Heat Engine.

Work $\leftrightarrow$ Heat

We are mostly interested in conversion of heat into work.

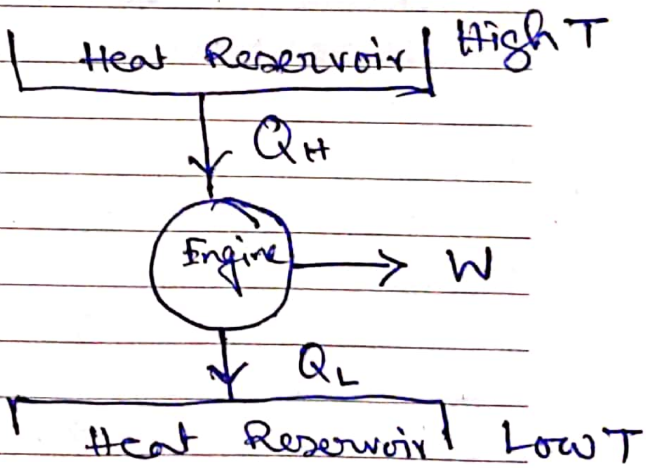
Ideal Gas $\Rightarrow$ isothermal expansion.

$\Rightarrow$ no change in internal energy since T. is const.

$\Rightarrow$ Change of state. Volume increases.

$\Rightarrow$ Cycle:

Engine $\Rightarrow$ Carnot Engine.



Efficiency = $\dfrac{\text{Useful workdone}}{\text{Heat Absobed}}$.

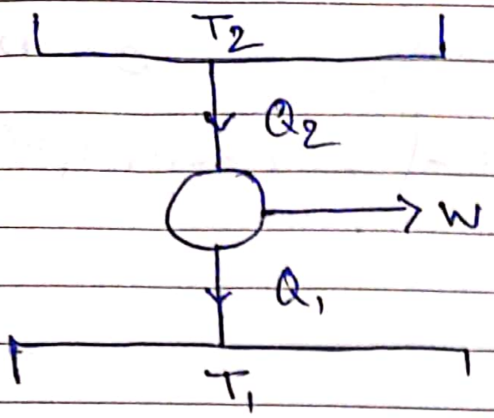
$$\eta = \frac{|W|}{|Q_H|}$$

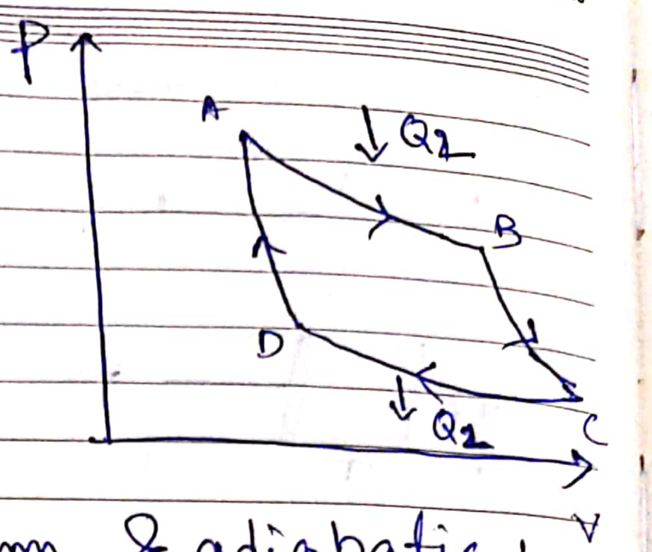
$$\eta = \frac{|Q_H| - |Q_L|}{|Q_H|}$$

$\Delta U = 0$.

$$= 1 - \frac{|Q_L|}{|Q_H|}$$

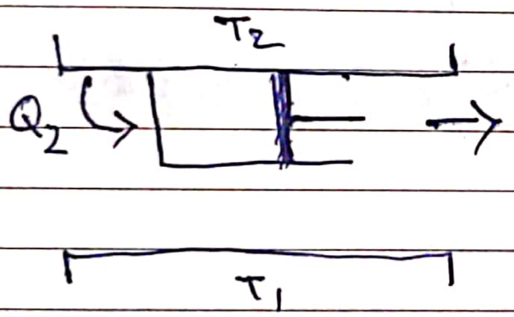
$0 < \eta < 1$.





i) A series of isotherm & adiabatic process

1.> Reversible isothermal expansion



$W_1 = -\int_A^B p\,dv$

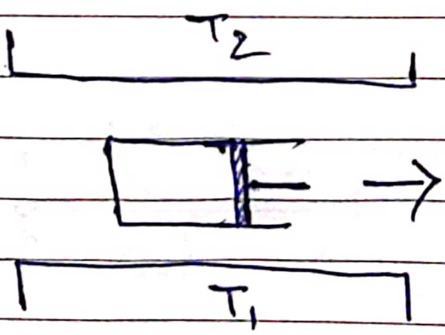
$-Q_2 = -nRT_2 \ln\left(\frac{v_B}{v_A}\right)$

$\Delta U = 0$

$V_B > V_A$

$\Rightarrow W_1 < 0$

2. reversible adiabatic expansion.



