Unit II Internal Combustion Engine:

I.C Engine :-

Combustion of fuel take place inside the Cylinder that engine called as I.C Engine

Heat Engine :-

Any engine that Converts the heat energy released due to Combustion of fuel into usefull Mechanical Work is Known as heat engine.

It has two type

(1) External Combustion engine
(2) Internal Combustion engine

E.C Engine :

External Combustion engines, the Combustion of fuel takeplace outside the cylinder.

. The fuel is not mixed with air in external Combustion engine

Classification :-

(1) No. of. Stroke
- 2. Stroke
- 4 - Stroke

(2) According to the thermodynamic
- Otto
- Diesel
- Duel
- Brayton

Ignition :- i Spark Ignition
ii Compression Ignition

fuel :- Petrol diesel gas

Speed :- Slow Speed, Medium Speed, High Speed

Cylinder :- Inline engine, Radial Engine, Opposed cylinder engine
V-engines, Rotary Engine, Delta engine
Opposed Piston engine, Vertical horizontal Engine.

Cooling :- Air Cooled, Water Cooled

fuel Injection :- Carburettor engines, Air Injection Engines
Airless or Solid Injection engines.

No. of. Cylinder :- Single Cylinder, Multi cylinder

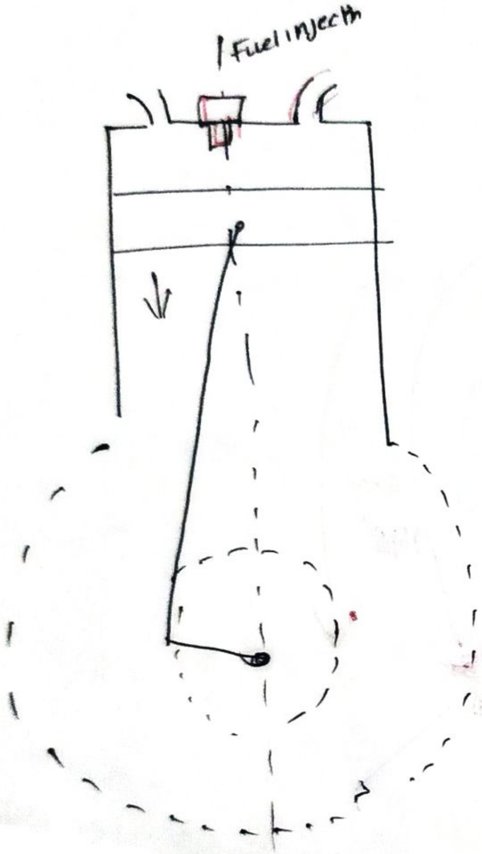
Governing :- Hit and Miss governed engine
Quality Governed Engines
Quantity Governed Engines

Valve :- Over head Valve, Side Valve, L-head Val
T-head type, h-head type

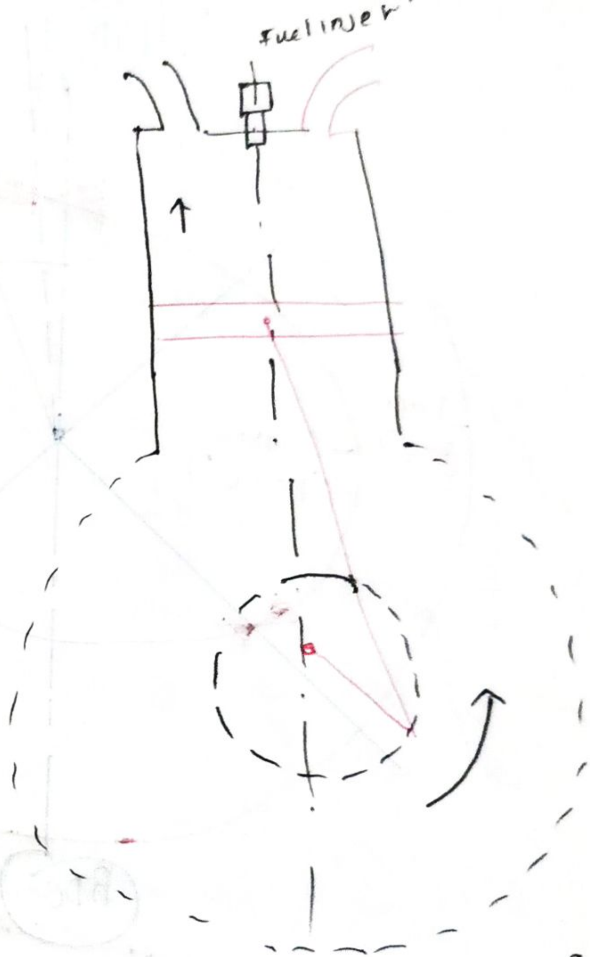
Application : Stationary, Automobile, Locomotive
Aero, Marine

Four stroke Engine [Diesel]

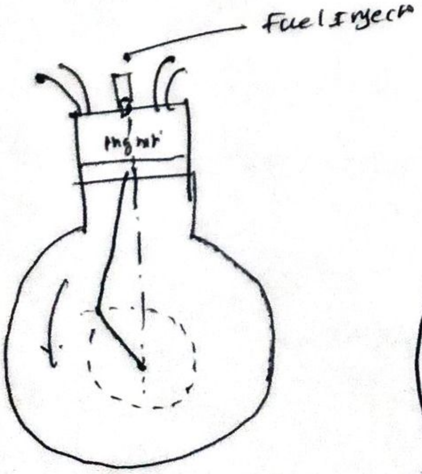
Diesel engines are also known as Compression ignition engine as Combustion take place due to high pressure and temperature generated during Compression stroke.



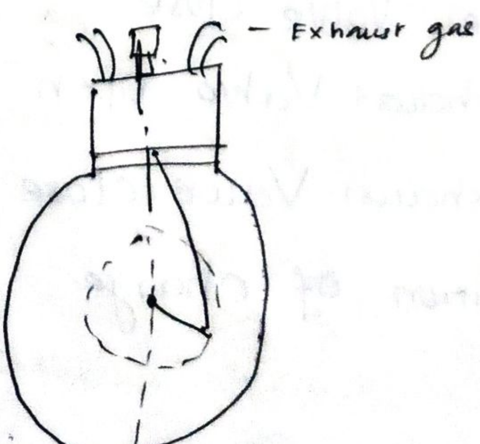
Suction stroke
(IV - open)



Compression stroke (IV & EV close)



(IV & EV Close)



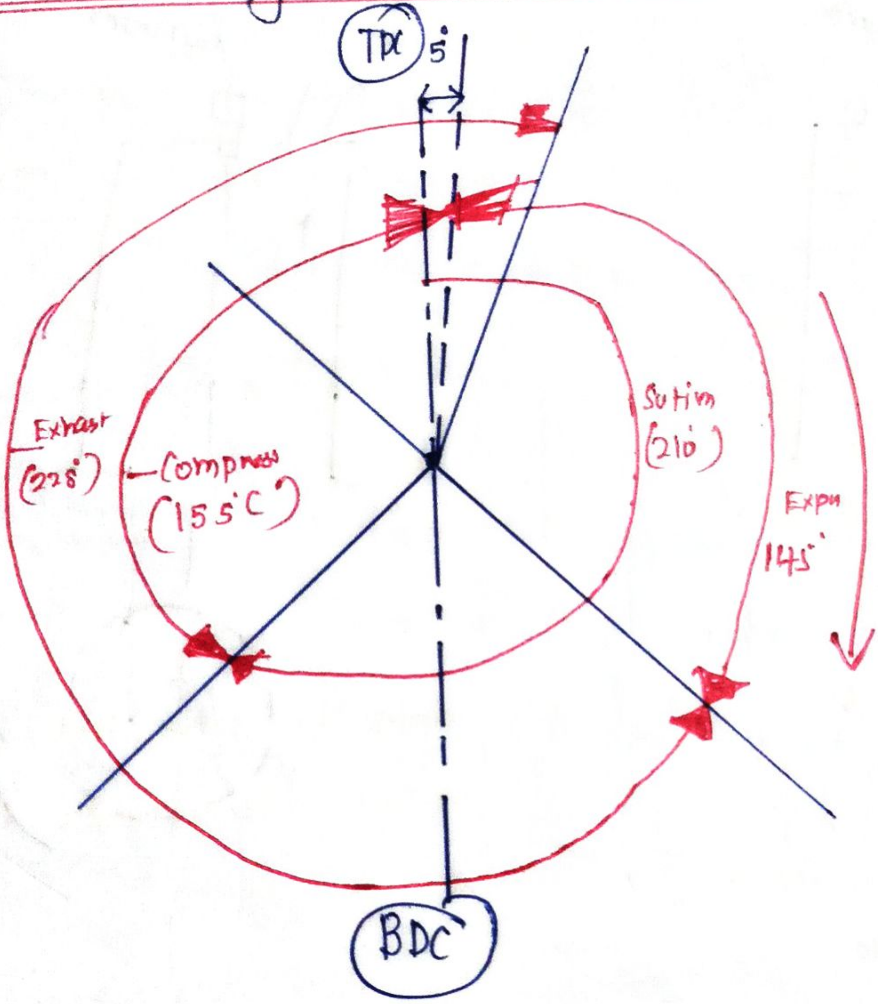
Exhaust stroke (EV open)

