Thermodynamics I

Chapter 1

Basic Concepts of Thermodynamics

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Thermodynamics and Energy

Thermodynamics = Therme + dynamis

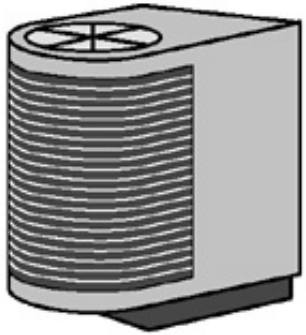
Therme = heat

Dynamis = power

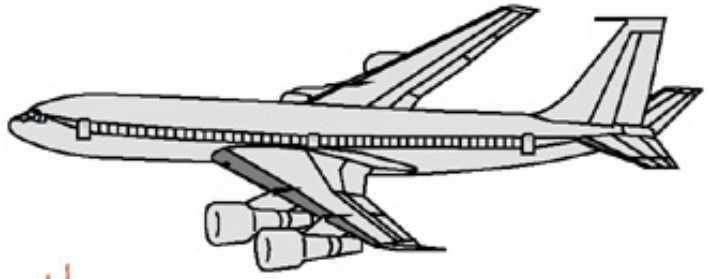
Thermodynamics is most descriptive of the early efforts to convert heat to power.

Application Areas of Thermodynamics

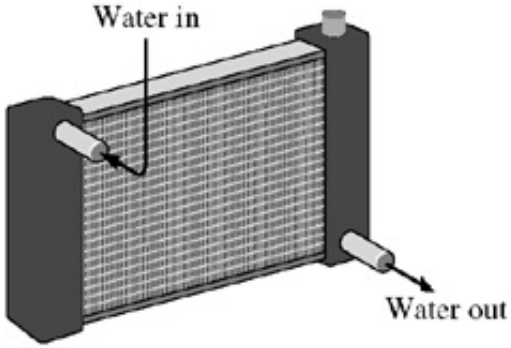
The human body



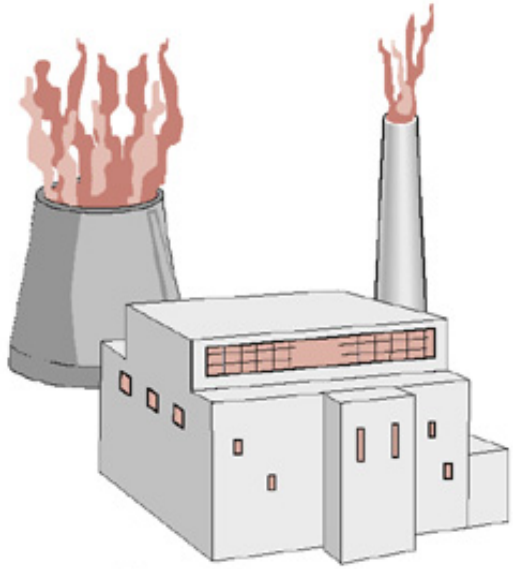
Air-conditioning systems



Airplanes



Car radiators



Power plants

Refrigeration systems

Dimensions and Units

- Any *physical quantit:y* can be characterized by **dimensions**.
- The *arbitrary magnitudes* assigned to the dimensions are called **units**.

- **Primary (fundamental) dimensions** :- basic dimension such as mass, length, time, and temperature
- **Secondary (derived) dimensions** :- dimensions that expressed in term of primary dimensions

Systems of Unit

- Two systems of units that are widely used in engineering are the British Gravitational (BG) System and the International System (SI).
- British Gravitational System (BG)
  - Length (foot, ft), Time (second, s), Force (pound, lb), Temperature (Fahrenheit °F, Rankine °R)
- International System (SI)
  - Length (meter, m), Time (second, s), mass (kilogram, kg), Temperature (Kelvin, K)
- When solving problems it is important to use a consistent system of units, *e.g.*, don't mix BG and SI units

Systems of Unit

$m = 1\ \text{kg}$ → $a = 1\ \text{m/s}^2$ → $\text{F} = 1\ \text{N}$

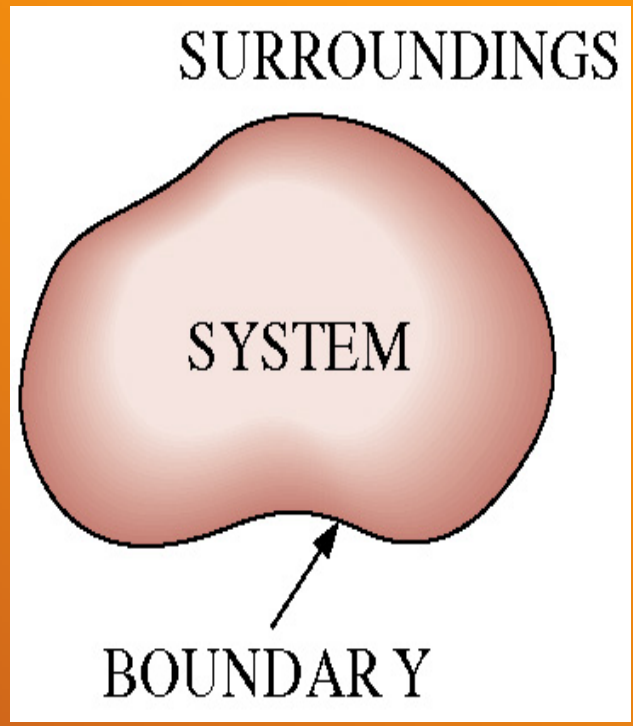
$m = 32.174\ \text{lbm}$ → $a = 1\ \text{ft/s}^2$ → $\text{F} = 1\ \text{lbf}$

