Limitation of 1st L.T

(i) It does not tell about feasibility of process or cycle.

(ii) It also does not tell about direction of heat flow.

exp → Natural process occur in one direction.

Second Law of thermodynamics

↓ direction of heat flow

work → heat (completely)
heat → work (Not completely) } → By Joule experiment

Statement of Second Law

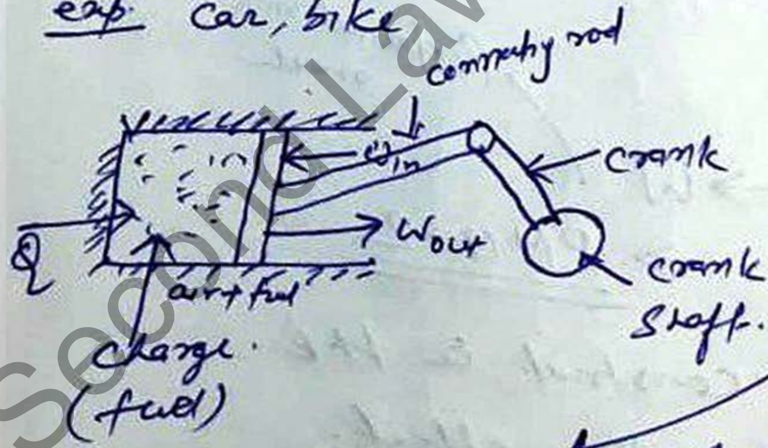
(1) Kelvin-plank's statement

Cyclic Heat engine → Heat converted into work

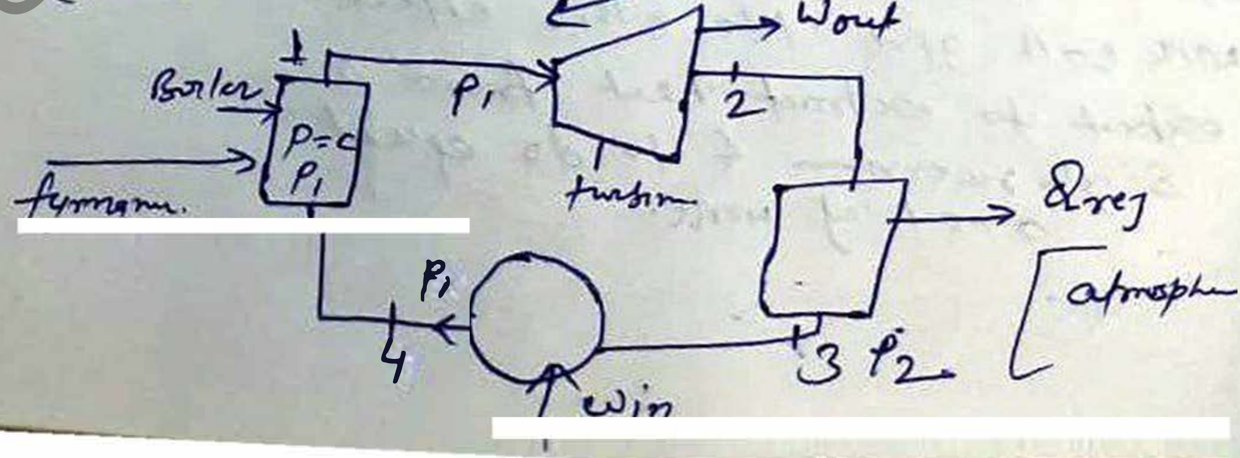
Reciprocating (Back & forth motion)

Rotary (Rotodynamic)

exp. car, bike



exp. gas turbine
steam turbine
(It gives +ve work)



$$Q_{net} = W_{net} \text{ (for complete cycle)}$$

$$Q_{add} - Q_{rej} = W_{out} - W_{in}$$

$$Q_{add} = Q_{rej} + W_{net}$$

Thermal Efficiency

It measure the performance of any heat engine.

