Program : **B.Tech**

Subject Name: **Thermodynamics**

Subject Code: **ME-302**

Semester: **3rd**

UNIT I -THERMODYNAMICS

Thermodynamics is the science that deals with heat and work interactions between system and surroundings and effect of properties on them.

Macroscopic and Microscopic Approaches:

In microscopic approach we deal with "average" for all particles under consideration. This is the approach used in the kinetic theory and statistical mechanics.

In the macroscopic point of view, of classical thermodynamics, one is concerned about the time-averaged influence of many molecules that can be perceived by the senses and measured by the instruments.

System:

Area or region under consideration is called **system**. Everything other than system is called **surroundings**. These both together forms **universe.**

- **Isolated systems:** no exchange of mass and energy .
- **Closed systems:** no exchange of mass but some interaction of energy is there.
- **Open systems:** exchange of both mass as well as energy.

Control Volume

- Control volume is defined as a volume which encloses the matter and the device inside a control surface.
- Everything other than control volume is the surroundings which are separated by the control surface.
- The surfaces can be closed or open to mass flows and it may have flows from energy in terms of heat transfer and work across it.

Property

- In thermodynamics a property is any measurable characteristic of a system that defines the state of the system.
- The property of a system should have a definite value when the system is in a particular state.
- Thermodynamic property is a point function.
- Properties like volume of a system that depend on the mass of a system are called **extensive properties** as they are mass dependent.
- Properties like pressure or temperature which do not depend on the system mass are called **intensive properties** as they are mass independent.

Equilibrium

- The system is said to be in thermodynamic equilibrium when it is in thermal, mechanical and chemical equilibrium.

Process

A process is transition from one equilibrium state to other.

- **Reversible**: if the process happens slow enough to be reversed and there is no friction.
- **Irreversible**: The process with some friction.

- **Isobaric:** process occurring at constant pressure .
- **Isochoric:** process occurring at constant volume .
- **Isothermal:** process done at constant temperature .
- **Adiabatic:** process with no heat transfer.
- **Cyclic:** process where initial state and final state are equal.

Internal Energy

The energy stored in a system.
The total energy possessed by the body is given by:

E = KE + PE + U

Work

If the expansion of gas occurs from one state to other, then the work done by closed system is given by-

$$W = \int p\, dV$$

The integration denotes the area under P-V curve. Therefore the work is a path function and not a property of the system.

Heat

Heat is also a form of energy.

The Zeroth Law of Thermodynamics

If two bodies A and B are in thermal equilibrium with a third body C separately, then bodies A and B will also in thermal equilibrium with each other. This law is the basis for temperature measurement.

FIRST LAW OF THERMODYNAMICS

The first law of thermodynamics defines expression of **the conservation of energy**.
This law states that "energy cannot be created or destroyed" it only can only be change from one form to other.
Energy is a property of the system: By rearranging terms we get

$$\int_{2b1} (dQ - dW) = \int_{2c1} (dQ - dW)$$

It shows that the value is the same for both the paths 2-b-1 and 2-c-1, connecting the state's 2 and 1. That is, the quantity $\int (dQ - dW)$ does not depend on the path followed by a system, but depends only on the initial and the final states of the system. That is $\int (dQ - dW)$ is an exact differential of a property. This property is called energy (E). It is given by

$$dE = dQ - dW$$

$$E = KE + PE + U$$

Where U is the internal energy. Therefore,

$$dE = d(KE) + d(PE) + dU = dQ - dW$$

Quit often in many situations the KE or PE changes are negligible.

$$dU = dQ - dW$$

An isolated system does not exchange energy with the surroundings in the form of work as well as heat. Hence dQ = 0 and dW = 0. Then the first law of thermodynamics minimizes to the expression dE = 0 or $E_2 = E_1$ that is energy for an isolated system remains unchanged.

Limitations of First Law

First law defines statement of conservation of energy principle. Fulfilling only the first law statement alone does not guarantee that the process will actually happen.

Examples:

1. A cup of hot tea left in a cooler room eventually cools down. The reverse of this process- tea getting hotter as a result of heat transfer from a cooler room does not take place.
2. Consider heating of a house by passage of electric current through an electric resistor. Transferring of heat from closed house will not cause electrical energy to be generated in the wire.

Thermal Reservoir

A thermal reservoir is a large system (very high mass x specific heat value) from which a quantity of energy can be absorbed or added as heat without changing its temperature. The ocean and our atmosphere are examples of thermal reservoirs.
Any physical body whose thermal energy capacity is large relative to the amount of energy it supplies or absorbs can be modeled as a thermal reservoir.
The source is a reservoir that supplies heat is called a source and one which absorbs energy in the form of heat is called a sink.