$W_2 = -\int_B^C p\,dv$ $\quad PV^{\gamma} = K$

$= -\frac{K}{1-\gamma}\left[\frac{1}{V_C^{\gamma-1}} - \frac{1}{V_B^{\gamma-1}}\right]$

$= \frac{nR(T_1 - T_2)}{(\gamma-1)}$

$T_1 < T_2$

$\Rightarrow W_2 < 0$

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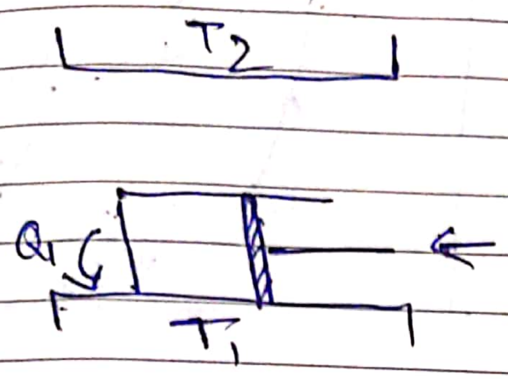
3. Isothermal compression. $V_C > V_D \Rightarrow W_3 > 0$

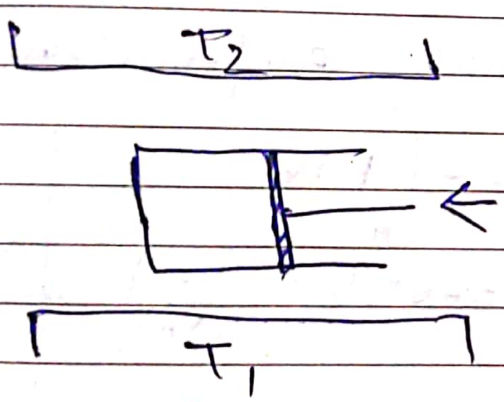
$$W_3 = -Q_1 = -\int_C^D p\,dV = -nRT_1 \ln\left(\frac{V_D}{V_C}\right)$$



4. Adiabatic compression.

$$W_4 = -\int_D^A p\,dV = \frac{nR}{\gamma-1}(T_1 - T_2) =$$

$T_1 < T_2 \Rightarrow W_4 > 0$



$$\cancel{W = -\oint p\,dV = W_1 + W_2 + W_3 + W_4}$$

$$\cancel{= W_1 + W_3}$$

$$\cancel{= -nRT_2 \ln\left(\frac{V_B}{V_A}\right) - nRT_1 \ln\left(\frac{V_D}{V_C}\right)}$$

$$W = -\oint p\,dV = W_1 + W_2 - W_3 - W_4$$

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BC is adiabatic

$$\Rightarrow T_2 V_B^{\gamma-1} = T_1 V_C^{\gamma-1}$$

$$\Rightarrow \frac{T_2}{T_1} = \left(\frac{V_C}{V_B}\right)^{\gamma-1}$$

DA is adiabatic

$$\frac{T_2}{T_1} = \left(\frac{V_D}{V_A}\right)^{\gamma-1}$$

$$\Rightarrow \left(\frac{V_C}{V_B}\right)^{\gamma-1} = \left(\frac{V_D}{V_A}\right)^{\gamma-1}$$

$$\Rightarrow \frac{V_B}{V_A} = \frac{V_C}{V_D}$$

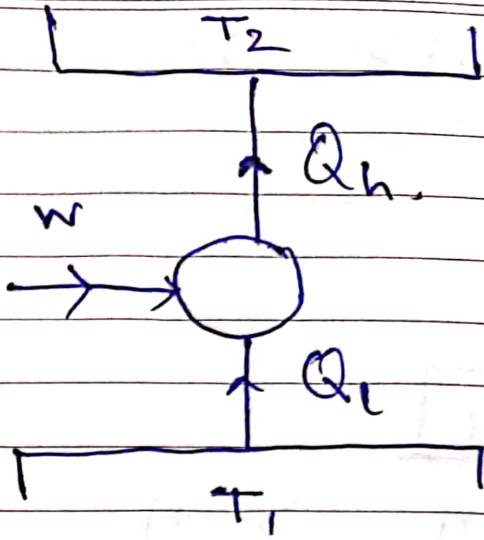
$$\eta = 1 - \frac{Q_1}{Q_2} = 1 - \frac{T_1}{T_2} \qquad T_2 > T_1$$