$$\eta = \frac{W_{net}}{Q_{add}}$$

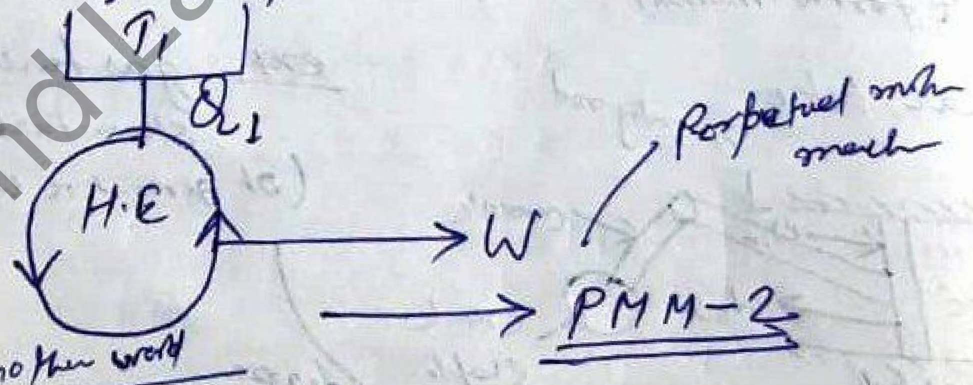
$$Q_{add} > W_{net}$$

$$\eta < 100\%$$

$$\eta < 1$$

Kelvin-plancks statement

It is impossible for a heat engine to produce net work in a complete cycle if it exchanges heat only with bodies at single temp.



In another word

It is impossible to construct a H.E with will give No other effect. except to extract heat from a single reservoir & to do equal amount of work.

In case of PMM-2

$Q_{rej} = 0$

$\eta = \frac{W}{Q_{add}} = 1$ or 100%.

↓

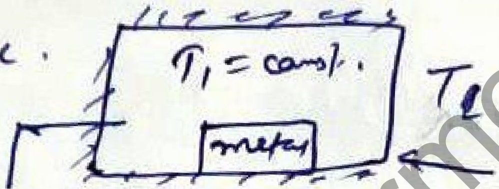
This is violation of Kelvin-planck statement.

TER

Thermal Energy Reserviour.

→ are the bodies of infinite heat capacity

exp furnace.

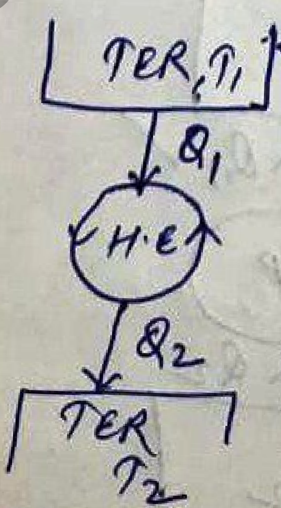


Part of TER ← (Thermal energy Reserviour)

↙ Source — supply

↘ Sink — reject

TER → T - not changed.



$T_1 > T_2$

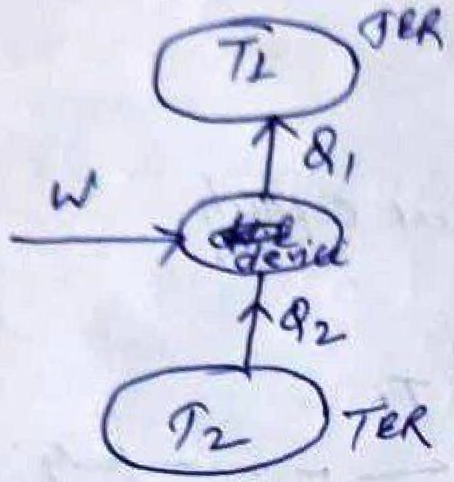
$W_{net} = Q_1 - Q_2$

$\eta = \frac{Q_1 - Q_2}{Q_1}$

$\boxed{\eta = 1 - \frac{Q_2}{Q_1}}$

Clausius Statement

It is impossible to construct a device which, while operating in a cycle will produce no other effect other than the transfer of heat from cooler to hotter body.

