UNIT-3 INTERNAL COMBUSTION ENGINES

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INTRODUCTION

- In 1876 four stroke engine based on Otto cycle was developed by a German engineer Nikolaus Otto. Diesel Engine was developed by another German engineer Rudolf Diesel in the year 1892.
- Engine refers as “Heat engine is a device which converts chemical energy of fuel into heat energy and this heat energy further convert into mechanical work”.
- Based on where the combustion of fuel take place. Whether outside the working cylinder or inside the working cylinder
- (a) External combustion engines (E.C.ENGINES), (b) Internal combustion engines (I.C.ENGINES)

I. C. ENGINES	E. C. ENGINES
Fuel combustion take place inside t he cylinder.	Fuel combustion take place outside the cylinder.
Compact in size and more efficient.	Larger in size and less efficient.
Low initial cost.	More initial cost.
Working fluid is mixture of air and fuel.	Working fluid is steam.
Easier and quick starting of these engines .	Starting is difficult and more time is required.
Costly fuels are required like petrol and diesel.	Cheaper fuel may be used like coal.
More suitable for mobile applicatio ns.	Less suitable for mobile applications.

CLASSIFICATION OF IC ENGINE

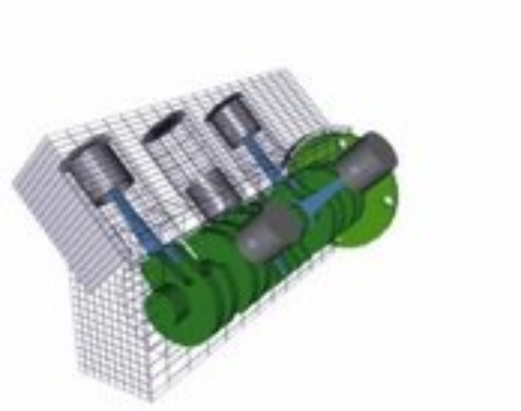
- I.C.ENGINES are may be classified according to
- Type of fuel used as (1)Petrol engine (2)Diesel engine (3)Gas engines (4)Bi-fuel engine (two fuel engine)
- Nature of thermodynamic cycle as: (1)Otto cycle engine (2)Diesel engine cycle (3) Duel or mixed cycle engine
- Number of stroke per cycle as : (1) Four stroke engine (2) Two stroke engine
- Method of ignition as : (1) Spark Ignition engines (Mixture of air and fuel is ignited by electric spark)
  (2) Compression Ignition engines (The fuel is ignited as it comes in contact with hot Compressed air)
- Method of Cooling as

(1) Air cooled engines (2) Water cooled engines

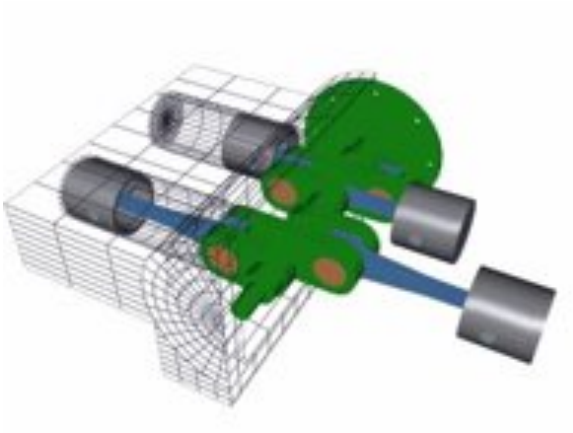
- Speed of the engines as:
  (1) Low speed engines (2) Medium speed engines (3) High speed engines

- Number of cylinder as:(1) Single cylinder engines
  (2) Multi cylinder engines
- Position of the cylinder as
  :(1) Inline engines (2) V-engines (3) Radial engines (4) Opposed cylinder e ngines
  (4) Opposed piston engines