$$\boxed{\eta = \frac{T_2 - T_1}{T_2}} = \left(\frac{T_h - T_l}{T_h}\right)$$

Refrigerator:

8

Heat engine running
9 backwards.



10

$$\eta = \frac{Q_l}{W}$$

11

$$= \frac{Q_L}{Q_h - Q_l} =$$ [illegible]

12

1

$$= \frac{T_1}{T_2 - T_1}$$ (show) H.W.

2

3

4

5

6

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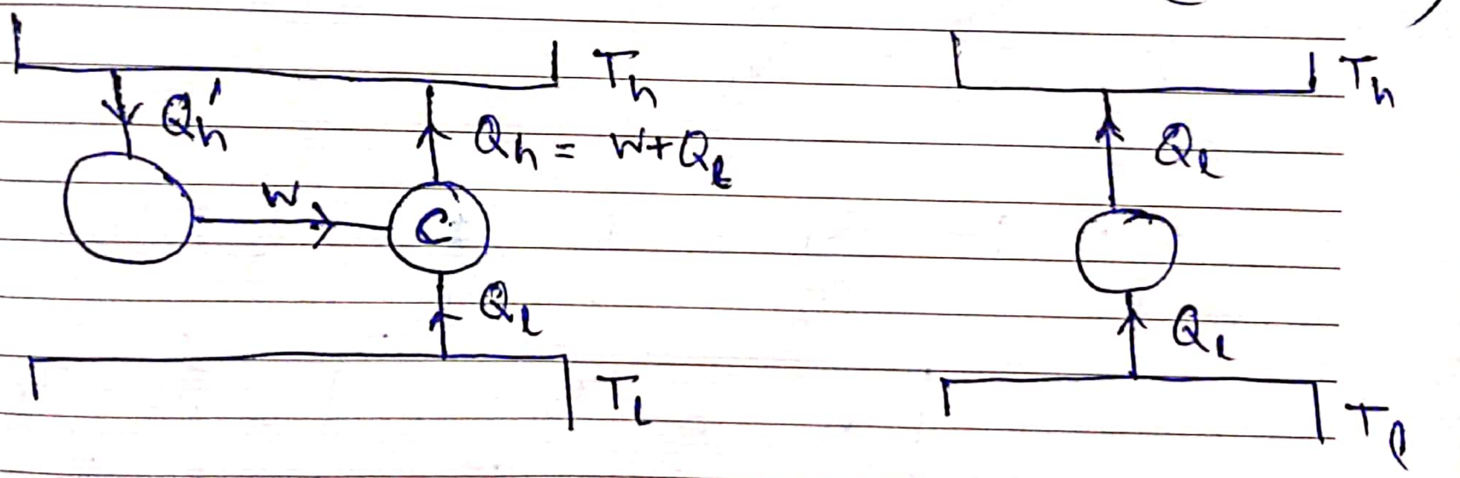
Carnot's Th: Of all heat engines working between two given temp none is more efficient than an Carnot engine;

