Second law of Thermodynamics

Heat Engine: Heat engine is a device which convert the heat energy into mechanical energy. main parts of heat engine are:

a) source ⇒ (reservioir)

It is a hot region at constant hight temperature from where heat engine can draw any amount of heat with out changing temperature.

* The main characterstics of source is whatever the heat energy is taken out from it, it ~~wal~~ always maintains the constant temperature.

b) sink ⇒ It is the cold region at constant low temperature ~~From where~~ To which any amount of the heat can be rejected without changing the temperature.

* The main characterstics of sink is whatever the heat energy is rejected to it, it ~~w~~ always maintains the constant low temperature.

c) working substance ⇒ It is an ideal gas. The amount of heat is absorbed from the source and converted into mechanical work or enrgy. Then remaining energy is rejected to sink

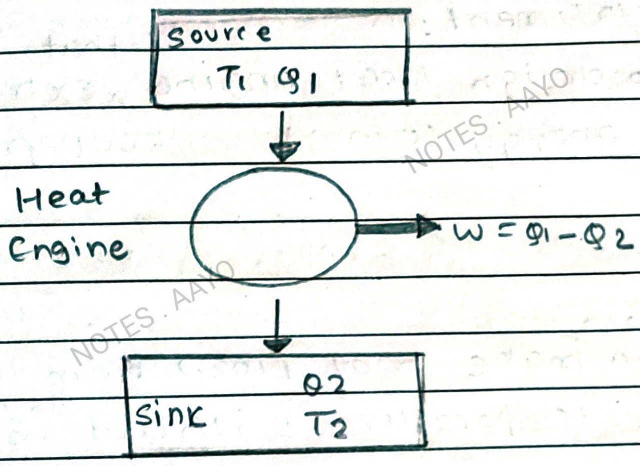


Fig: Block diagram of Heat engine

let Q_1 be the amount of heat absorbed by heat engine at constant high temperature. T_1, let W be the work done while changing heat energy into mechanical energy.
let Q_2 ~~be~~ be the amount of heat rejected to sink at constant low temperature T_2. Then,

$$\text{work done } (W) = Q_1 - Q_2$$

Then, efficiency is define as the ratio of work done to amount of heat absorb

$$\therefore \text{Eficiency}(\eta) = \frac{W}{Q_1} \times 100\%$$

$$= \frac{Q_1 - Q_2}{Q_1} \times 100\%$$

$$\left(1 - \frac{Q_2}{Q_1}\right) \times 100\%$$

Efficiency in term of temperature,

$$\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100\%$$

Second law of thermodynamics:

⇒ This law is stated as:

a) Kelvin-Planck's statement:

It is impossible to design heat engine that extract and fully utilize heat energy to work without providing the othe effect.

b) Clausius statement:

It is impossible to make heat flow from lower temperature to high temperature without doing external work.

Carnot engine:

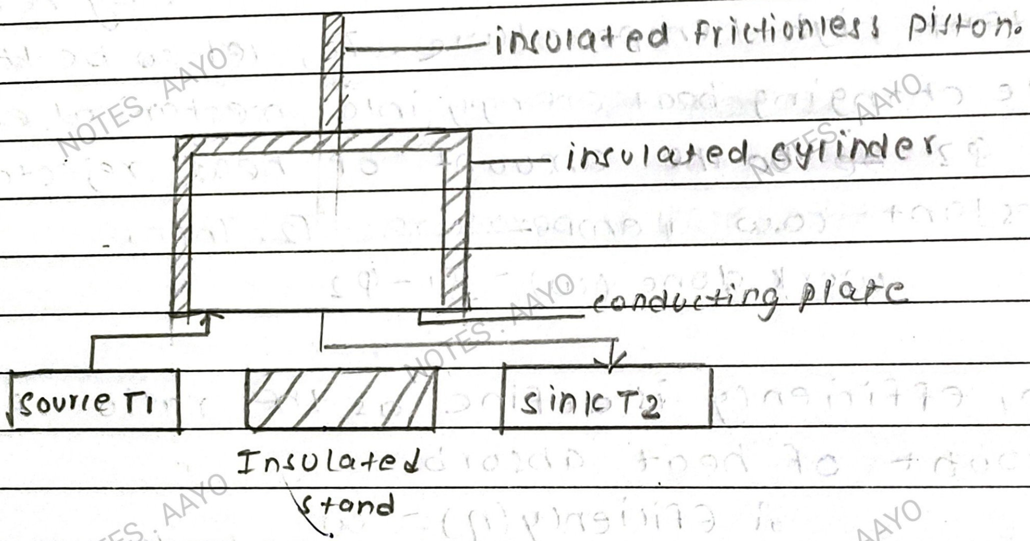


Fig: carnot engine

Carnot engine is the heat engine which converts heat energy into mechanical energy. It's parts are:

a) Source

→ It is a hot region at constant high temperature from where heat engine can draw any amount of heat without changing temperature. Whatever the heat energy is taken out from it, it always maintains the constant temperature.

b) sink =>

It is a cold region at constant low low temperature. To which any amount of heat can be rejected to it without changing temperature. whatever the heat energy is rejected to it, it always maintains low temperature.

c) cylinder: It consists of an ideal gas and wall of cylinder is perfectly insulated along with conducting plate.

d) Insulated stand: It provides the platform for cylinder during the adiabatic process.

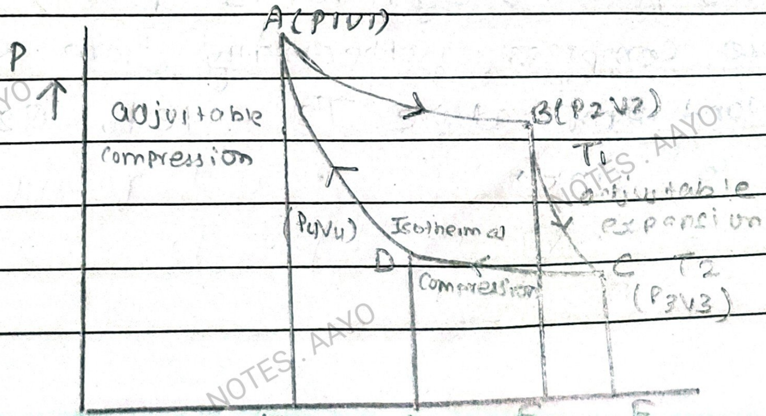
Carnot cycle:

It is reversible process in which working substance is subjected to four successive reversible process. which are:

a) Isothermal expansion
b) Adiabatic expansion
c) Isothermal compression
d) Adiabatic compression

let us consider 'n' mole of gas having initial pressure (P_1) initial volume(V_1) and initial temperature (t_1). Then, carnot's cycle involves following process:

(a) P.V diagram for carnot's cycle is as shown in figure:



a) Isothermal expansion:

The cylinder is placed on the source and allowed to expand isothermally from $A(P_1V_1)$ to $B(P_2V_2)$ at constant temperature (T_1).

From First law of thermodynamics,

workdone (W_1) = Q_1 $\because du = 0$

where, Q_1 be the amount of heat absorbed by working substance from source.

or, $W_1 = Q_1 = \int_{V_1}^{V_2} P\,dV$

$$= nRT_1 \ln\left(\frac{V_2}{V_1}\right)$$

= Area of ABEHA.

b) Adiabatic expansion:

During this process, cylinder is placed on the insulated stand. And allowed to expand adiabatically from $B(P_2V_2)$ to $C(P_3V_3)$ till the temperature decreases from T_1 to T_2. ~~Th~~ Then

workdone (W_2) = $\int_{V_2}^{V_3} P\,dV$

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

= Area of BCFEB.

~~d~~(c) Isothermal compression:

During this process, cylinder is placed on the sink and allowed to compress isothermally from $C(P_3V_3)$ to $D(P_4V_4)$ at constant temperature T_2. let, Q_2 amount of heat rejected to sink.