5-1 Suction stroke 1-2 Compression Stroke

3-4 Expansion stroke 1-6 Exhaust Stroke

2-3 Instanteneous Combustion & 4-1 Sudden fall in Pressure

Valve Timing Diagram for 4-stroke Petrol engine



IVO : Inlet Valve Open

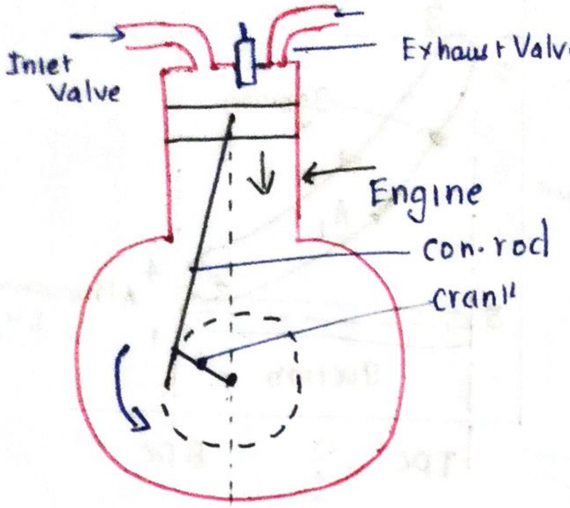
IVC : Inlet Valve Close

EVO : Exhaust Valve open

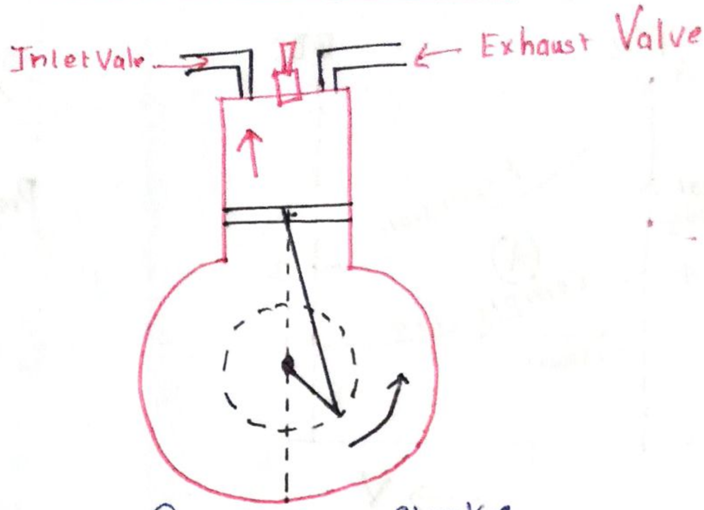
EVC : Exhaust Valve close

IG : Ignition of charge

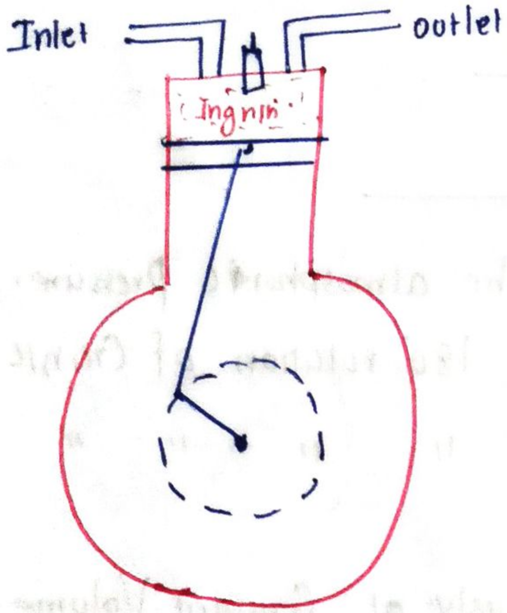
Four Stroke engine [Petrol]



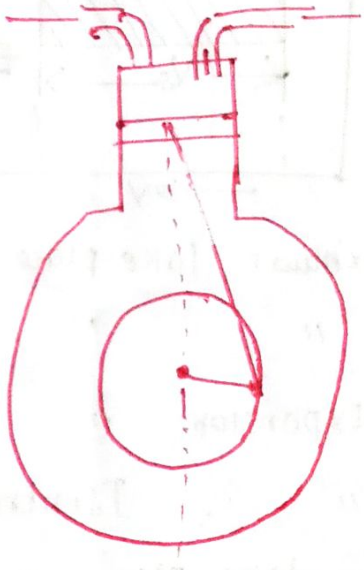
Suction Stroke
(Inlet Valve open)



Compression Stroke
[In. V & Ex. Val closed]

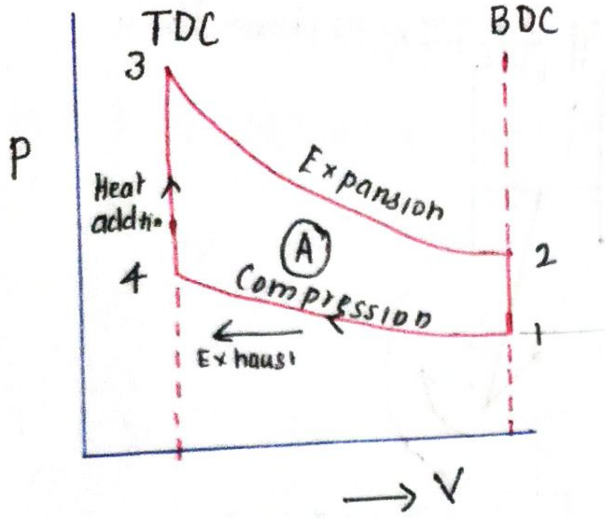


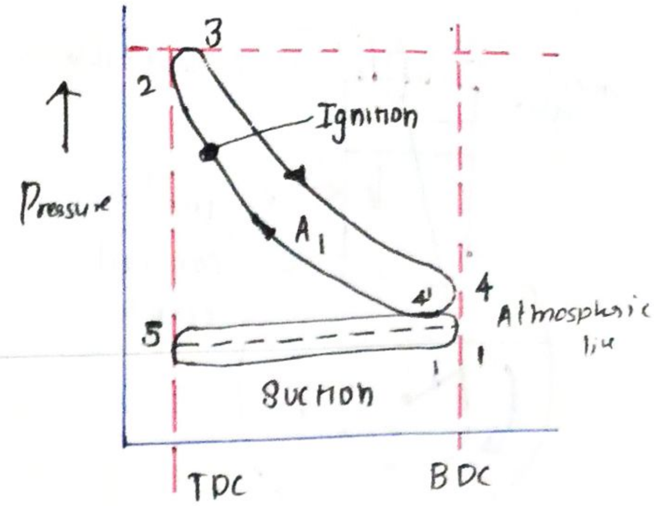
(Working Stroke)