Inline Engine

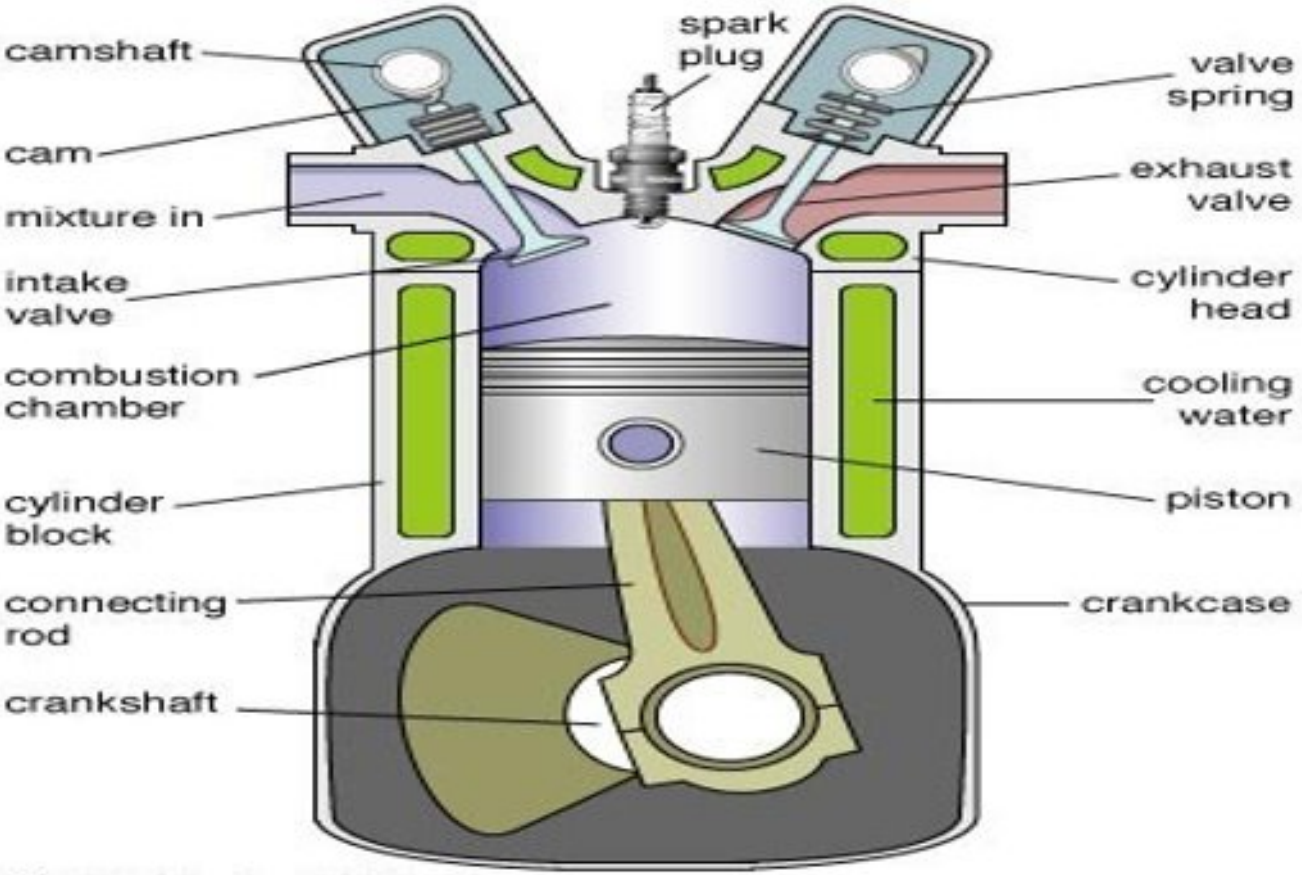


V- Engine



Opposed Piston Engine

ENGINE DETAILS



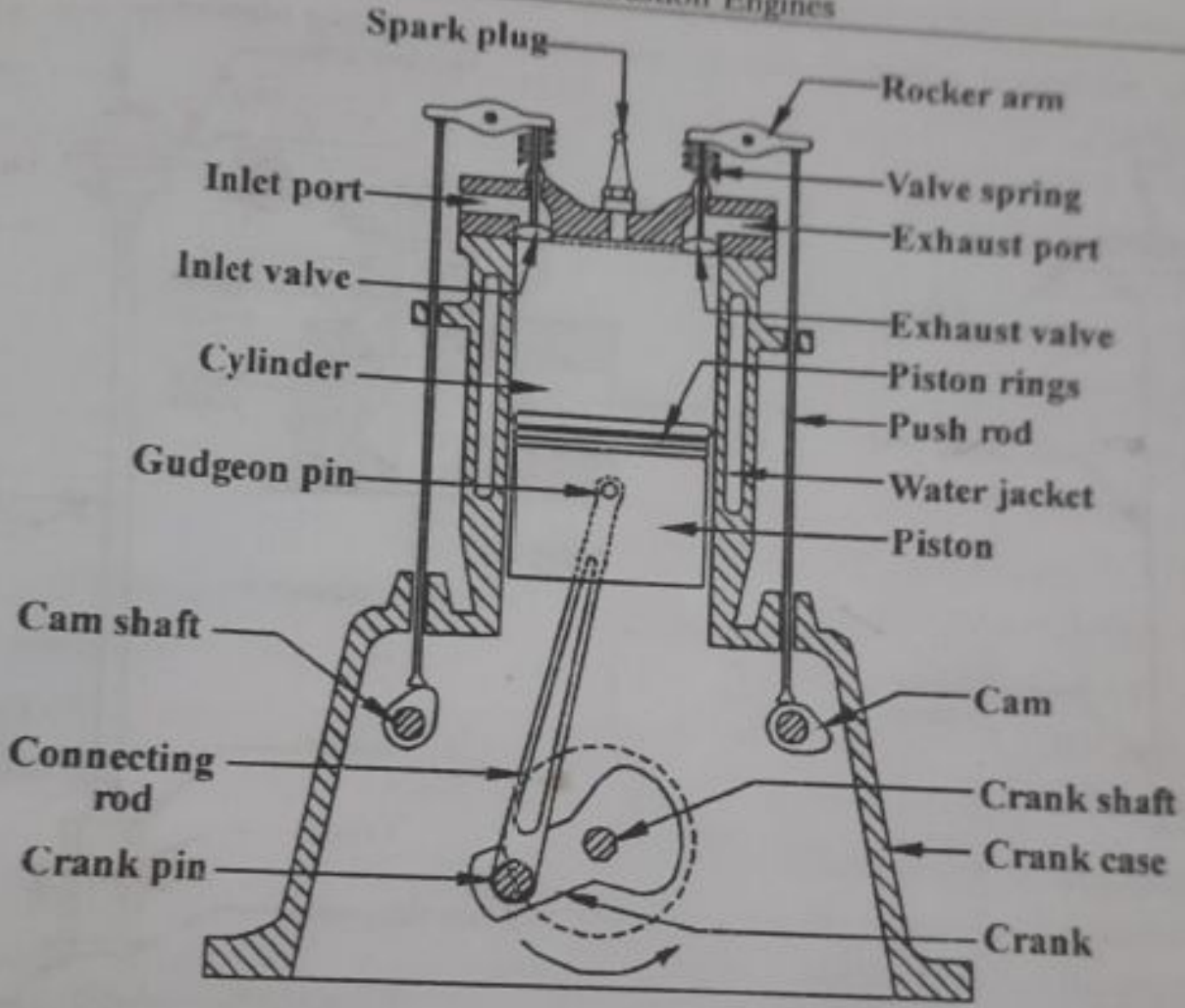


Fig. 4.17 Main components of I.C. engine

Engine Terminology

- Bore : Inner diameter of Engine Cylinder is Called a Bore.
- Stroke : It is the linear distance traveled by the piston when it moves from one end of the cylinder to the other end.
- Dead Centers : In the vertical engines ,Top position of Piston is called TOP DEAD CENTER (TDC).

  When the piston is at bottom position , It is called BOTTOM DEAD CENTER (BDC).

• Clearance Volume,(Vc) : It is the volume contained between the piston top and cylinder head when the piston is at top or inner dead center.

•Stroke Volume (swept volume) : It is the volume displaced by the piston in one stroke is known as stroke volume or swept volume.

•Clearance Volume (Vc) : It is the volume Contained between the piston top and cylinder head when the piston at top or inner dead center .

