RV College of Engineering®

Go, change the world

Department of Mechanical Engineering
RV College of Engineering®, Bengaluru – 560059

ELEMENTS OF MECHANICAL ENGINEERING

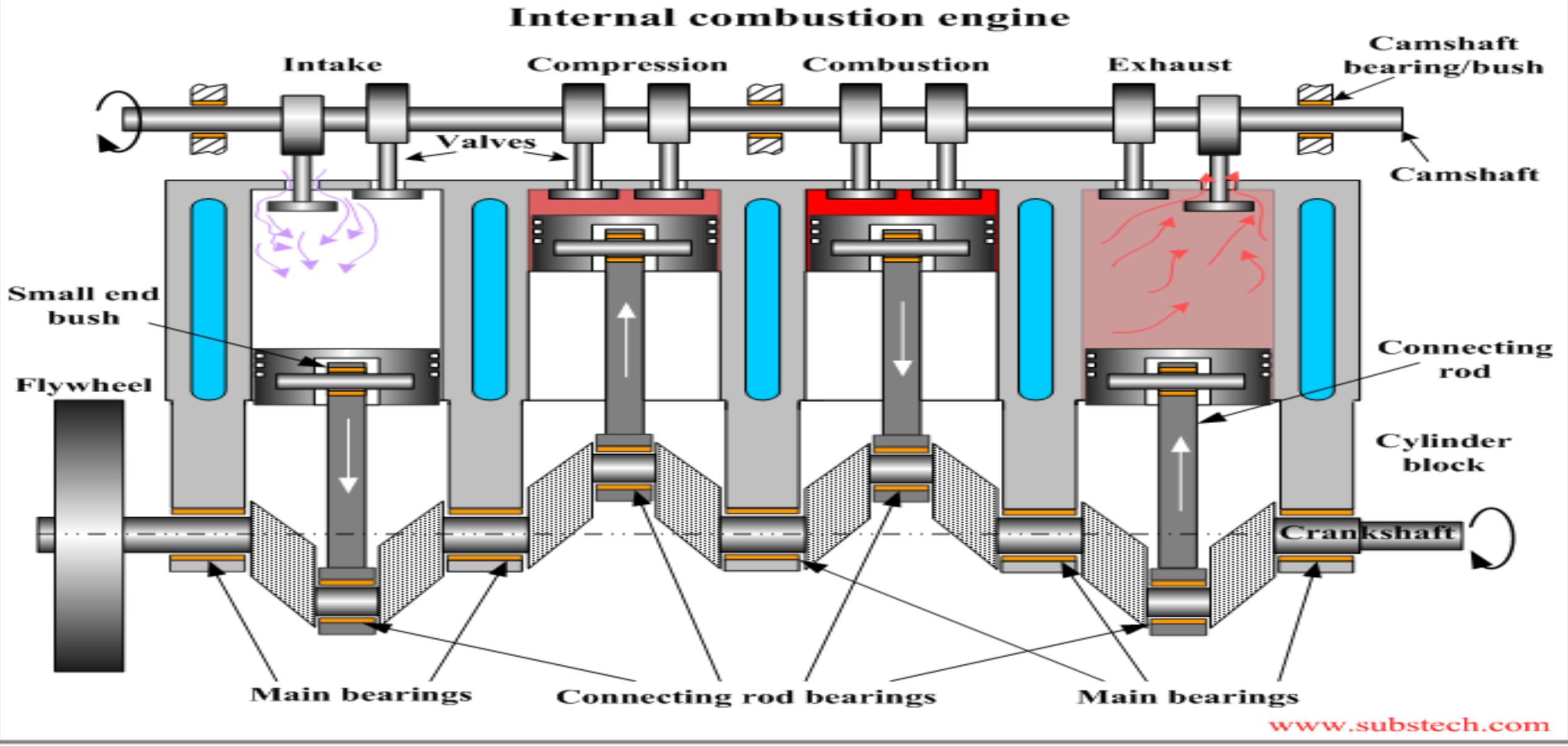
UNIT-IV
MECHANICAL & ELECTRICAL DRIVES

UNIT-IV (6 hours)

•Mechanical and Electrical Drives

•**Mechanical Drives:** Classification of IC Engines, Working of 4-S direct injection engines, Performance characteristics, Classification of gears, velocity ratio for simple and compound gear trains.

•**Electrical Drives:** History, Well to Wheel analysis, Electric vehicles, Configurations, EV/ICEV comparison, Performance, Traction Motor Characteristics, Concept of Hybrid Electric Drive Trains, Classification of hybrid electric vehicles.


Internal combustion engine
Intake
Compression
Combustion
Exhaust
Camshaft bearing/bush
Valves
Camshaft
Small end bush
Flywheel
Connecting rod
Cylinder block
Crankshaft
Main bearings
Connecting rod bearings
Main bearings
www.substech.com

Any type of engine which derives heat energy from the combustion of fuel and converts it in to mechanical work is termed as a ***heat engine.***

Heat engines may be classified in to two main types;

1)External Combustion engines (EC engines)

2)Internal combustion engines (IC engines)

In an *external combustion engine*, the combustion of fuel takes place outside the engine cylinder.

Ex: Steam engines

In an *internal combustion engine*, the combustion of fuel takes place inside the engine cylinder.

Ex: Petrol engines, Diesel engines.

ADVANTAGES OF I.C ENGINES OVER E.C ENGINES

- High efficiency:
- Simplicity
- Compactness
- Light weight
- Easy starting
- Comparatively low cost

CLASSIFICATION OF IC ENGINES:

I.C. Engines are classified according to:

1. Nature of thermodynamic cycle

- Otto cycle engine.
- Diesel engine.
- Dual combustion cycle engine.

2. Type of the Fuel used

- Petrol engine.
- Diesel engine.
- Gas engine.
- Bi-fuel engine.

3. Number of strokes

- Two stroke engine.
- Four stroke engine.

4. Type of Ignition

- Spark ignition engine, known as S.I. Engine.
- Compression ignition engine, known as C.I engine.

5. Number of Cylinder as

- Single cylinder engine.
- Multi cylinder engine.

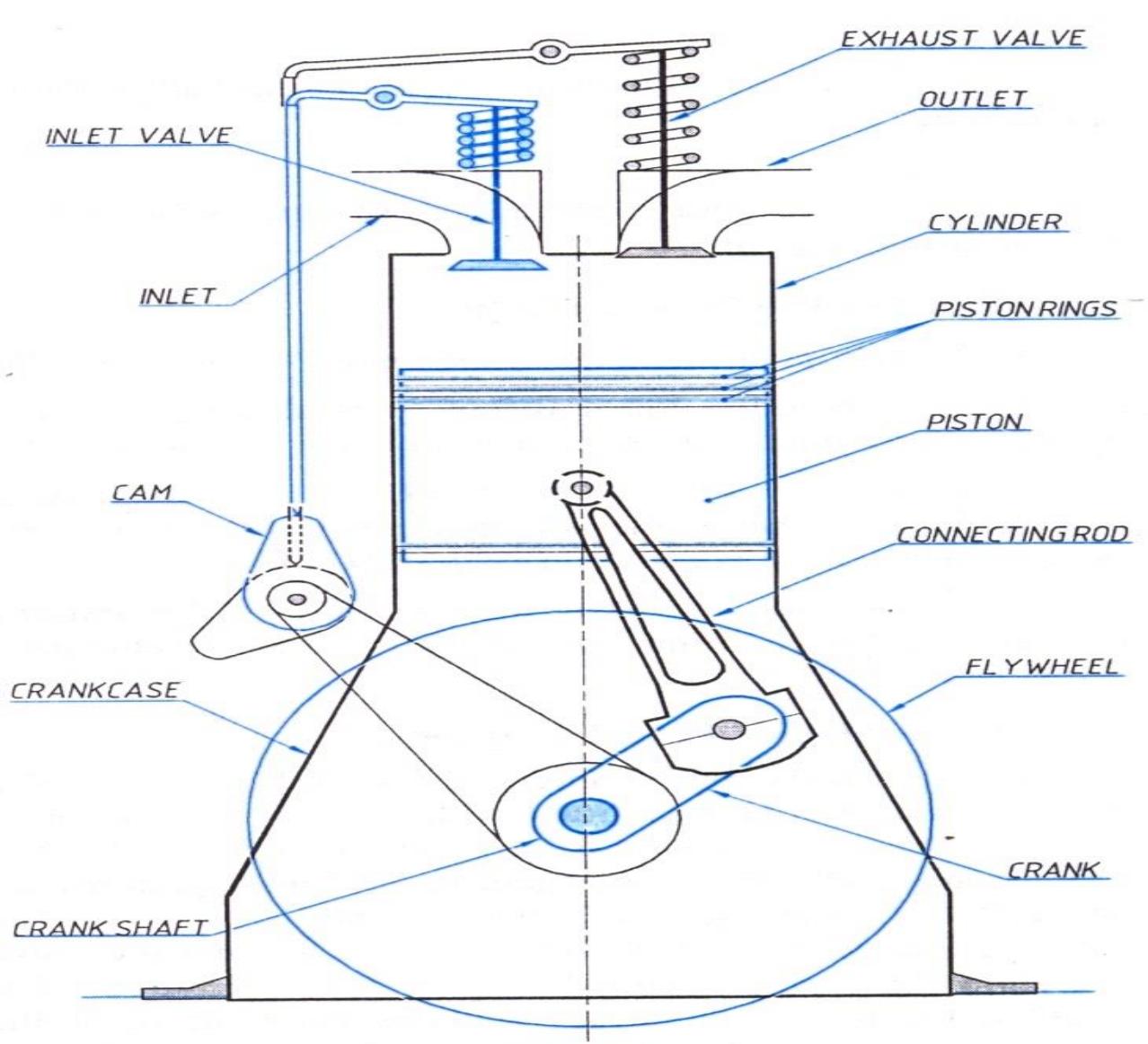
6. Position of the Cylinder

- Horizontal engine.
- Vertical engine.
- Radial engines
- In-line engines

7. Method of Cooling

- Air cooled engine.
- Water cooled engine.