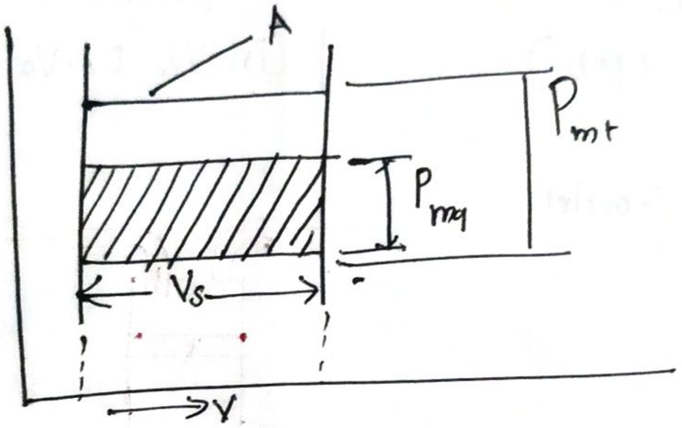


Outlet Valve open
Exhaust Stroke

Theoratical and actual PV diagram:-

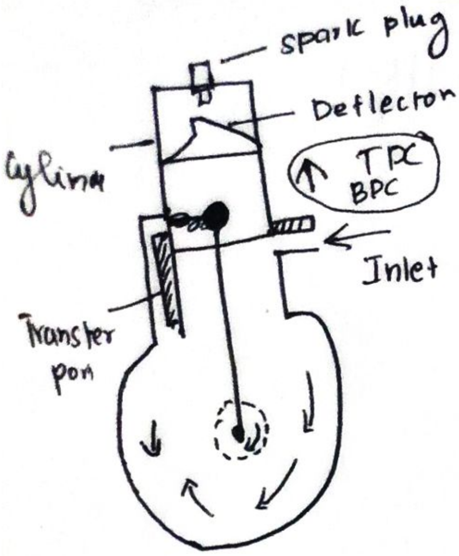






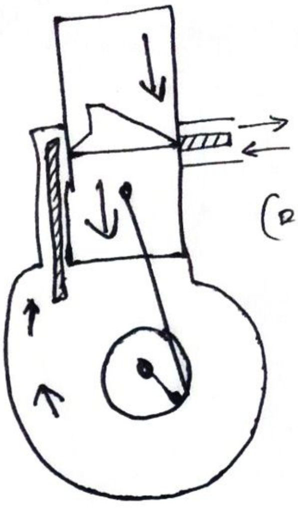
1. The suction & Exhaust take place outside the atmospheric Pressure.
2. " " " " through 180° rotation of Crank
3. Compression & Expansion " " " " " "
4. " " Isentropic
5. The Combustion take place instantaneously at Constant Volume at the end of Compression Stroke.
6. The Inlet Valve Closes beyound the state [after Combustion begins]
7. The Pressure Suddenly fall to atmosphere at the end of expansion Stroke.
8. Sudden Pressure rises after ignition is not Possible. The Pressure Increases after some crank rotation or increase in Volume.
9. Exhaust Valve open little before the end of the expansion stroke.
10. Burened gas can be Pushed out into atmosphere only if the Pressure of Exhaust gas is above atmospheric level.

2 Stroce petrol



(a)

I Suction



b

both are closed condition

(1) Suction:-

- piston move TDC to BdC
- Inlet port closed.
- transfer port & Exhaust port open
- Fresh air & fuel enter into cylinder

(a)

(2) Compression stage:-

- piston move Bdc to TDC
- Fresh fuel & Air enter into Crack case
- close tranfer port & Exhaust port
- After Air fuel mixture is compressed piston move upwards
- pre & temp increased at end of compre

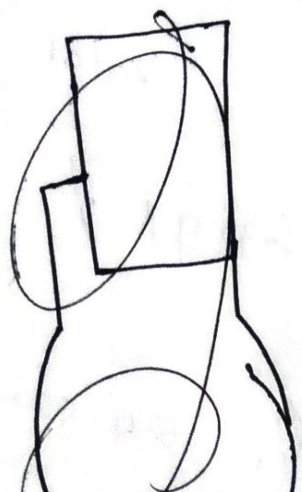
(b)

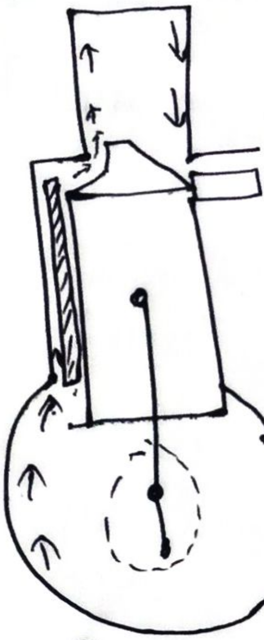
(3) Expansion stage:

- charge is Ignited with help of Spark plug
- piston pushed downwards with high force
- hot bared gases expand due to high speed of piston

(4) Exhaust stage:-

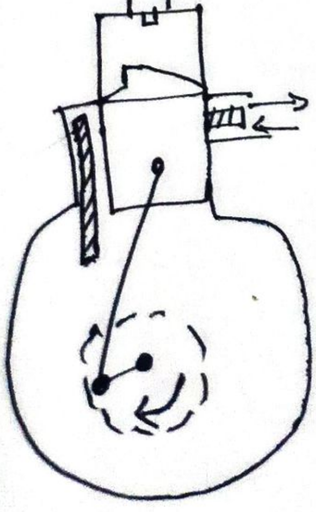
- Exhaust port is opened as the piston move downwards.
- Burent gases go out side when port is open
- Complete the cycle and start ready to suction stage.





(c)

Tranfer Port open
Exhaust port open
Suction port close.



(d)

Both are closed co...

$$\eta_{bth} = \frac{3600}{0.2387 \times 43000} \quad (43\ MJ/kg)$$

$$\boxed{\eta_{bth} \ 35.069\ \%}$$

Relative efficiency :-

$$\eta_r = \frac{\eta_{bth}}{\eta_{air}}$$

$$\eta_{air} = 1 - \frac{1}{(r_K)^{\gamma - 1}} \qquad V_s = \frac{\pi}{4} d^2 \times l$$

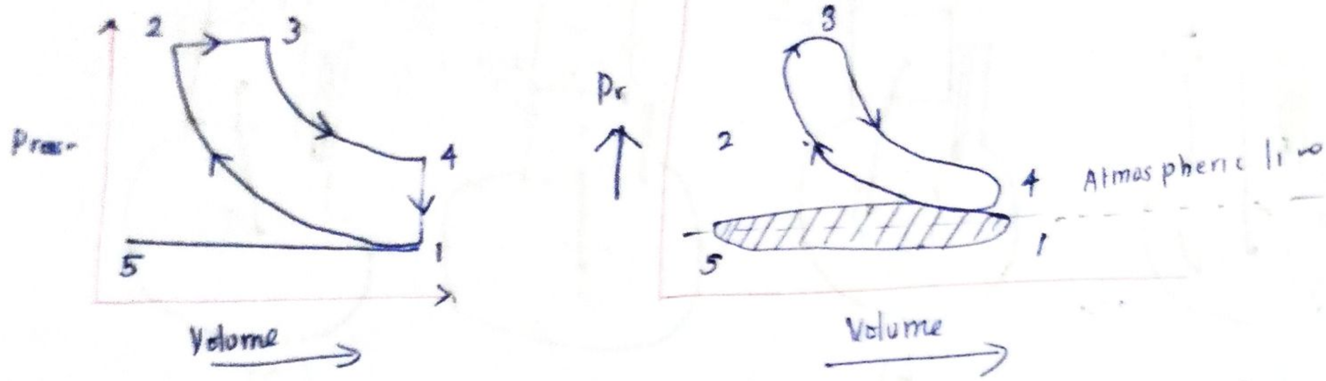
$$\pi/4\ 100^2 \times 12 = 942.478\ cm^3$$

$$r_K = \frac{V_s + V_c}{V_c} = \frac{942.478 + 80}{80} = 12.781$$

$$\eta_{air} = 1 - \frac{1}{(12.78)^{1.4-1}} = 63.911\ \%$$

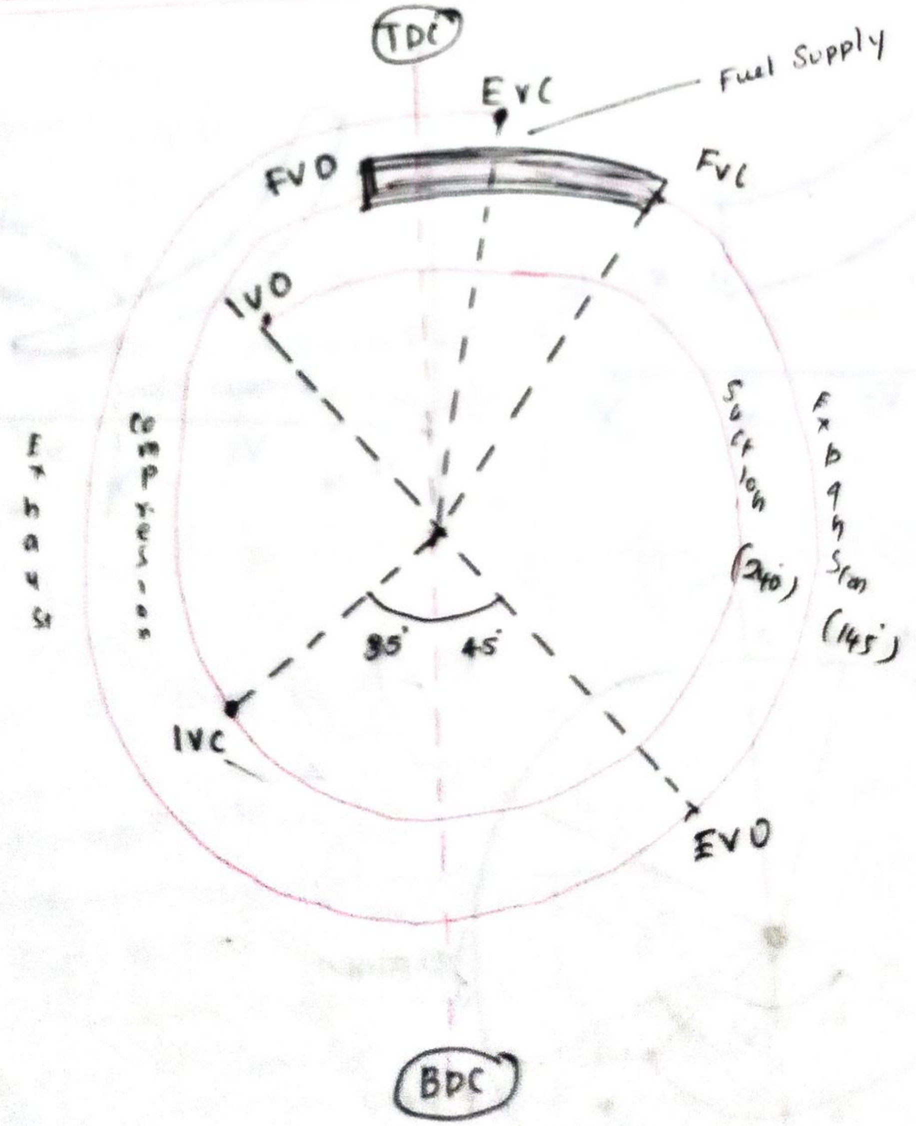
$$\eta_r = \frac{0.35069}{0.63911} \qquad \boxed{\eta_r = 54.872\ \%}$$