Thermodynamic System

System :- a quantity of matter or a region in space chosen for study

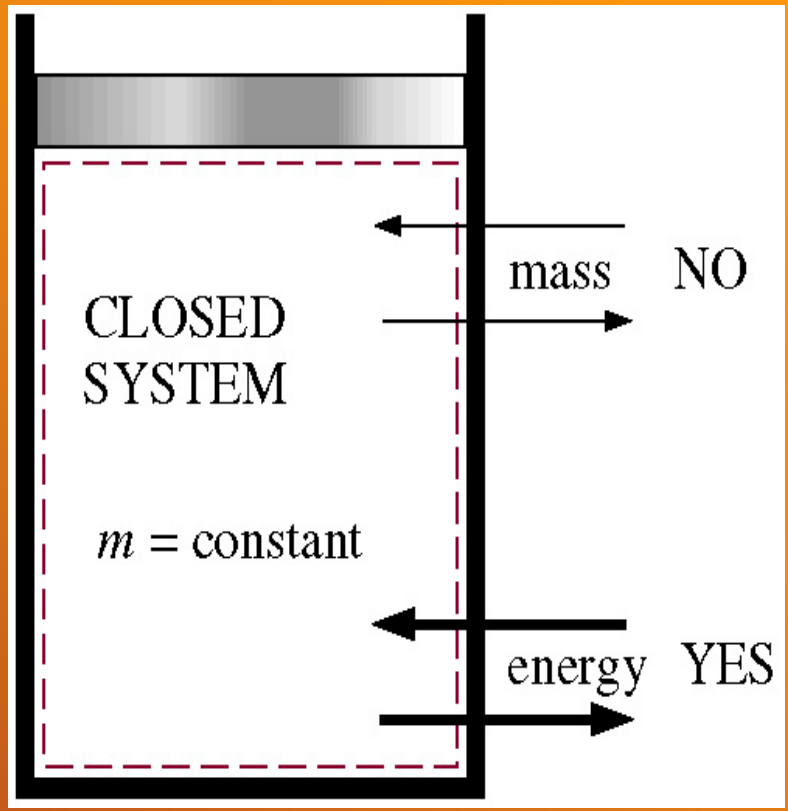
Surroundings :- the mass or region outside the system

Boundary :- the real or imaginary surface that separates the system from its surroundings

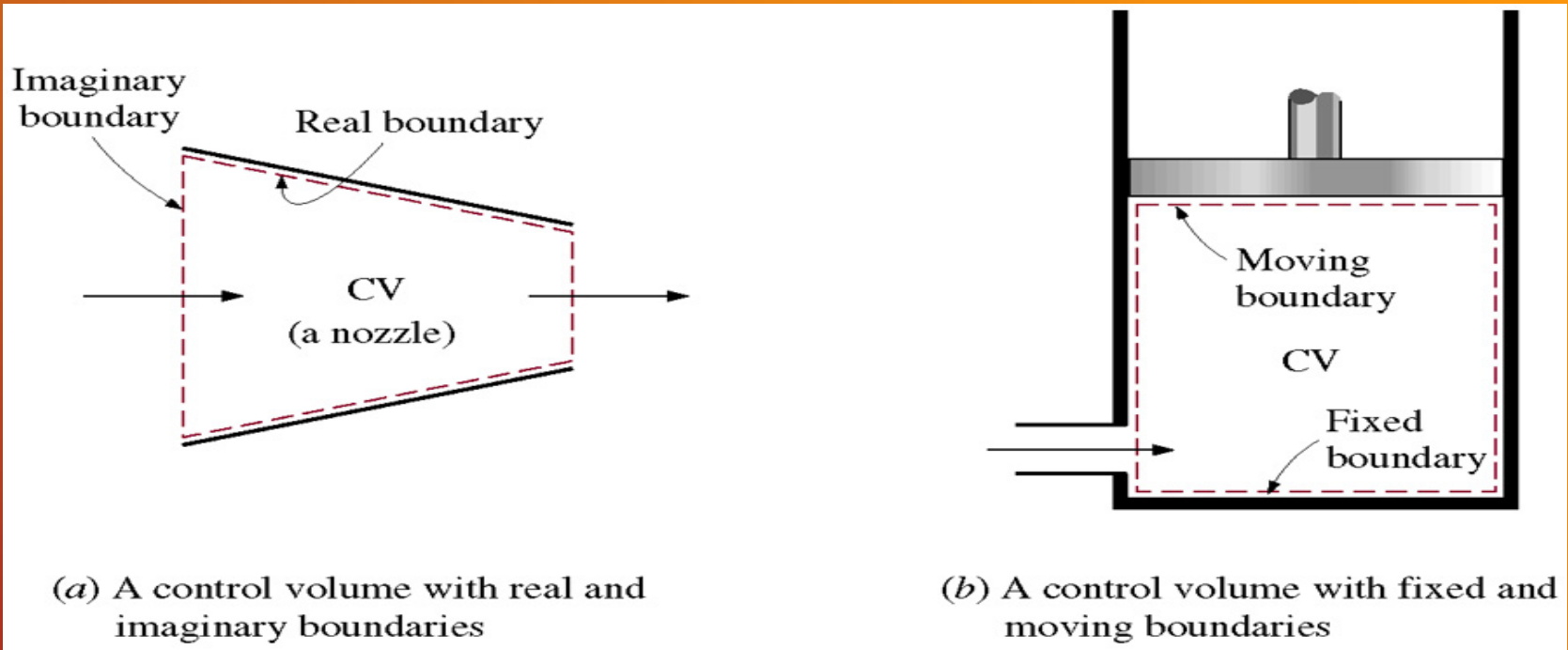


Closed System (Control Mass)

- Consist of a fixed amount of mass
- No mass can cross its boundary
- Energy, in form of heat and work, can cross the boundary
- Also called isolated system



Open System (Control Volume)



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

(*b*) A control volume with fixed and moving boundaries

- A properly selected region in space.
- It usually encloses a device that involves mass flow such as a compressor, turbine, nozzle.

