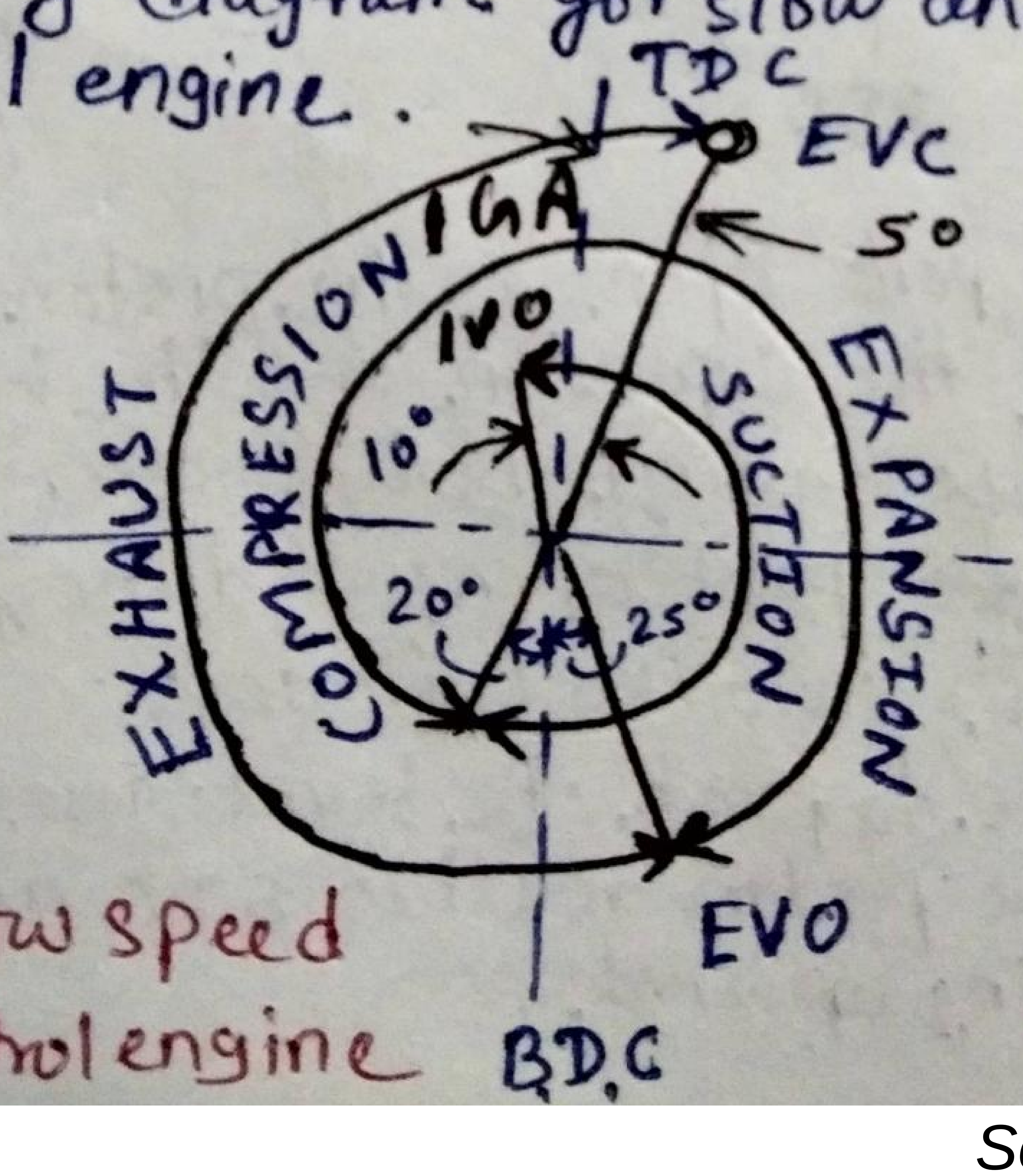
* Valve Timing Diagram for Petrol Engine:-

- Consider the actual cycles discussed above, the valves need to be operated to meet the mechanical and dynamic requirements.

- The correct timing of opening and closing of inlet and exhaust valves improves the power and efficiency of the engine and it reduces the specific fuel consumption.