PARTS OF I C ENGINE



PARTS OF I C ENGINE

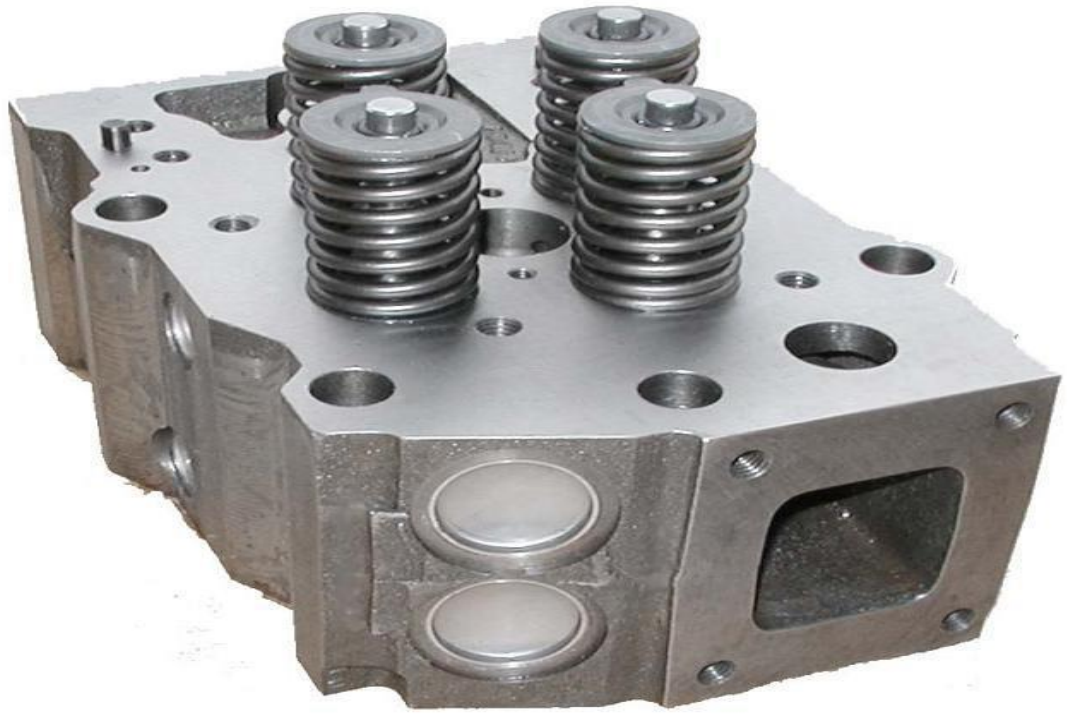
- Cylinder
- Piston
- Piston rings
- Connecting rod
- Crank and crankshaft
- Valves
- Flywheel
- crankcase

1.Cylinder:

- It is made of grey cast iron.
- Fuel is burnt inside the cylinder and power is developed by action of hot gases on the piston.

2.Cylinder head:

- One end of the cylinder is closed by means of are movable cylinder head which is made of cast iron with alloying elements such as nickel, chromium, molybdenum, etc.
- Cylinder head houses the inlet & exhaust valves.



3.Piston:

It is a close fitting hollow cylindrical plunger moving to & fro inside the cylinder.

It is made of aluminium alloys for light weight.

The power developed by the combustion of fuel is transmitted by the piston to the crankshaft through the connecting rod

4. Piston rings:

These are metallic rings made of cast iron. They are inserted in to the circumferential grooves provided at the top end of the piston. Piston rings maintain a gas tight seal between the cylinder & the piston. They also help in conducting the heat from piston to cylinder.

5.Connecting rod:

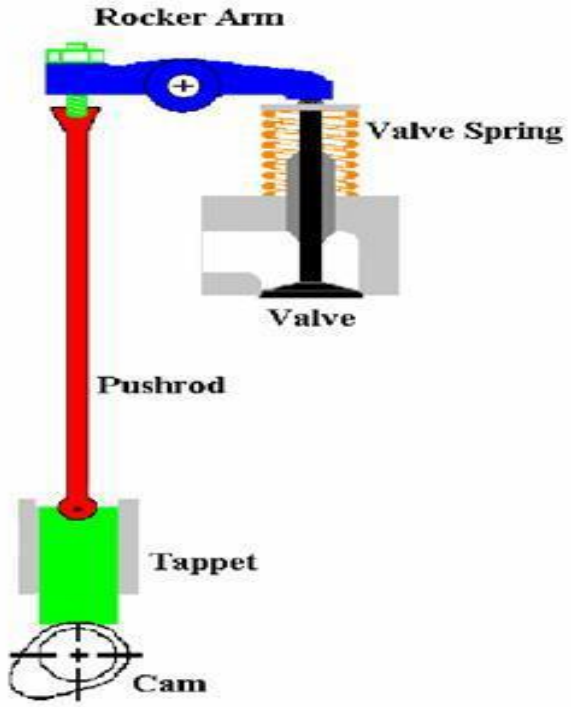
- It is the link that connects the piston and the crankshaft by means of pinjoints.
- It converts the linear motion of the piston in to rotary motion of the crankshaft.
- Connecting rods are made of alloy steels.

6.Crank & Crankshaft:

- Crank is a lever (made of carbon steel) that is connected to the end of the connecting rod by a pin joint.
- The other end of the crank is rigidly connected to a shaft known as '*crankshaft*'.
- As the connecting rod oscillates, the crank and hence the crankshaft rotate about an axis.

7.Valves:

- Valves are devices which control the flow of in take an exhaust gases to & from the cylinder.
- They are also called as '*Poppet Valves*' and are operated by means of cams driven by the crankshaft through belt or gears



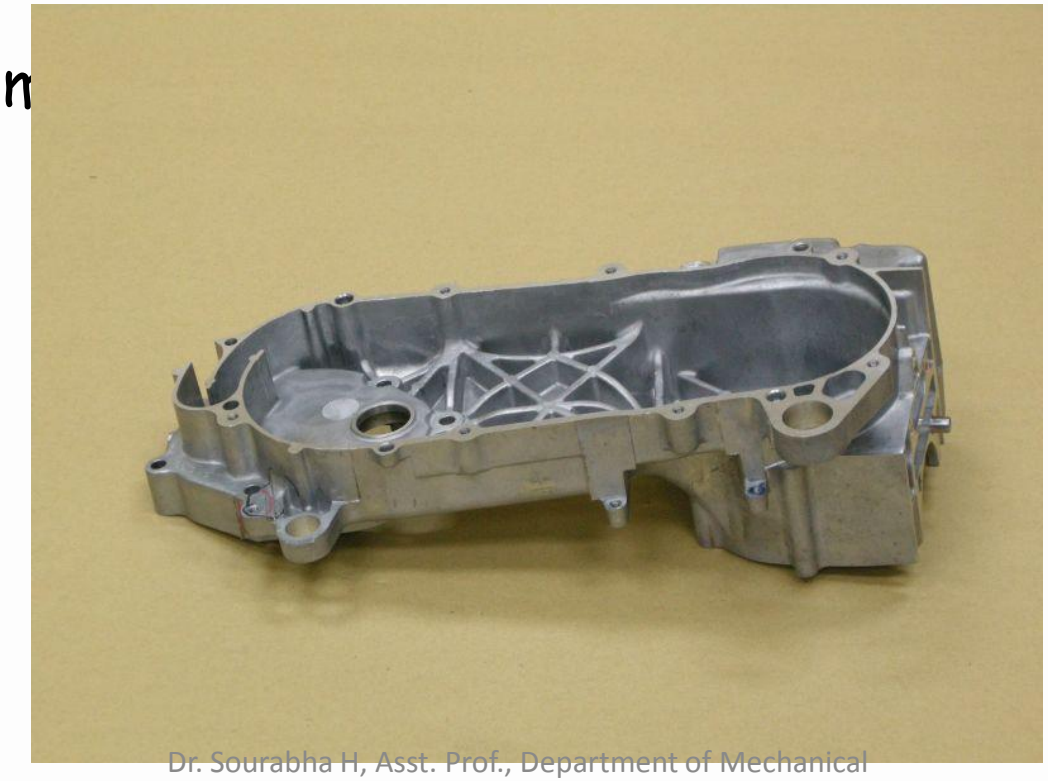
8.Flywheel:

- It is a heavy wheel mounted on the crankshaft of the engine to maintain uniform rotation of the crankshaft.
- It absorbs kinetic energy during power stroke & delivers energy during other strokes.
- Fly wheel is made of cast iron.

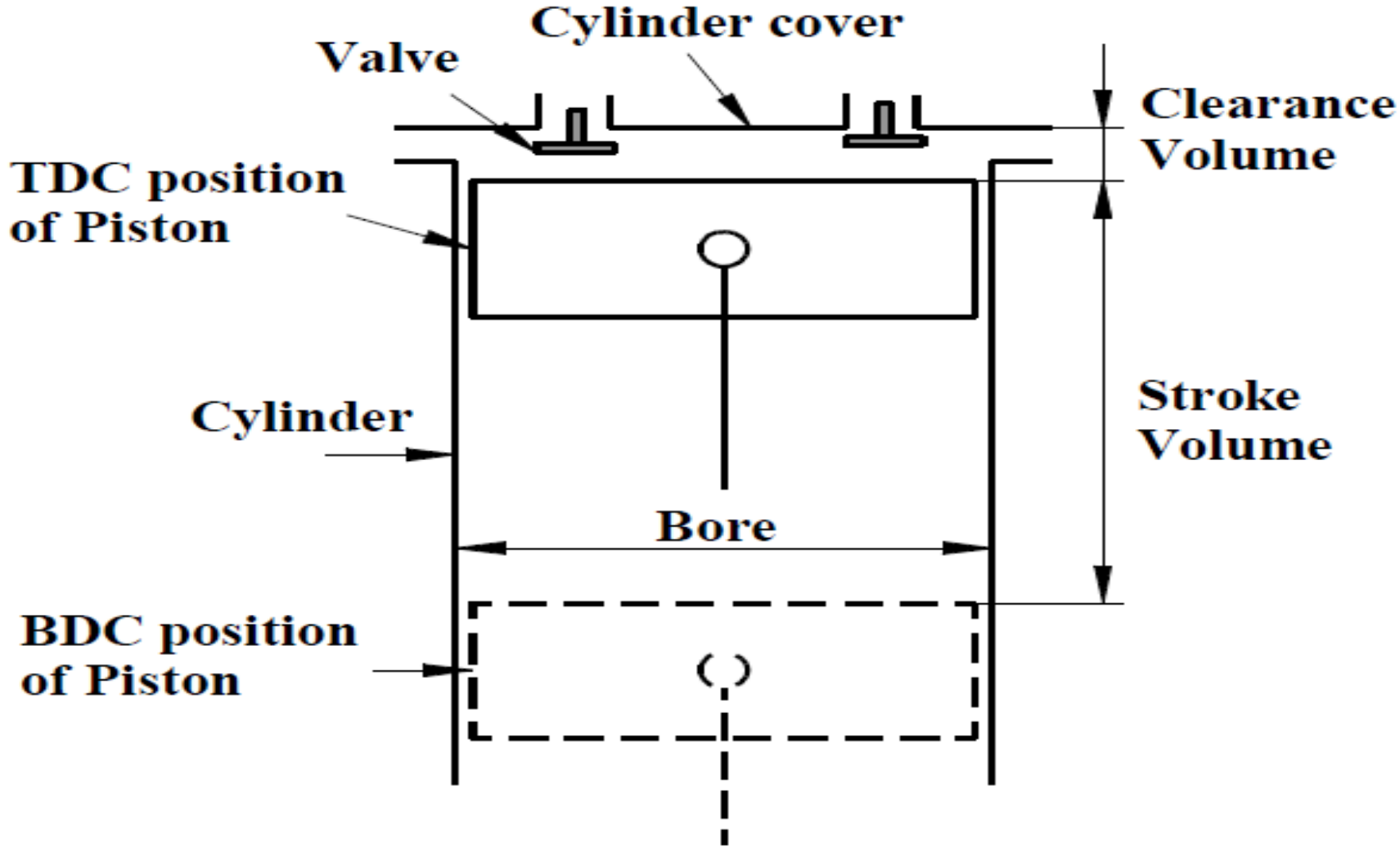
9. Crankcase:

It is the lower part of the engine serving as an enclosure for the crankshaft.