Properties of a System

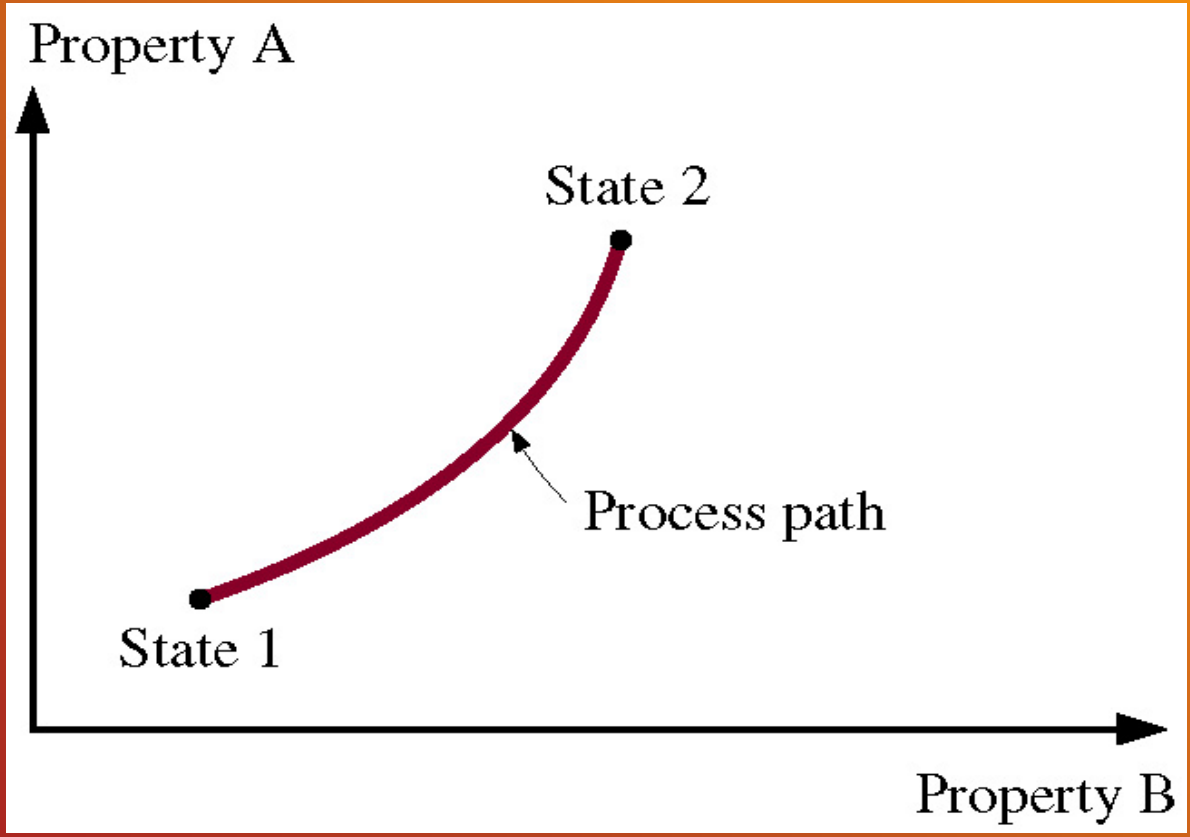
- Density, ρ :- mass per unit volume
- Specific volume, v :- volume per unit mass
- Specific gravity, SG :- the ratio of the density of a substance to the density of some standard substance at a specified temperature
- Intensive properties :- independent of the size of the system
- Extensive properties :- depend on the size of thesystem

State and Equilibrium

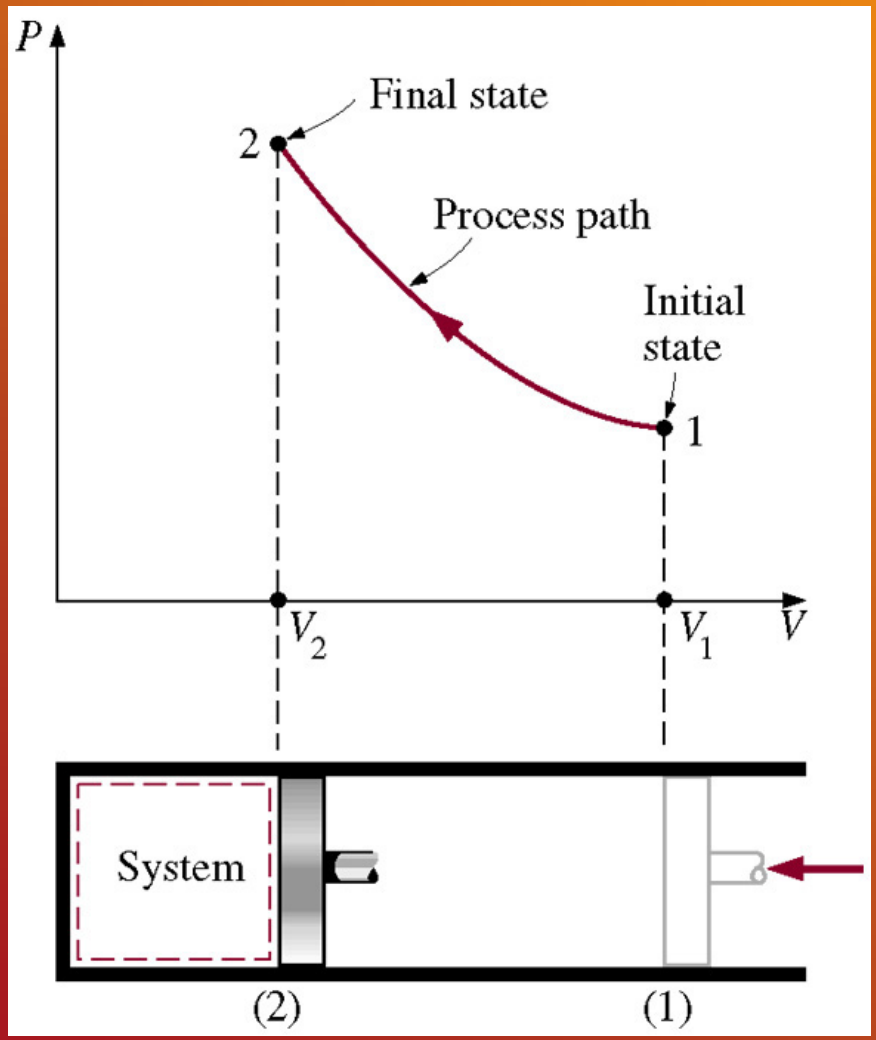
- State :- a set of properties that completely describes the condition
- Equilibrium :- a state of balance, no unbalance potential in the system
  - Thermal equilibrium, $T = const.$
  - Mechanical equilibrium, $P = const.$
  - Phase equilibrium
  - Chemical equilibrium

