Basic Mechanical Engineering

Chapter 1 Introduction

Introduction:

- Prime movers and its types,
- System, Change of state, Path, Process, Cycle
- Concept of Force, Pressure, Energy, Work, Power
- Concept of, Heat, Temperature, Specific heat capacity, Internal energy, Enthalpy,
- Statements of Zeroth Law and First law

Prime movers

- It is a device which uses the energy from natural sources and converts it into mechanical energy

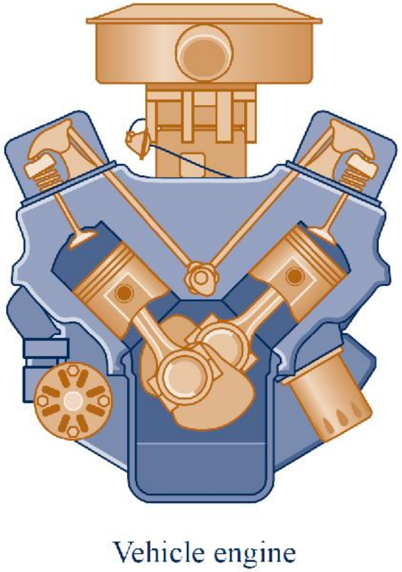


Fig. Heat Engine (IC)

Fig. Wind Mill

Fig. Solar Power Plant (Central Tower Receiver type) Up to 2000 °C

Que. What is Prime mover ? How prime movers are Classified ?	GTU : June 2009, Jan 2011
Que. Define the following terms : Prime mover	GTU : Dec 2010

Types of Prime Movers

Thermal

- Heat Engines
- Nuclear Power Plant
- Geothermal Power Plant
- Biogas Power Plant
- Solar Energy Power Plant

Non Thermal

- Hydraulic Turbines Power Plants
- Tidal Power Plant
- Wind Mills

Que. What are the various forms of energy ? List the non conventional sources of energy	GTU : Dec 2008
Que. What do you mean by non-conventional energy sources ? How does it differ from conventional sources ?	GTU : Dec 2010

Natural Energy Sources

Conventional or Non-Renewable

- Wood
- Coal
- Coke
- Petrol
- Diesel
- Kerosene
- LPG
- CNG
- Methane
- Propane
- Nuclear energy (Unstable U_{235}, Th_{232})

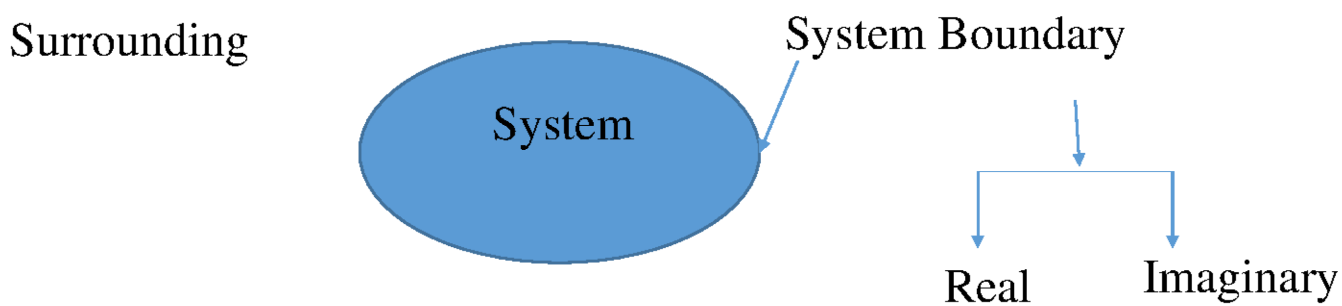
Non Conventional or Renewable

- Hydraulic Power
- Geothermal
- Solar
- Bio gas and Bio mass
- Wind energy
- Tidal energy
- Wave energy
- Ocean thermal energy

Que. Define the following terms : Boundary | GTU : Nov-Dec 2010

Thermodynamic System

- ~~It is a fixed mass in region of space under consideration to analyze problem~~