It also serves as a sum

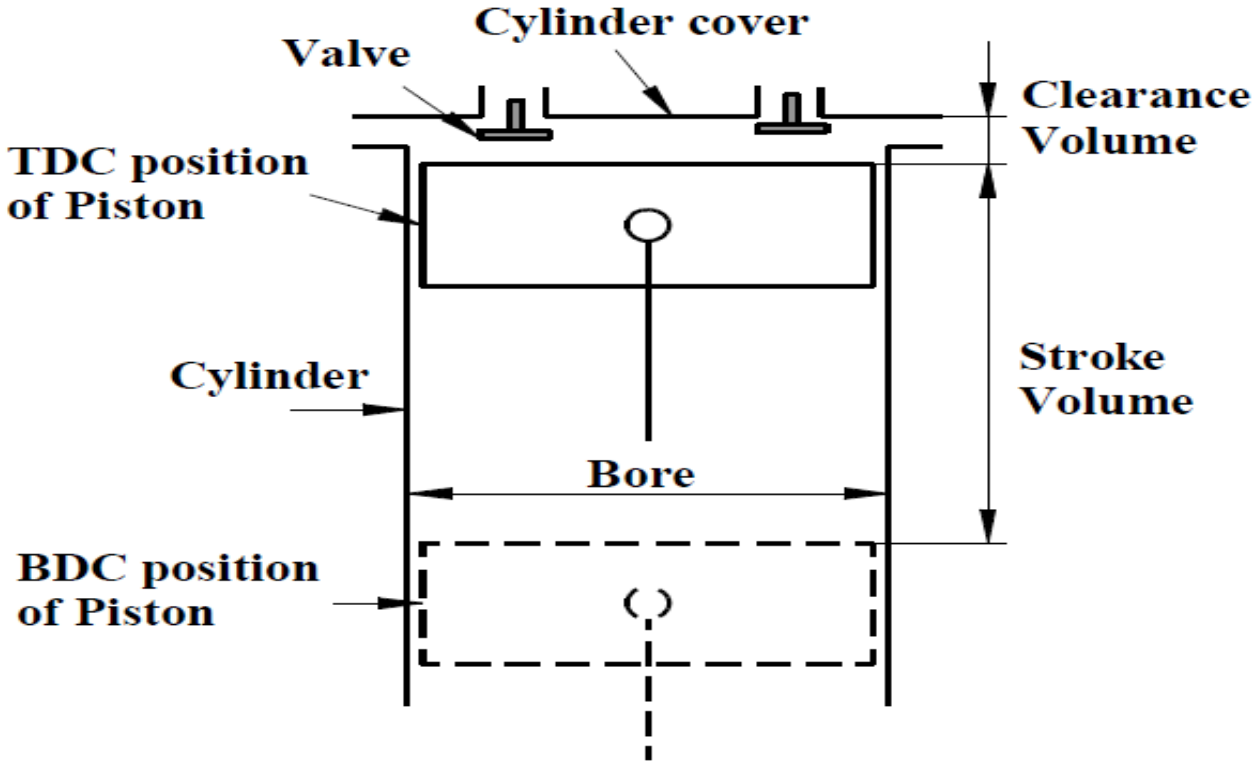


I.C ENGINE TERMINOLOGY



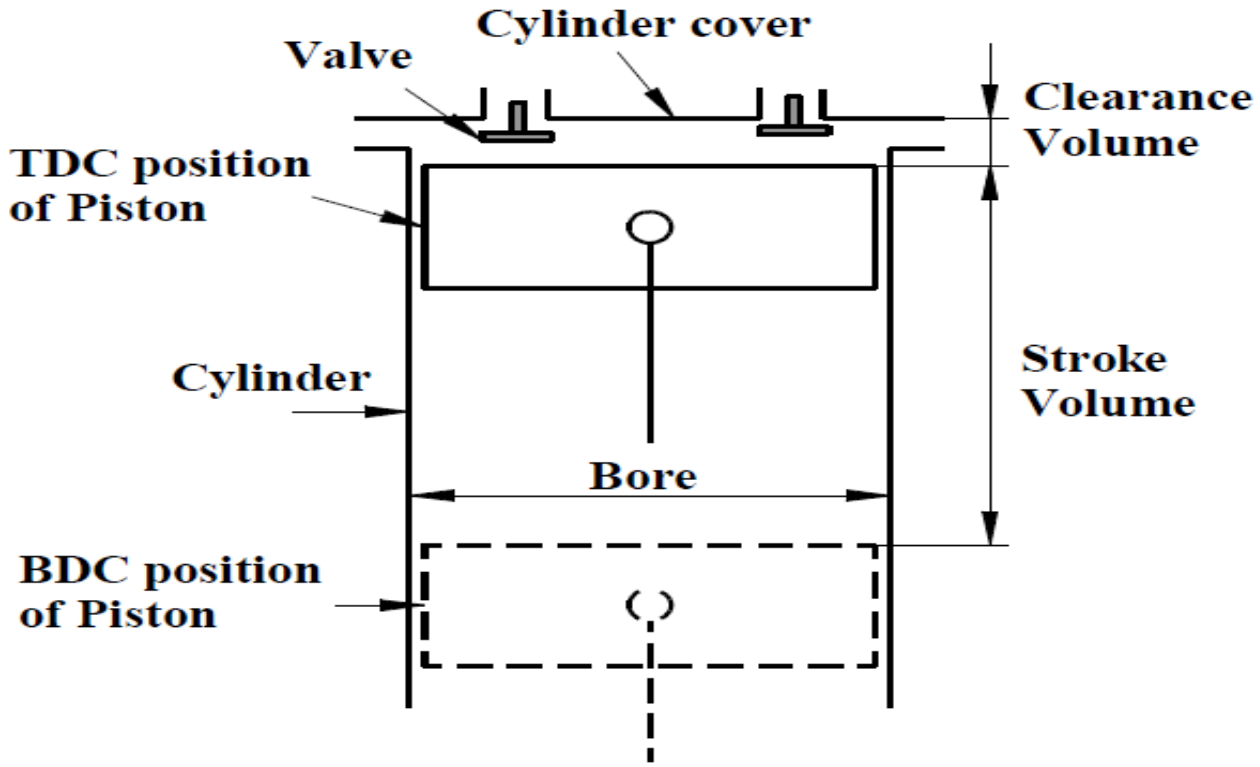
I.C ENGINE TERMINOLOGY

- **Bore**- inside diameter of the cylinder
- **crank radius- Rc** it is the linear distance between the shaft centre and crank pin centre. It is equal to half the stroke l



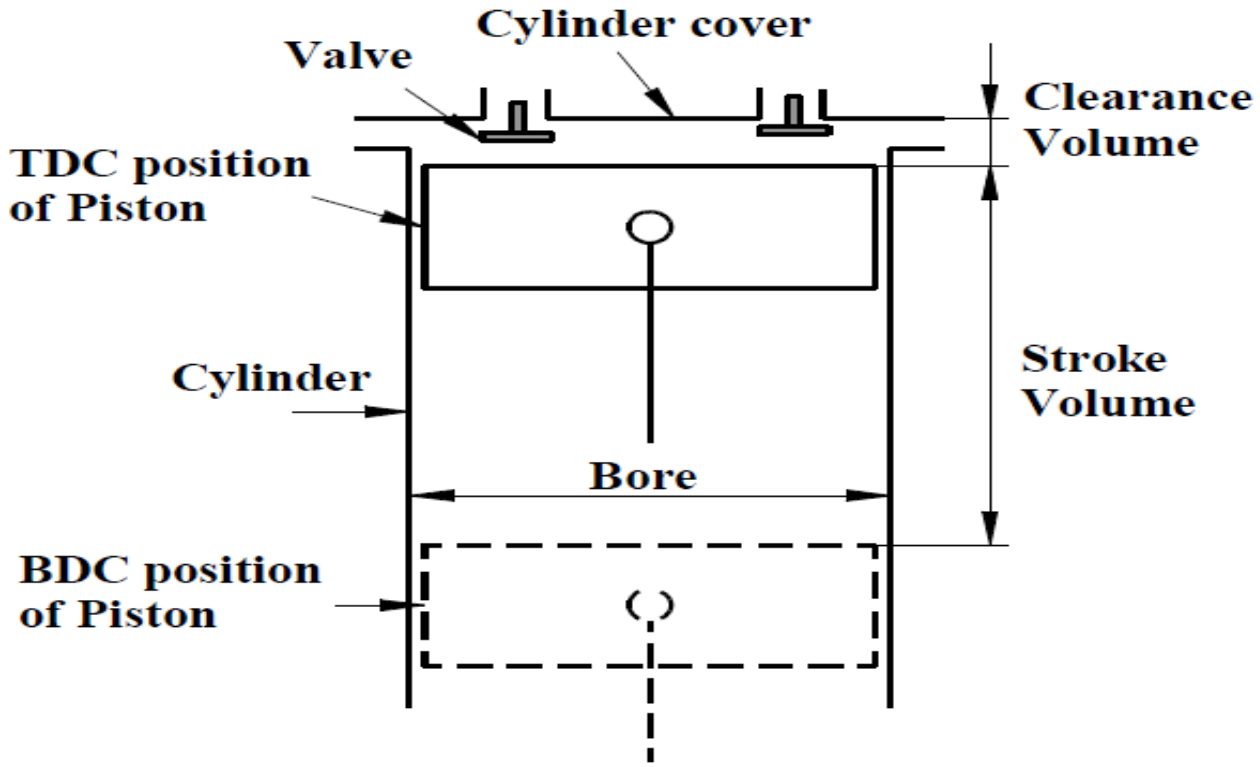
I.C ENGINE TERMINOLOGY

Top Dead centre / inner dead centre - it is the extreme position of the piston towards cover end side of the cylinder. The crank pin comes between the piston and the crankshaft.