- Valve timing has to be adjusted accourding to speed of the engine. A typical valve timing diagram for slow and high speed Petrol engine.



(a.) Low speed Petrol engine

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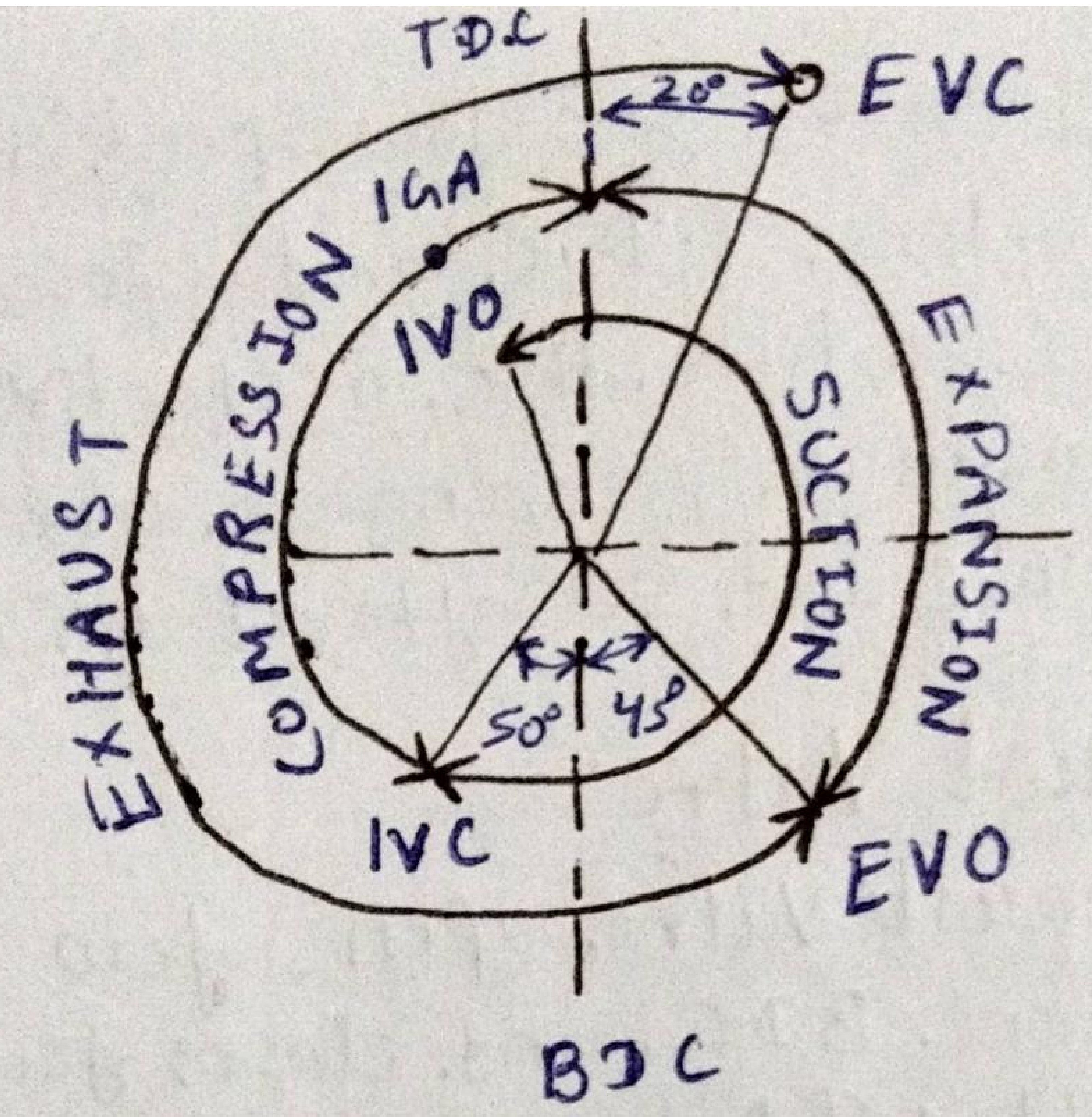

(b). High speed petrol engine.