Heat Engine

It is a device that operates in a cycle and converts a part of heat into work and a part of heat is rejected to the atmosphere.

The working fluid is a substance, which absorbs heat from a high temperature source, and rejects heat to a low temperature sink.

Thermal Power Plant

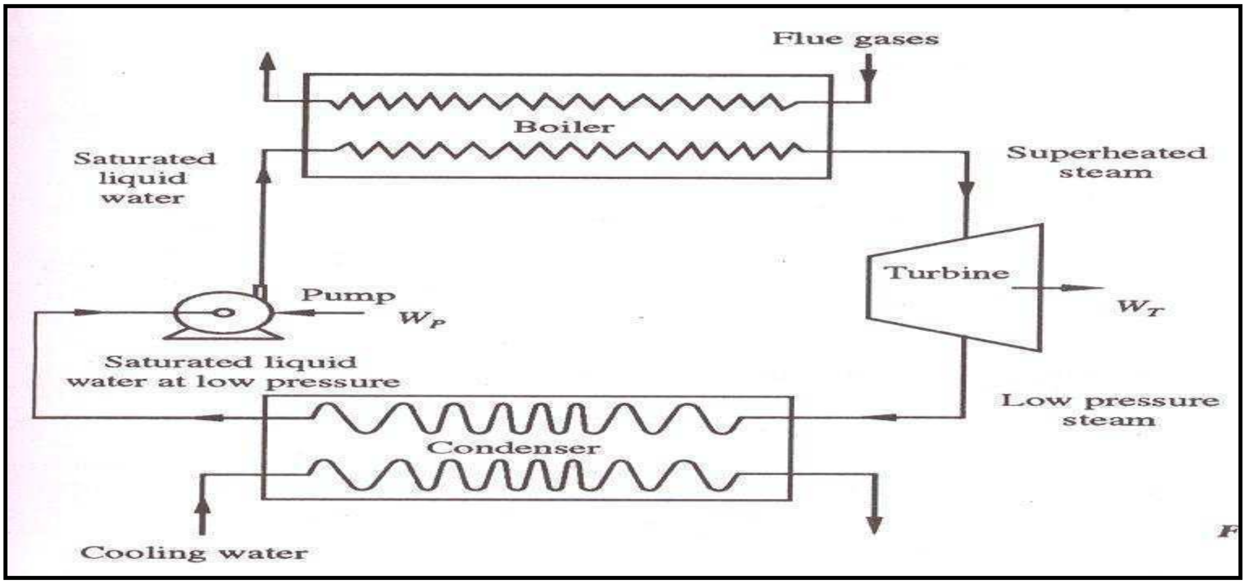

Fig.1.1 Thermal Power Plant

Working Fluid is Water here-

Q_1 – Heat supplied from hot gases
W_T –Turbine work
Q_2 – Heat rejected to condenser
W_P –Pump work
$W_{net}=W_T-W_P$
$W = Q_1 – Q_2$
Thermal Efficiency,

$$\eta = \frac{W_{net}}{Q_1} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$

