UNIT-I: BASIC CONCEPTS AND FIRST LAW OF THERMODYNAMICS

1. System

A **system** is a specified quantity of matter or a region in space selected for study.

Everything outside the system is called the **surroundings**.

Example:

- Gas inside a cylinder
- Water in a boiler
- Steam in a turbine

Types of Systems

(a) Closed System (Control Mass)

- No mass crosses the boundary.
- Energy can cross as heat or work.
- Mass remains constant.

Examples

- Gas inside a piston-cylinder
- Pressure cooker (closed)

Diagram

```
      Heat
        ↑
 ------------------
|                  |
|       GAS        |
|                  |
 ------------------
        ↓
      Work

Mass cannot enter or leave
```

(b) Open System (Control Volume)

Mass and energy can cross the boundary.

Examples:

- Turbine

- Compressor
- Pump
- Boiler
- Nozzle

```
Mass in → [ Turbine ] → Mass out
          Heat & Work
```

(c) Isolated System

Neither mass nor energy crosses the boundary.

Examples:

- Thermos flask (approximately)
- Universe

2. Control Volume

A **control volume** is a fixed region in space through which mass flows.

Used in:

- Turbines
- Compressors
- Pumps
- Heat exchangers

3. Surroundings

Everything outside the system boundary is called surroundings.

Example:
If the system is water inside a boiler,
the atmosphere is the surroundings.

4. Boundary

The real or imaginary surface separating the system and surroundings.

Boundary may be

- Fixed
- Moving
- Real
- Imaginary

5. Universe

```
Universe = System + Surroundings
```

6. Macroscopic Viewpoint

Studies the overall behaviour of matter.

Does not consider molecular motion.

Uses measurable properties:

- Pressure
- Temperature
- Volume
- Density

Example:
Pressure of steam in a boiler.

Advantages

- Simple
- Used in engineering

7. Microscopic Viewpoint

Studies individual molecules.

Based on statistical mechanics.

Considers

- Molecular velocity
- Molecular collisions
- Molecular energy

Applications

- Gas kinetic theory
- Molecular physics

8. Concept of Continuum

Matter is assumed to be continuously distributed.

Although matter consists of molecules, in thermodynamics we ignore molecular spacing.

This assumption is called the **continuum hypothesis**.

Example:
Water flowing through a pipe is treated as a continuous fluid.

9. Thermodynamic Equilibrium

A system is in equilibrium when all properties remain constant with time.

Conditions

Thermal Equilibrium

Temperature is uniform.

Mechanical Equilibrium

Pressure is uniform.

Chemical Equilibrium

No chemical reaction occurs.

Phase Equilibrium

No change of phase.

10. Property

A property is any measurable characteristic of a system.

Examples

- Pressure
- Temperature
- Volume
- Density
- Internal Energy

Types of Properties

Intensive Properties

Independent of mass.

Examples

- Temperature
- Pressure
- Density

Extensive Properties

Depend on mass.

Examples

- Volume
- Mass
- Energy

Specific property

```
Specific Property
=
Extensive Property / Mass
```

Example

Specific volume

```
v = V/m
```

11. Process

A process is the change of state of a system.

Examples

Heating water

Compression

Expansion

Types of Processes

Isothermal Process

Temperature remains constant.

```
T = Constant
```

Isobaric Process

Pressure remains constant.

```
P = Constant
```

Isochoric Process

Volume remains constant.

```
V = Constant
```

No boundary work.

Adiabatic Process

No heat transfer.

```
Q = 0
```

Polytropic Process

$PV^n = \text{Constant}$

12. State

The condition of a system described by properties.

Example

Pressure = 2 bar

Temperature = 150°C

Volume = 0.5 m^3

These define one state.

---

13. Point Function

Depends only on the state.

Examples

Pressure

Temperature

Volume

Internal energy

Represented by exact differential.

```
dU
```

---

14. Path Function

Depends on the path followed.

Examples

Heat

Work

Represented by inexact differential.

```
δQ
δW
```

Exact Differential

Depends only on initial and final states.

Examples

```
dU
dH
dV
```

Inexact Differential

Depends on the path.

Examples

```
δQ
δW
```

17. Cyclic Process

System returns to its initial state.

```
Initial State
```

```
      ↓
Several Processes
      ↓
Final State = Initial State
```

For a cycle

$\Delta U = 0$

Reversible Process

Occurs infinitely slowly.

The system passes through equilibrium states.

No friction.

Maximum work output.

Examples

Slow compression

Slow expansion

Irreversible Process

Occurs rapidly.

Causes

- Friction
- Heat loss
- Mixing
- Unrestrained expansion

Most practical processes are irreversible.

Energy

Energy is the capacity to do work.

Units

SI Unit = Joule (J)

Forms of Energy

Internal Energy (U)

Energy due to molecular motion and molecular forces.

Kinetic Energy (KE)

$KE = mv^2 / 2$

Potential Energy (PE)

$PE = mgh$

Heat

Energy transferred due to temperature difference.

Unit

Joule (J)

Positive when entering the system.

Work

Energy transferred when a force moves through a distance.

$W = \text{Force} \times \text{Distance}$

Boundary work

$W = \int PdV$

Work (Boundary Work)

Occurs when system volume changes.

$W = \int PdV$

For constant pressure

$W = P(V_2 - V_1)$

Other Forms of Work

- Shaft work
- Electrical work
- Paddle wheel work
- Spring work
- Flow work

Heat and Work are Path Functions

They depend on the path taken.

They are **not** properties of the system.

Zeroth Law of Thermodynamics

Statement:

If two systems are separately in thermal equilibrium with a third system, they are in thermal equilibrium with each other.

Importance:

- Forms the basis for temperature measurement.
- Enables the use of thermometers.

27. Temperature Scales

- Celsius (°C)
- Kelvin (K)
- Fahrenheit (°F)
- Rankine (°R)

Conversion

```
K = °C + 273.15
°F = (9/5 × °C) + 32
```

28. Pressure Measurement

Absolute Pressure

Measured from absolute vacuum.

Gauge Pressure

Measured above atmospheric pressure.

Vacuum Pressure

Pressure below atmospheric pressure.

Relation

```
Pabsolute = Patmospheric + Pgauge
```

29. PMM-I (Perpetual Motion Machine of the First Kind)

A hypothetical machine that produces work without any energy input.

It violates the **First Law of Thermodynamics**, so it is impossible.

30. Joule's Experiments

James Prescott Joule showed that mechanical work can be converted into heat.

This established the **mechanical equivalent of heat** and supported the conservation of energy.