(i) Inlet Valve :-

- The inlet valve opens few degrees before T.D.C. when the pressure drops below atmosphere inside the cylinder, fresh charge is admitted.
- when the piston reaches BDC and starts its compression stroke, the stroke, the charge continues to move into the cylinder due to its K.E. To take its advantage, the inlet valve is kept opened for few degree B.D.C.
- The K.E of the charge produces a ram effect which forces more charge to be admitted into the cylinder.

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- The inlet valve for slow speed engine opens 10° before T.D.C and closes 20° after B.D.C., while the respective valves for a high speed engine are 10° before T.D.C and 50° after B.D.C.

(ii). Exhaust Valve:-

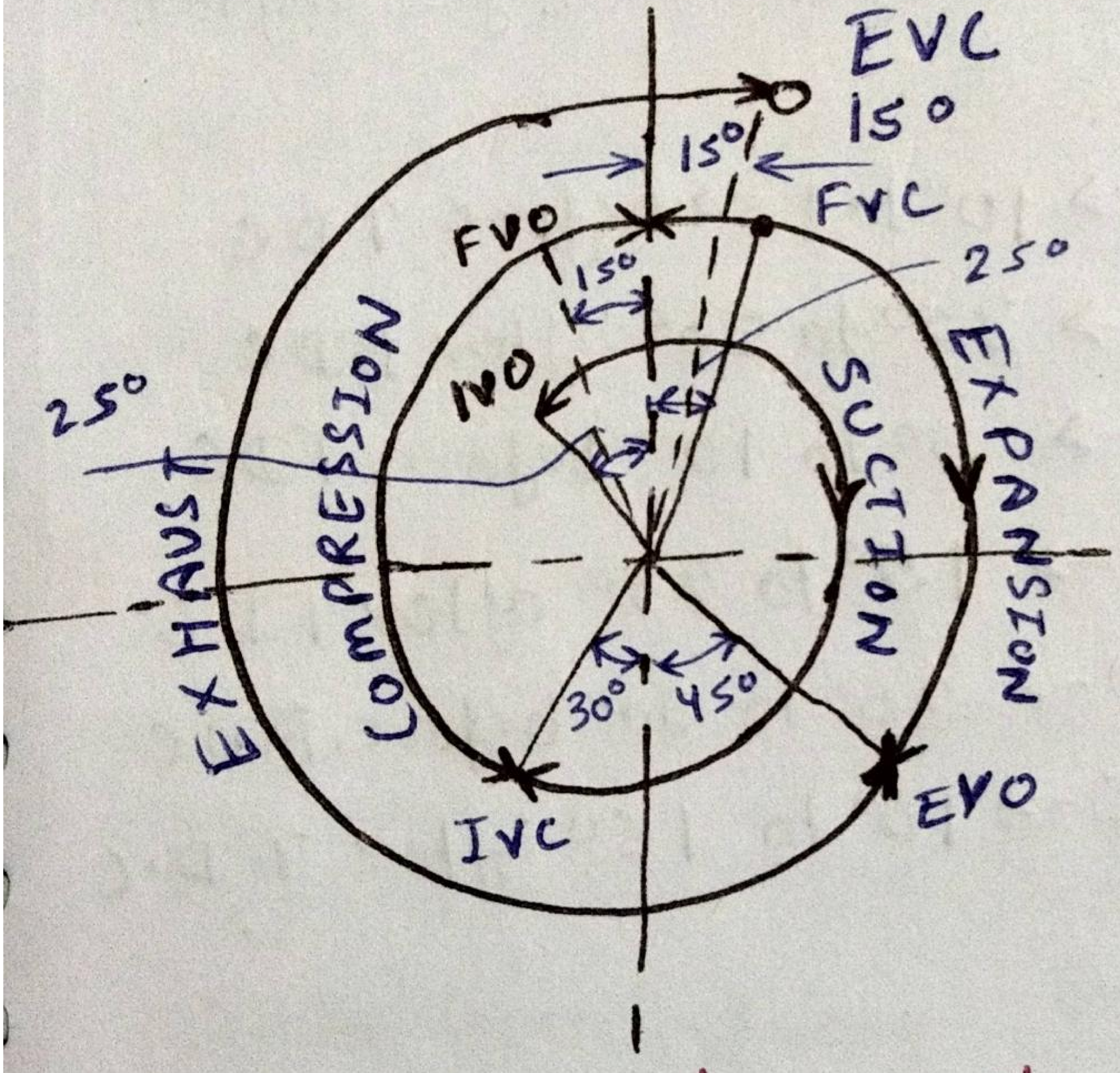
- The exhaust valve opens few degree before B.D.C. and closes few degree after T.D.C.
- The exhaust valve remains open even after the inlet valve has opened This period of valve overlaps helps in driving out the exhaust gases efficiently.
- Exhaust valve opens 25° before B.D.C and closes 5° after TDC for slow speed engines. while it opens 45° before BDC and closes 20° after TDC for High speed engines.