Then,

workdone $(w_3) = Q_2$

$$w_3 = Q_2 = -\int_{V_3}^{V_4} PdV$$

$$= nRT_2 \ln\left(\frac{V_3}{V_4}\right)$$

= Area of CDGFC

(d) Adiabatic compression :

$$\text{workdone} = (w_3) = \int_{V_2}^{V_3} PdV$$

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

= Area of BCFEB

During this process, cylinder is placed on the isolated stand and allowed to compress adiabatically from $D(P_4V_4)$ to $A(P_1V_1)$ till the temperature increases from T_2 to T_1.

$$\text{workdone } (w_4) = -\int_{V_4}^{V_1} PdV$$

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

= Area of DAHGD.

Then,

Total workdone $(w) = w_1 + w_2 - w_3 - w_4$

$$= nRT_1 \ln\left(\frac{V_2}{V_1}\right) + \frac{nR(T_1 - T_2)}{\gamma - 1} - nRT_2 \ln\left(\frac{V_3}{V_4}\right)$$

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

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$$= nRT_1 \ln\left(\frac{V_2}{V_1}\right) - nRT_2 \ln\left(\frac{V_3}{V_4}\right)$$

$$\boxed{W = Q_1 - Q_2}$$

From graph;

Total workdone = $W_1 + W_2 - W_3 - W_4$

= area of ABEHA + area of BCFEB − area of CDGFC − area of DAHGD

$$\boxed{\therefore W = \text{area of } ABCDA}$$

Hence, area of ABCDA gives the work done during the carnot's cycle.

Efficiency of carnot's cycle:

It is defined as the ratio of workdone to amount of heat absorbed. let, Q_1 be the amount of heat absorbed by working substance and Q_2 be the amount of heat rejected to sink. Then, workdone $(W) = Q_1 - Q_2$

$$\therefore \text{efficiency}(\eta) = \frac{W}{Q_1} \times 100\%$$

$$= \frac{Q_1 - Q_2}{Q_1} \times 100\%$$

$$= \left(1 - \frac{Q_2}{Q_1}\right) \times 100\%$$

$$= \left\{ \frac{1 - nRT_2 \ln\left(\frac{V_3}{V_4}\right)}{nRT_1 \ln\left(\frac{V_2}{V_1}\right)} \right\} \times 100\%$$

$$\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100\%$$

REVERSIBILITY OF CARNOT'S CYCLE

Carnot's cycle is reversible process due to:

↳ There is no friction between priston and wall of ~~they~~ the cylinder.

↳ Operation of gas is in slow rate.

↳ The heat lost is prevented due to insulated piston and insulated wall of the cylinder.

↳ conducting base plate of the cylinder maintains constant temperature during isothermal process.

TYPE OF HEAT ENGINE

~~They~~ There are two types of heat engine.