Processes

System undergoes from one equilibrium state to another.



Processes and Cycle



Iso-Process

- Isothermal process
  T = constant
- Isobaric process
  P = constant
- Isochoric process
  v = constant

Cycle

- System undergoes and return to the initial state at the end of processes

The Steady-Flow Process

Steady :- no change with time

Uniform :- no change with location

Steady-flow process :- a process during which a fluid flows through a control volume steadily.

Forms of Energy

- Thermal, mechanical, kinetic, potential, electric, magnetic, chemical, and nuclear
- Total energy, E :- sum of all energy of the system
- Total energy per unit mass, e

$$e = \frac{E}{m} \quad \text{(kJ/kg)}$$

Macroscopic and Microscopic

Macroscopic energy :- consider energy as a whole of system such as kinetic and potential energy.

Microscopic energy :- relate to the molecular structure of a system and degree of molecular activity

Internal energy, *U* :- sum of macroscopic energy and microscopic energy

Kinetic and Potential Energy

$$\mathrm{KE} = \frac{m\mathscr{V}^2}{2} \qquad \text{(kJ)}$$

$$\mathrm{ke} = \frac{\mathscr{V}^2}{2} \qquad \text{(kJ/kg)}$$

$$\mathrm{PE} = mgz \qquad \text{(kJ)}$$

$$\mathrm{pe} = gz \qquad \text{(kJ/kg)}$$

Forms of Energy

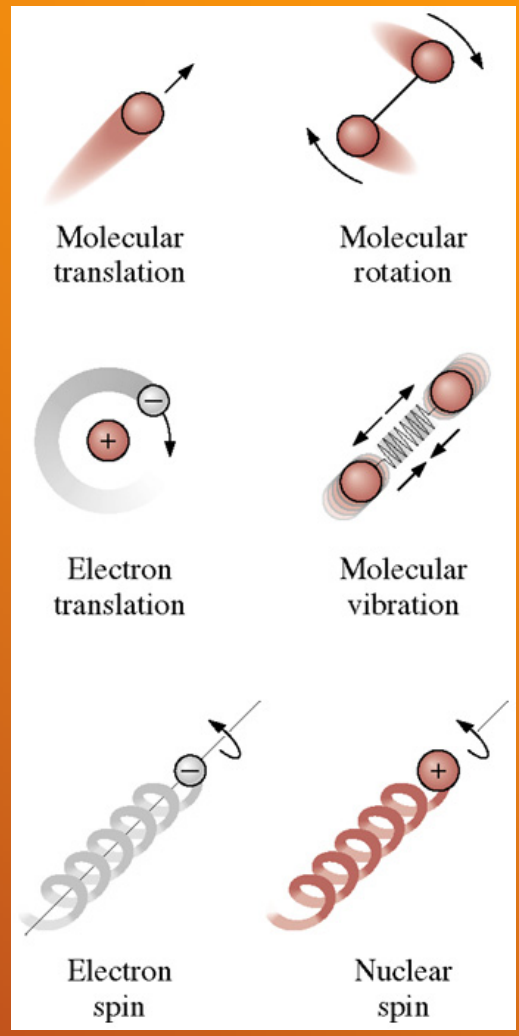
The magnetic, electric, and surface tension effects can be ignored in most systems.

$$E = U + \text{KE} + \text{PE} = U + \frac{m\mathscr{V}^2}{2} + mgz \qquad \text{(kJ)}$$

$$e = u + \text{ke} + \text{pe} = u + \frac{\mathscr{V}^2}{2} + gz \qquad \text{(kJ/kg)}$$