(iii). Ignition

- Spark is provided 15° before in case of slow speed engine and 30° before TDC in high speed engines.

* Valve Timing Diagram for Diesel Engines:-

- The various strokes are modified for similar 8 reasons as explained in case of Petrol engine.



Valve timing diagram of a diesel engine.

FVC - fuel valve close 25° after TDC

IVO - 25° before TDC

IVC - 30° before BDC

EVO - 45° before BDC

EVC - 15° after TDC

FVO - fuel valve opens 15° before TDC

Fuel injection timing:-

- The fuel needs to be injected few degr
  before TDC for better evaporation
  and mixing of fuel and air.
- The fuel valve is closed few degree
  after TDC

IVO → 10° to 25° before TDC

IVC → 25° to 50° after BDC

FVO → 5° to 10° before TDC

FVC → 15° to 25° after TDC

EVO → 30° to 50° before BDC

EVC → 10° to 15° after T.D.C

*** Indicated Thermal efficiency :-** Indicated thermal efficiency is defined as the ratio of heat equivalent of Power produced in the cylinder in unit time and heat supplied to the engine in unit time.

$$\boxed{\text{Indicated thermal efficiency} = \frac{\text{Indicated Power}}{mf \times CV}}$$

where mf = fuel oil supplied in kg per sec
CV = Calorific value of fuel in kJ/kg.

*** Brake Thermal efficiency :-** It is defined as the ratio of heat equivalent of brake power in unit time and heat supplied to the engine in unit time.

$$\boxed{\text{Brake thermal efficiency} = \frac{\text{Brake Power}}{mf \times CV}}$$

Brake thermal efficiency is also termed as overall efficiency.

(iii) Volumetric Efficiency :- It is defined as the ratio of volume of air actually induced at ambient conditions to the swept volume of the engine.

$$\text{Volumetric efficiency} = \frac{\text{Mass of charge actually induced}}{\text{Mass of charge represented by swept volume at ambient temp and pressure.}}$$

* Relative Efficiency :- Relative efficiency or efficiency ratio is the ratio of thermal efficiency of an actual cycle to that of the ideal cycle. The relative efficiency is a very useful criteria which indicates the degree of development of the engine.