Universe = System + Surrounding

Que. Classify thermodynamic system and give example of each. | GTU : Dec 2011

Types of System

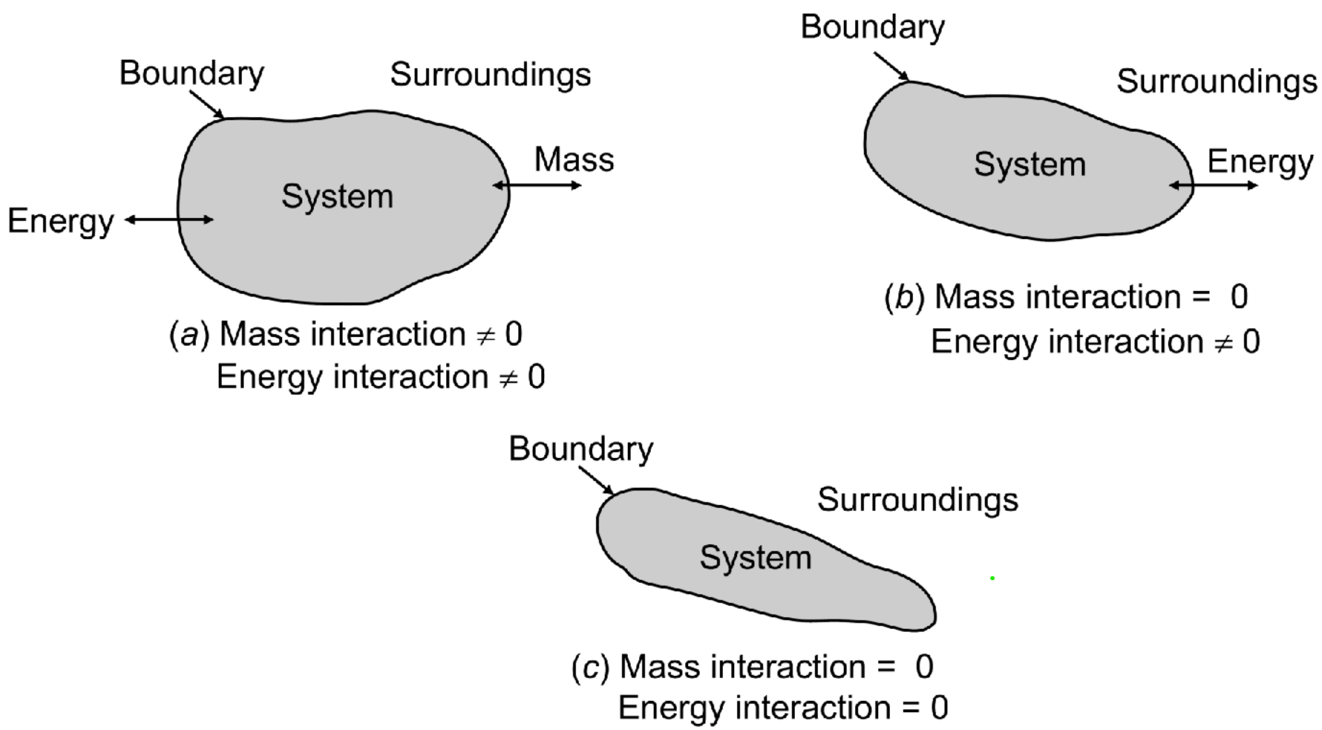
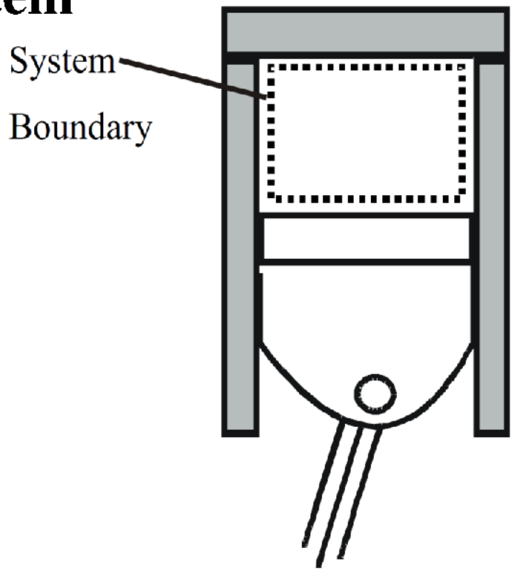


Fig. (a) Open System (b) Close System (c) Isolated System

Que. Classify thermodynamic system and give example of each.	GTU : Dec 2011

Types of System



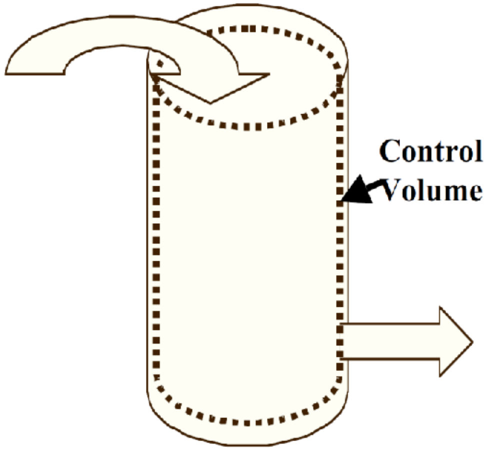


Fig. a) Close System *b) Open System with Control Volume*

Open system CV :- The fixed volume in space of the open system under study is called control volume and surface surrounding this volume is called control surface

State of system

The Identification of the system by observable or measurable quantities is called the state of the system

Important aspects of thermodynamic properties

- Distinguish one system form another
- Unique value of system
- Independent of the path followed by system
- Exact Differential, Example

$$\int_1^2 dT = T_2 - T_1$$

Properties :

It’s measurable quantity to describe the system which only depends on the state of system and not on the path follow by system

Properties Types :

1. **Intensive Properties** :- Independent of the mass of the system

 (Pressure (p), Temperature (T), Entropy (S), Enthalpy (H))

2. **Extensive Properties** :- Dependent of the mass of the system

(length (L), Volume (V), mass (M))

- **Point Function**

When two co-ordinates are located on the graph, They define a point and the two properties on the graph define state. These properties (p, T, v) are called point function.

- **Path Function**

There are certain quantities like heat and work can not be located on a graph by a point but there are represented by the area. It is not a state or point function, rather it depends on the path of the process. Such quantities are called path function and they are inexact differentials

Process

- If any one or more properties of the system undergo a change due to energy or mass transfer we say that the system has undergone a *change of state*
- The successive change of state of the system due to energy or mass transfer defined by definite path is called a *process*.
- The curve joining the successive state represents the *process path*
- If a system undergoes two or more processes and returns to its original state after conclusion of processes, the system is said to have undergone a *cycle*

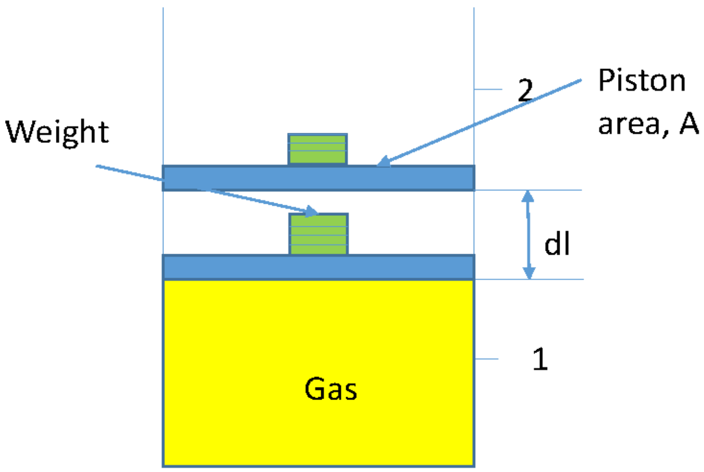
Thermodynamic equilibrium

- A system is said to be in thermodynamic equilibrium which is incapable of any spontaneous change of its macroscopic properties (p, v, t) and it is in complete balance with its surroundings.
- A system will be in thermodynamic equilibrium if it satisfies the condition of mechanical, thermal and chemical equilibrium
  - Mechanical equilibrium :- No unbalance forces
  - Thermal Equilibrium :- Uniformity of temp. inside with surrounding
  - Chemical Equilibrium :- Absence of any chemical reaction

