UNIT –IV (ME-201)

(Thermodynamics)

Heat

Heat may be defined as the energy interaction at the system boundary which occurs due to the temperature difference only.

When heat is removed from a body or supplied to it, there are some changes found to happen such as (a) change of temperature, (b) change of volume, (c) change of state (solid to liquid, liquid to gas, etc.), (d) change of physical properties, etc.

Positive and Negative Heat

In general, the heat transferred to the system is considered as positive heat while the heat transferred from the system is considered as negative heat.

Mass of the substance, specific heat, and temperature difference are the factors on which the heat transfer rate depends.

Comparison of Work and Heat

Similarities:

(a) Both are path functions

(b) Both are boundary phenomenon

(c) Both are associated with a process, not a state

(d) Systems possess energy, but not work or heat

Dissimilarities:

(a) In heat transfer, temperature difference is required.

(b) In a stable system there cannot be work transfer, however, there is no restriction for the transfer of heat.

(c) Heat is low grade energy while work is high grade energy.

Temperature

Qualitative indication of the relative hotness can be exactly defined by using thermodynamic property known as temperature.

The temperature of a body is proportional to the stored molecular energy i.e. the average molecular kinetic energy of the molecules in a system.

Unit of temperature

In the International system (SI) of unit, the unit of thermodynamic temperature is **Kelvin.** It is denoted by the symbol K. However, for practical purposes the Celsius scale is used for measuring temperature.

Absolute zero temperature:

It has been found that a gas will not occupy any volume at a certain temperature. This temperature is known as absolute zero temperature. This is the lowest temperature that can be measured by a gas thermometer.

Units of Heat

Heat is a form of energy. In SI system, unit of heat is taken as joule. Kilojoules (kJ) and Mega joule (MJ) are recommended larger units of heat.

Calorie (cal.) is also unit of heat. Generally Kilocalorie (kcal) is quantity of heat required to raise temperature of unit mass of water through one degree Celsius or Kelvin.

1 kcal = 4186.8 joules = 4.1868 kilojoules

Specific heat capacity

Specific heat capacity is also known as specific heat. The specific heat capacity of a substance may be defined as the quantity of heat required to raise the temperature of unit mass of the substance by one degree.

The unit of specific heat is J/kg °c. This unit is small, so kJ/kg-K or kJ/kg °c is recommended larger units.

Mathematically, the heat transfer rate Q is written as

$$Q = m \times c \times \Delta T$$

Where, C = specific heat in kJ/kg.K, m = mass of substance in kg,

ΔT =Temperature difference in K.

The product of mass and specific heat is called the heat capacity of the substance.

Specific heat is function of temperature; hence it is not constant but varies with temperature.

Specific heats in thermodynamics:

The solids and liquids have only one value of specific heat but a gas is considered to have two distinct values of specific heat capacity.

(i) A value when the gas is heated at constant volume, Cv

(ii) A value when the gas is heated at constant pressure Cp

The specific heat at constant volume Cv may be defined as the heat required to increase the temperature of the unit mass of a substance by one degree as the volume is maintained constant.

Same way one can define the specific heat at constant pressure (Cp), here pressure p is maintained constant.

Internal Energy

In non flow processes, fluid does not flow and has no kinetic energy. There is very small amount of change in potential energy because change in centre of gravity is negligible. From the first law of thermodynamics, we can say that the amount of heat transferred to a body is not fully converted to work. When heat (Q) is supplied to a body, some amount of heat is converted into external work (W) due to expansion of fluid volume and remaining amount of heat causes either to increase its temperature or to change its state. Internal Energy is one type of energy which is neither heat nor work; hence it is stored form of energy. It is denoted by U.

Mathematically,

$$Q=W+U$$

Where Q is amount of heat, W is work and U is internal energy.

The internal energy per unit mass is called specific internal energy. Above equation is referred as non flow energy equation.

Enthalpy

Enthalpy is a thermodynamic property of fluid, denoted by H. It can be defined as the summation of internal energy and flow energy.

Mathematically, it is given as

$$H = U + pV$$

On unit mass basis, the specific enthalpy could be given as

$$h = u + pv$$

Efficiency

It is observed that amount of energy supplied to engine or machine is not completely converted into work because some amount of energy is lost due to friction and several other reasons. So a fraction of the energy supplied to engine is converted into useful work.