Theoratical and actual P V diagram

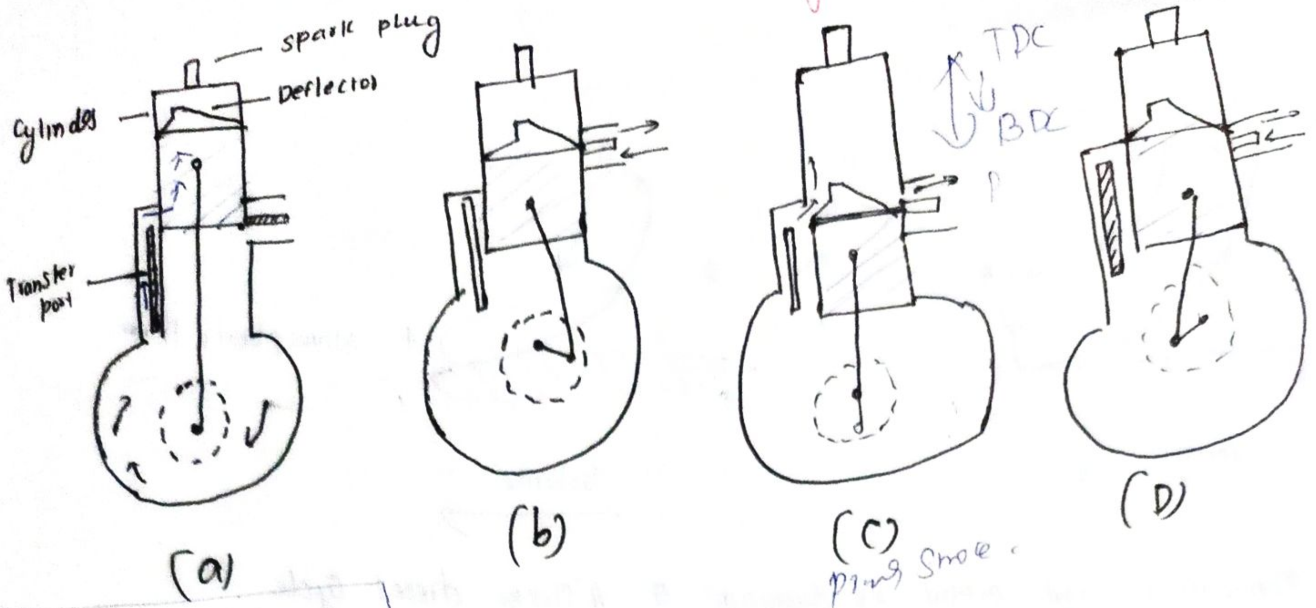


Theoratical and actual Pv diagram of 4 stroke diesel cycle

Valve timing diagram of four stroke disel engine



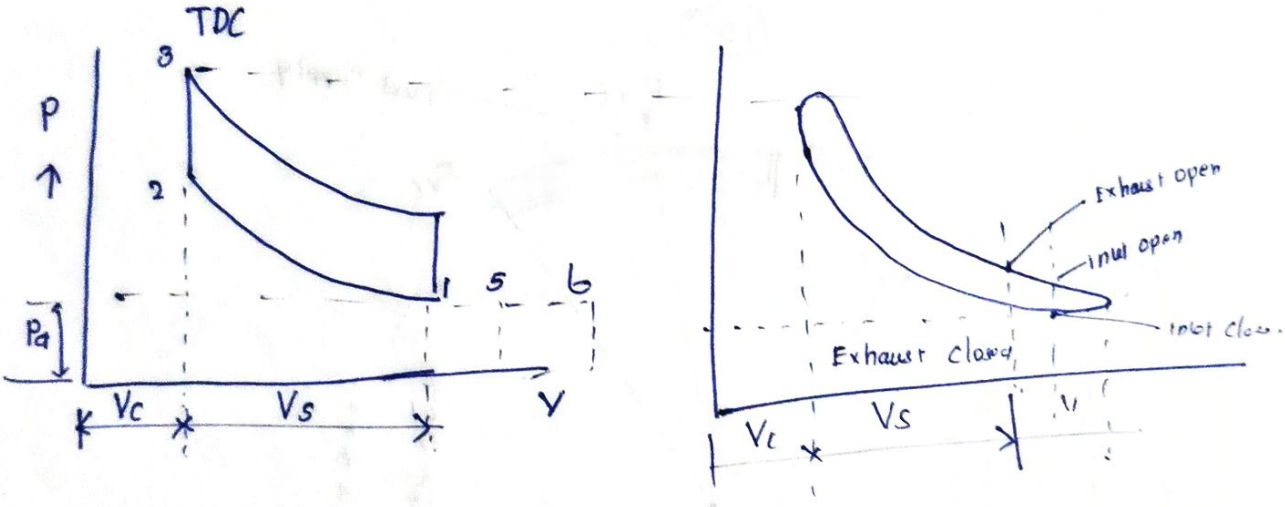
Two stroke petrol engine



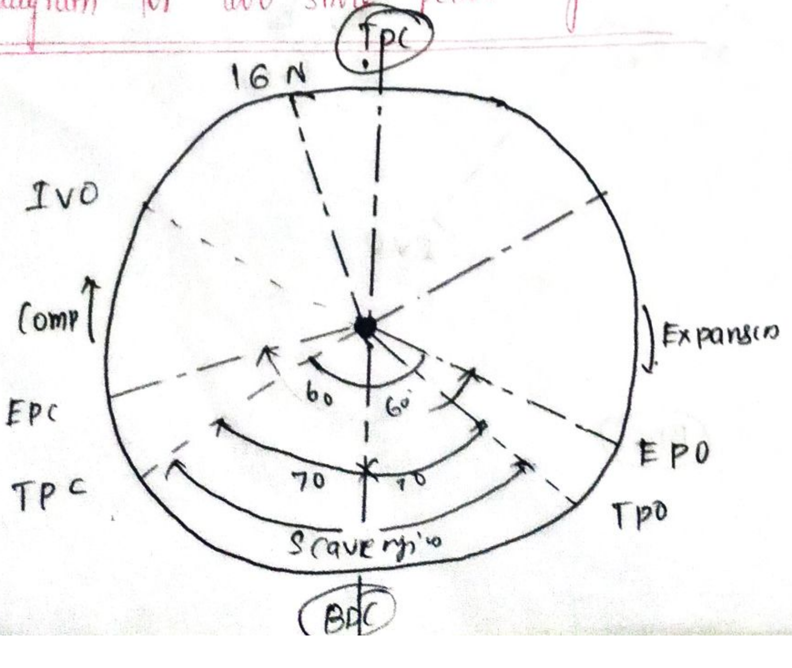
1/2 rotation
Suction & Compress – Completed.