Quasi Static Process / Reversible

- A quasi static process is defined as a process in which the properties of the system depart infinitesimally (extremely small) from the thermodynamic equilibrium path
- If the properties of the system has finite departures from thermodynamic equilibrium path the process is said to be non quasi static
- Quasi static process is the succession of thermodynamic equilibrium state while in case of non-quasi static process the end states only represent the thermodynamic equilibrium.
- Condition for reversible process are
  1. No Friction
  2. Heat transfer is through infinitely temperature difference.
  3. There are no spontaneous changes in the system.
- All processes in nature are irreversible.

Work done in moving boundary of close system in quasi-static process displacement work



- Force Exerted on piston, F = P A
- Small work done,

$$\delta w = F\, dl$$
$$\delta w = P\, A\, dl$$
$$\delta w = P\, dV$$
$$W = \int_1^2 \delta w = \int_1^2 P\, dV$$

- In non-quasi-static process, $W \neq \int_1^2 P\, dV$ because there is non unique value of 'P'

- We conclude that the equation $W = \int_1^2 P\, dV$ is valid for quasi-static & reversible process only.

Work done in moving boundary of close system in quasi-static process displacement work

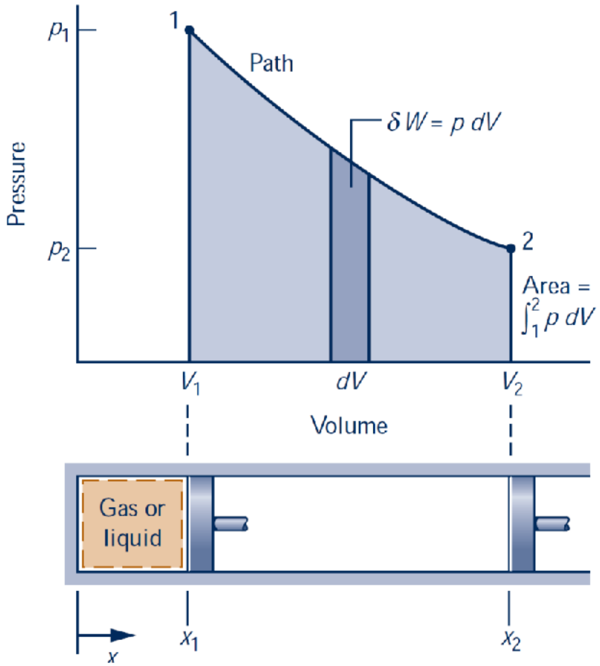


Fig. Work of a quasi-equilibrium expansion or compression process.

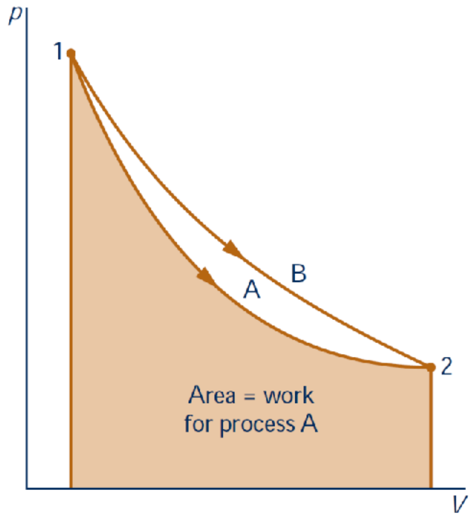


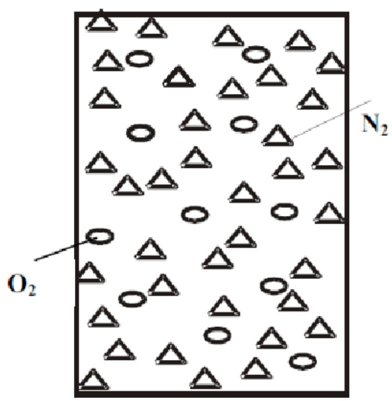
Fig. Illustration that work depends on the process.

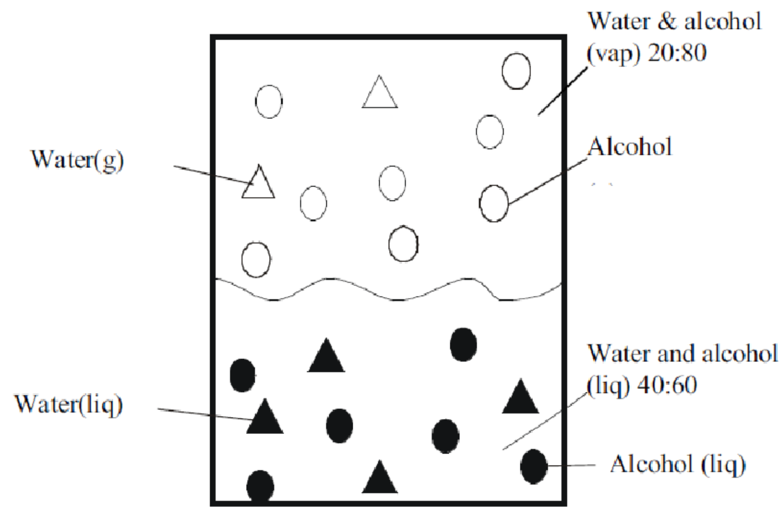
Homogeneous and Heterogeneous System

- If a system consist of homogeneous matter throughout in chemical composition and physical Structure, it is called homogeneous system
- Example :- Ice, Water, Air, Vapor etc.