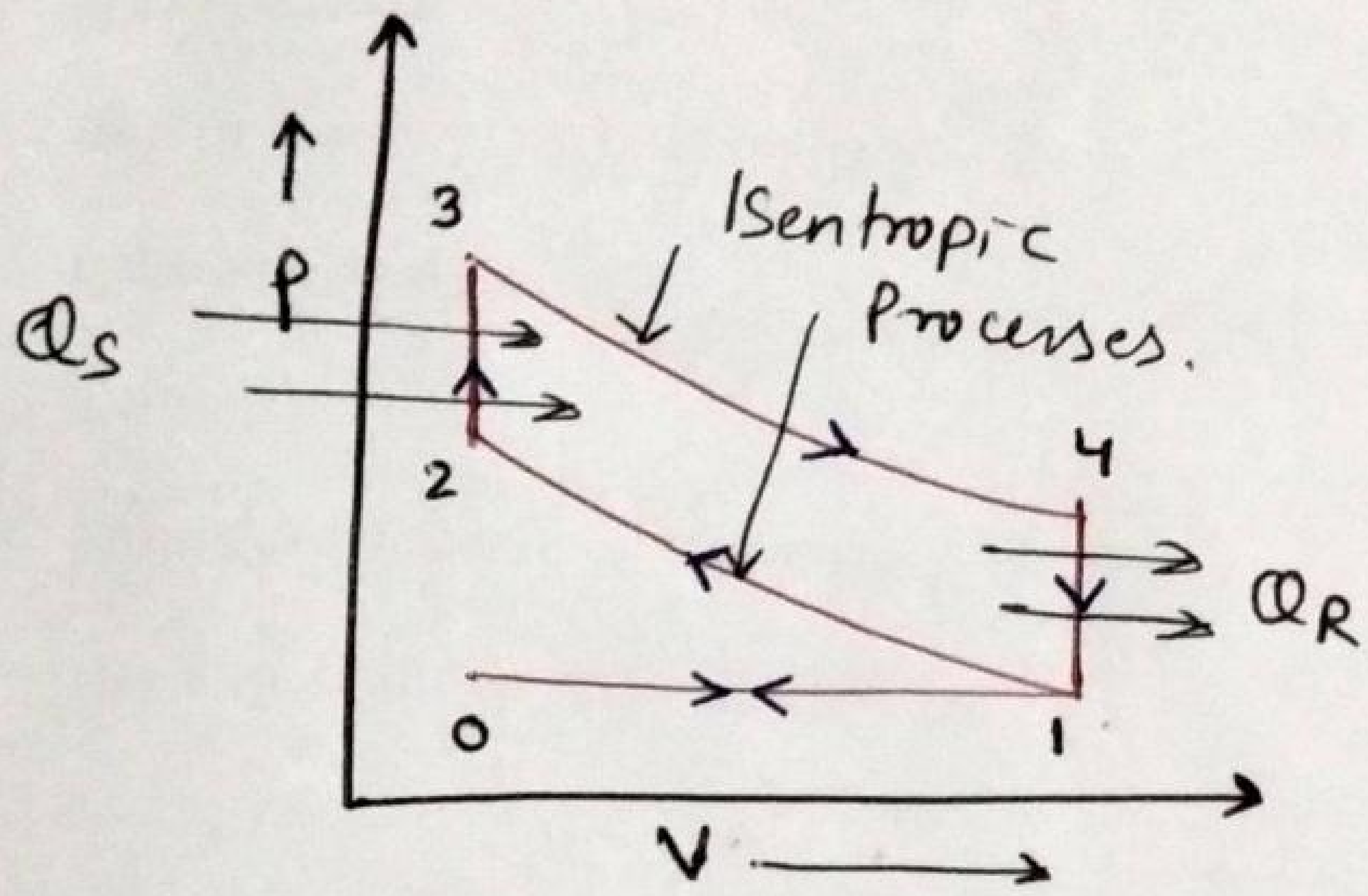
$$\text{Relative efficiency} = \frac{\text{Air thermal Efficiency}}{\text{Air-standard efficiency.}}$$