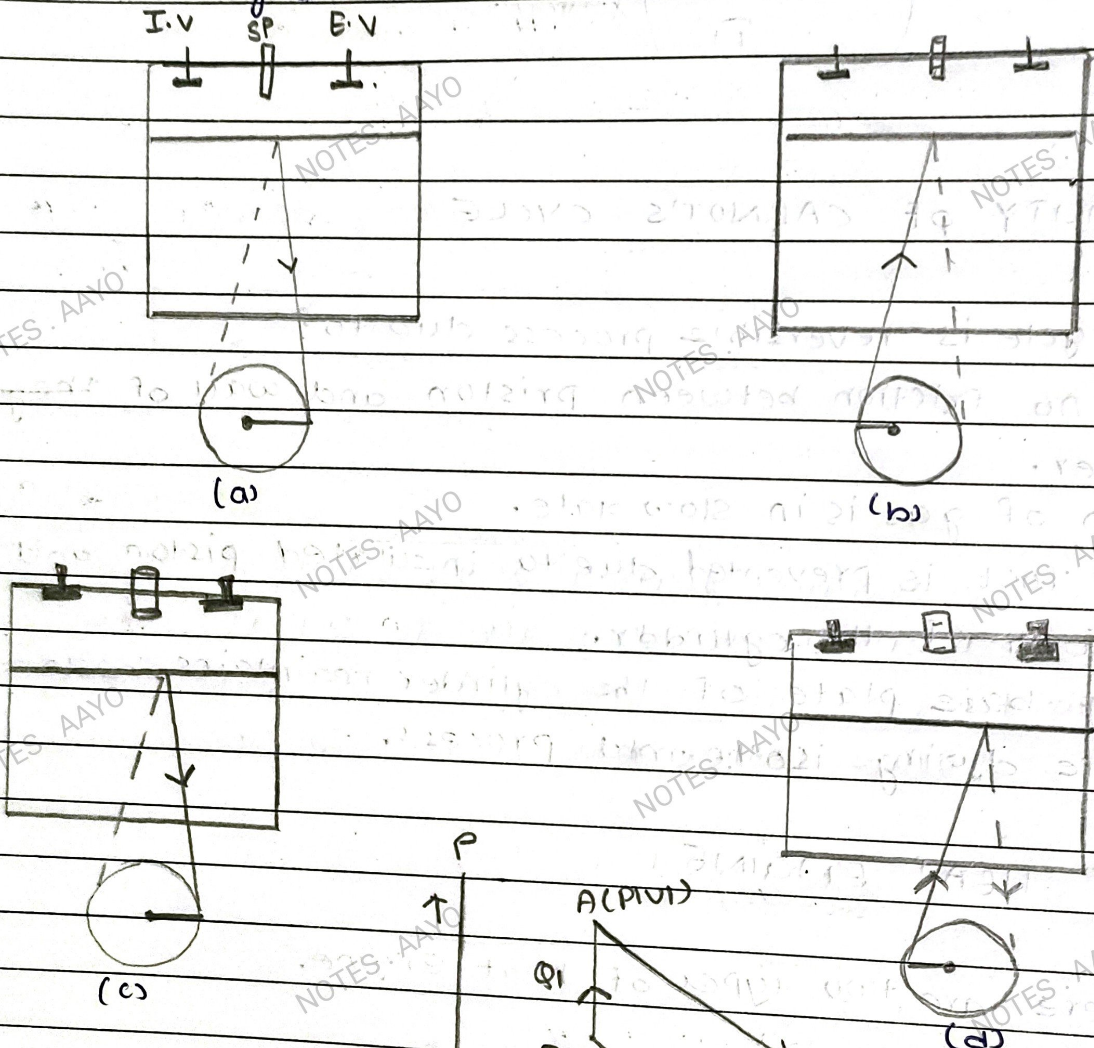
a) External combustion engine: In this process, combustion of the fuels take place outside the engine.

b) Isothermal combustion engine: In this process, combustion of the fuels take inside the engine.

For example: petrol engine, dieseal engine.

PETROL ENGINE or OTTO ENGINE consists of 4 stroke:

Internal combustion engine which uses the mixture of air and petrol (98% and 2%) respectively as working substance is called petrol engine. Cylinder of this petrol engine consist of inlet valv, sparking plug and exhaust valv along with movable piston.