- While System Consisting of matter of different chemical compositions and/or physical Structure is called heterogeneous system.
- Example :- Ice + Water, Two non miscible Liquid etc.

Homogeneous System





Heterogeneous System

Pure Substance :- A pure substance is one which has a homogeneous and invariable chemical composition even though there is a change of phase.

- Example:- liquid water, mixture of water and steam (Vapor), Mixture of ice and water etc.

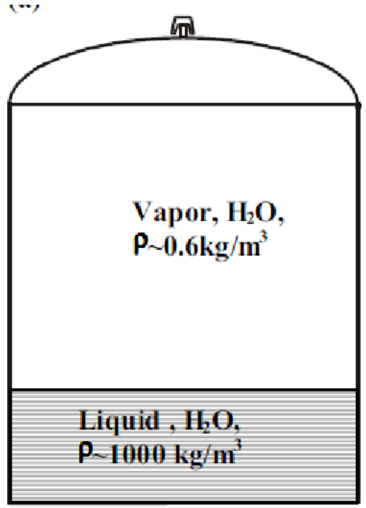


Fig. Pure Substance

Working Substance :- The fluid used in a thermodynamic system to serve as a medium for transfer of energy between the system and its surrounding.

Energy

- Energy can be defined as the capacity to do work
- Various form of energy

1) Internal
    - Chemical Energy (chemical Bond)
    - Atomic Energy (Atomic Structure of matter)
    - Molecular Energy (Molecular motion and its configure)
2) External
    - Potential Energy (P.E.) = m g h
    - Kinetic Energy (K.E) = $\frac{1}{2}\ m\ v^2$

Concept of Force

- Fundamental Physical Dimensions

1) Length L (m)
2) Mass M (kg)
3) Time T (s)

Force :- **Newton's Second law**

Force is Directly Proportional to the rate of change of moment

$$F = \frac{d}{dt}(m\,v)$$

$$F = ma$$

Where,

F= Force (N)

m = mass (kg)

v = velocity (m/s)

a = Acceleration (m/s^2)

Que. Define Pressure. | GTU : May 2013

- **Weight**
  - Weight :- The weight of a body (W) is the force with which a body is attracted to the centre of earth.

$$W = m\,g \qquad \text{(unit, N)}$$

- **Pressure**

It is the normal force exerted by a system per unit surface area

$$\boxed{P = \frac{F}{A}}$$

P = Pressure (Pa)

F = Force (N)

A = Area (m^2)

1 bar = 10^5 Pa

1 atm = 1.01325×10^5 Pa

Que. Explain Absolute pressure, Gauge pressure and Atmospheric pressure.	GTU : May 2013

➢ Absolute Pressure

The pressure measured relatively to perfect vacuum is called absolute pressure

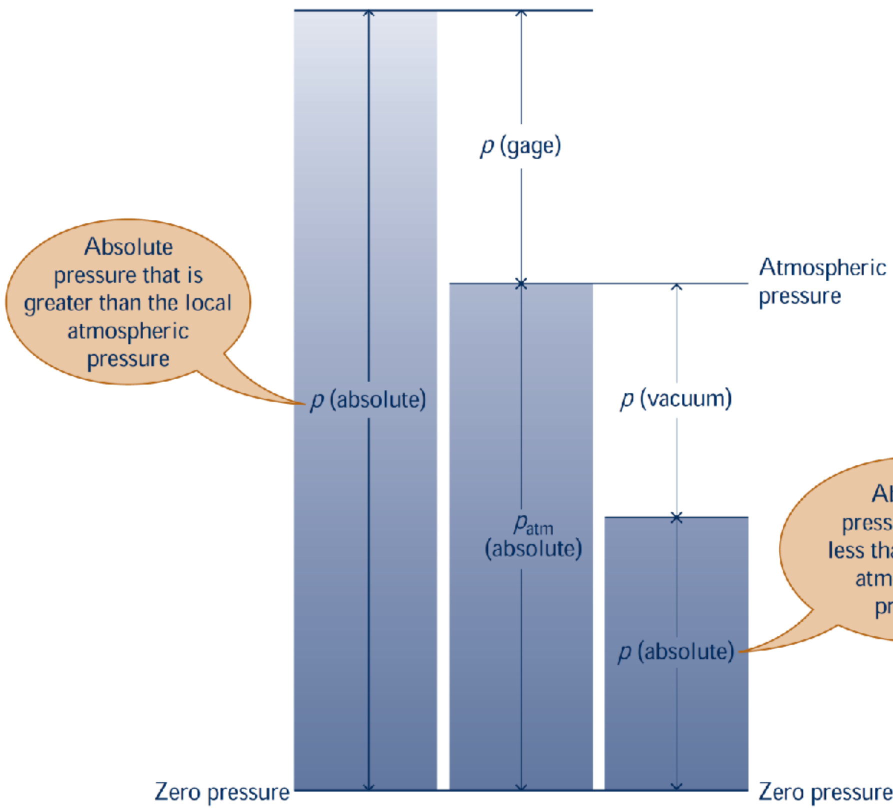
➢ Gauge Pressure

The pressure measured relatively to atmospheric pressure is called gauge pressure

➢ Pressure Measuring Devices

- Barometer
- Manometer
- Bourdon Pressure Gauge

Relationships among the absolute, atmospheric, gage, and vacuum pressures.