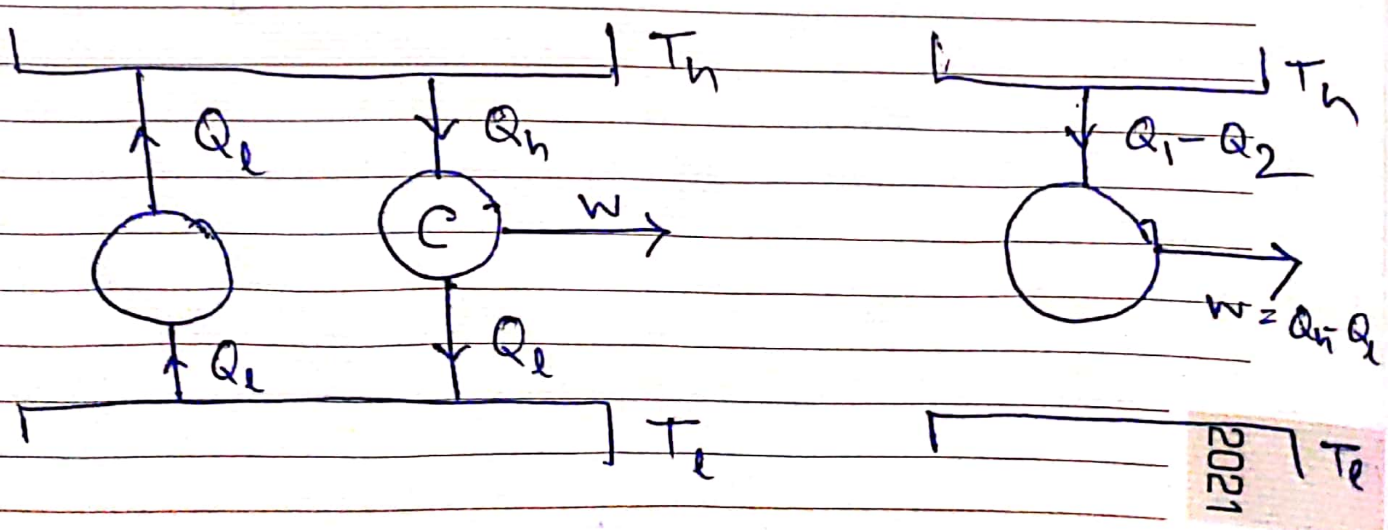
Equivalence of Kelvin & Clausious statement

⇒ If one statement is untrue ⇒ other is also necessarily untrue.

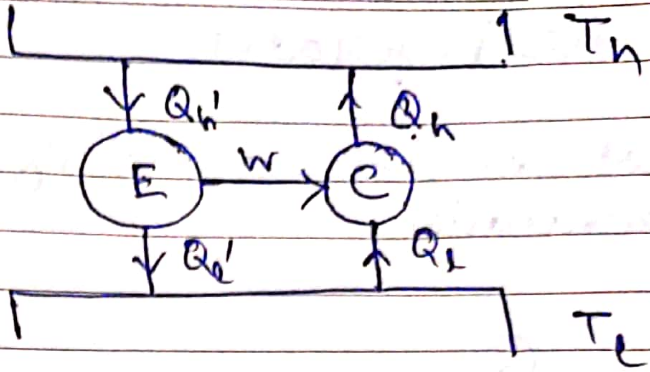
1. Kelvin statement is violated (Assume)



2.>



Carnot's Th:.



Assume

$$\eta_E > \eta_{Co}$$

$$\Rightarrow \frac{W}{Q_h'} > \frac{W}{Q_h} \Rightarrow Q_h > Q_h'$$

$\Rightarrow$

From 1st law of Thermodynamics

$$W = Q_h' - Q_l' = Q_h - Q_l$$

$$\Rightarrow Q_h' - Q_h = Q_l' - Q_l$$

$\Rightarrow$

$$\Rightarrow Q_h - Q_h' = Q_l - Q_l'$$

+ve $\Rightarrow$ +ve.

$\Rightarrow$ Violate Clausions Statement of 2nd Law of Thermodynamics

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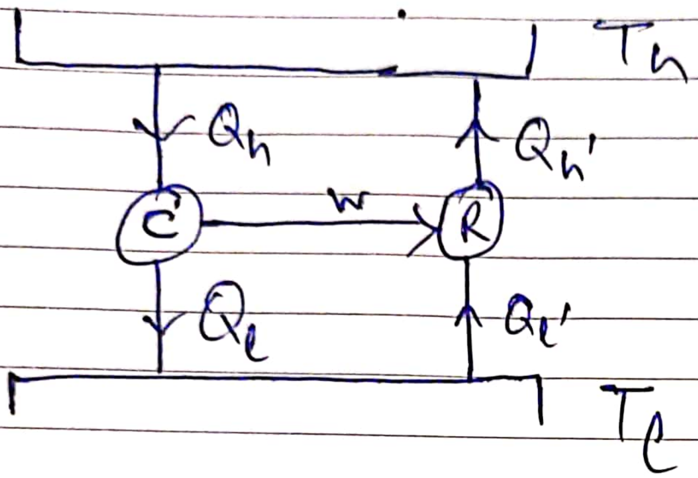
☐ All reversible engines have same efficiency η_{carnot}.



$$\eta_R \leq \eta_C$$

Show with the same argument discussed above that

$\eta_R = \eta_C$ otherwise violate Clausius st of 2nd Law.

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