I.C ENGINE TERMINOLOGY

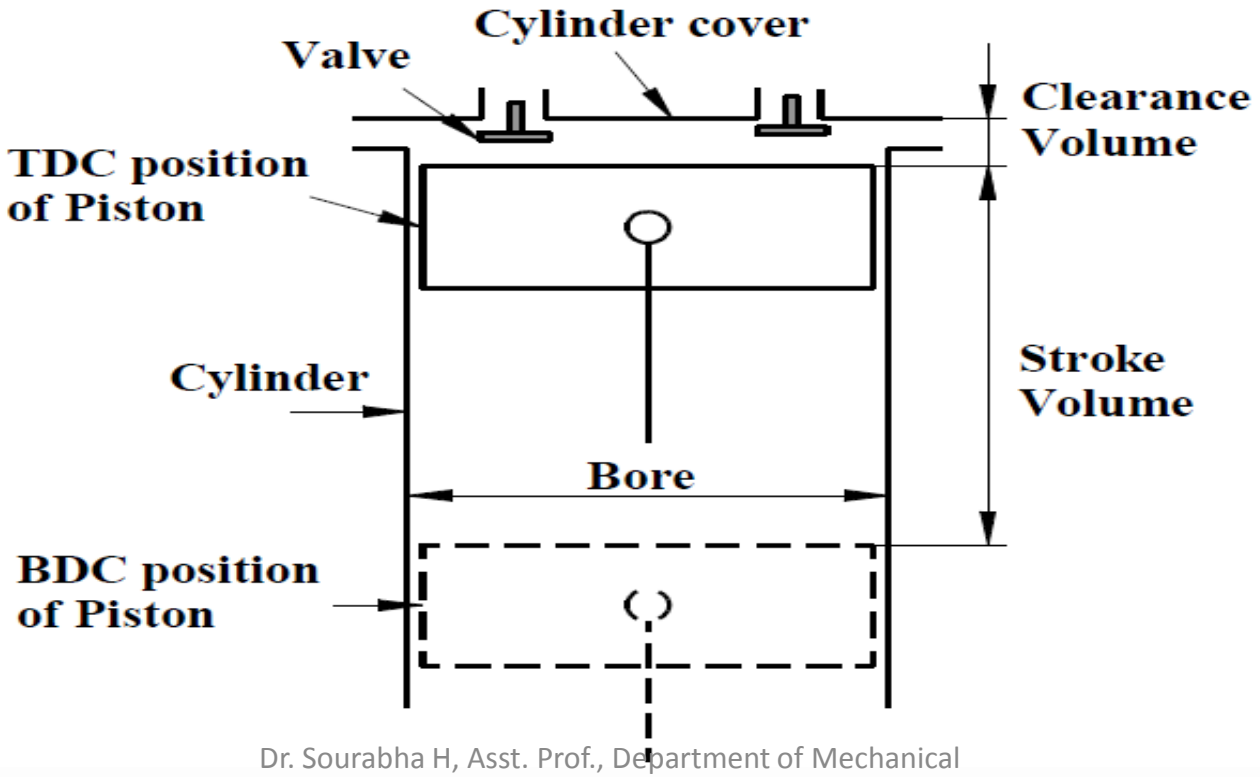
Bottom dead centre / outer Dead centre: It is the extreme position of the piston towards the crank end side of the cylinder. The crank pin moves to the farthest distance from the cylinder.



I.C ENGINE TERMINOLOGY

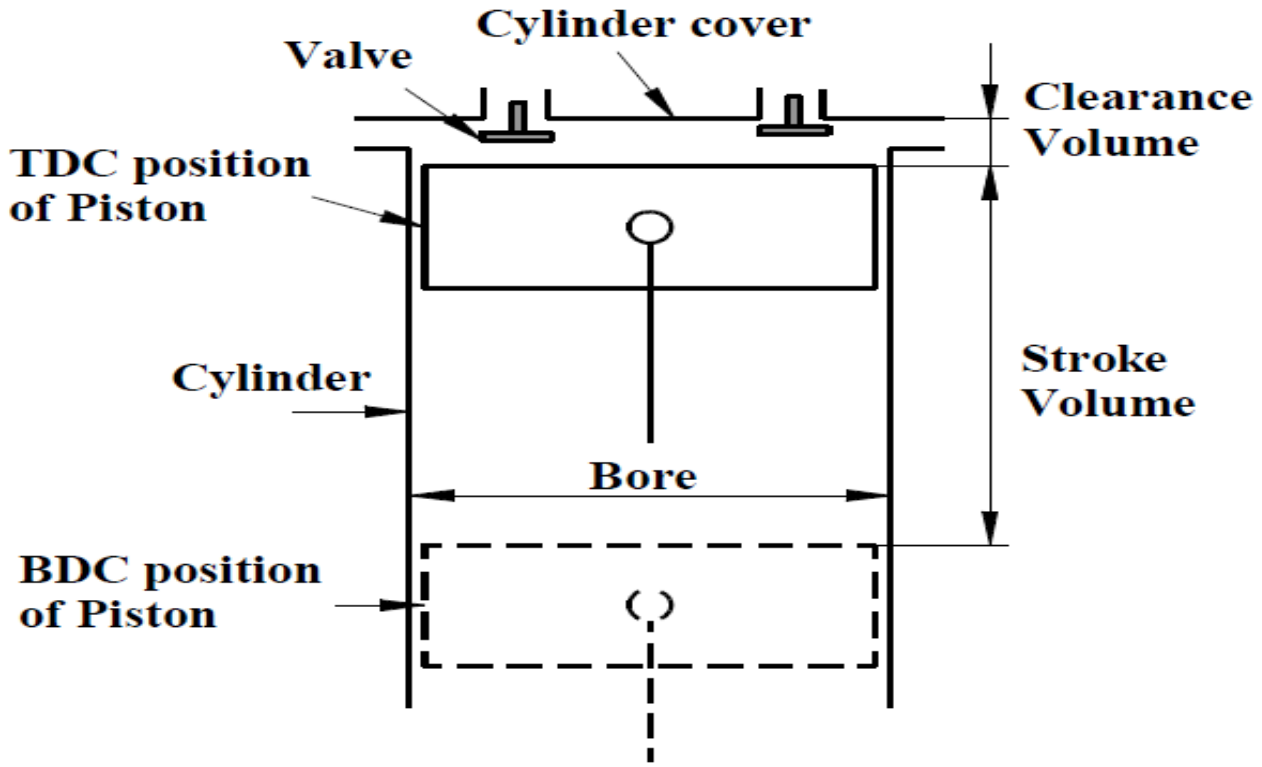
Swept volume : It is the volume through which the piston sweeps during a stroke.

It is equal to the product of surface area of piston and its stroke length.



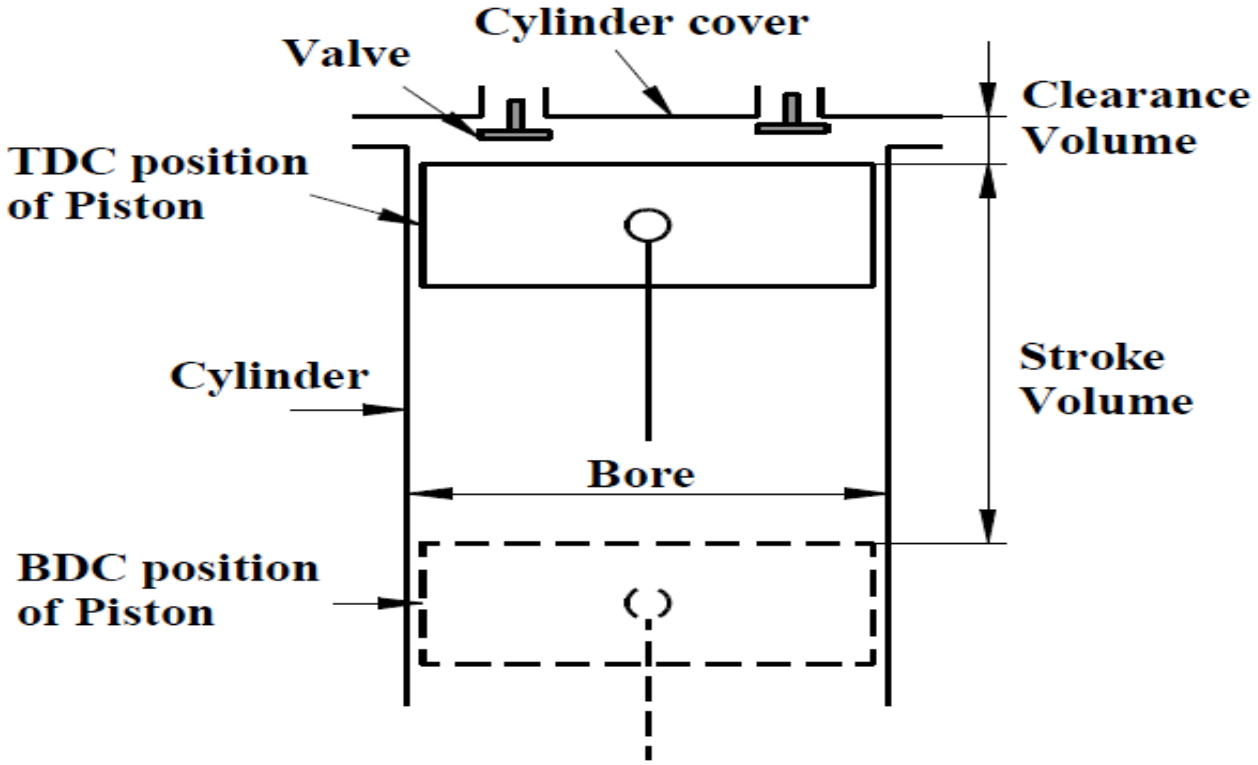
I.C ENGINE TERMINOLOGY

Stroke- ($L=2r_c$) It is the linear distance travelled by the piston from one dead centre position to the another dead centre position. It is equal to twice the crank radius.



I.C ENGINE TERMINOLOGY

Clearance volume V_c- It is the volume included between the top of the piston and the cylinder head when the piston is at TDC . It is expressed as a percentage of the swept volume . The piston never touches the cylinde

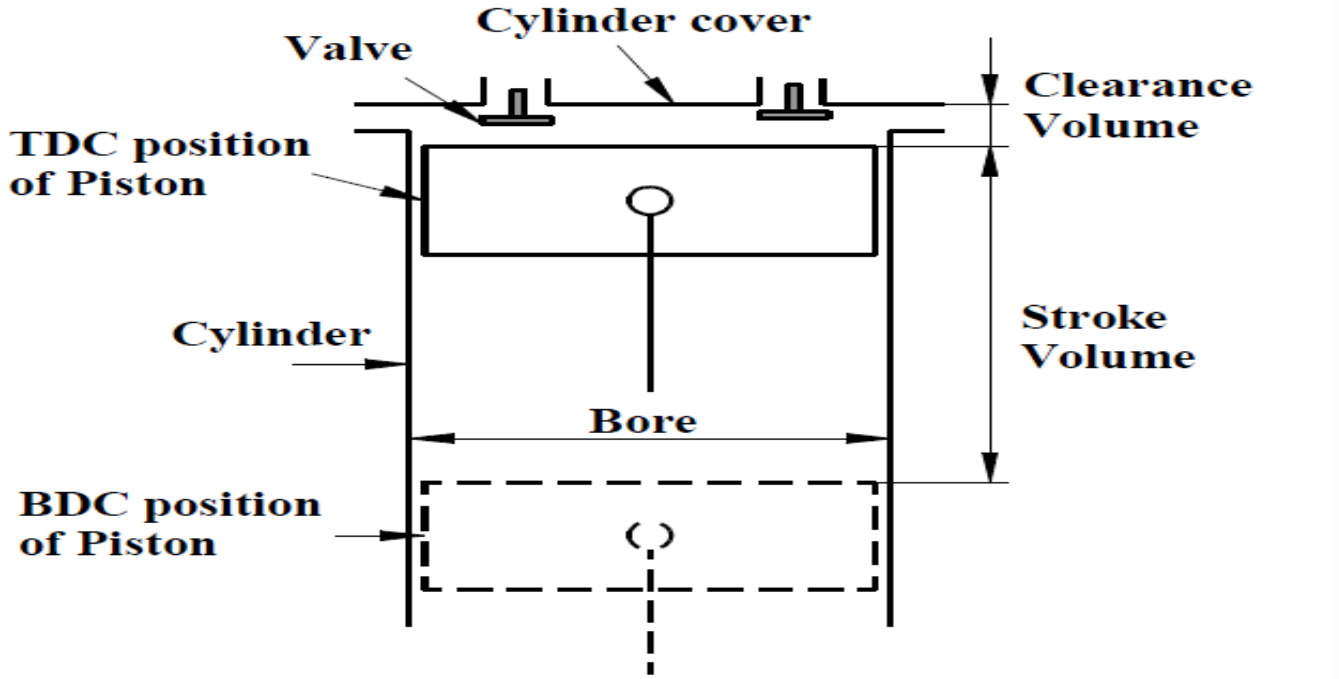


I.C ENGINE TERMINOLOGY

Compression Ratio: It is the ratio of the total cylinder volume to the clearance volume