Perfect Vacuum

Absolute Pressure = Atmospheric Pressure + Gauge Pressure

Barometric Pressure :-

- Atmospheric Pressure is defined as the pressure exerted by the atmosphere.
- Atmospheric pressure measured at Mean Sea Level (M.S.L) is equal to 1.01325 bar

$$\boxed{P_{atm} = \rho_f \, g \, L}$$

$$1.01325 \times 10^5 = \rho_f \times 9.8 \times h_f$$

- Water, ρ_w = 1000 kg/m^3
- Height of water column, L_w = 10.33 m

- Mercury ρ_m = 13 600 kg/m^3
- Height of mercury column, L_m = 0.76 m

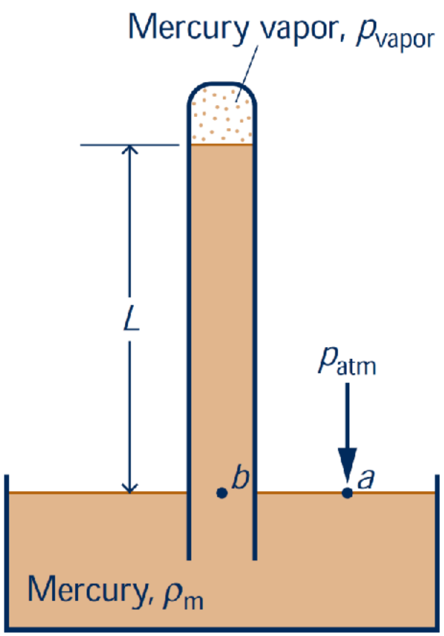


Fig. Barometer

Manometer

Manometer is measuring device which measure the gauge pressure of fluid.

$$\boxed{P_{gauge}(\text{Tank}) = \rho_f\, g\, L}$$

Absolute Pressure =

Atmospheric Pressure + Gauge Pressure

Liquid Used :- Mercury, oil etc.

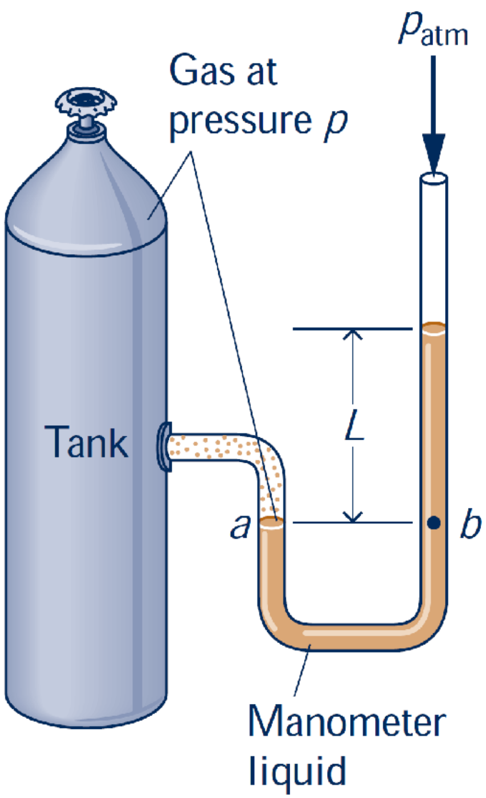


Fig. Manometer

Que. Explain with neat sketch Bourdon tube type pressure gauge	GTU : June 2011

Bourdon tube Pressure gauge

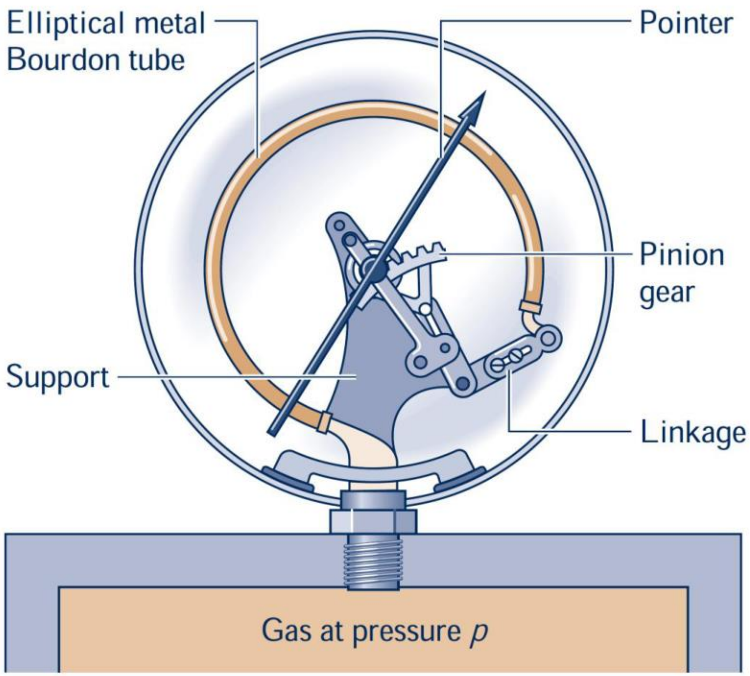


Fig. Bourdon tube Pressure gauge

- Cross Sectional :- Elliptical
- The bent tube tends to unbend when subjected to fluid pressure
- Deformation will transmitted from bend tube to needle will show the gauge pressure of the fluid on the calibrated scale.

Similarity of Different Quantities in Electrical and Mechanical System

Phenomena	***Potential Difference***	***Flow Quantity***	***Resistant***
Currant flow in Wire	e.m.f. $(V_1 - V_2)$	Electric Current (I)	Resistant (R)
Fluid Flow in Pipe	Pressure Difference $(P_1 - P_2)$	Discharge/ Volume flow rate $(\dot{V})$	Surface friction (f) and Viscosity (μ)
Heat flow in bar	Temperature Difference $(T_1 - T_2)$	Heat Flow $(\dot{Q})$	$\frac{1}{\text{Thermal Conductivity (k)}}$

Que. Define the following terms : Temperature. GTU : Nov-Dec 2010

Temperature

- The temperature is a property of the system or thermal state of a body which distinguishes a hot body with a cold body
- Temperature of a body is proportional to stored molecular energy i.e. the average molecular kinetic energy of the molecules in a system.
- Thermal Equilibrium means equality of temperature
- Measuring Device :- Thermometer