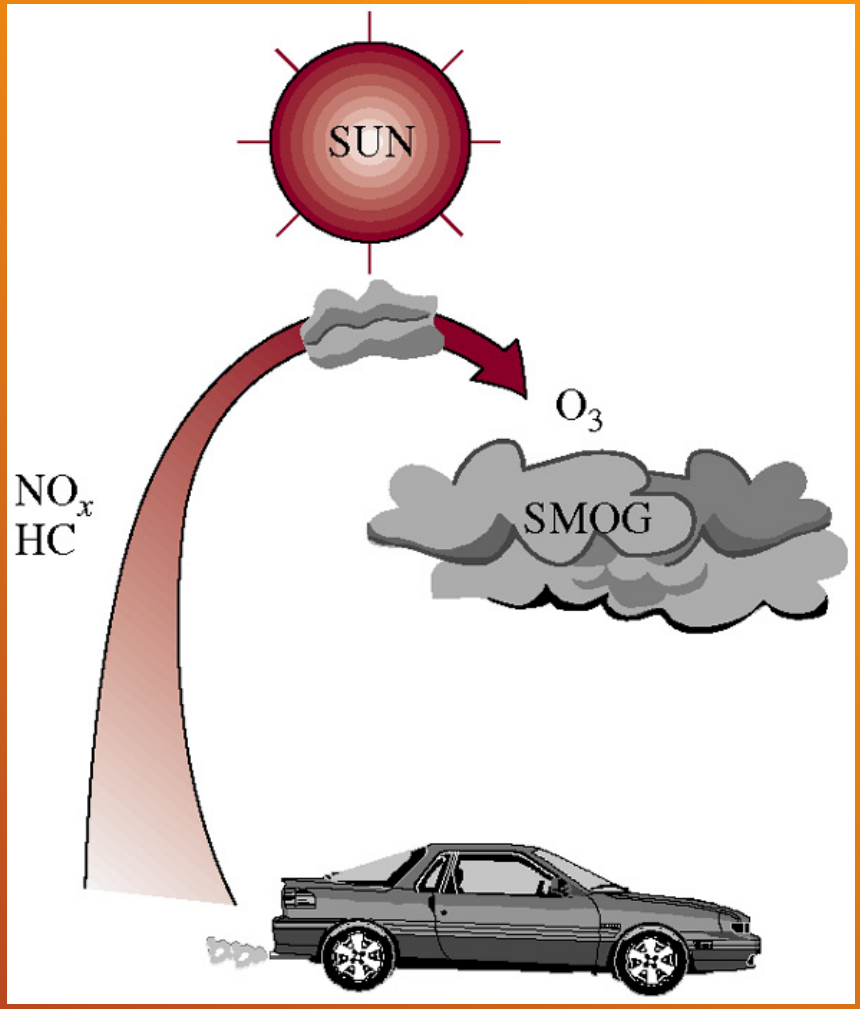
Some Physical Insight to Internal Energy

- Sensible energy
- Latent energy
- Chemical energy
- Nuclear energy



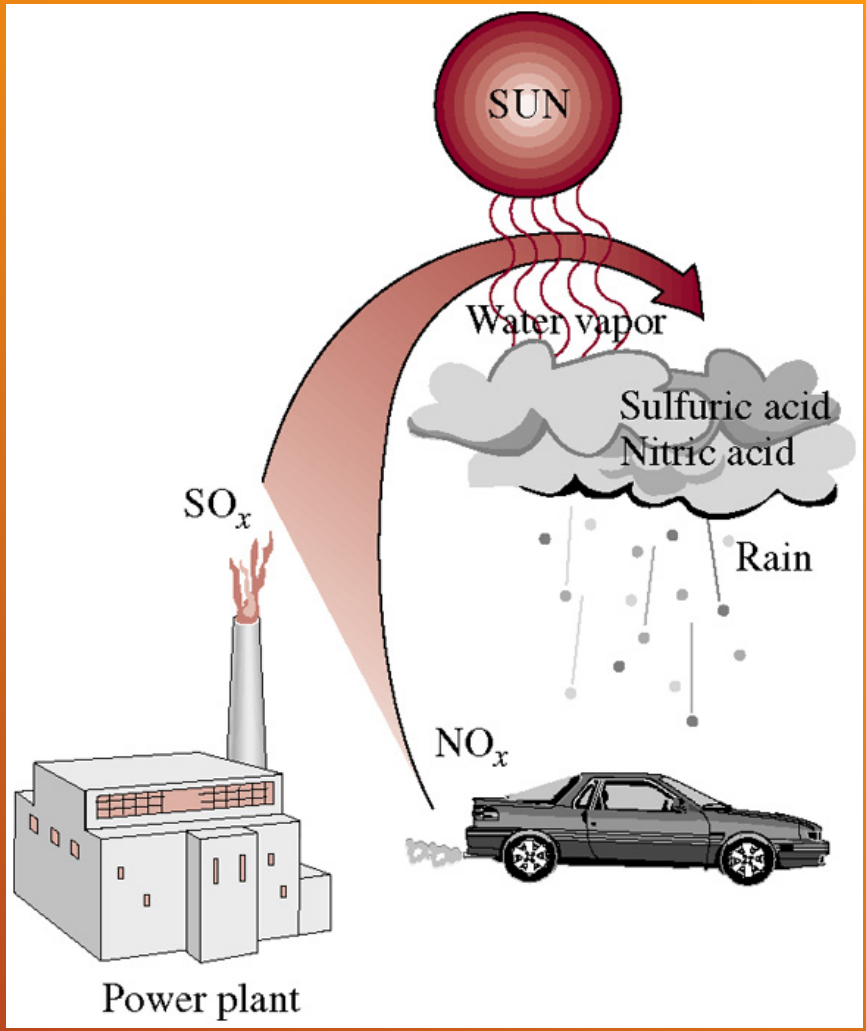
Energy and Environment

Ground-level ozone, which is the primary component of smog, forms when HC and NOx react in the presence of sunlight in hot calm days.