For petrol engine CR varies from 4:1 to 10:1

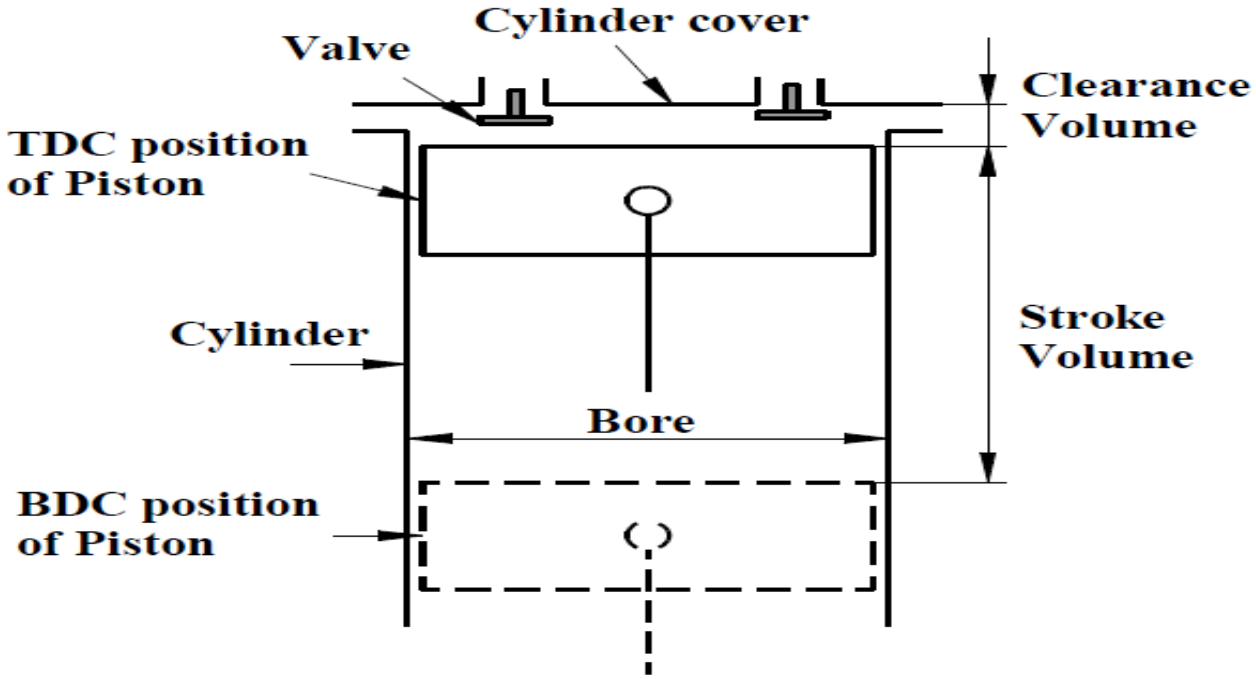
For diesel engine CR varies from 12:1 to 22:1



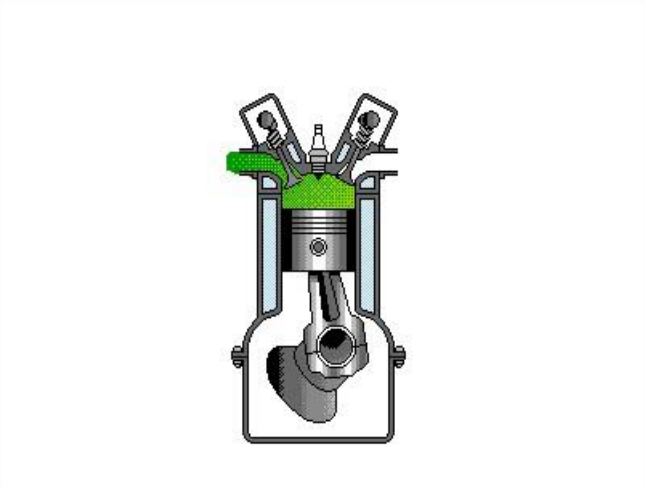
I.C ENGINE TERMINOLOGY

Piston Speed: It is the distance travelled by the piston per unit time.

Cycle of Operation: It is complete series of events



FOUR STROKE CYCLE PETROL ENGINE



Petrol engines work on the principle of theoretical ***Otto cycle***.

- It is also known as *constant volume cycle*, shown in fig.
- The piston performs four strokes (one each in half revolution of crankshaft) to complete the working cycle. (in 2 revolutions of crank shaft)
- The four strokes are:

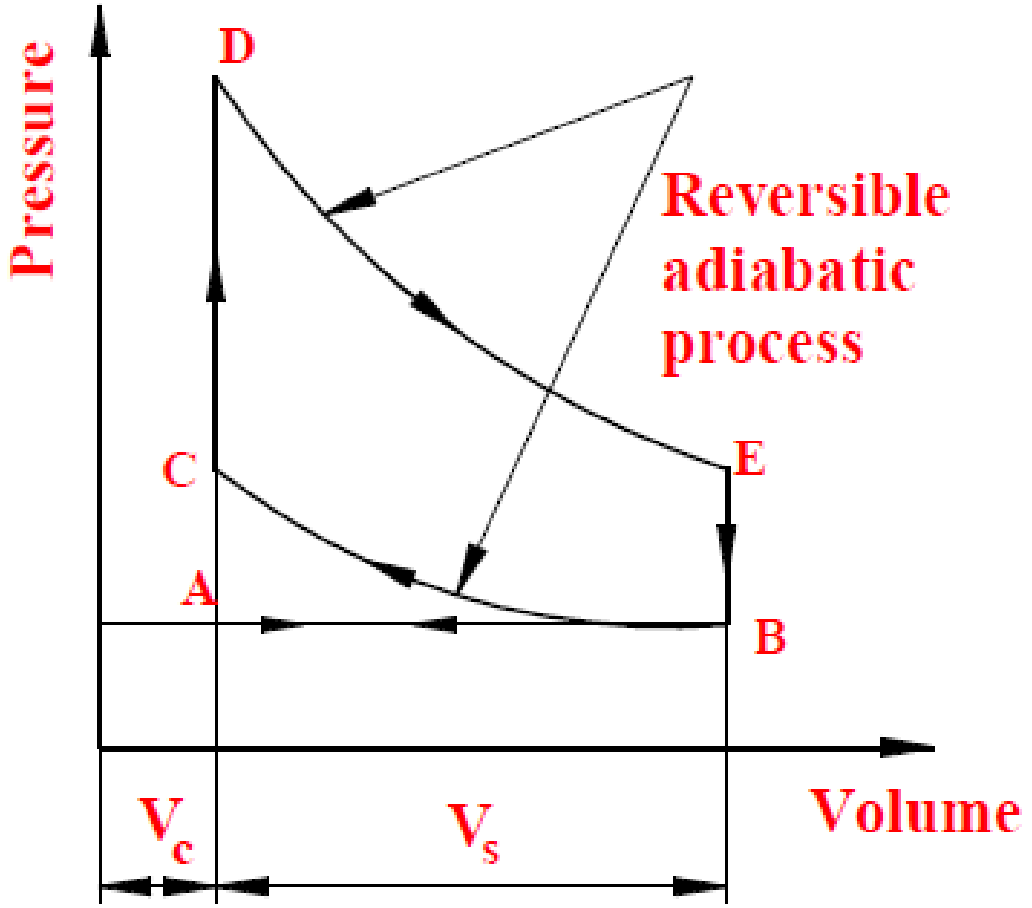
(i) Suction

(ii) Compression

(iii) Working (or) Power stroke

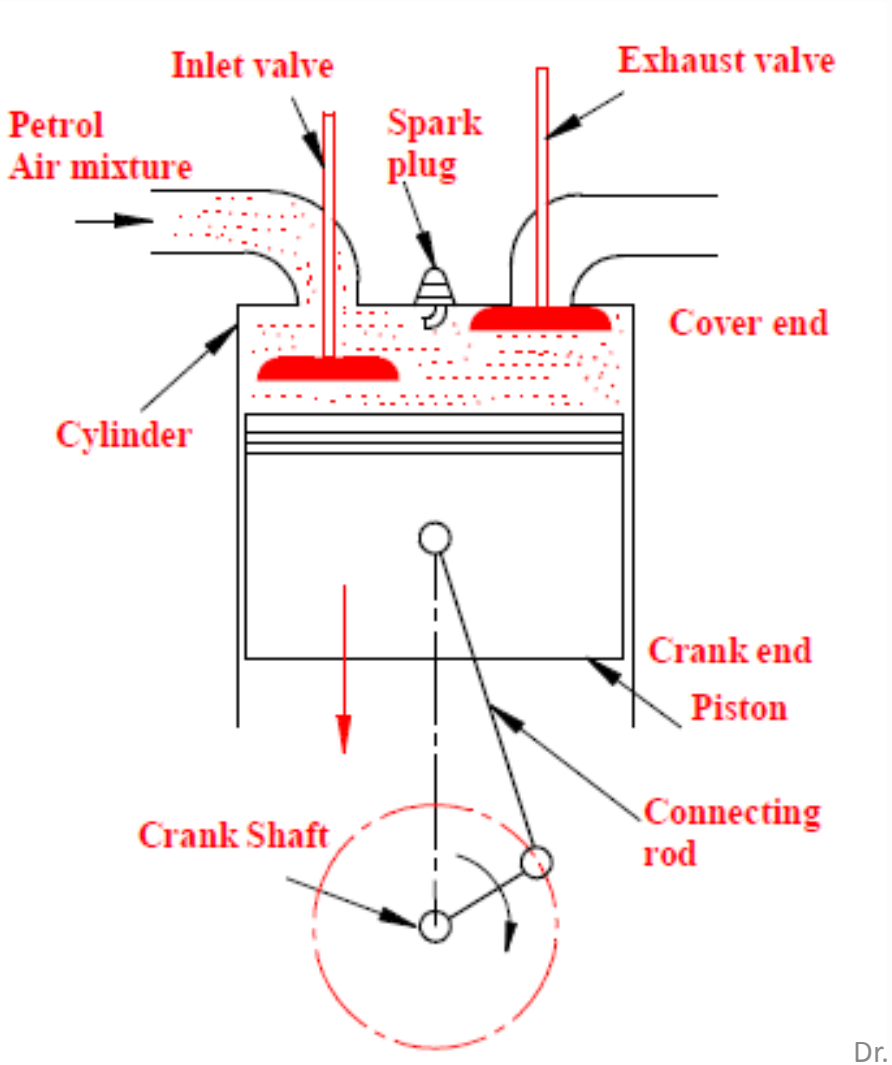
(iv) Exhaust stroke

FOUR STROKE CYCLE PETROL ENGINE



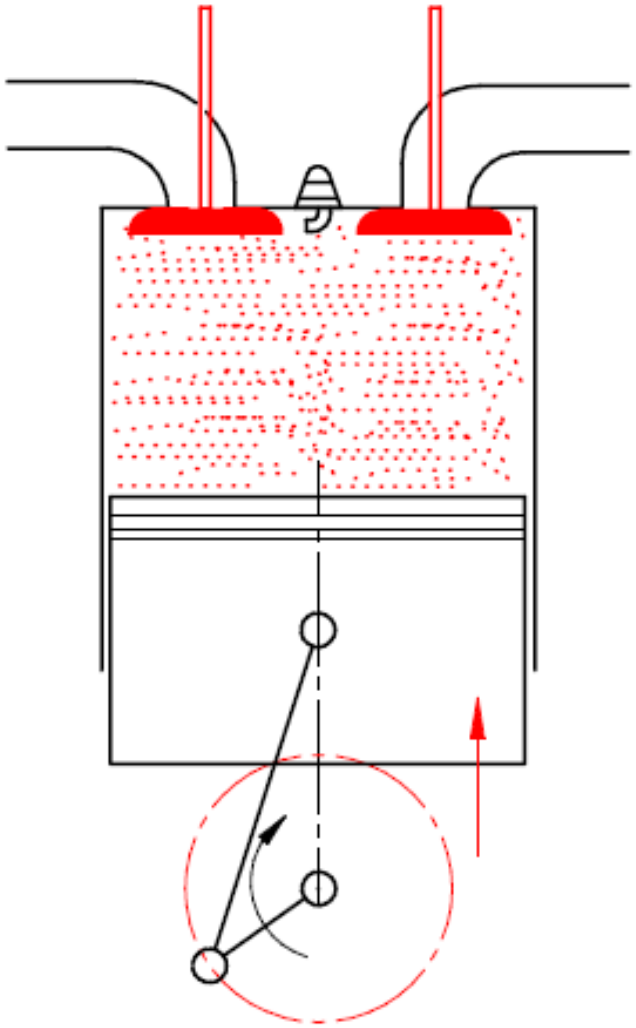
P-V Diagram

SUCTION STROKE



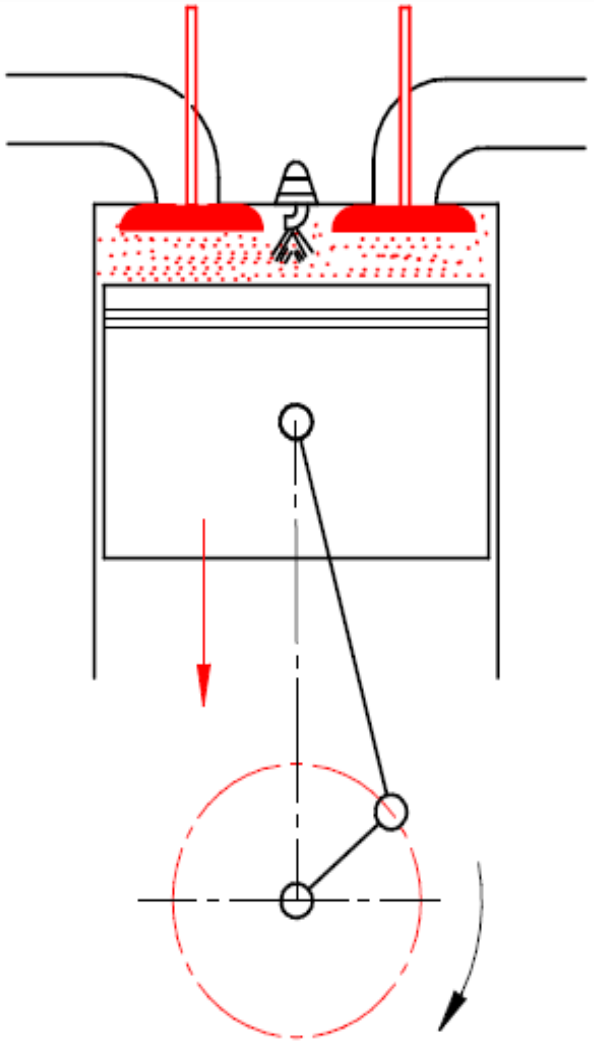
- During suction stroke, the inlet valve is open and exhaust valve is closed.
- The piston moves from cover end to crank end during half revolution of crankshaft.
- The air-petrol mixture is drawn into the cylinder and completely fills the cylinder.
- Suction takes place at atmospheric pressure and is indicated by horizontal line AB in the p-v diagram.
- The process is initiated by '***cranking***' using external energy source.

COMPRESSION STROKE



- During this stroke, both inlet & exhaust valves are closed. The piston moves from crank end to cover end during half revolution of crankshaft.
- The air fuel mixture in the cylinder will be compressed adiabatically as shown by curve BC in the p-v diagram.
- At the end of compression stroke, the air-petrol mixture is ignited by an electric spark given out by the ***spark plug***.
- The combustion of the mixture causes increase in pressure as shown by line CD in P-V diagram

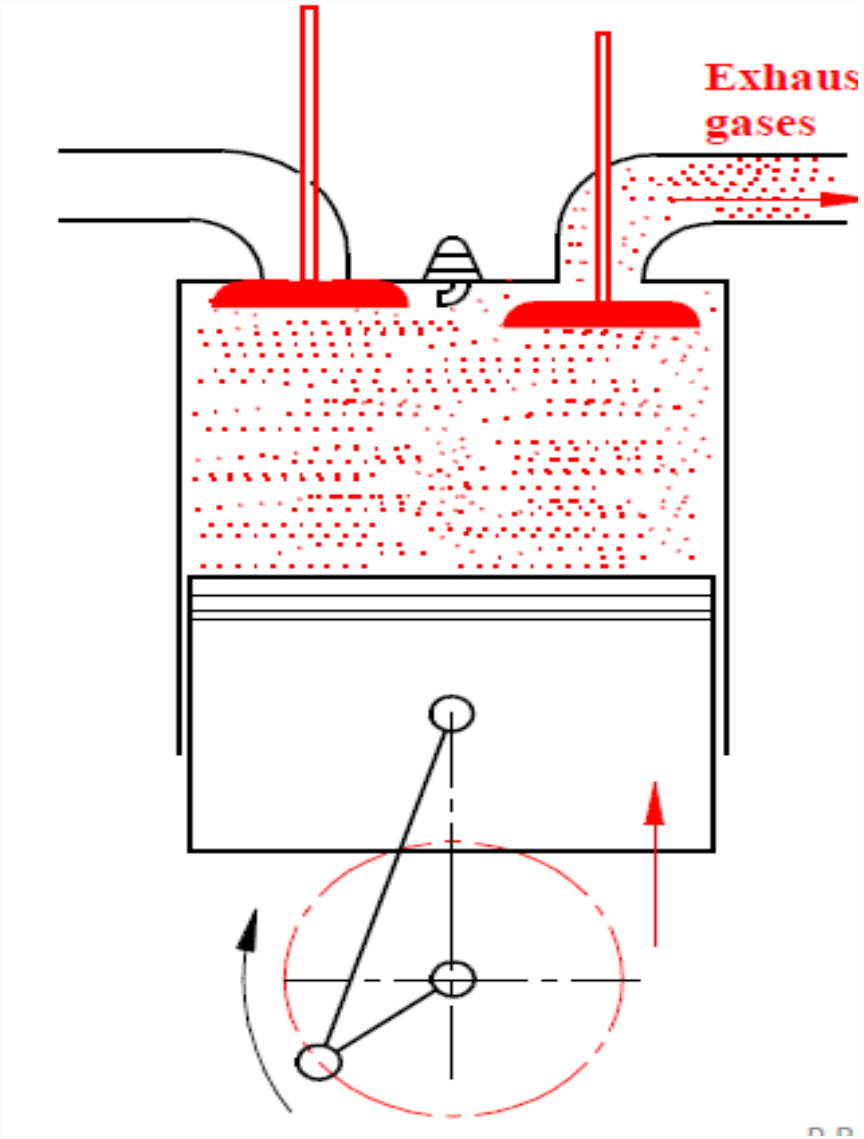
POWER STROKE



During this stroke, both inlet & exhaust valves are closed.

- The expansion of gases due to heat of combustion exerts a pressure on the piston forcing it to move towards the crank end.
- The expansion of gases is indicated by adiabatic process DE in the P-V diagram.
- At the end of this stroke, the exhaust valve will open release the burnt gases to the atmosphere thus bringing down the pressure as indicated by vertical

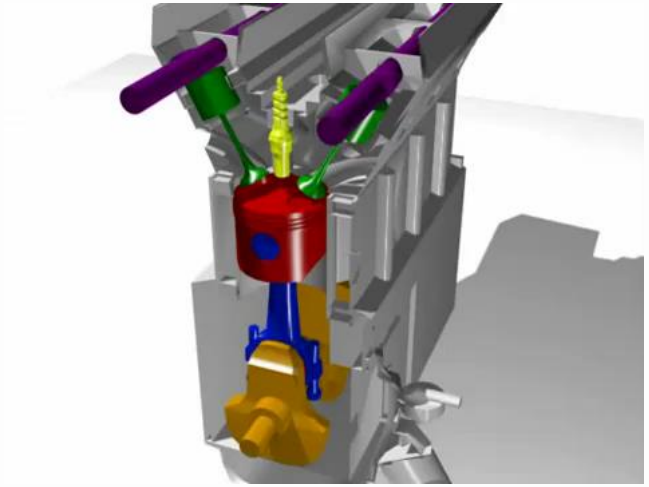
EXHAUST STROKE



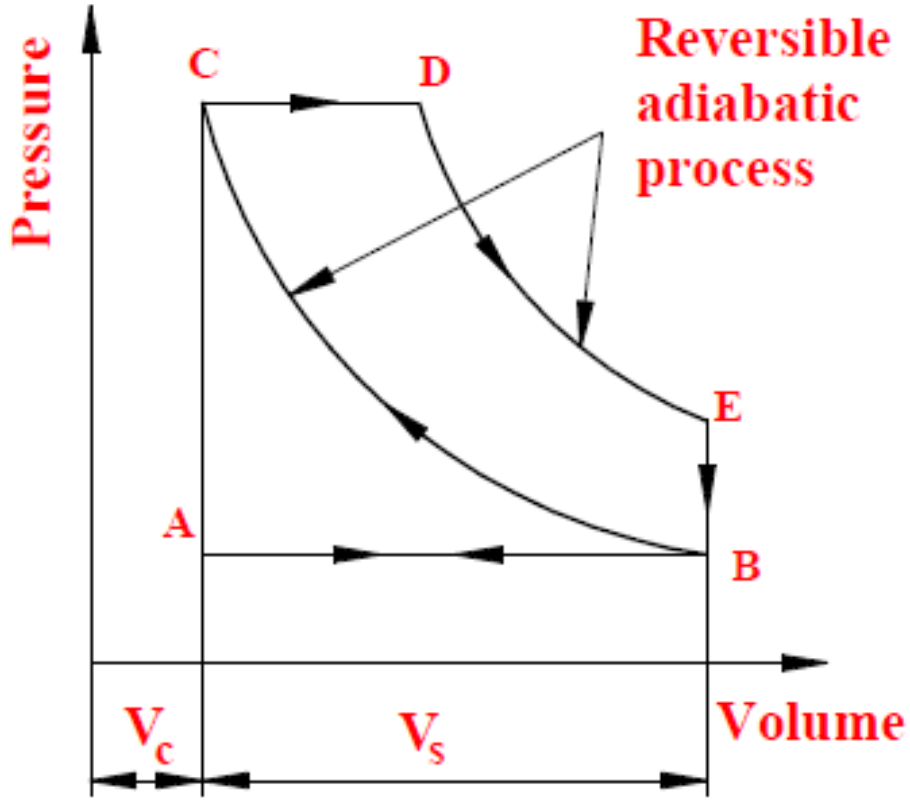
During this stroke, the inlet valve remains closed & the exhaust valve remains open.