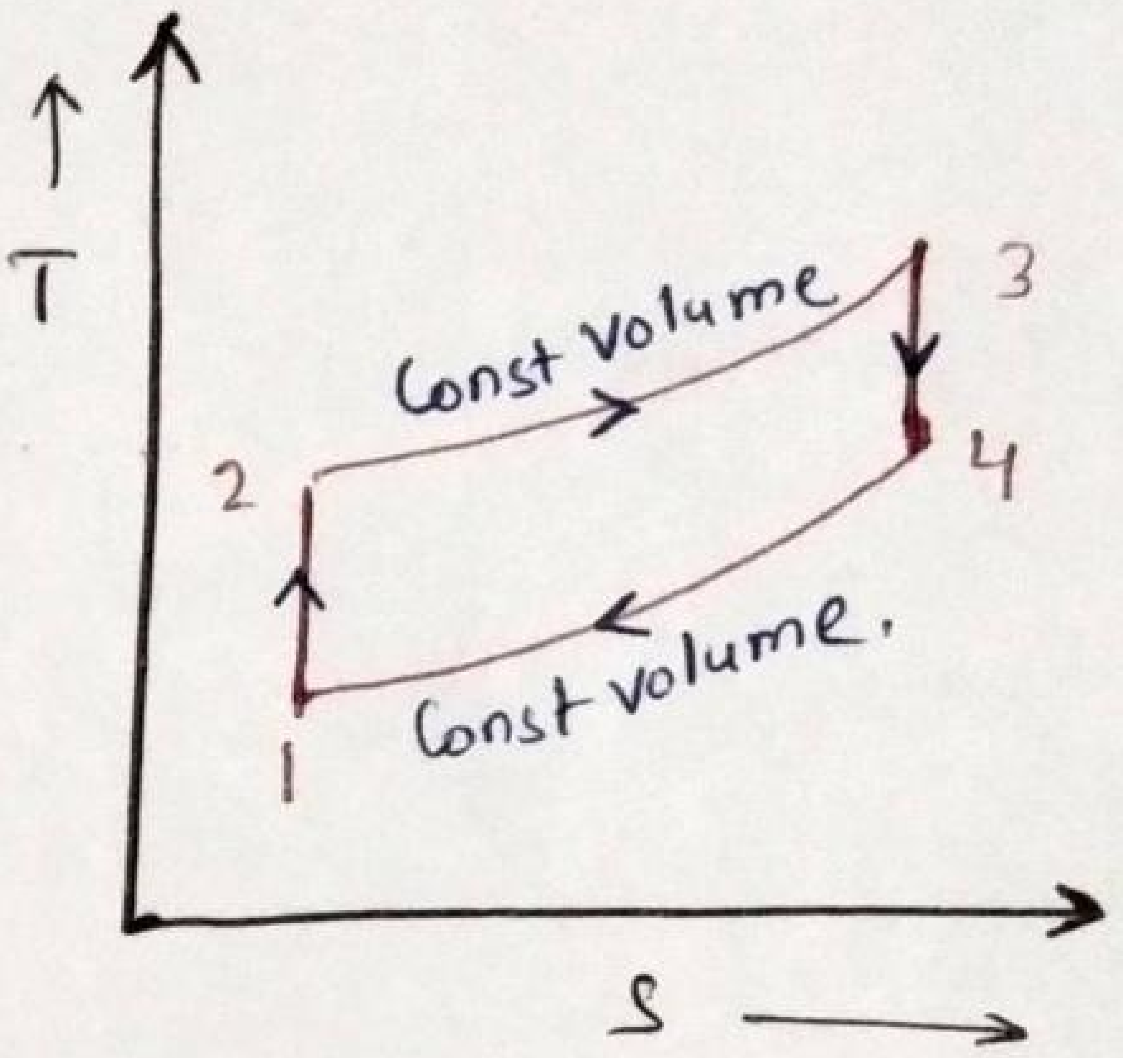
*** Mechanical efficiency:-** It may be defined as the ratio of useful power available at the engine crank shaft and Power developed in the engine cylinder.

$$\boxed{\text{Mechanical Efficiency} = \frac{\text{Brake Power}}{\text{Indicated Power}}}$$

* Expression for the air standard efficiency of otto cycle

The ottocycle is a Constant volume heat addition cycle which forms the basis for the working of today's spark ignition engines P-V and T-S diagram.





Consider 1 kg of air in the Cylinder of otto engine.

So heat is supplied during 2-3 $= mC_v(T_3 - T_2)$

Heat is rejected during Process 4-1 $= mC_v(T_4 - T_1)$

Work done = Heat Supplied − Heat rejected.

$$\boxed{W.D = mC_v(T_3 - T_2) - mC_v(T_4 - T_1)}$$

we know that

Thermal efficiency $\eta = \dfrac{\text{Workdone}}{\text{Heat Supplied.}}$

$$= \frac{mC_v(T_3 - T_2) - mC_v(T_4 - T_1)}{mC_v(T_3 - T_2)}$$

$$\boxed{\eta = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)}} \quad \text{——(1)}$$

For ideal gas $PV = RT$ and $PV^{\gamma} = \text{Constant}$

Consider isentropic processes 1-2 and 3-4

$$\boxed{\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{(\gamma-1)}} \quad \text{—— (ii)}$$

and $$\boxed{\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{(\gamma-1)}} \quad \text{—— (iii).}$$