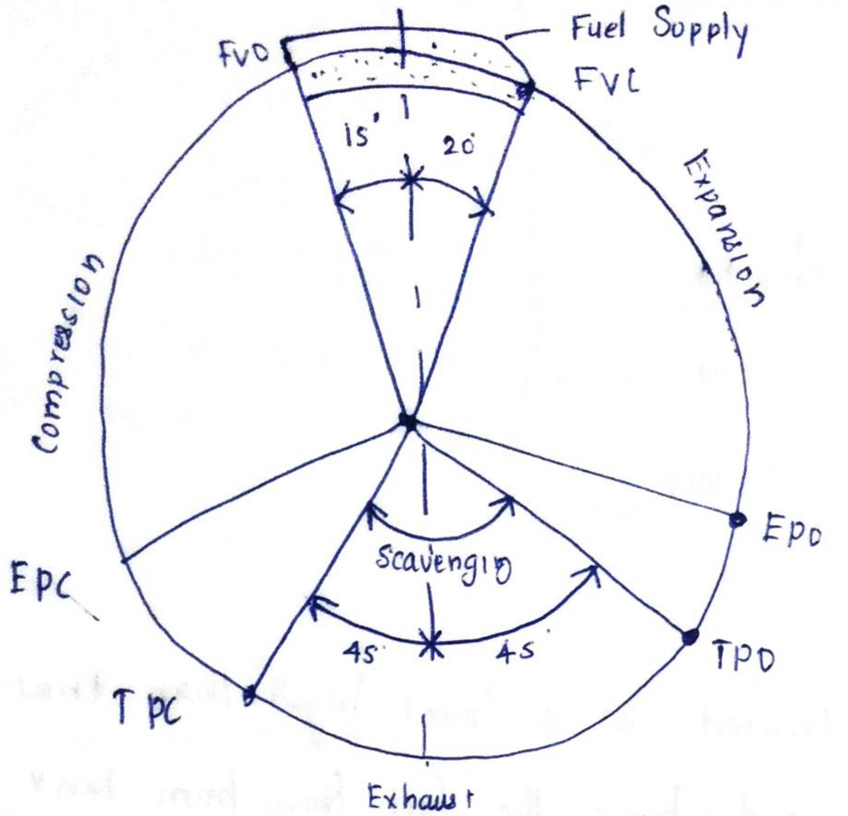
Working of two stroke petrol engine.

Theoratical and actual Pv diagram:



Port diagram for two stroke petrol engine





1. Inlet
2. Exhaust
3. Transfer
4. Ignition

Port timing diagram for two stroke diesel Engine

Two Stroke	Four stroke
Thermodynamic cycle completed in two stroke of the piston or in one revolution of the crank	two revolution of the crank
Turning moment is more uniform and hence lighter flywheel can be used	non uniform and hence heavier flywheel is needed
Engine is easier to start	Engine is difficult to start
High rate of wear & tear	Low rate of wear & tear
Low volumetric efficiency	High volumetric efficiency
Initial cost is low	High
Maintenance is simple	difficult

Fuel Supply System

Fuel system in SI Engines:

(i) Gravity system

(ii) Pressure System

Gravity System:-

• fuel tank is located at a level higer than that of the engine Cylinder and hence the fuel flow from tank to engine Cylinder under gravitational force.

Pressure System:-

tank is located below the engine Cylinder and hence, the fuel is forced or Pumped from tank to engine cylinder by means of external Source such as feed Pump

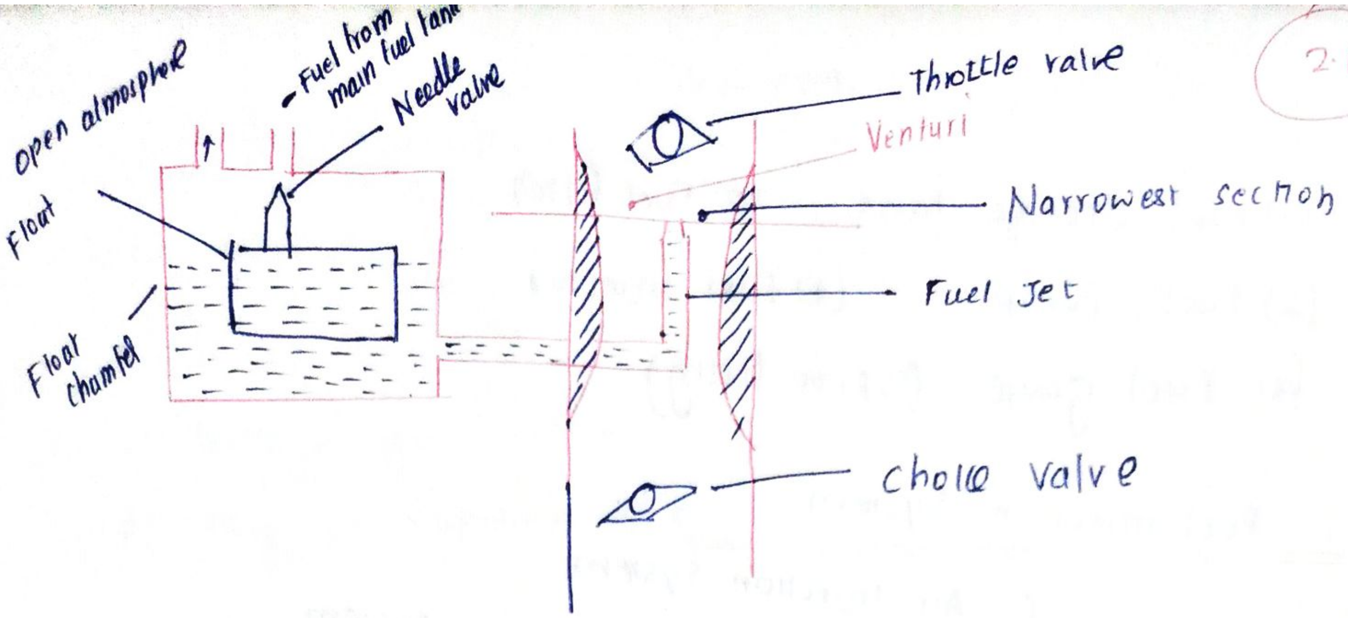
(a) Fuel storage tank

(b) fuel Pump

(c) Fuel filter

(d) Carburetor

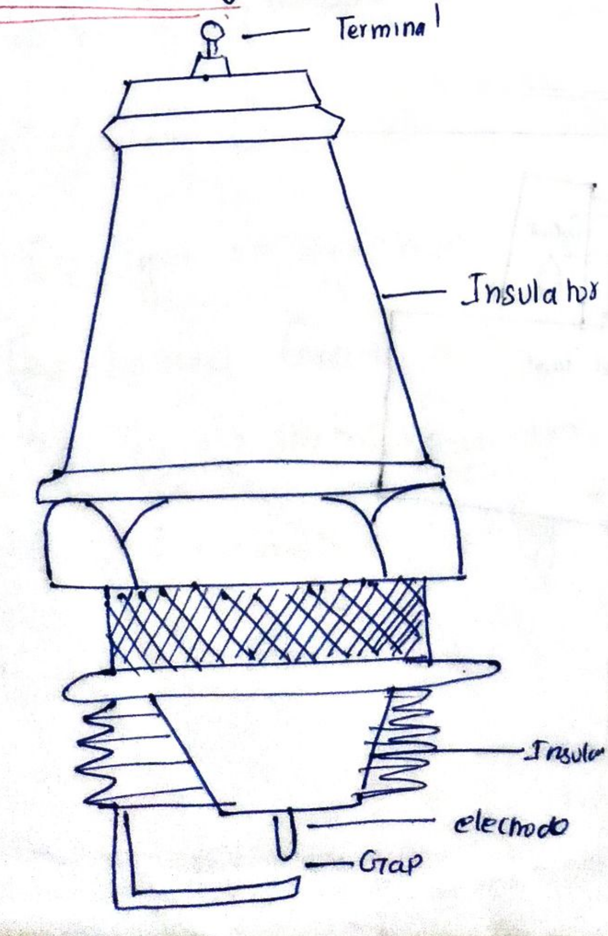
(e) inlet Manifold.