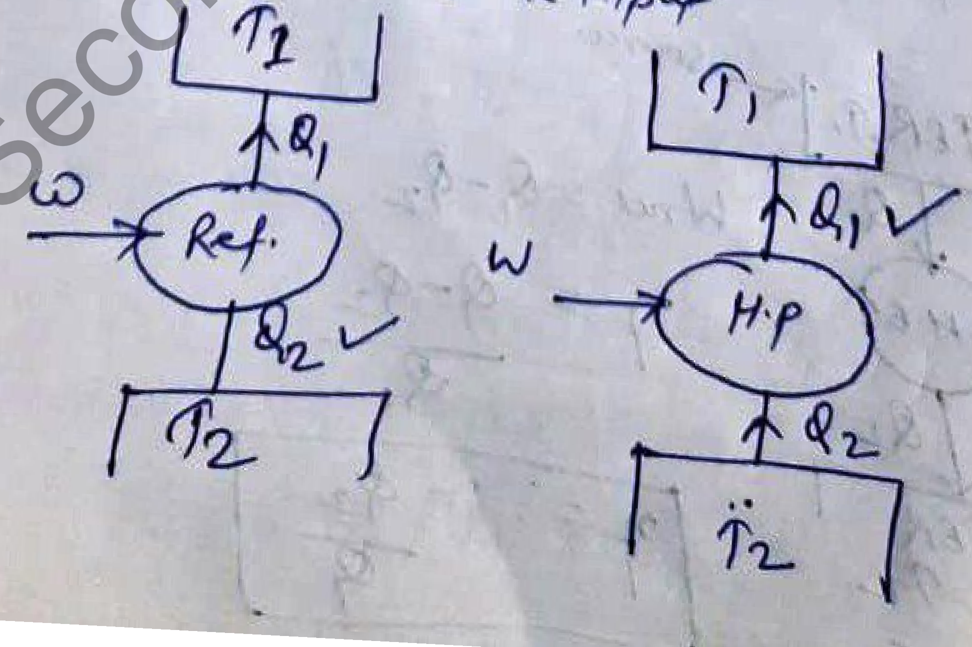


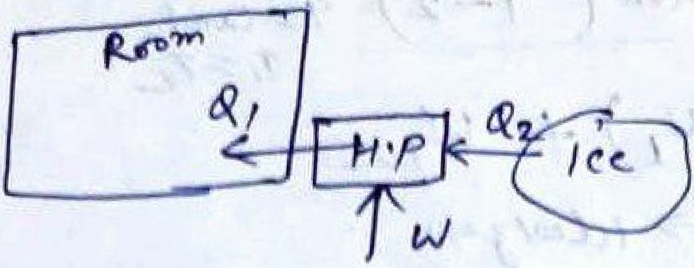
Refrigerator & Heat pump

Maintain the temp of any body at particular temp.

Co-efficient of Performance

$$[COP] = \frac{\text{Desired effect}}{\text{work input}}$$





$$[COP]_{Ref} = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$$

$$[COP]_{H.P} = \frac{Q_1}{W} = \frac{Q_1}{Q_1 - Q_2}$$

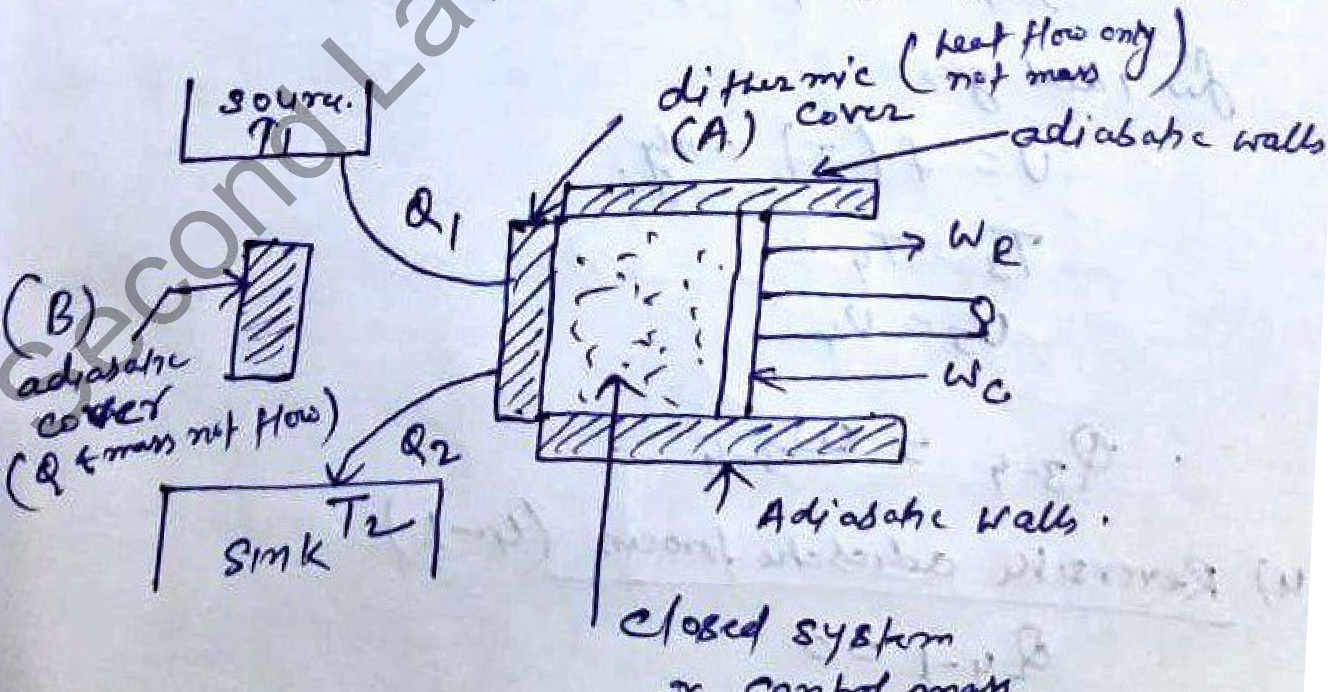
Relation b/w Both. [COP]

$$[COP]_{H.P} = [COP]_{Ref} + 1$$

So $[COP]_{H.P} > [COP]_{Ref}$ by unity.