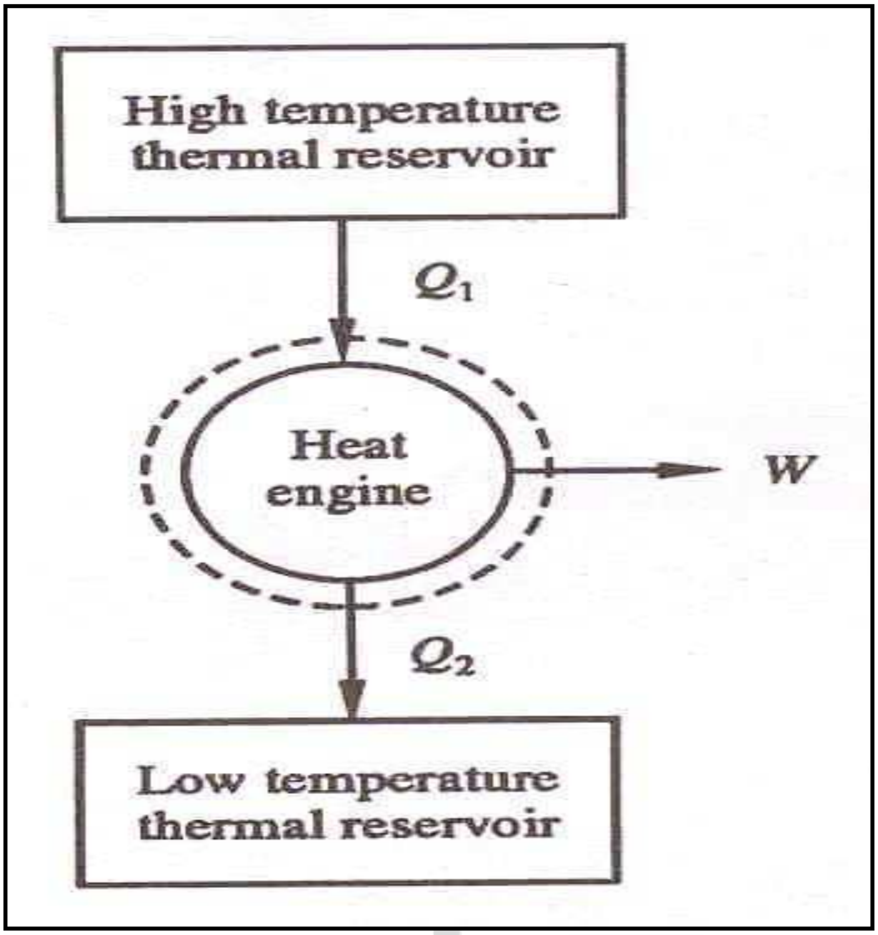

Fig.1.2 schematic representation of Refrigerator and Heat pump.

Q_L – Heat absorbed from low temperature thermal reservoir

Q_H – Heat rejected to a high temperature thermal reservoir when work (W) is done on it.

$$(COP)_R = \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L}$$

$$(COP)_{HP} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_L}$$

In a reversible, isothermal expansion of an ideal gas, all the energy absorbed as heat by the system is converted completely into work. However this cannot produce work continuously (not a cycle).
Single reservoir heat engine (1 T engine) is not possible.

Second Law of Thermodynamics

Kelvin-Planck Statement: - It is impossible to construct device which operates in a cycle, which produces no other effect than the extraction of heat from a single thermal reservoir and delivers an equivalent amount of work.
Heat engine with single thermal reservoir is not possible.
For a 1-T engine the thermal efficiency $\eta=W/Q=1$. No heat engine can have efficiency equal to unity.

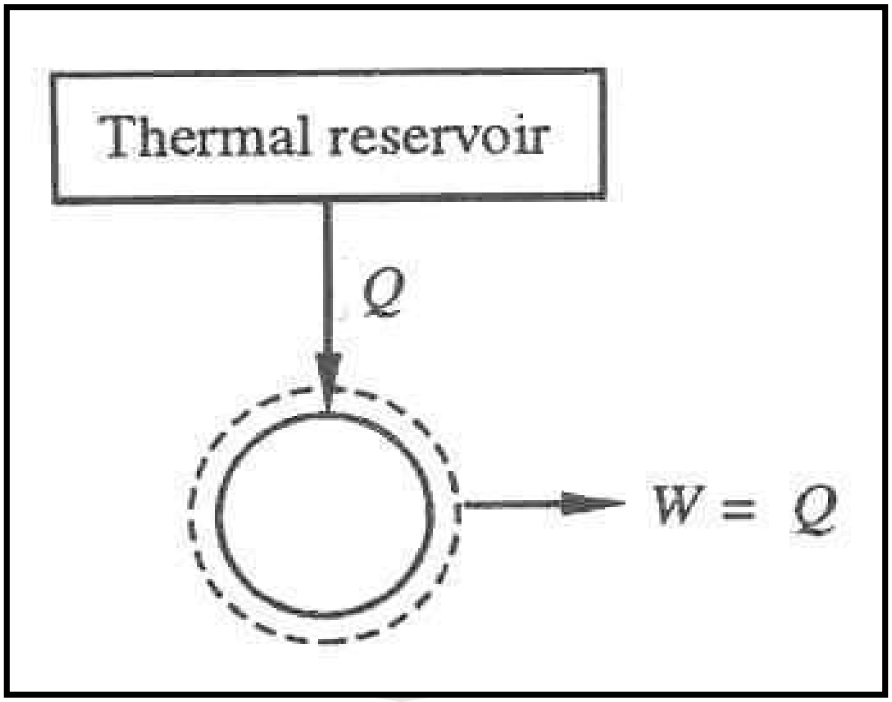

Fig.1.3 Kelvin Planck statement

Clausius Inequality: -

1. When $dQ/T < 0$ the process is irreversible.
2. When $dQ/T = 0$ the process is reversible.
3. When $dQ/T > 0$ the process is not possible.

Clausius Statement: - It is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a lower-temperature body to higher-temperature body.
Entropy: - Entropy is the degree of randomness or disorder.

Mathematically: - s **= dQ/T**

Availability- Availability or available energy is the maximum energy available for the wok.