Simple Carburettor

(1) Float and Float chamber
(2) Venturi
(3) Throttle Valve
(4) Choke Valve
(5) Fuel Nozzle

Spark plug:



Fuel Supply in C.I engines:

(1) Fuel Storage tank (2) Fuel filter

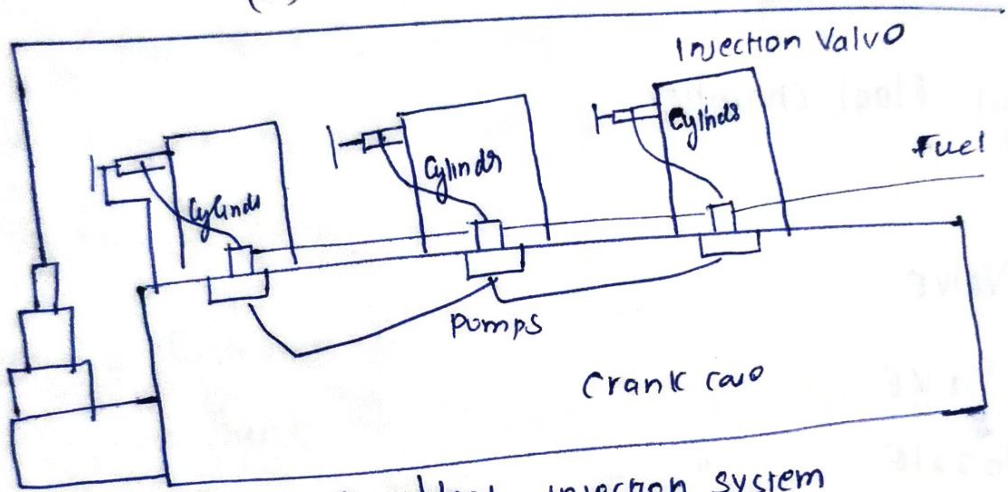
(3) Fuel Pump (4) Fuel injector

(5) Fuel gauge (6) pipe fitting)

Fuel injection System

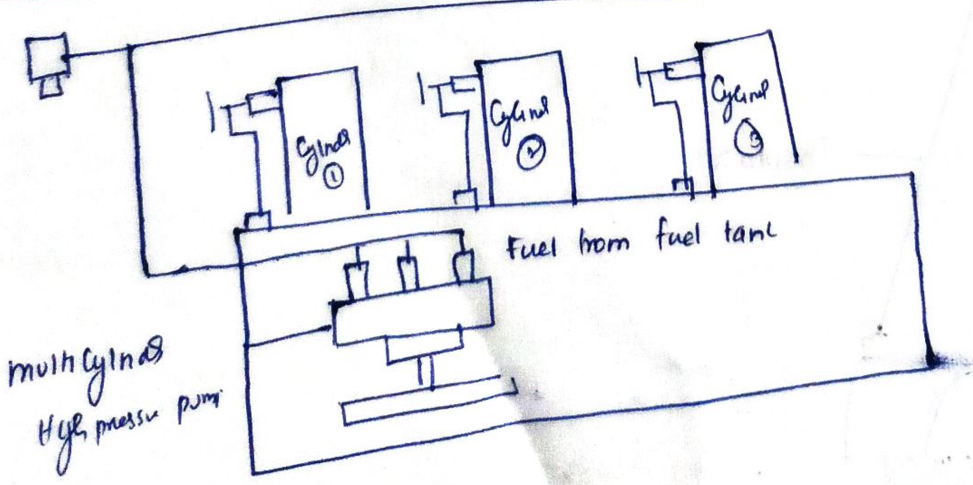
(1) Air injection system

(2) Airless or solid injection system



Air blast injection system

Common rail system



Component of Solid fuel injection Systems:-

(1) Fuel pump

(ii) Fuel atomiser or injector

Ignition System:

(i) Battery ignition system

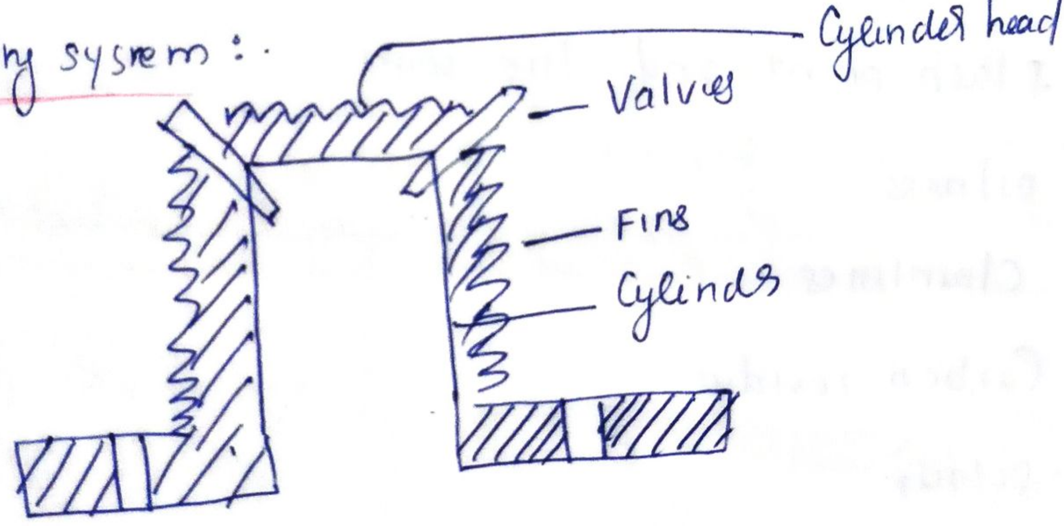
(2) Magneto ignition system

Cooling system:-

(i) Air Cooling system

(ii) Water Cooling system

Air Cooling system:-



Water Cooling system:-

(1) Thermo syphon System

(2) Forced Circulation

(3) Thermo static regulator system

(4) Evaporative cooling system

Lubricating System :-

• Lubrication is the admittance of oil b/w two surfaces having relative motion.

• Lubrication is required to reduce the klear of the parts earlier and to carry out the part of the heat generated inside the engine.

Properties of lubrication oil :

1. Viscosity
2. Viscosity index
3. Cloud point and Pour point
4. Flash point and fire point
5. oilness
6. Cleanlines
7. Carbon residue
8. Colour.

Types of lubrication system :

(1) Wet sump lubrication

(2) Dry sump lubrication

(3) Mist lubrication

Fuels :-

The Performance of an I.C engine is satisfactory only when the properties of fuel used is good and hence the fundamental knowledge of type of fuel and their characteristic is essential.

Requirements of fuel:

1. high energy density
2. Easy to handle and store
3. High thermal stability
4. low toxility
5. Easy Availability
6. low deposit forming tendency
7. Good Combustion Quality

Types of fuel

(i) Gaseous fuel
(ii) liquid fuel

Knocking and detonation

Combustion stages in S.I engine

(1) Delay period
(2) Combustion
(3) buring

Factors affecting the ignition lag:

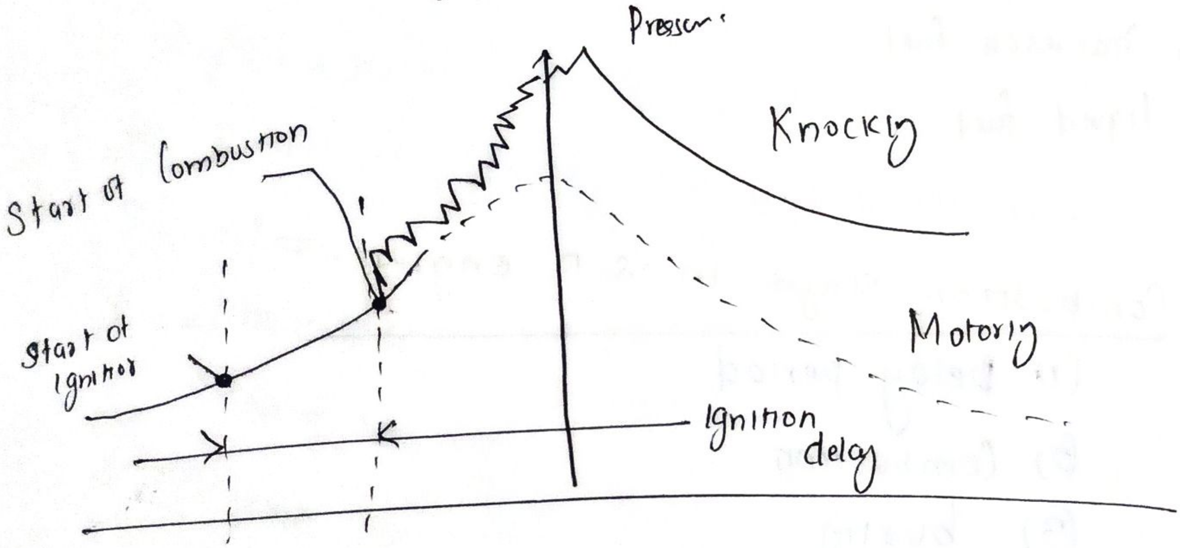
(i) ~~Ignition~~ Initial Pressure & temp
(2) Compression ratio
(3) Speed or turbulence of the engine
(4) Chemical nature of fuel A:F ratio

Combustion stage in C.I engine:

(i) Ignition delay period
(ii) Rapid or un Controlled Combustion period
(iii) Controlled combustion Period
(iv) bur·

Diesel Knock:

- In Compression ignition engine ~~Compression~~ Combustion Process leads to Smooth Pressure rise.
- For abnormal Combustion, the ignition delay Period of the fuel is quite long.
- When ignition begins, the fuel start burning and Can Cause high rapid rate of Pressure rise.