Carnot Cycle

It is a ideal cycle & completely hypothetical cycle.



(1) Isothermal process (1-2) $T = \text{const.}$ $T_1 = T_2$

Heat added $Q_{1-2} = (U_2 - U_1) + W_{12}$

of working fluid → Ideal gas

$U_2 = U_1$

$\therefore \boxed{Q_{12} = W_{12}}$

(2) Reversible adiabatic process (2-3)

$Q_{23} = 0$

$Q_{2-3} = (U_3 - U_2) + W_{2-3}$

$\therefore \boxed{W_{2-3} = U_2 - U_3}$

(3) Isothermal process (3-4)

$-Q_{3-4} = U_4 - U_3 - W_{3-4}$

for ideal gas

$U = f(T)$ only.

$T_3 = T_4$

$U_3 = U_4$

$\therefore Q_{3-4} = W_{3-4}$

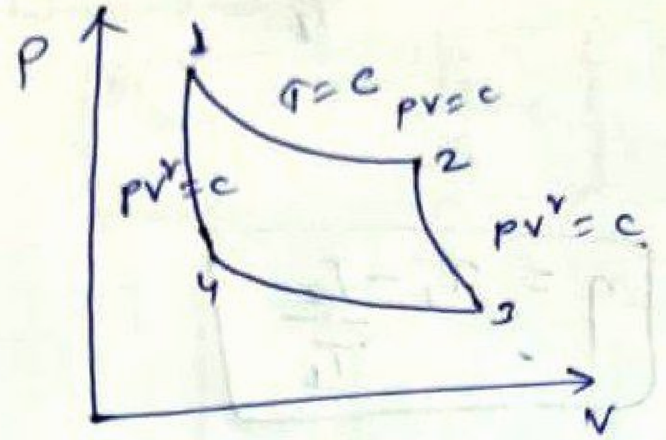
(4) Reversible adiabatic process (4-1)

$Q_{4-1} = 0$

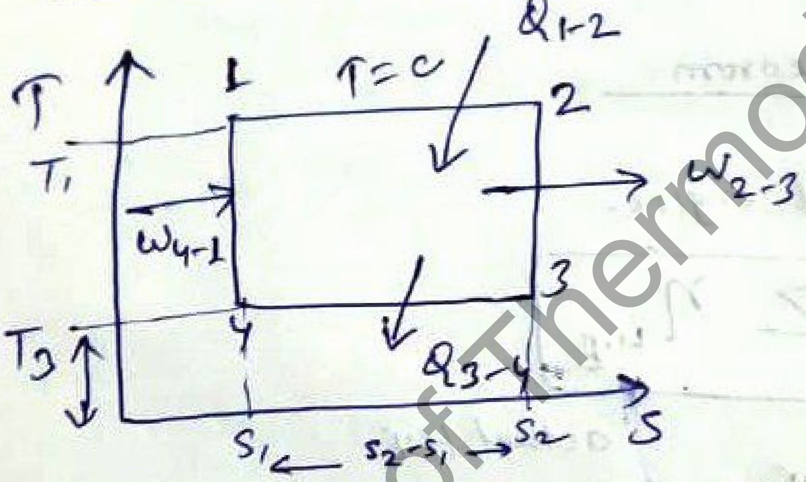
$Q_{4-1} = U_1 - U_4 + W_{4-1}$

$\boxed{U_4 - U_1 = W_{4-1}}$

PV-diagram: Carnot cycle.