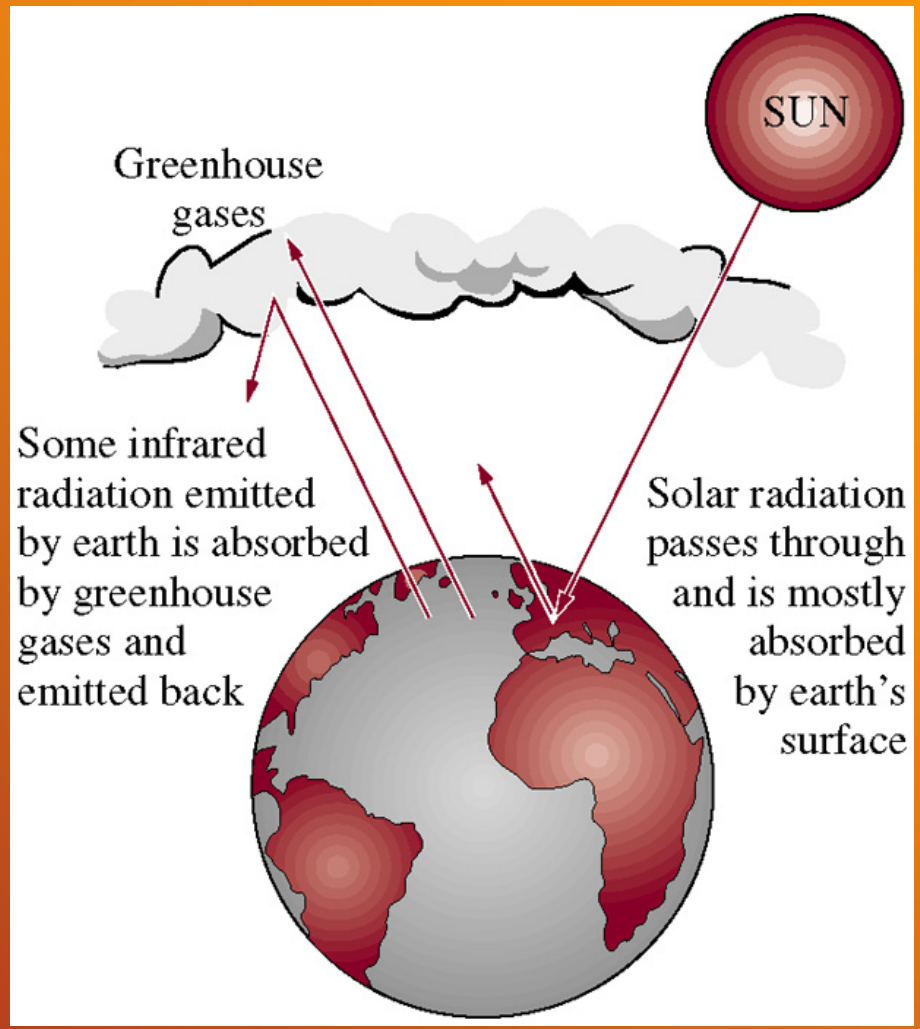
Energy and Environment

Sulfuric acid and nitric acid are formed when sulfur oxides and nitric oxides react with water vapor and other chemicals high in the atmosphere in the presence of sunlight.



Energy and Environment

The greenhouse effect on earth.



Temperature

- A measure of hotness and coldness.
- Hard to have an exact definition.
- Heat is transfer from the body at higher temperature to the one at lower temperature.
- At the point, where two bodies attain sam temperature, heat transfer stops called thermal equilibrium.

The Zeroth Law of Thermodynamics

If two bodies are in thermal equilibrium with the third body, they are also in thermal equilibrium with each other.

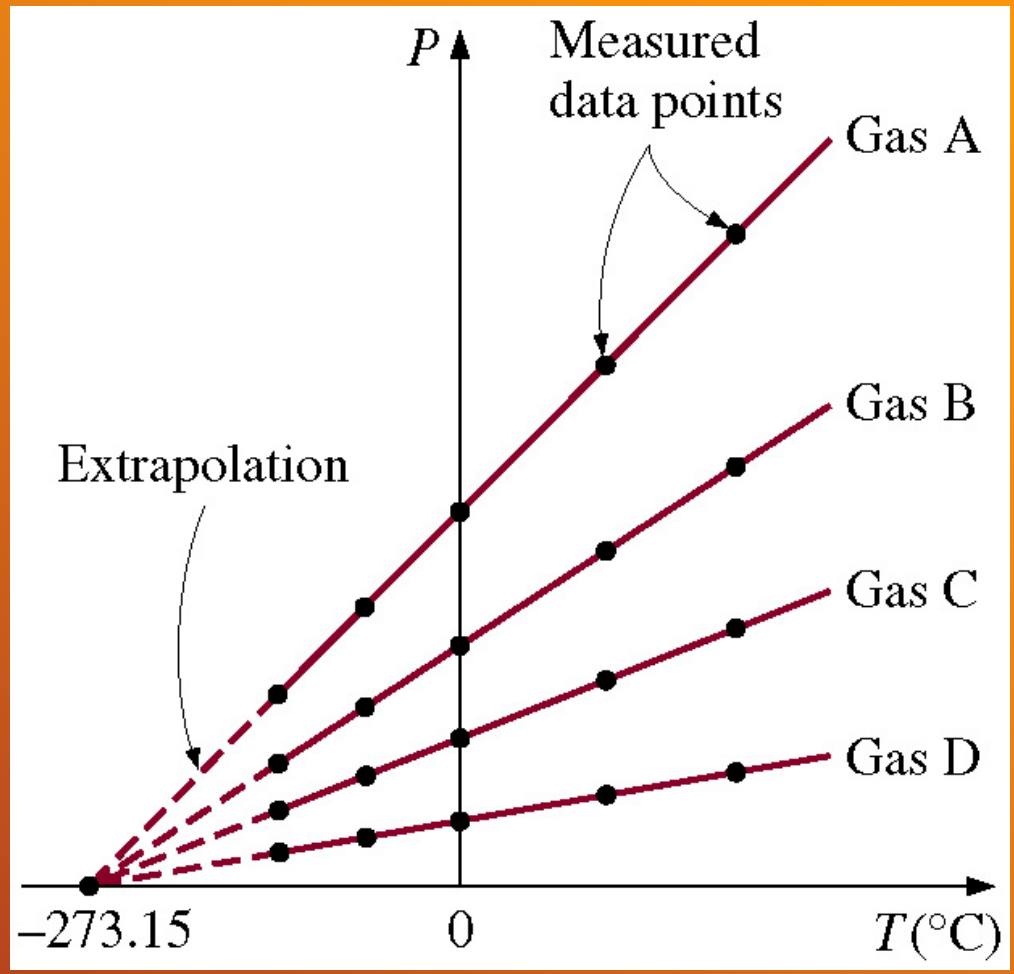
Two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact.