Air fuel ratio Calculations:

$$u_1 + P_1 V_1 + \frac{C_1^2}{2} + Q = P_2 V_2 + \frac{C_2^2}{2} + W + u_2 \quad \text{--- (1)}$$

$$h = u + PV_s \quad \text{--- (2)}$$

From (1) & (2)

$$h_1 + \frac{C_1^2}{2} + Q = h_2 + \frac{C_2^2}{2} + W$$

Assuming adiabatic flow, we have

$Q = 0$ and initial Velocity at the Nozzle i/p $C_1 = 0$

$$\therefore C_2^2 = 2(h_1 - h_2)$$

$$C_2 = \sqrt{2(h_1 - h_2)} \quad \text{——— (3)}$$

We know that

$$h = C_p T$$

$$\therefore h_1 - h_2 = C_p (T_1 - T_2) \quad \text{——— (4)}$$

For isentropic flow

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$T_2 = T_1 \left[P_2/P_1\right]^{\gamma-1/\gamma}$$

Sub (5) in (4) We get

$$h_1 - h_2 = C_p T_1 \left[1 - \left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}}\right] \quad \text{——— (6)}$$

sub 6 in 3 We get

$$C_2 = \sqrt{2 C_p T_1 \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{1}}\right]}$$

hence the above equation becomes

$$C_2 \sqrt{\frac{2\gamma}{\gamma-1} R T_1 \left[1 - (P_2/P_1)^{\frac{\gamma-1}{\gamma}}\right]} \quad \left[\because c_p \left(\frac{\gamma}{\gamma-1}\right.\right.$$

Theoratical Mass flow of air

$$m_a = \rho_1 A_1 C_1 = \rho_2 A_2 C_2$$

We Know that

The theoratical Mass flow rate of air

$$m_a = \rho_1 A C_1 = \rho_2 A_2 C_2 \quad \text{--- (8)}$$

A_1 & A_2 - Cross sectional area of inlet & Venturi throat

For Isentropic law

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$\frac{P_1}{\rho_1^{\gamma}} = \frac{P_2}{\rho_2^{\gamma}}$$

$$\frac{\rho_2^{\gamma}}{\rho_1^{\gamma}} = \frac{P_2}{P_1}$$

$$\rho_2 = \rho_1 \left(P_2/P_1\right)^{1/\gamma} \quad \text{--- (9)}$$

From equation 7 8 9

$$m_a = \rho_1 \left(\frac{P_2}{P_1}\right)^{1/\gamma} A_2 \sqrt{\frac{2\gamma}{\gamma-1} R T_1 \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right]}$$

$$= \frac{P_1}{RT_1} \left[\frac{P_2}{P_1}\right]^{1/\gamma} A_2 \sqrt{\frac{2\gamma}{\gamma-1} R T_1 \left[1 - \left(P_2/P_1\right)^{\frac{\gamma-1}{\gamma}}\right]}$$

$$= A_2 \cdot \frac{P_1}{RT_1} \sqrt{\frac{2\gamma}{\gamma-1} R \left[\left(\frac{P_2}{P_1}\right)^{2/\gamma} - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma+1}{\gamma}}\right]}$$

$$m_a = A_2 \cdot \frac{P_1}{\sqrt{RT_1}} \sqrt{\frac{2\gamma}{\gamma-1} \left[\left(P_2/P_1\right)^{2/\gamma} - \left(\frac{P_2}{P_1}\right)^{\gamma+1/\gamma}\right]} \quad \text{--- (10)}$$

We Know that air $\gamma = 1.4$ & $R = 0.287$ kJ/kg K

$$\therefore m_a = A_2 \frac{P_1}{\sqrt{0.287 \times 10^3 \times T_1}} \sqrt{\frac{2 \times 1.4}{1.4-1}\left[\left(\frac{P_2}{P_1}\right)^{2/1.4} - \left(\frac{P_2}{P_1}\right)^{\frac{1.4+1}{1.4}}\right]}$$

$$A_2 = \frac{P_1}{16.94\sqrt{T_1}} \sqrt{7\left[\left(P_2/P_1\right)^{1.43} - \left(\frac{P_2}{P_1}\right)^{1.72}\right]}$$

$$A_2 = \frac{\sqrt{7} \cdot P_1}{16.94\sqrt{T_1}} \sqrt{\left(\frac{P_2}{P_1}\right)^{1.43} - \left(\frac{P_2}{P_1}\right)^{1.72}}$$

$$m_a = 0.1562 A_2 \frac{P_1}{\sqrt{T_1}} \sqrt{\left(\frac{P_2}{P_1}\right)^{1.43} - \left(\frac{P_2}{P_1}\right)^{1.72}}$$

$$= \phi \left(\frac{P_1}{\sqrt{T_1}}\right) \times 0.1562 A_2 \quad \cdots (11)$$

$$\phi_1 = \sqrt{\left(\frac{P_2}{P_1}\right)^{1.4} - \left(\frac{P_2}{P_1}\right)^{1.72}}$$

P = Pressure in N/m^2

A = area in m^2

T = temperature in K

The actual mass flow rate

$$m_{act} = C_d \times 0.1562 A_2 \frac{P_1}{\sqrt{T_1}} \phi_1$$

$$m_{act} \propto \frac{P_1}{\sqrt{T_1}} \phi_1$$

Theoratical Mass flow rate of fuel is

$$m_f = \rho_f A_f C_f \quad \text{---} \quad (13)$$

Applying Bernoullis equation for section 1-1 & 2-2

$$\frac{P_1}{\rho_f} - \frac{P_2}{\rho_f} = \frac{C_f^2}{2} + 2g$$

ρ_f, and C_f are the density and Velosity fuel respectively

$$\therefore C_f^2 = 2\left[\frac{(P_1 - P_2)}{\rho_f} - 2g\right]$$

$$C_f = \sqrt{2\left[\frac{(P_1 - P_2)}{\rho_f} - 2g\right]}$$

$$m_f = \rho_f A_f \sqrt{2\left[\frac{(P_1 - P_2)}{\rho_f} - 2g\right]} = A_f \sqrt{2\rho_f^2\left[\frac{P_1 - P_2}{\rho_f}\right] - 2g}$$