$$\boxed{\oint dq = \oint \omega}$$



$$\therefore Q_{1-2} - Q_{3-4} = \omega_{2-3} - \omega_{4-1}$$

→ Q_{12} = Area under process 1-2 in T-S plot

$$Q_{1-2} = T_1 \Delta S = T_1(S_2 - S_1)$$

→ Q_{3-4} = Area under process 3-4 in T-S plot

$$Q_{34} = T_3(S_2 - S_1)$$

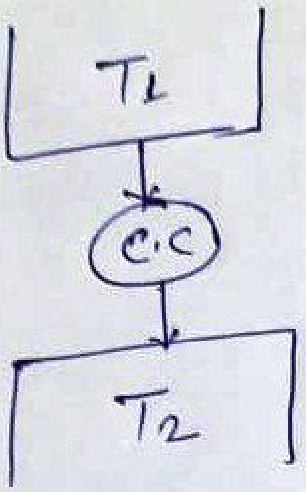
$$\therefore W_{net} = Q_{12} - Q_{34}$$

for Carnot engine

$$\eta = \frac{W_{net}}{Q_{1-2}} = \frac{Q_{12} - Q_{34}}{Q_{1-2}}$$

$$= \frac{T_1(\cancel{S_2 - S_1}) - T_3(\cancel{S_2 - S_1})}{T_1(\cancel{S_2 - S_1})}$$

$$\eta = \frac{T_1 - T_3}{T_1} = T_1 - \frac{T_3}{T_1}$$



$$\boxed{\eta = \frac{T_1 - T_2}{T_1}}$$

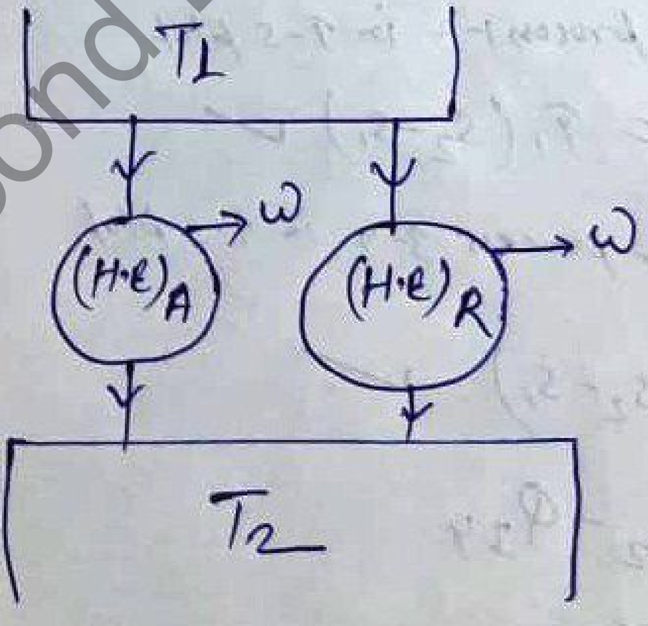
Carnot theorem

for all heat engine.

$$\boxed{\eta_{rev\,H.e} \geq \eta_{H.E}}$$

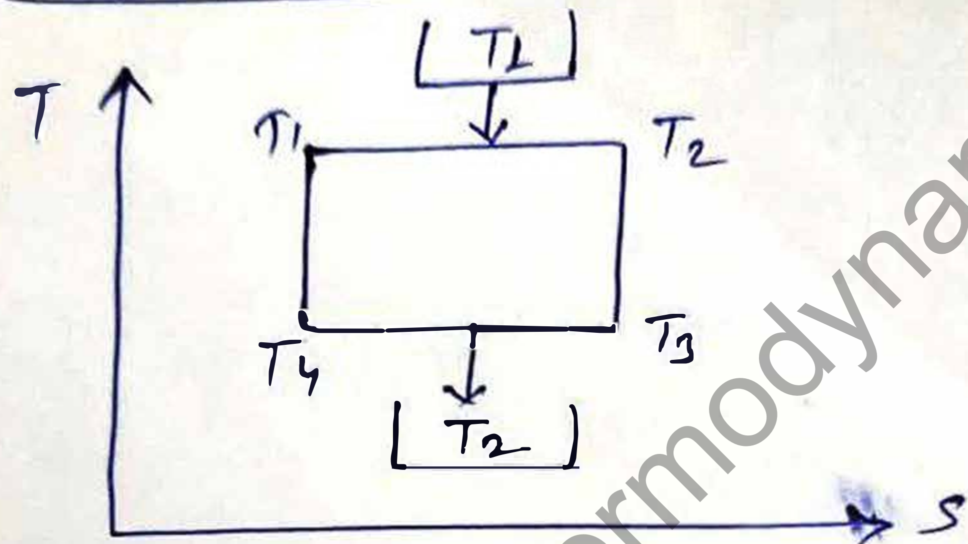
Reversible H.e

actual H.e



$$\boxed{\eta_{max} = \eta_{Rev}}$$

$$\boxed{\eta_{Rev} = 1 - \frac{T_2}{T_1}}$$



$T_3 = T_4 = T_2$ (Sink)

$T_1 = T_2 = T_1$ (source)