Temperature Scales

- Celsius and Fahrenheit are scales that based on some easily reproducible states of a substance.
- Temperature scale that independent for any state of any substance or substances is called **thermodynamic temperature scale**.
- Kelvin and Rankine are thermodynamic temperature scales.

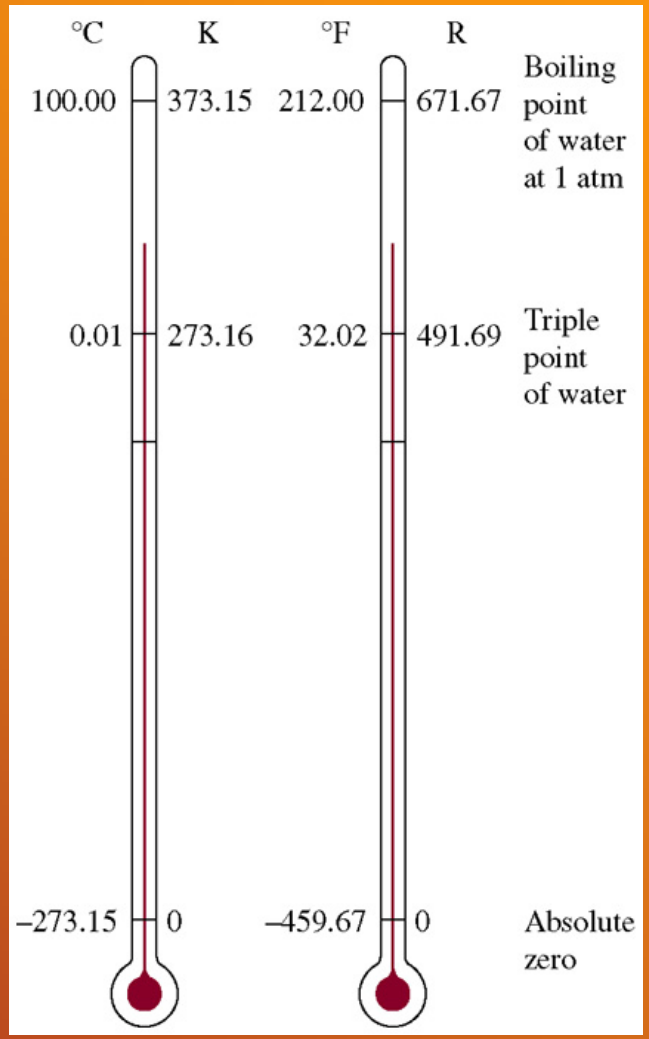
Thermodynamic Temperature Scale

P versus *T* plots of the experimental data obtained from a constant-volume gas thermometer using four different gases at different (but low) pressures.