- The piston moves from crank end to cover end forcing exhaust gases out of the cylinder.
- The process is indicated by the horizontal line BA in the P-V diagram, thus completing the cycle.
- Thus the cycle is completed in four strokes of the piston or two revolutions of the crankshaft.
- Thereafter, the entire process repeats itself.

FOUR STROKE CYCLE DIESEL ENGINE

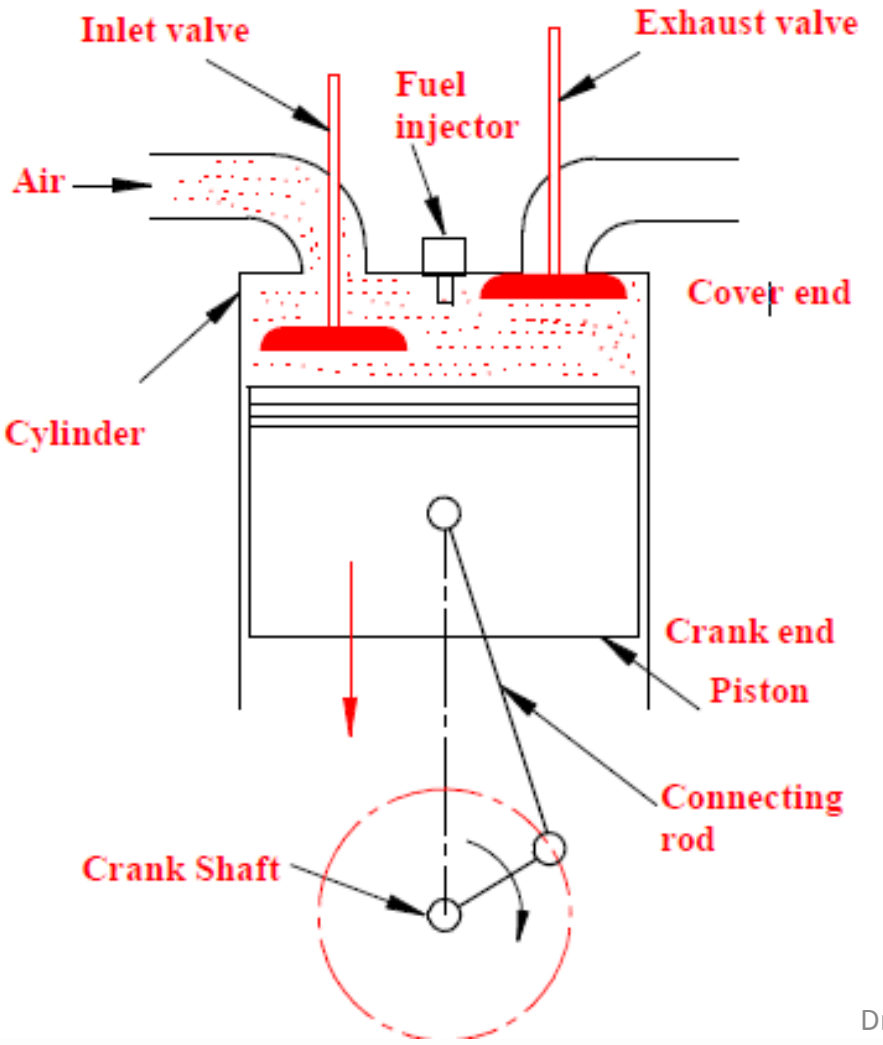


FOUR STROKE CYCLE DIESEL ENGINE



P-V Diagram

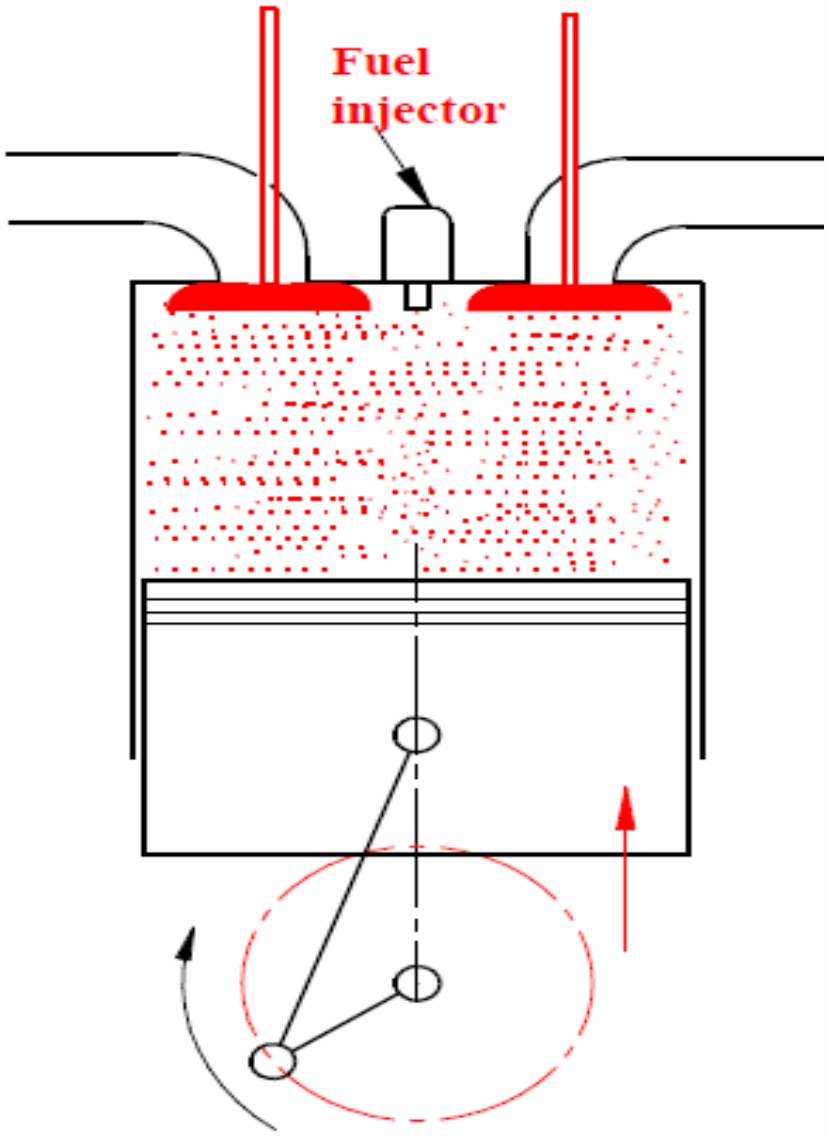
SUCTION STROKE



During suction stroke, the inlet valve is open and exhaust valve is closed.

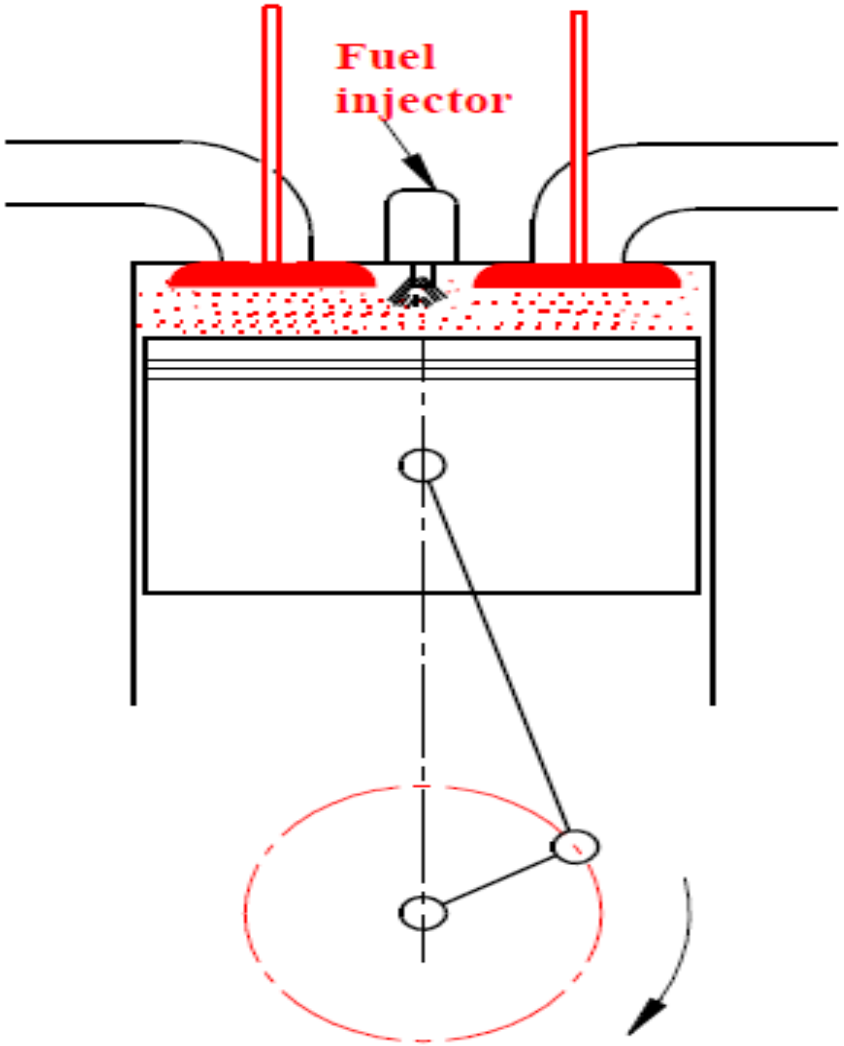
- The piston moves from cover end to crank end during half revolution of crankshaft, and draws ***only air*** into the cylinder.
- The energy required for this stroke is obtained by 'cranking' only at the time of starting & by the flywheel while running.
- Suction takes place at atmospheric pressure and is indicated by horizontal line AB in the p-v diagram.