Temperature measuring Devices

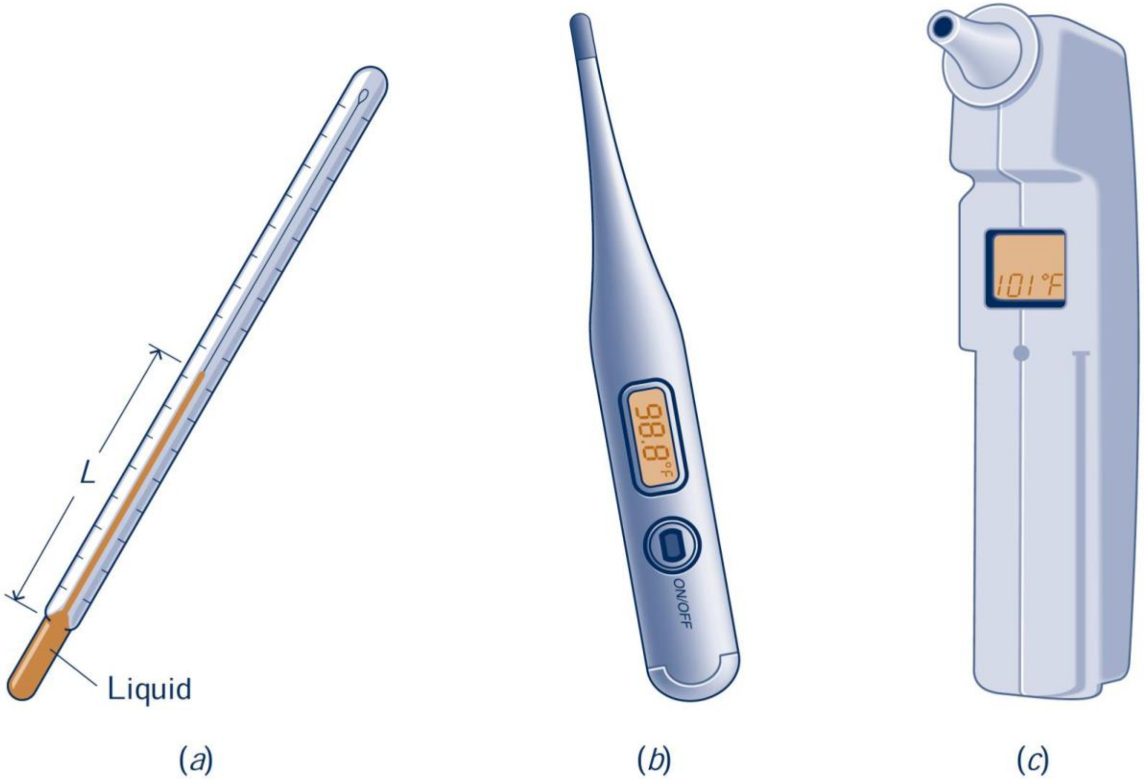
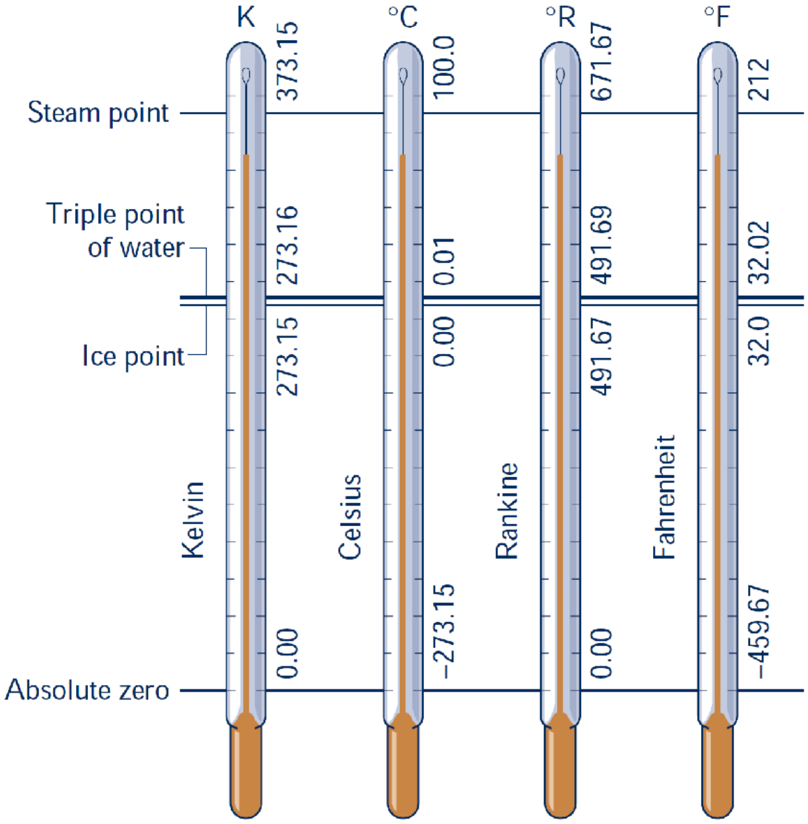


Fig. Thermometers. (a) Liquid-in-glass. (b) Electrical-resistance (c) Infrared-sensing ear thermometer.

Temperature Scale
Relation Between (Celsius (C), Fahrenheit (F), Kelvin (K), Rankine (R))