$$m_f = 1.414\, A_f \sqrt{\rho_f^2\left[\frac{P_1 - P_2}{\rho_f}\right] - 2g}$$

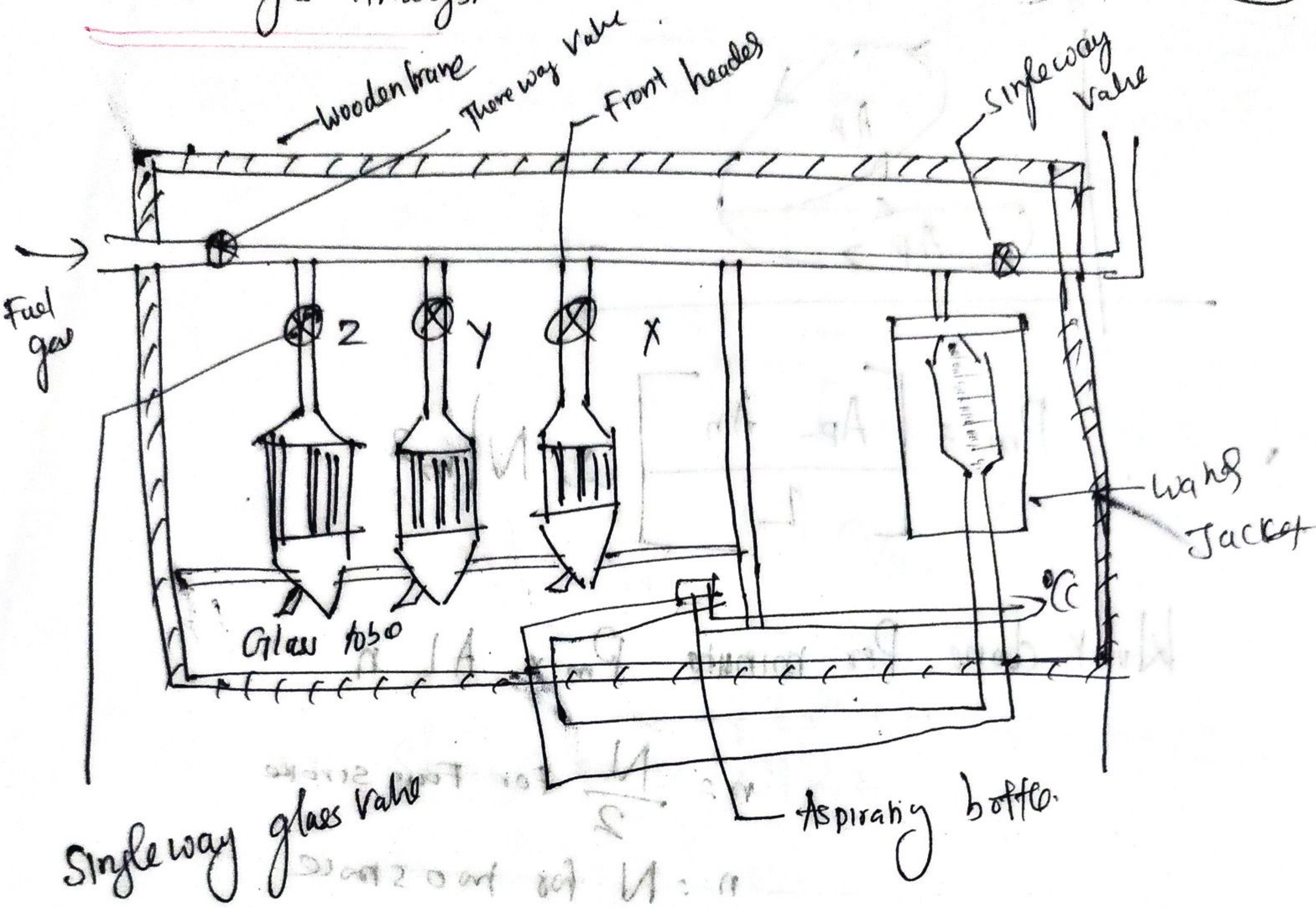
$$m_f = 1.414\, A_f \sqrt{\rho_f (P_1 - P_2) - 2g\rho_f} \quad \text{---} \quad (14)$$

The actual Mass flow rate

$$C_{df}\, 1.414\, A_f \sqrt{\rho_f (P_1 - P_2) - 2g\rho_f}$$

2.19

Exhaust gas Analysis



Performance Calculation:

Power developed by various Method listed below

(1) Indicated Power

(2) Brake power

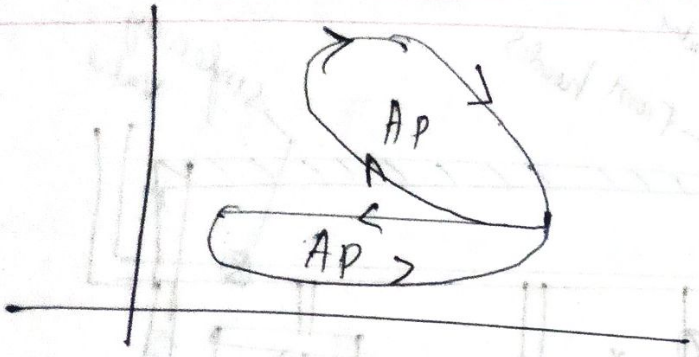
(3) BMEP

(4) Friction Power (F.P)

Ip =

$$Ip = \frac{K P_m L A n}{60} \, KW$$

...ment of Indicated Power :



$$P_m = \left[\frac{A_p - A_n}{L}\right] S, N/m^2$$

Work done per minute $P_m \times A L n$

$n = \frac{N}{2}$ for four stroke

$n = N$ for two stroke

$$I.P.K = \frac{K P_m A L N}{60} \text{ KW}$$

2.19

$$A:F = \frac{m_{act}}{m_{fuel}} = \frac{0.1562\, A_2\, C_{da}\, \frac{P_1}{\sqrt{T_1}}\, Q1}{1.414\, A_f\, C_{df} \sqrt{P_f (P_1 - P_2) - 2gP_f}}$$

$$0.11\, \frac{A_2}{A_f}\, \frac{C_{da}}{C_{df}}\, \frac{P_1 \sqrt{\left(\frac{P_2}{P_1}\right)^{1.43} - \left(\frac{P_2}{P_1}\right)^{1.72}}}{\sqrt{T_1} \sqrt{P_f (P_1 - P_2) - 2gP_f}}$$

$$A:F = 0.11\, \frac{A_2}{A_f}\, \frac{C_{da}}{C_{df}}\, P_1 \frac{\sqrt{\left(P_2/P_1\right)^{1.43} - \left(\frac{P_2}{P_1}\right)^{1.72}}}{\sqrt{(P_f (P_1 - P_2)\, 2gP_f)T_1}}$$

Pressure Should be in N/m^2

Morse test

For all Cylinder Operative

$$(B.P)_n = (I.P)_n - (F.P)_n$$

When one Cylinder is in operative

$$(B.P)_{n-1} = (I.P)_{n-1} - (F.P)_{n-1}$$

$$(B.P)_n - (B.P)_{n-1} = (I.P)_n - (I.P)_{n-1} = (I.P)_1$$

B.P = Brake power

I.P = Indicated power

F.P = friction power.

Brake Power (B.P)

$$B.P = \frac{2\pi NT}{60 \times 1000} \text{ Kw}$$

N - Engine Speed in rpm T- Torque in N-m

Measurement of Brake power :-

(1) Rope brake dynamometer

(2) Prony brake dynamometer

(3) Hydraulic dynamometer

IMEP

$$P_m = \frac{\text{Work done per Cycle}}{\text{Stroke Volume}}$$

IMEP

(1) Equivalent rectangular Method

Mid ordinate Method

plain meter Measurement

Measurement of fuel Consumption :

$$\text{Fuel Consumption} = \frac{V \times \rho_{fuel}}{t}, \text{ Kg/sec}$$

where t - time taken, sec

Measurement of Air Consumption:.

Head of Air

$$h_a \times \rho_a = h_w \times \rho_w$$

$$h_a = h_w \times \frac{\rho_w}{\rho_a}, m$$

$$h_a = \frac{1000 h_w}{\rho_a} \text{ in m}$$

Velocity of Air Passing through the orifice

$$C_a = \sqrt{2gh_a} = \sqrt{2 \times 9.81 \frac{1000 h_w}{\rho_a}}$$

$$C_a = \sqrt{19620 \frac{h_w}{\rho_a}} \text{ in m/sec}$$

Mass flow rate of air

$$m \; C_d \; \rho_a \; AC_a = \rho_a \; \pi/4 \; d^2 \times c_d \times \sqrt{19620 \frac{h_w}{\rho_a}}$$

$$m = \pi/4 \; d^2 \times C_d \times \sqrt{19620 \; h_w . \rho_a}$$

$$m = 110.026 d^2 \times C_d \times \sqrt{h_w . \rho_a}$$

$$m = 6.5 \times d^2 \times C_d \times \sqrt{\frac{h_w \; P_a}{T_a}}$$

Various efficiency of an engine

1. Mechanical efficiency

$$\eta_m = \frac{B.P}{I.P} = \frac{B.P}{B.P + F.P}$$

2. Over all efficiency

$$\eta_o = \frac{B.P \times 3600}{m_f \times C.V}$$

3. Brake thermal efficiency

$$\eta_{bt} = \frac{B.P \times 3600}{m_f \times C.V}$$

4. Indicated thermal efficiency

$$\eta_{it} = \frac{I.P \times 3600}{m_f \times C.V}$$

5. Relative efficiency

$$\eta_{rel} = \frac{\eta_{it}}{\eta_{air}}$$

6. Volumetric efficiency

$$\eta_v = \frac{V_a}{V_s}$$

Where :-

Unit II formula

Ap. Area of Positive loop, m^2

An - Area of Negative loop, m^2

L - Length of the Indicator diagram, m

s - Spring scale $N/m^2/m$

Force on the piston $P_m \times A$, KN

P_m - m.e.p KPa (or) KN/m^2

A = Cross Sectional area of Piston, m^2

Work done per stroke = $P_m \times A \times L$

L = length of stroke

Work done per minute = $P_m \times A \times L \times n$

$n = \frac{N}{2}$ for Four stroke engine

$n = N$ for Two stroke engine

Work done per second $\frac{P_m \times A \times L \times n}{60}$

Indicated Power 'K' cylinder = $K P_m \frac{ALn}{60}$ kW

B.P [Brake power]

B.P N = Engine rpm

T = Torque N-m

D = Dia of flywheel

d = " of rope

S = Spring balence reading

N = rpm of the engine

T_f = frictional Torque

W = Weight

L = length or stroke.