This fraction is called efficiency of the engine.

Hence, Efficiency = (Brake power) / (Indicated power)

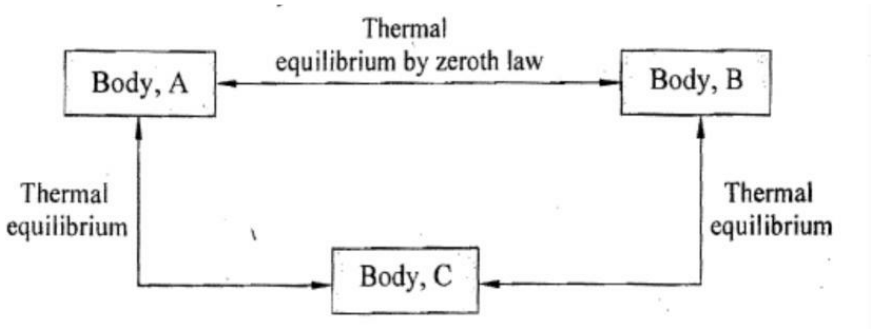
Brake Power of an engine (B.P.) is the power available at engine output shaft. It is measured by dynamometer.

Indicated Power (I.P.) is power developed inside engine cylinder by burning of fuel.

Zeroth Law of Thermodynamics

Zeroth law of thermodynamics states that "If the bodies A and B are in thermal equilibrium with a third body C separately then the two bodies A and B shall also be in

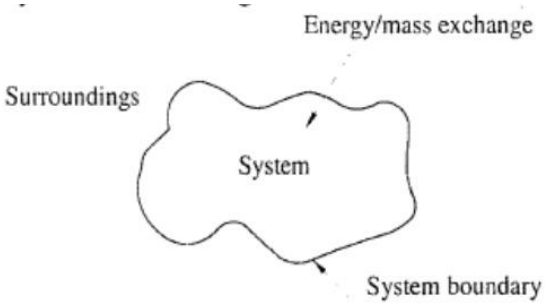
thermal equilibrium with each other".



This is the principle of temperature measurement.

Thermodynamic systems

A Thermodynamic system is defined as a quantity of matter or region in space under consideration for analysis.



Examples: piston cylinder assembly, turbine etc.

The system is identified by a boundary around the system. The boundary may be real or imaginary. Everything outside the system boundary is called surroundings. A system and its surroundings together are called the universe.

Universe = system + surroundings

Types of system: The systems may be classified as

1. Open system

2. Closed system

3. Isolated system

1. **Open system:** Open system in which energy and mass transfers take place at the system boundary. Examples: Turbine, I.C. engines etc.

2. Close system

A system in which no mass is permitted to cross the system boundary but heat and work is permitted to enter or leave, is called the closed system.

3. Isolated Systems:

A system, which is not influenced by the surrounding means there is no interaction between system and surrounding, is called isolated system.

Thermodynamic properties-

Properties are any measurable characteristics of a system. eg. pressure, temperature, volume, mass and density.

Extensive properties are the mass-dependent properties of a system. i.e. the properties that will vary proportionally with mass of the system. E.g. volume

Intensive properties are the properties that are not dependent on mass. eg. temperature density. If any Extensive Property is divided by the mass we would also obtain an intensive property.

Properties: Systems have certain characteristics by which its physical condition can be described such as pressure, temperature, etc. these are called properties.

All system properties having definite values, the system is said to be in definite state.

Any operation in which one or more properties change is called change of state.

Path:-succession of states passed through change of state is called path

Process:-If path is completely specified it is called process

Cycle:-A series of change of states such that final state is same as initial state, it is a cyclic process.

First law of thermodynamics-

First law of thermodynamics provides for studying the relationships between the various forms of energy and energy interactions.

This law states that energy can neither be created nor destroyed; it can be converted from one form to another form.

First law may be expressed as,

$$\Delta E = Q - W$$

Where ΔE is summation of various energies like Internal energy (ΔU), Kinetic energy

(ΔKE), Potential energy (ΔPE) etc.

$$\Delta E = Q - W = \Delta U + \Delta KE + \Delta PE\ldots.$$

In closed system, mass is fixed and there is no elevation difference and movement. Hence

$\Delta KE = 0$ and $\Delta PE = 0$

$\Delta U = Q - W$

For cyclic process $\Delta E = 0$