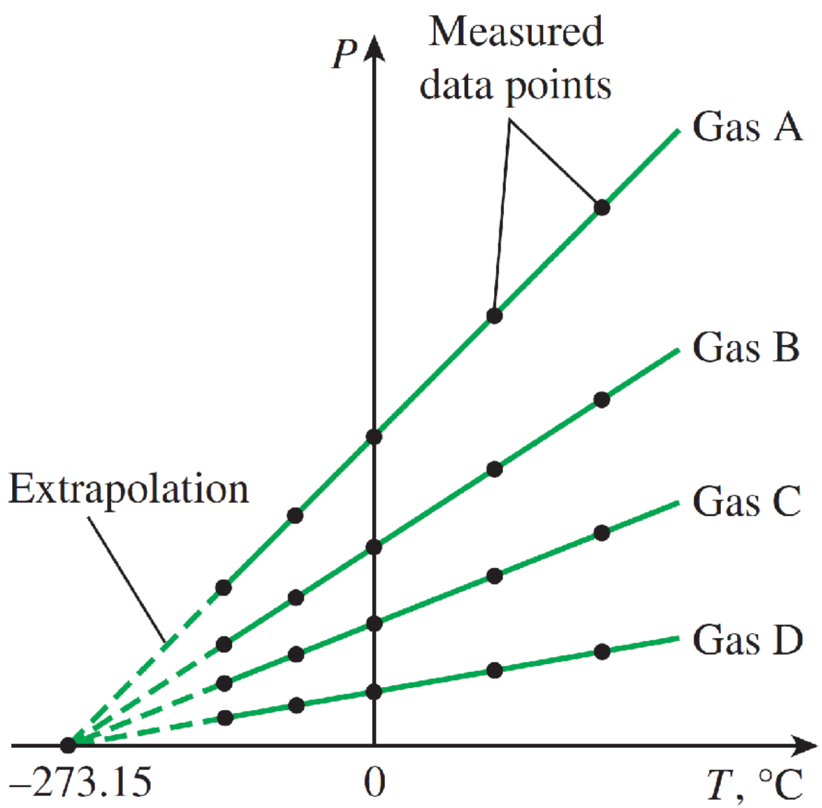
$$\mathbf{F = 1.8C + 32} \qquad \text{...(1)}$$

$$\mathbf{K = C + 273.15} \qquad \text{...(2)}$$

$$\mathbf{F = R - 459.67} \qquad \text{...(3)}$$

- Fine relation between F & K from equation (1) and (2)
- Kelvin is SI Unit of temperature

Temperature Scales



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

Concluded that

Absolute zero Temperature

$$= -273.15\ ^\circ\mathrm{C} = 0\ \mathrm{K}$$

Heat

- Heat is the form of energy which transfer without transfer of mass, from one body to another body (or between system and surroundings) from higher temperature to lower temperature by virtue of temperature difference between two bodies.
- Abbreviated as 'Q' and Unit is J (Joule)
- Heat Addition into system :- Positive (+Q)
- Heat Rejection from system :- Negative (-Q)

Sign Convention

- Extensive Property and Path Function (Inexact Differential)

$$Q = \int_{1}^{2} \dot{Q}\, dt$$

Work

- Analogous to heat, work is also a transient form of energy which is observed when it crosses the boundaries of the system without transfer of mass
- It is Path Function
- Small work done due to displacement ds

$$\delta W = F \cdot ds$$

- $Total\ Work\ Done,\ W = \int_1^2 F \cdot ds$

External and Internal Work

- System whose sole effect external to the system is to exert a force on the surroundings. This work is called an *external work*.

- When the work done by the force of one part of the system (internal force) on to another part of the same system, it is said that it has done an *internal work.*
- *We are only concerned with external work.*

Work

Work done with displacement

- Work is a scalar quantity having the dimension of energy

$$W = F \times d$$

- **Power :-** It is the time rate of doing work.

$$P = \frac{dw}{dt} = \frac{W}{t} = \dot{W}$$

Sign Convention:-

Work done by system +W

Work done on system –W

Heat addition in system +Q

Heat rejection from system -Q

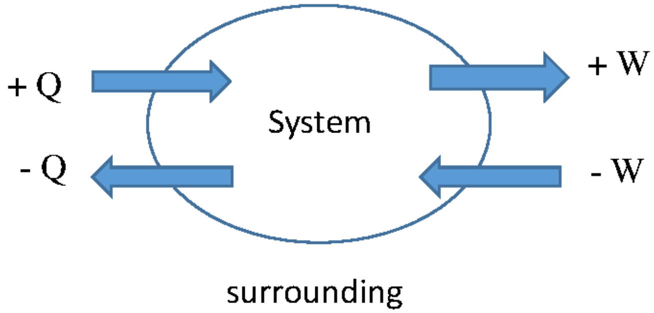


Fig. Sign Convention

$$\boxed{Q - W = \Delta U}$$

Difference between heat and work

1. Heat can only transfer when there is difference of temperature between the system and surrounding, while work transfer can take place even without the change in temperature
2. In constant volume process though work can not take place, however heat can be transferred.
3. In case of work transfer, its sole effect could be raising or lowering a weight in the surrounding but in case of heat transfer other effects are also observed.

Que. Write similarities between heat transfer and work transfer. | GTU : June 2011

Similarities between heat and work

1. Both heat and work exist in transit and these are never possessed or contained in a system.
2. Both heat and work refer to boundary phenomena.
3. Both heat and work are path function and do not represent as the properties of system (Inexact difference, δx)

Que. Define Specific heat of a substance.	GTU : Jan 2011

Specific heat of a substance.

- It is defined as the amount of heat required to raise the temperature of 1 kg of substance by 1 degree of temperature

$$\boxed{\mathbf{Q = m\,C\,(\Delta T)}}$$

$$C = \frac{Q}{m\,(\Delta T)} \quad \text{J/kg K}$$

Q = heat transfer (J)

$\Delta T = T_2 - T_2$= temperature change

C = Specific heat, J/kg K

Specific heat of gas

1) Specific heat of gas at constant volume (C_V)

It is the amount of heat required to raise the temperature of unit mass of gas by one degree at constant volume.

2) Specific heat of gas at constant pressure (C_p)

It is the amount of heat required to raise the temperature of unit mass of gas by one degree at constant pressure.

