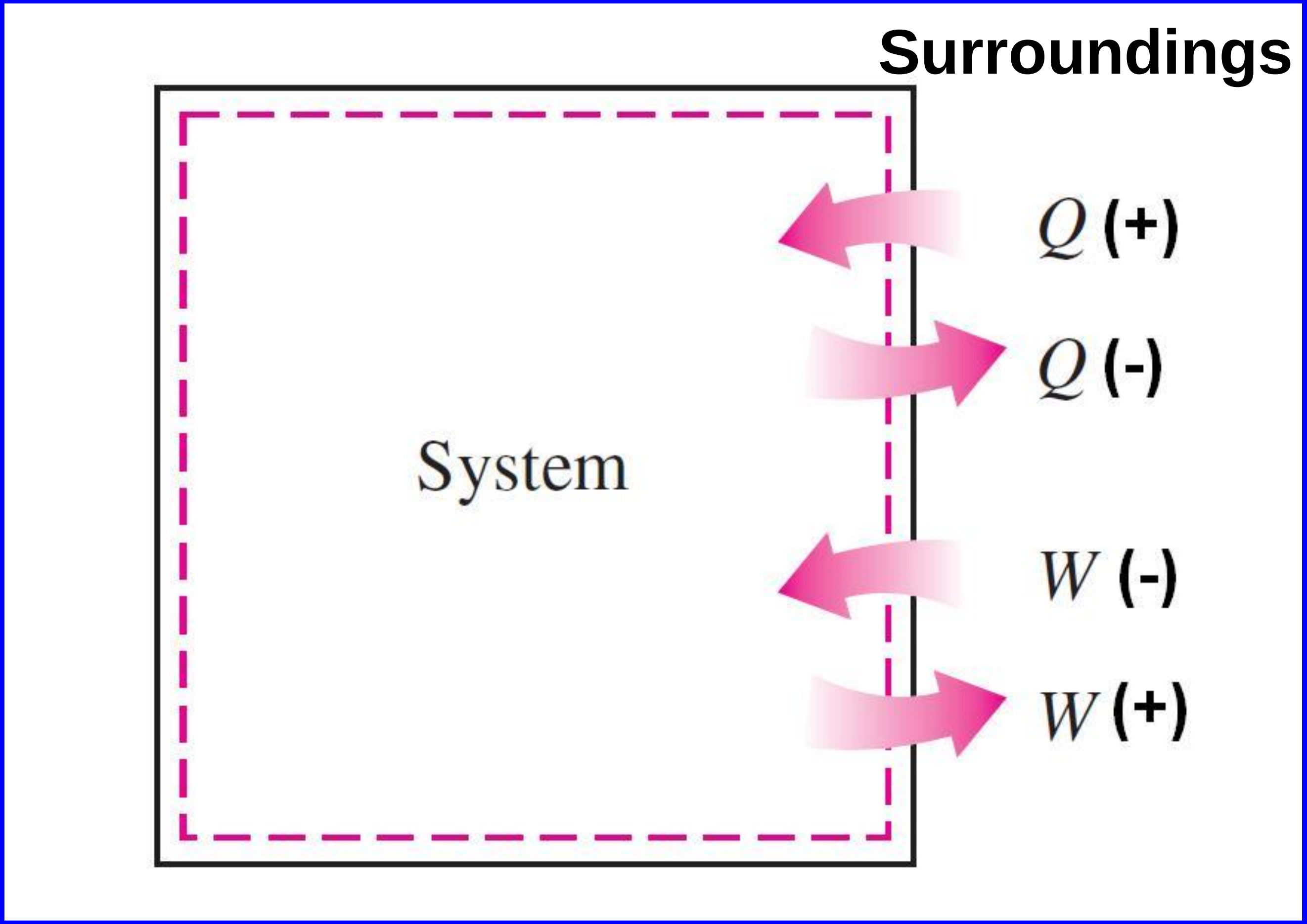
- Heat and work are directional quantities.
- Hence the complete description of heat or work interaction requires the specification of both the magnitude and direction.
- A sign convention has been established for analyzing work and heat transfer.

Sign Convention

- Heat transfer to the system from the surroundings and work done by the system on the surroundings are positive.

- Heat transfer from the system to the surroundings and work done on the system by the surroundings are negative.

Sign Convention contd..

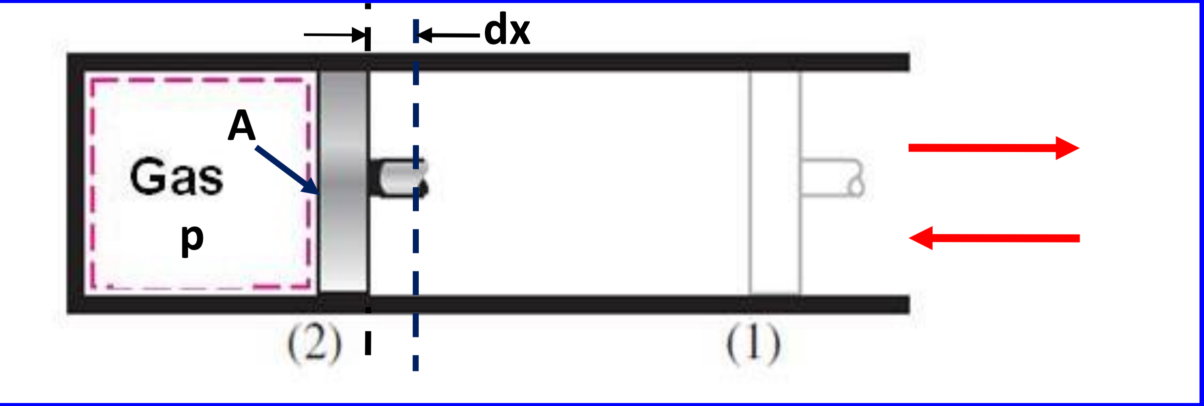


Different Types of Work

- Expansion and Compression Work
- Shaft Work
- Spring Work
- Electrical Work
- Magnetic Work
- Electrostatic Work