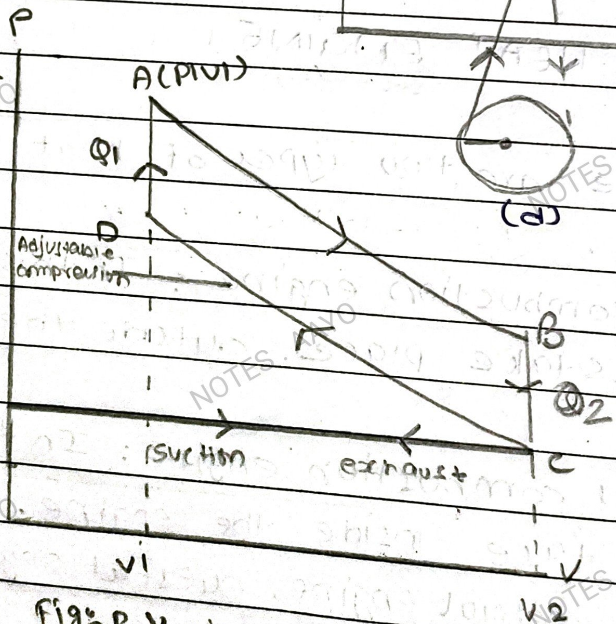


Fig: P.V diagram for petrol engine

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(a) Suction stroke: During this stroke, inlet valve is opened such that enough amount of mixture of air and petrol inside the cylinder. In this case, volume goes on increasing but pressure remain constant. This cycle is represented by E-C in PV diagram.

(b) compression stroke: In this stroke, both inlet valve and outlet valve are closed. So that adiabatic ~~expansion takes place~~ compression takes place from C to D in PV diagram. Due to this, volume of working substance decreases and pressure increases. As the result, its ~~this~~ temperature ~~becomes 600~~ aprox. reaches to 600°c.

(c) working stroke: In this ~~valve,~~ stroke both inlet and outlet valve are closed. ~~such that~~ Due to compression, ignition of mixture takes place rising the temperature approx. to 2000°c. During this process, Q1 amount of heat is absorbed by working substance. And it is represented by DA. As the result, adiabatic expansion takes place from A to B.

(d) Exhaust stroke: In this stroke. ~~both~~ inlet valve is closed whereas exhaust valve is opened. In this process, burn out gas exhausted out rejecting Q2 amount of heat energy to the surrounding. It is represented by CE in the PV diagram.

Diseal engine: It is internal combustion engine in which mixture of air and diseal used as working substance. cylinder of this engine consist of inlet valve, fuel injector and outlet valve.

Diseal engine consist of 4 strokes.

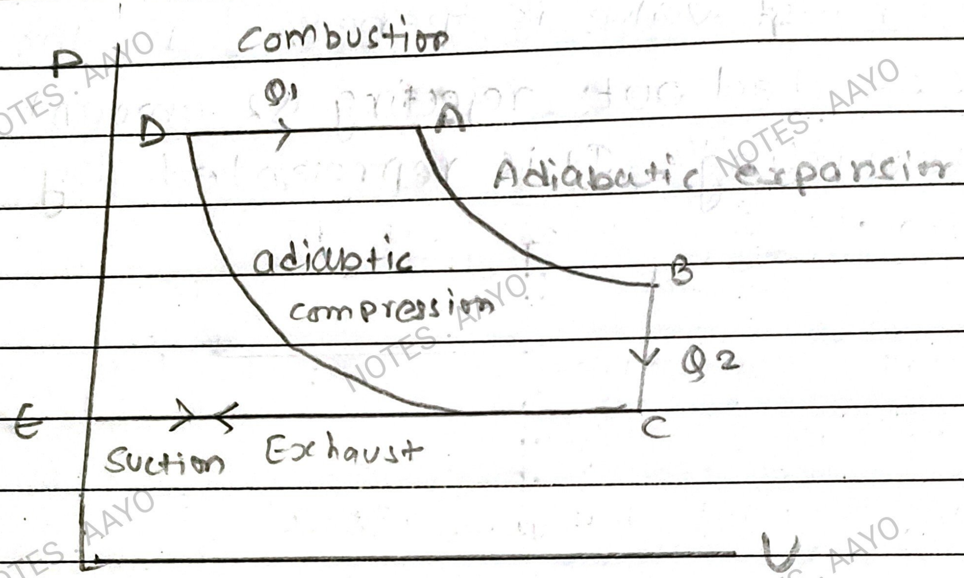


Fig: P. V diagram for diseal engine

a) Suction stroke:

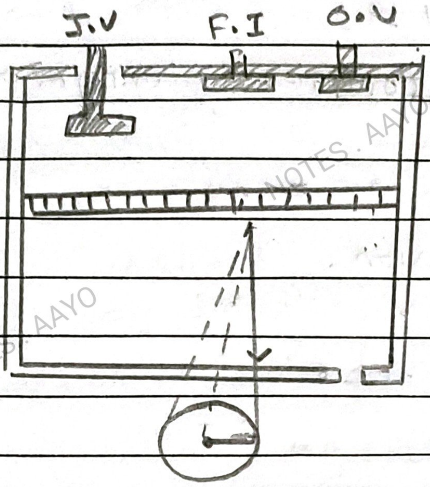


Fig: suction stroke

In this stroke,

a) I.V - open

↳ enough air enter inside cylinder due to movement of piston.

It is represented by E-C in graph.

* pressure: constant   ~~vol~~ volume: increases

* O.C closed

(b) compression stroke

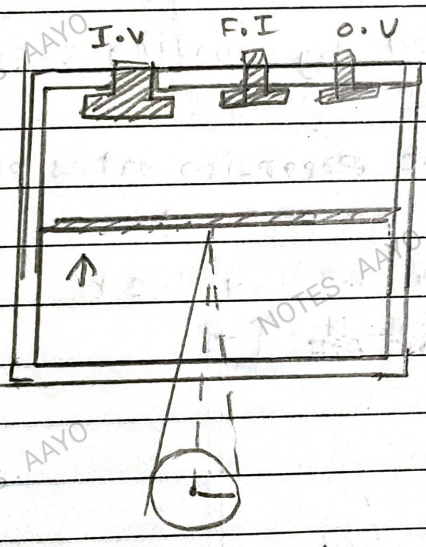


Fig: compression stroke

In this stroke,

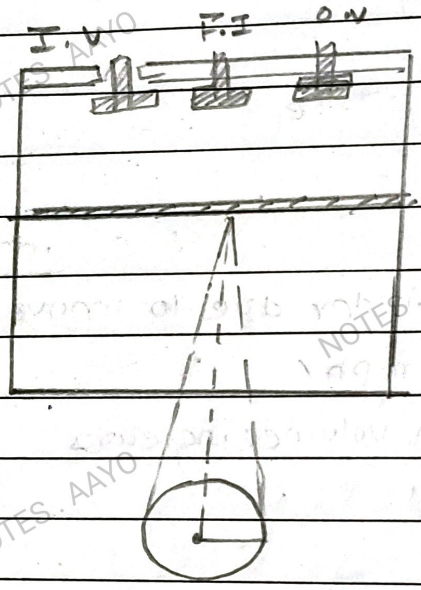
=> I.V and O.V are closed.

=> During this process, air compressed to high pressure and temperature (1000°C)

=> It is represented by CD.

=> It is adiabatic compression.

c) working stroke



In this stroke,

→ I.V and O.V are closed.

→ fuel inject to compressed air.

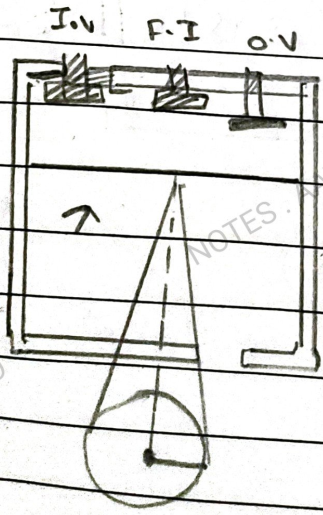
→ ignition takes place at high temp (2000°C)

→ Q_1 amount of heat is absorbed by working substance.

→ It is represented by DA.

→ As the result, adiabatic expansion takes place from A to B.

d) Exhaust stroke



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In this stroke,

→ I.V closed and O.V open are closed.

→ Fuel inject to compressed air.

→ Burnt out gas exhausted out ~~and~~ to surrounding rejecting O_2.

=) amount of heat energy which is represented by BC.

=) CE represents the exhaust stroke in PV diagram.

In this way, diseal cycle is completed in four stroke.