Now Compression ratio $\frac{V_1}{V_2}$ = Expansion ratio $\frac{V_4}{V_3} = r$

$$\therefore \quad \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = \left(\frac{V_4}{V_3}\right)^{(\gamma-1)} = \frac{T_3}{T_4} = r^{(\gamma-1)}$$

$$\therefore \quad T_3 = T_4\, r^{(\gamma-1)} \text{ and } T_2 = T_1\, r^{(\gamma-1)}$$

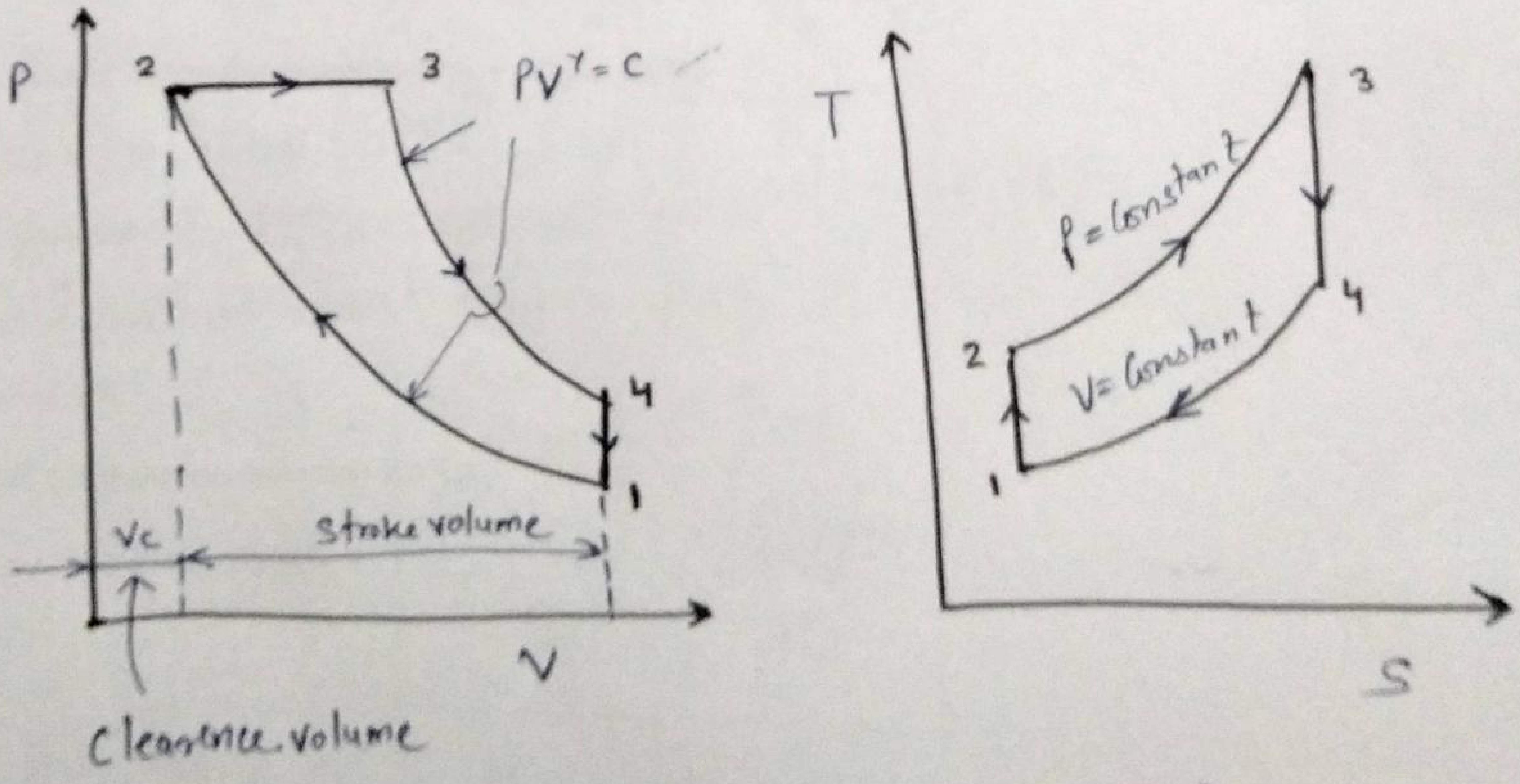
Put the values of T_3 and T_2 in eq^n -(i)

$$\eta = 1 - \frac{(T_4 - T_1)}{(T_4 - T_1)\, r^{(\gamma-1)}}$$

$$\boxed{\eta = 1 - \frac{1}{r^{\gamma-1}}}$$

* Expression for Air standard Diesel Cycle:- Diesel engines are also called as Compression ignition (C.I) engines.