COMPRESSION STROKE



- During this stroke, both inlet & exhaust valves are closed. The piston moves from crank end to cover end during half revolution of crankshaft.
- The air in the cylinder will be compressed adiabatically as shown by curve BC in the p-v diagram.
- At the end of compression stroke, diesel is injected into the hot compressed air as a fine spray by the fuel injector.
- The fuel will be burnt at constant pressure as shown

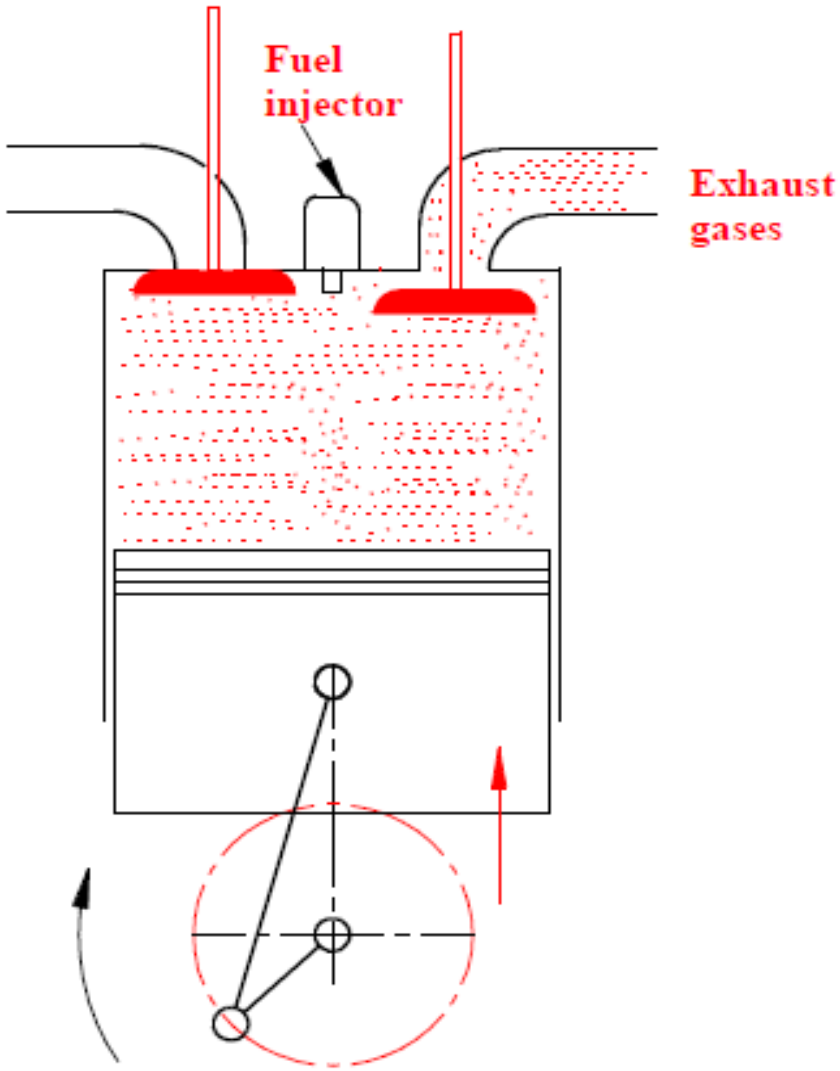
POWER STROKE



During this stroke, both inlet & exhaust valves are closed.

- The expansion of gases due to heat of combustion exerts a pressure on the piston forcing it to move towards the crank end.
- The expansion of gases is indicated by adiabatic process DE in the P-V diagram.
- At the end of this stroke, the exhaust valve will open release the burnt gases to the atmosphere thus bringing down the pressure as indicated by vertical line EB in the P-V diagram.

EXHAUST STROKE



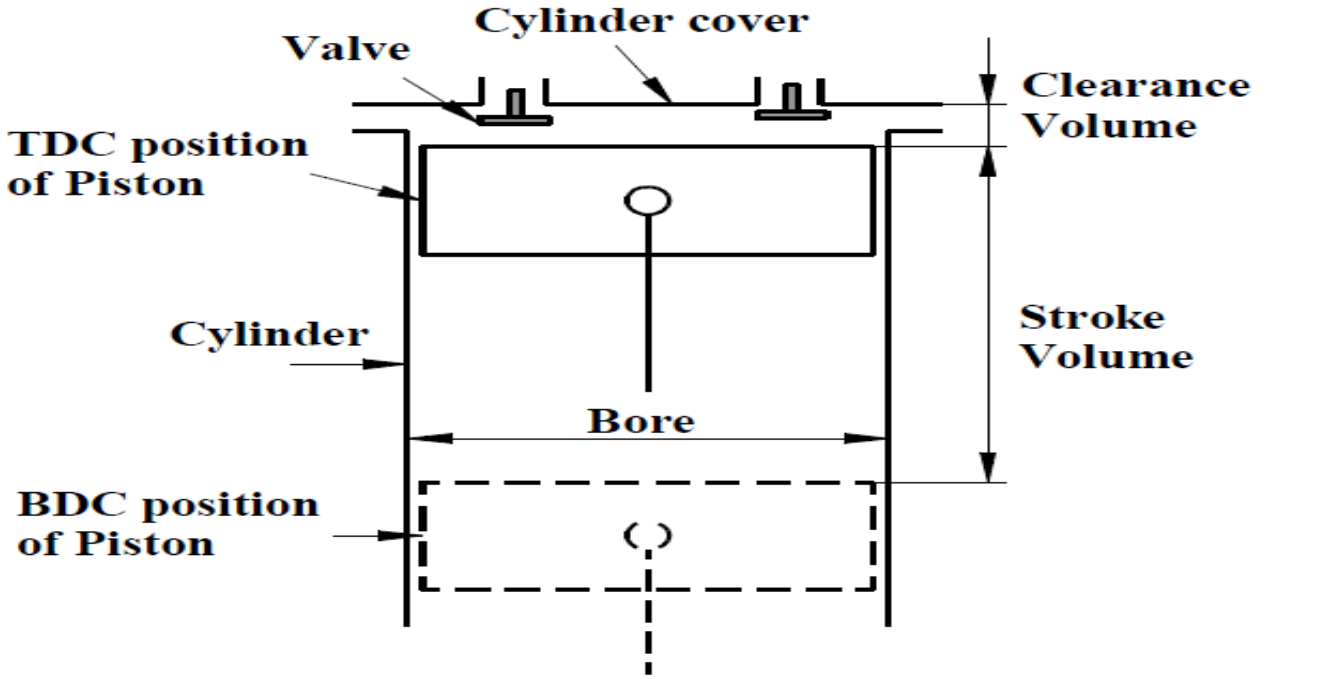
During this stroke, the inlet valve remains closed & the exhaust valve remains open.

- The piston moves from crank end to cover end forcing exhaust gases out of the cylinder.
- The process is indicated by the horizontal line BA in the P-V diagram, thus completing the cycle.
- Thus the cycle is completed in four strokes of the piston or two revolutions of the crankshaft.
- Thereafter, the entire process repeats itself.

I.C ENGINE TERMINOLOGY

Piston Speed: It is the distance travelled by the piston per unit time.

Cycle of Operation: It is complete series of events



COMPARISON BETWEEN PETROL ENGINE & DIESEL ENGINE

Petrol Engine	Diesel Engine
It works on Otto cycle.	It works on diesel cycle.
Air & petrol are mixed in the carburettor before they enter into the cylinder.	Air only enters the cylinder & diesel is sprayed into the hot air.
Cylinder is fitted with a spark plug.	Cylinder is fitted with a fuel injector.
Less thermal efficiency and more fuel consumption.	More thermal efficiency and less fuel consumption.
Low compression ratio ranging from 7:1 to 12:1	High compression ratio ranging from 16:1 to 20:1

Petrol Engine	Diesel Engine
Less initial cost & more running cost.	More initial cost & less running cost.
Light weight & occupies less space.	Heavy & occupies more space.
Easy to start even in cold weather.	Difficult to start even in weather
Quantitative governing is used	Qualitative governing is used.
High engine speeds about 3000 rpm	Low engine speeds about 1500 rpm.
Used in light vehicles like cars, motor cycles, Scoters, etc.	Used in heavy duty vehicles like trucks, buses, locomotives, etc.

COMPARISON BETWEEN FOUR STORKE ENGINE & TWO STROKE ENGINE

Four Stroke cycle Engine	Two Stroke cycle Engine
One working cycle for every two revolutions of the crank shaft.	One working stroke for each revolution of the crankshaft.
Requires heavy flywheel because of high torque fluctuations.	Requires light flywheel because of more or less uniform torque on crankshaft.
It has inlet & exhaust valves.	It has inlet, exhaust & transfer ports.
Less fuel consumption & high thermal efficiency.	More fuel consumption & lower thermal efficiency.
For a given power output, the engine is heavy &	For the same power output, the engine is light

Four Stroke cycle Engine	Two Stroke cycle Engine
Requires lesser cooling & lubrication.	Requires greater cooling & lubrication.
Less noise while running as the exhaust valves open gradually.	More noise due to sudden opening of exhaust port & release of gases.
Engine crankshaft can rotate only in one direction.	Engine crankshaft can rotate in either direction.
Mechanical efficiency is less because of more moving parts.	Mechanical efficiency is less because of less moving parts such as valves, cams.
Used in cars, buses, trucks, etc.	Used in motorcycles, scooters, etc.

IC ENGINE CALCULATION

INDICATED POWER (IP) :

It is the power produced inside the cylinder and calculated by finding the actual mean effective pressure.

$$IP = 100 P_m L A n / 60 \text{ KW}$$

Where: P_m Mean effective Pressure in bar

L= Stroke Length in meters

A= Cross section area of cylinder bore in m : $A=\pi d^2/4$

Where : d= bore diameter in meters

n=Number of cycles per min; n=N (For 2 stroke engine)

N/2 for four stroke engine

BRAKE POWER (BP):

It is the net power available calculated at the crank shaft is called *Brake Power.*

BP=2πNT/60 KW

Where: N= Rpm of crank shaft

T= Engine torque (in KN-m) $= \frac{(W - S)\, R}{1000} * 9.81$

Where: W= Load on brake drum

S=Spring balance reading

R=Radius of the brake drum

Also **FP =(IP - BP) KW**

Where: FP= Loss of power due to friction

EFFICIENCIES OF ENGINE :

(i) Mechanical Efficiency

$\eta_{mech} = BP/IP*100$

(ii) Thermal Efficiency

a. Indicated thermal efficiency

$\eta_{indicated-thermal} = IP/m_f*C_v *100$

Where: m_f =Mass of fuel burnt in Kg/Sec

C_v= Calorific value of the fuel in KJ/Kg

EFFICIENCIES OF ENGINE :

b. Brake thermal efficiency

$$\eta_{Brake\text{-}thermal} = BP/m_f * C_v \ *100$$

Where: m_f =Mass of fuel burnt in Kg/Sec

C_v= Calorific value of the fuel in KJ/Kg

NOTE:

a. The mean effective pressure is given by

$$P_m = sa / l \quad N/m^2$$

Where: a=Area of the indicator diagram, cm

l=Base width of indicator diagram, cm

s= spring constant or spring value, $N/m^2/cm$

b. If a brake load is in Kg, Torque on brake drum

$$T=(9.81*W*R) /1000 \quad KN-m$$

BRAKE DYNAMOMETER