Second law of thermodynamics :→ While mechanical energy can always be converted entirely into heat, the reverse is not true. Attempts to convert heat completely into energy always produce some waste heat. This observation is the basis of the second law of thermodynamics.

Complete conversion of heat into work is impossible, as learnt from the theory of Carnot's engine from the basis of second law of thermodynamics.

Kelvin's statement - "It is impossible to derive continuous supply of work by cooling a body to a temp. lower than that of the coldest of its surroundings.

Clausius statement → It is impossible for a self-acting machine when it operates in a cycle unaided by an external agency, to convey heat from a body at a low, to one at a higher temp. or heat cannot of itself, i.e. without the performance of work by some agency pass from a colder to a warmer body.

The second law as stated above implies that heat is not directly transferred from a cold body to a hot body, an intermediary substance absorbs heat from the cold body and rejects it into the hot body. Take the case of refrigerator (ammonia ice plant), Heat is absorbed from the brine solution at a lower temp. and rejected into water at higher temperature. This does not happen to its own accord. An external agency 'the pump' has to do work in order to achieve this.

Ostwald's Statement → It is impossible to construct a perpetual motion machine of the second kind.

Thus, 1st law of Thermodynamics can be stated in a number of ways. "It is impossible for a self-acting machine unaided by any external agency to convey heat from a body at a low temp. to a body at a high temp."

"Heat cannot flow from a cold body to a hot body without the performance of work by some external agency".

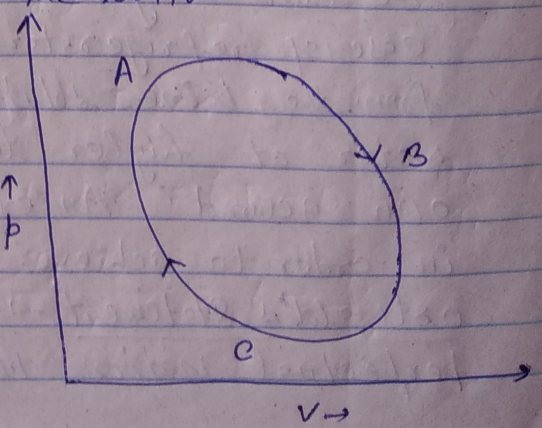
Explanation → It is clear from the above definitions that heat cannot flow from a body at a low temp. to a body at a high temp unless work is done by an external agency. This is in accordance without experience in other branches of Physics.

"A body cannot move from a lower to a higher level unless work is done on it by an external agency.

Electrical current doesnot flow from a lower to a higher potential unless work is done on it.

Heat can flow from a higher temp. to a lower temp. A heat engine may absorb a certain amount of heat at higher temp, convert a part of it into mechanical work and give out the rest of it at a low temp. Thus we see that a heat engine works essentially by destroying the temp. difference between the source and the sink.

Cyclic process is a sequence of processes as a result of which a system returns to its original state. For a cyclic process the change in internal energy is zero.



Reversible process is that process which can be exactly reversed so that the system passes through the same intermediate states as in the forward process. A reversible process implies no wastage of energy.

In completing a cycle of operation an ideal Carnot engine will take infinite time.

In reversible processes the entropy of the universe remains stationary.

In irreversible processes the entropy of the universe increases.

(i) Steam Engine (ii) Internal combustion Engine

↓ ↓

Autto engine (Petrol) Diesel engines

→ The upper limit of the efficiency of a Petrol engine is about 52%.

→ The upper limit of the efficiency of a Diesel engine is about 70%.

→ Which is the most efficient engine:

(a) a steam engine (b) a petrol engine (c) a Diesel engine.

→ The working substance of a petrol engine is → air.

→ The working substance of a Diesel engine is → air.

→ The working substance is compressed to $\frac{1}{5}$ th. of the original volume in a petrol engine.

→ The working substance is compressed to $\frac{1}{17}$ th. of the original volume in a Diesel engine.

→ ~~The working substance of a petrol engine is air.~~

→ The force of energy of a Petrol engine is the energy of petrol.

→ The Petrol engine receives energy from the fuel (petrol) at constant volume.

→ The Diesel engine receives energy from the fuel at constant pressure.

(8)

CARNOT'S THEOREM : →

1. Statement → All reversible heat engines working between the same limits of temperature, have the same efficiency.

2. Statement → No heat engine can be more efficient than a reversible heat engine working between the same limits of temp.

Proof 1 : The efficiency of a Carnot's reversible heat engine working between the temp. limits T_1 and T_2 is given as $\eta = 1 - \frac{T_2}{T_1}$. Thus, '$\eta$' is independent of the nature of the working substance. Hence we conclude that the efficiency of all reversible heat engines working between the same limits of temp. is the same and equal to that of Carnot's engine.

A reversible heat engine operates in a cyclic manner. It absorbs Q_1 amount of heat from the source at a temp. T_1, converts a part of it into mechanical work and delivers the rest (i.e. Q_2) to sink at a temp. T_2.

Now, Decrease in Entropy of the source $= \frac{Q_1}{T_1}$

Increase in Entropy of the sink $= \frac{Q_2}{T_2}$

Since the net change in Entropy = 0 for the reversible cycle.

$$\frac{Q_1}{T_1} - \frac{Q_2}{T_2} = 0$$

$$\text{or, } \frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \delta s \text{ (say)}$$

$$\therefore Q_1 = T_1 \cdot \delta s \quad \text{and} \quad Q_2 = T_2 \cdot \delta s$$

$$\therefore \text{Work done} = W = Q_1 - Q_2 = (T_1 - T_2)\delta s = (T_1 - T_2) \cdot \frac{Q_1}{T_1}$$

$$\therefore \text{Efficiency } \eta = \frac{W}{Q_1} = \frac{T_1 - T_2}{T_1} = 1 - \frac{T_2}{T_1}$$