Expansion & Compression Work

- Work transfer takes place when a fluid is subjected to expansion & compression in a system. (for e.g. gas in a cylinder-piston mechanism)



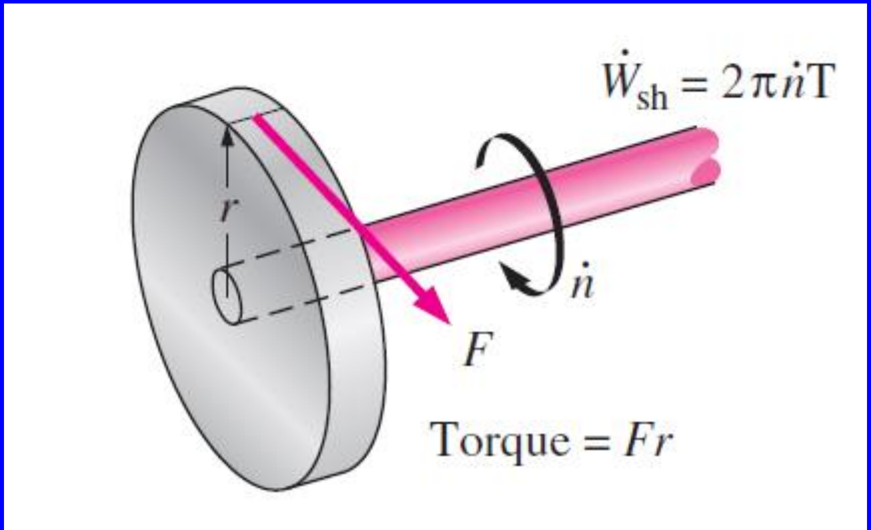
$$W_{12} = \int_1^2 F.dx$$

$$W_{12} = \int_1^2 p.A.dx$$

$$W_{12} = \int_1^2 p.dV$$

Shaft Work

- Energy transmission with a rotating shaft is very common in engineering practice.
- Often the torque T applied to the shaft is constant, meaning that the force F applied is also constant.



Shaft Work contd..

- A force F acting through a distance r generates a torque T given as

$$T = Fr$$

- This force acts along a distance s, which is related to the radius r by

$$s = (2\pi r)n$$

Shaft Work contd..

- Then the shaft work is determined from

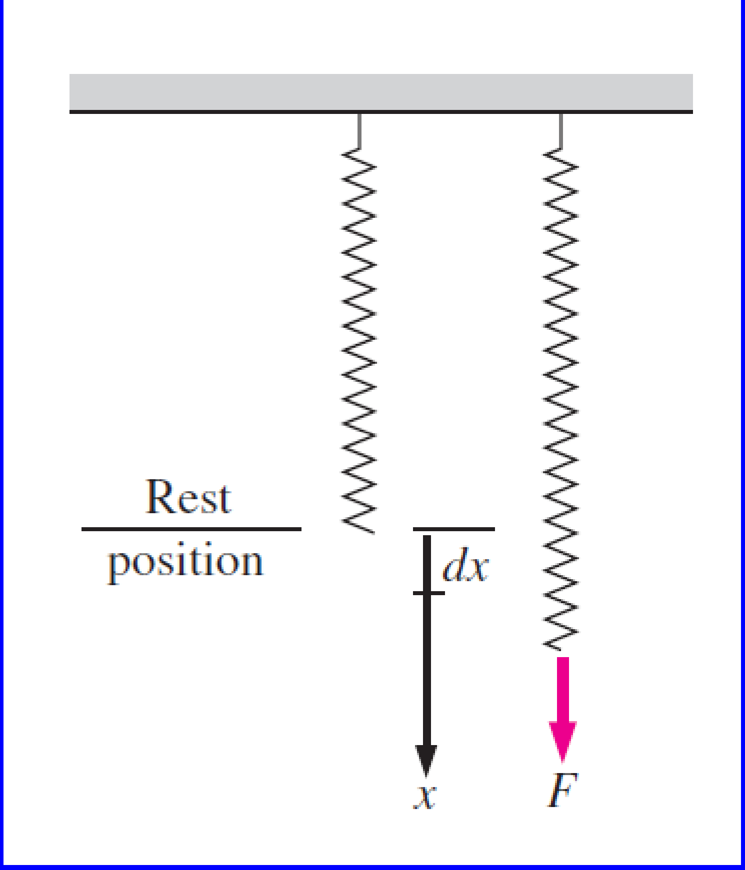
$$W_{sh} = Fs = \left(\frac{T}{r}\right)(2\pi rn) = 2\pi nT$$

- The power transmitted through the shaft is the shaft work done per unit time, which can be expressed as

$$\dot{W}_{sh} = 2\pi \dot{n} T$$

Spring Work

- For linear elastic springs, the displacement x is proportional to the force (F) applied.



Spring Work contd..

$$\boxed{F = kx}$$

- where k is the spring constant and the displacement x is measured from the undisturbed position of the spring.
- If x_1 and x_2 are the initial and the final displacements of the spring, respectively, measured from the undisturbed position of the spring, then spring work:

$$\boxed{W_{spring} = \frac{1}{2}k\left(x_2^2 - x_1^2\right)}$$

Electrical Work

- In an electrical field, electrons in a conductor move under the effect of electromotive forces, doing work.
- In general, both Voltage (V) and Current (I) vary with time, and the electrical work done during a time interval Δt is expressed as

$$W_e = \int_1^2 V(t)I(t)dt$$