3) Adiabatic Index, γ or k

The ratio of specific heat at constant pressure to the specific heat at constant volume is known as adiabatic index.

$$\boxed{\gamma = \frac{C_p}{C_V}}$$

γ = 1.4 di-atomic gas
γ = 1.67 mono-atomic gas

Enthalpy

- It is total energy of the system

$$\boxed{H = U + pV}$$

- Specific Enthalpy,

$$\boxed{h = u + pv}$$

- U, p, V are point function, so H is point function and property of system
- Unit of Enthalpy (H) is kJ
- Unit of Specific Enthalpy (h) is **kJ/kg**

Que. State and explain zeroth law of thermodynamics.	GTU : June 2009
Que. What is zeroth law of thermodynamics ?	GTU : Dec 2011

Zero law of thermodynamic

- If two bodies A and B are individually thermal equilibrium with a third body C then the two bodies A and B will also be in thermal equilibrium with each other

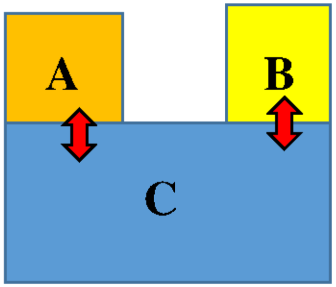


Fig. Body A, B, C

Another word,

$T_A = T_C$ & $T_B = T_C$ then $T_A = T_B$

Que. State first law of thermodynamics.	GTU : Dec 2008
Que. Define Following terms : First law of thermodynamics.	GTU : Nov-Dec 2010

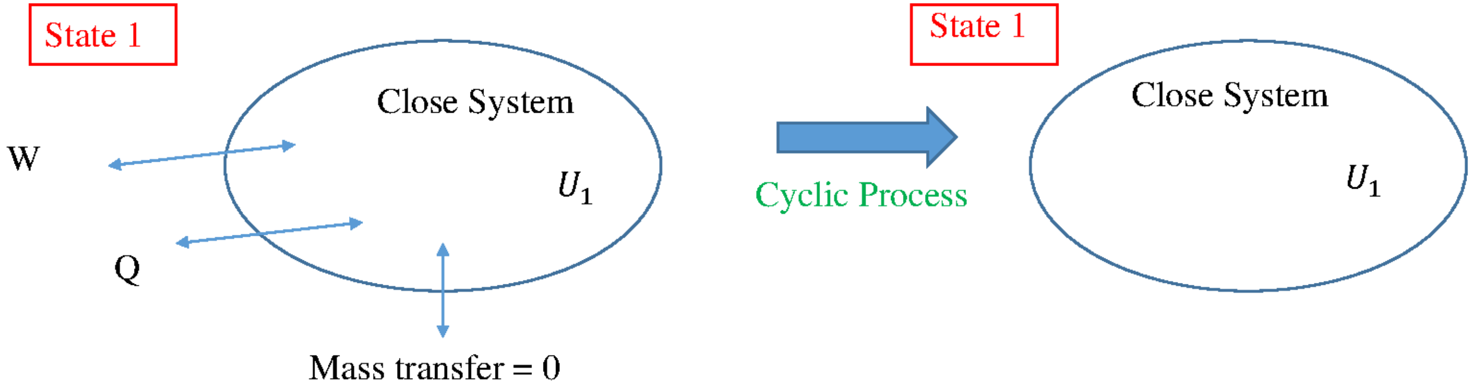
First law of thermodynamic (Energy conservation law)

- " Energy can neither be created nor-destroyed but it can be converted from one form to another."

First law of thermodynamic applied to close System, Cyclic Process

If a close system goes through a cycle, the algebraic sum of total energy transfer to it as heat and work is zero.

$$\boxed{\oint \delta Q - \delta W = 0}$$



First law of thermodynamic applied to close System subjected to change of state (Process)

- If a closed system undergoes a change of state or process having both as heat and work transfer as shown in fig., then the net energy transfer (Q - W) will be stored by the system as internal energy ΔU

$$\boxed{Q - W = \Delta U}$$

- If an infinitesimal process is carried out then,

$$\boxed{\delta Q - \delta W = dU}$$

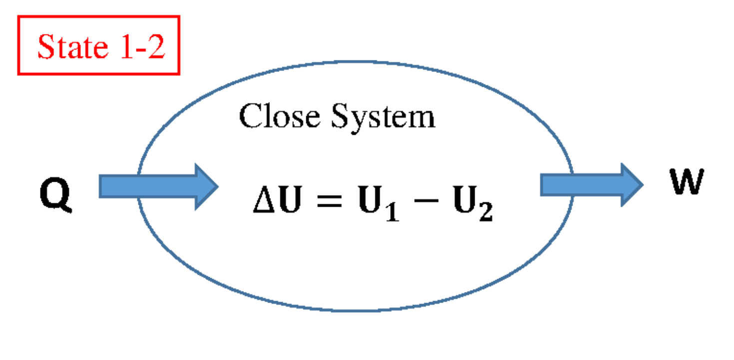


Fig. Heat and work transfer during a process

Questions of GTU Exam

Que. What is flow and non-flow process ?	GTU : Dec 2011
Flow Process :- Processes carried out in open systems having mass flow across the boundaries are called flow process. **Non-Flow Process** :- While the processes carried out in closed system without mass transfer its boundaries are called Non-flow process.	

Que. Barometer is used to measure ______(Ans. Pressure)	GTU : Dec 2012

Example. An artificial satellite has a mass of 600 kg and is moving towards moon. Calculate its kinetic and potential energies in (MJ) relative to earth when it is 50 km from launching and moving at 2500 km/hr. Take acceleration of earth's gravitational field as 790 cm/s^2	Nov 2010
Given Data :- m = 600 kg, g =7.9 m/s^2, h = 50 km = 50,000 m, v=2500 km/hr. = 694.44 m/s 1. Potential energy = m g h =2.37×10^8 J 2. Kinetic energy = $\frac{1}{2} mv^2 = 1.44 \times 10^8$ J	

Que. SI Units of Following — GTU : Dec 2012

1) Work	J
2) Enthalpy	J
3) Mean Effective Pressure	Pa or N/m^2
4) Heat	J
5) Power	W or J/s
6) Force	N
7) Energy	J
8) Specific Heat	J/kg K
9) Specific Volume	m^3/kg
10) Calorific value	J/kg
11) Stroke	m
12) Dryness Fraction	Dimensionless
13) Efficiency	Dimensionless
14) Swept Volume	m^3

Thank You…