- The difference between otto and diesel cycle is in this heat addition process. In case of ottocycle the heat is added at constant volume while in case of diesel cycle the heat is added at constant pressure.
- Point 1 represents the condition of air at the end of suction stroke or at the beginning of the compression stroke. This air is compressed isentropically with a comp ratio of 'r' which ranges from 14:1 to 20:1 represented by the process (1-2).
- Heat is transferred at constant pressure to air from a heat reservoir. This process (2-3) corresponds to the injection and burning of the fuel in an actual engine. The point 3 is called the point of cutt-off or the load ratio.



(a) (b)

Air standard diesel cycle.

Now the hot air expands isentropically to its initial volume represented by the process (3-4).

Finally the heat is rejected to a heat reservoir at Constant volume in the process (4-1) so as to Complete the cycle.

Let the Compression ratior, $r = \frac{V_1}{V_2}$

Cut off ratio, $\rho = \frac{V_3}{V_2}$

- Compression ratio and expansion ratio are not equal in dieselcycle.

Thermal efficiency of the Cycle.

Consider 1 kg of fuel.

$$\boxed{\eta = \frac{\text{Heat Supplied, } (Q_{2-3}) - \text{Heat rejected } (Q_{4-1})}{\text{Heat Supplied } (Q_{2-3})}}$$

$$\eta = \frac{Q_S - Q_R}{Q_S} = \frac{mC_p(T_3 - T_2) - mC_v(T_4 - T_1)}{mC_p(T_3 - T_2)}$$

$$\eta = 1 - \frac{C_v}{C_p}\frac{(T_4 - T_1)}{(T_3 - T_2)}$$

$$= 1 - \frac{1}{\gamma}\left[\frac{(T_4 - T_1)}{(T_3 - T_2)}\right]$$

For isentropic process (1-2):-

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{(\gamma-1)} = r^{(\gamma-1)}$$

$$\therefore \boxed{T_2 = T_1(r)^{(\gamma-1)}} \quad \text{——— (a).}$$

For Constant pressure process (2-3):-

$$\frac{P_2V_2}{T_2} = \frac{P_3V_3}{T_3} \qquad \text{but } P_2 = P_3$$

$$\therefore \boxed{T_3 = T_2 \cdot \frac{V_3}{V_2}}$$

Put the value of T_2 from eq^n-(a).

$$\boxed{T_3 = [T_1(r)^{(\gamma-1)}] \cdot \rho} \quad \text{——— (b)}$$

finally for Constant Volume process:-

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_2}\right)^{(\gamma-1)} = \left(\frac{\rho}{r}\right)^{(\gamma-1)}$$

$$\therefore \boxed{T_4 = T_3 \cdot \frac{(\rho)^{(\gamma-1)}}{(r)^{(\gamma-1)}}}$$

Put the value of T_3 from eq^n-(b) we get

$$T_4 = \left(T_1 \cdot r^{(\gamma-1)} \cdot \rho\right)\left(\frac{\rho^{(\gamma-1)}}{(r)^{(\gamma-1)}}\right)$$

$$\therefore \boxed{T_4 = \rho^{\gamma} \cdot T_1} \quad \text{———} (c)$$

Substituting the values of T_2, T_3 and T_4 from equation (a) to (c), in eqn (b)

$$\eta = 1 - \frac{1}{\gamma}\left[\frac{T_1 \cdot \rho^{\gamma} - T_1}{T_1 \cdot \rho \cdot r^{(\gamma-1)} - T_1 \cdot r^{(\gamma-1)}}\right]$$

$$\therefore \boxed{\eta = 1 - \frac{1}{(r)^{(\gamma-1)}}\left[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}\right]}$$