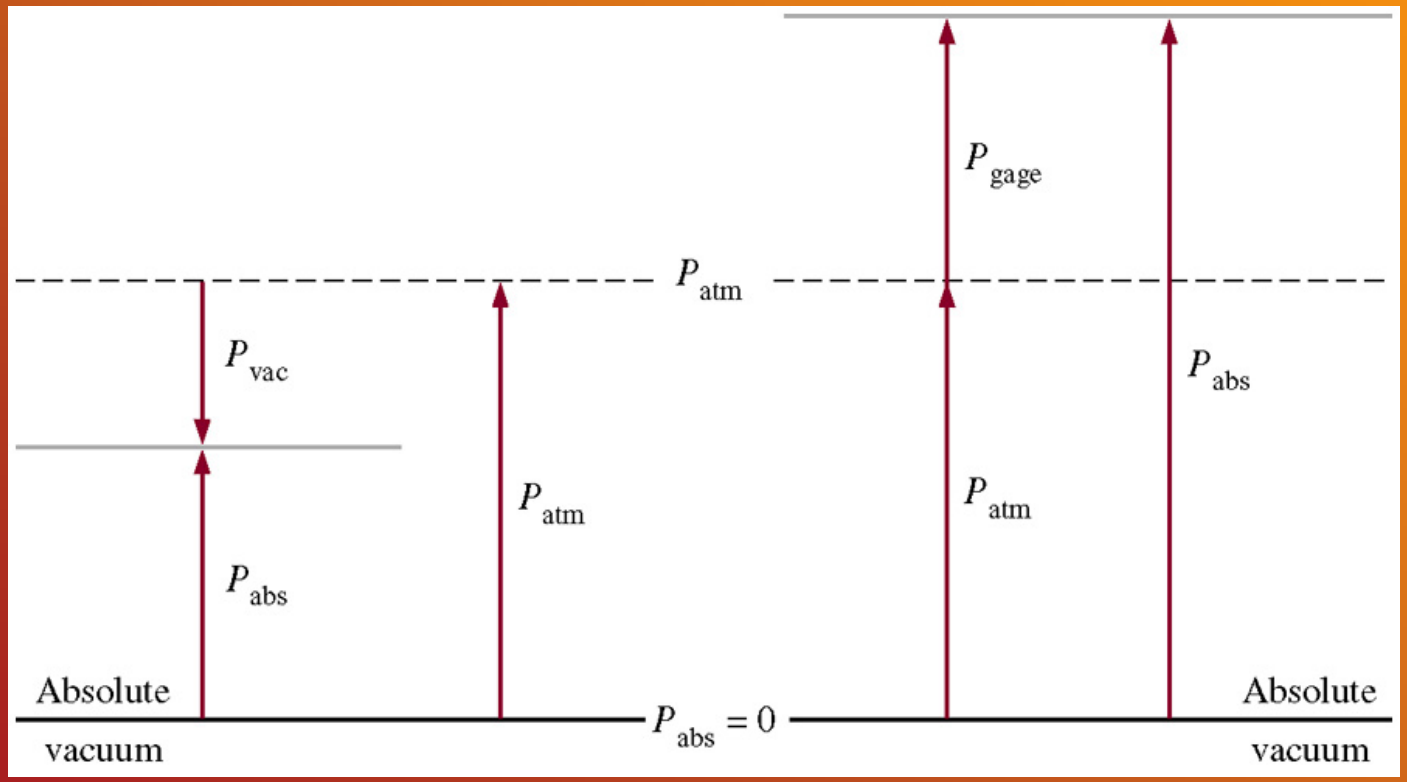
Temperature Scale

Comparison of temperature scale

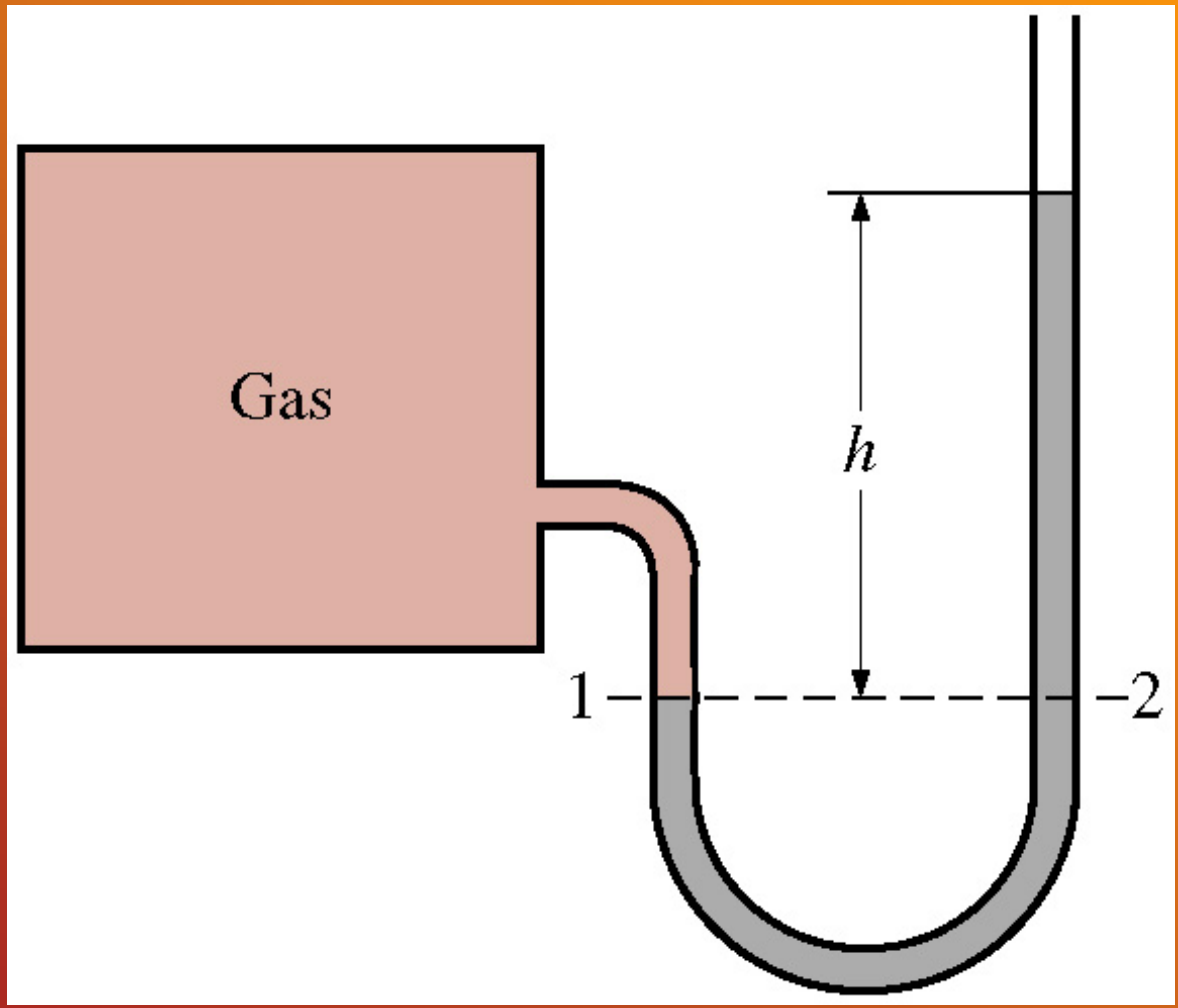


Pressure

Pressure :- the force exerted by a fluid per unit area



Manometer



Basic Barometer