

THERMODYNAMICS

3. HEAT ENGINES

1. Second law of thermo dynamics:

- Kelvin:** It is impossible to derive a continuous supply of work by cooling a body to the temperature lower than the coldest of the surroundings.
- Claussius:** It is impossible for a self acting machine unaided by any external agency to transfer heat from a body at a lower temperature to another at a higher temp.
- Planck:** It is impossible to construct a heat engine which can completely convert heat energy into mechanical energy with out rejecting heat to the surroundings.

2. Reversible process :

- A process which can be retraced back in the opposite direction in such a way that the system passes through the same state as that in the direct process and finally the system acquire the initial conditions is called a reversible process.
- The system must always be in thermal and chemical equilibrium with the surroundings.
- There should not be any loss of energy.
- Ex: fusion of ice, vaporization of water, seebeck effect etc.

3. Irreversible process :-

- A process which cannot be retraced back in opposite direction is called as an irreversible process.
- The system does not pass through the same intermediate states as that in the direct process.
- Ex: Work done against friction, joules heating effect, diffusion of gases into one another, the magnetic hysteresis.
- All most all natural process all irreversible.

4. Free expansion :-

- When a gas expands into vacuum absorbing no heat energy from the surroundings and performing no external work, then it is called free expansion (or) Joule expansion.
- In free expansion, $\Delta Q = 0$, $\Delta W = 0$ from the first law of thermodynamics,

$$\Delta Q = \Delta U + \Delta W \quad \text{OR} \quad \Delta U = 0$$

$$\therefore U = \text{constant} \quad \text{and} \quad T = \text{constant.}$$

- Boyle's law is applicable in free expansion.

5. Cyclic process :-

- If a system undergoes a series of processes such that it finally returns to the original state, then the system is said to undergo a cyclic process.
- The change in the internal energy is zero.
- $(\Delta Q = \Delta U + \Delta W)_{\text{max}} = 0 + W_{\text{max}}$ and $\Delta Q_{\text{net}} = W_{\text{heat}}$
- The net amount of heat energy absorbed by the ideal gas is equal to the net work done by the gas.
- If a cyclic process is represented by a PV graph the area bounded with in the closed curve gives the net work done by the gas.

6. When the door of a refrigerator is opened, the temperature of the room increases, because the motor of the refrigerator extract the heat from the freezing chamber and releases it to outer atmosphere.
7. When a thermos flask containing coffee is vigorously shaken, its temperature increases slightly due to work done against the viscous forces of the liquid.
8. A cyclic device by which heat energy can be continuously transformed into mechanical work by repeating the same thermodynamic process a number of times is said to be a heat engine.
9. The material used in the operation of an engine is called the working substance which is different for different heat engines.
10. There are three parts in a heat engine.
a) Source (hot body) b) Working substance c) Sink (cold body)
11. Efficiency $\eta = \frac{\text{Heat converted as work}}{\text{heat drawn from the source}} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$
 $\therefore \eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$
12. Efficiency depends on the temperature of the source and sink but not on the working substance.
13. For 100% efficiency $T_1 = \infty$ (or) $T_2 = 0$ k. As absolute zero and infinite temperature can not be realized in practice, the efficiency of a heat engine can not have 100%. The efficiency of a heat engine is always less than unity.
14. If $T_2 = 0$ then Q_2 is also zero. Since $T_2 = 0$ is not positive $Q_2 = 0$ is also not possible (i.e.) it is not possible to convert whole heat energy into work without rejecting a part to the sink.

Refrigerator:

- a. Any device capable of transferring heat from a cold body to a relatively hotter body is called refrigerator. An ideal heat engine operating in the reverse processes is called refrigerator.
- b. The working substance absorbs heat energy from the sink at lower temperature, a net amount of work is done on it by an external agent and a large amount of heat is refused to the source.
- c. The working substance is called refrigerant.
- d. If Q_2 is the heat energy absorbed from the sink at T_2 k and Q_1 is the heat given to the source at T_1 k. Then

The ratio of heat extracted from the sink and to the work required to be done on the refrigerator

is called the coefficient of performance $K = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} = \frac{1}{\left(\frac{T_1}{T_2} - 1\right)}$

- e. The coefficient of performance of a refrigerator is more than 100%.