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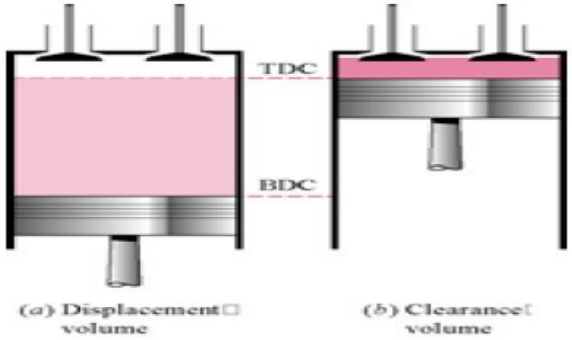


•Stroke Volume (Swept volume) : It is the volume displaced by the piston in one stroke is known as stroke volume or Swept volume .

Let $Vs = stroke\ volume\ , L = stroke\ lenght\ , d = bore$

$$Vs = \frac{\pi}{4} d^{2} L$$

- Compression ratio: The ratio of total Cylinder volume to clearance volume is called the compression ratio (r) of the Engine.

Total Cylinder volume $= Vc + Vs$

$$r = \frac{Cylinder\ Volume\ at\ BDC}{Cylinder\ Volume\ at\ TDC}$$

$$r = \frac{(Cylinder\ Volume + Cylinder\ Clearance\ Volume)}{Cylinder\ Clearance\ Volume}$$

$$r = \frac{V_s + V_c}{V_c} = 1 + \frac{V_s}{V_c}$$

For petrol engine r is varies from 6 to 10 and for diesel it is varies from 14 to 20 .

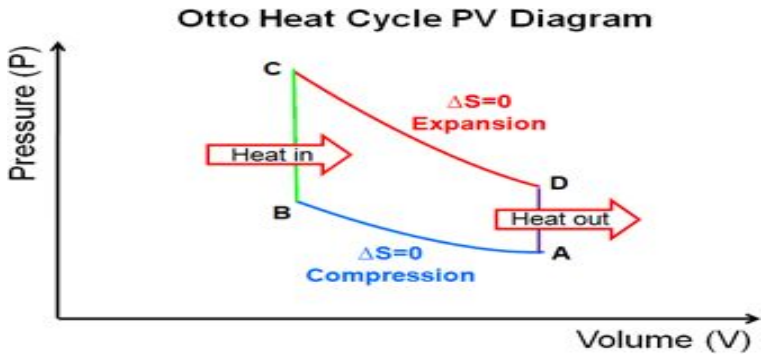
•Piston speed : It is average speed of piston. It is equal to 2LN , where N is speed of crank shaft in rev./second .

Piston Speed ,$Vp = \frac{2LN}{60}$ m/s, where L=Stroke Length ,m

N=speed of crank shaft ,RPM

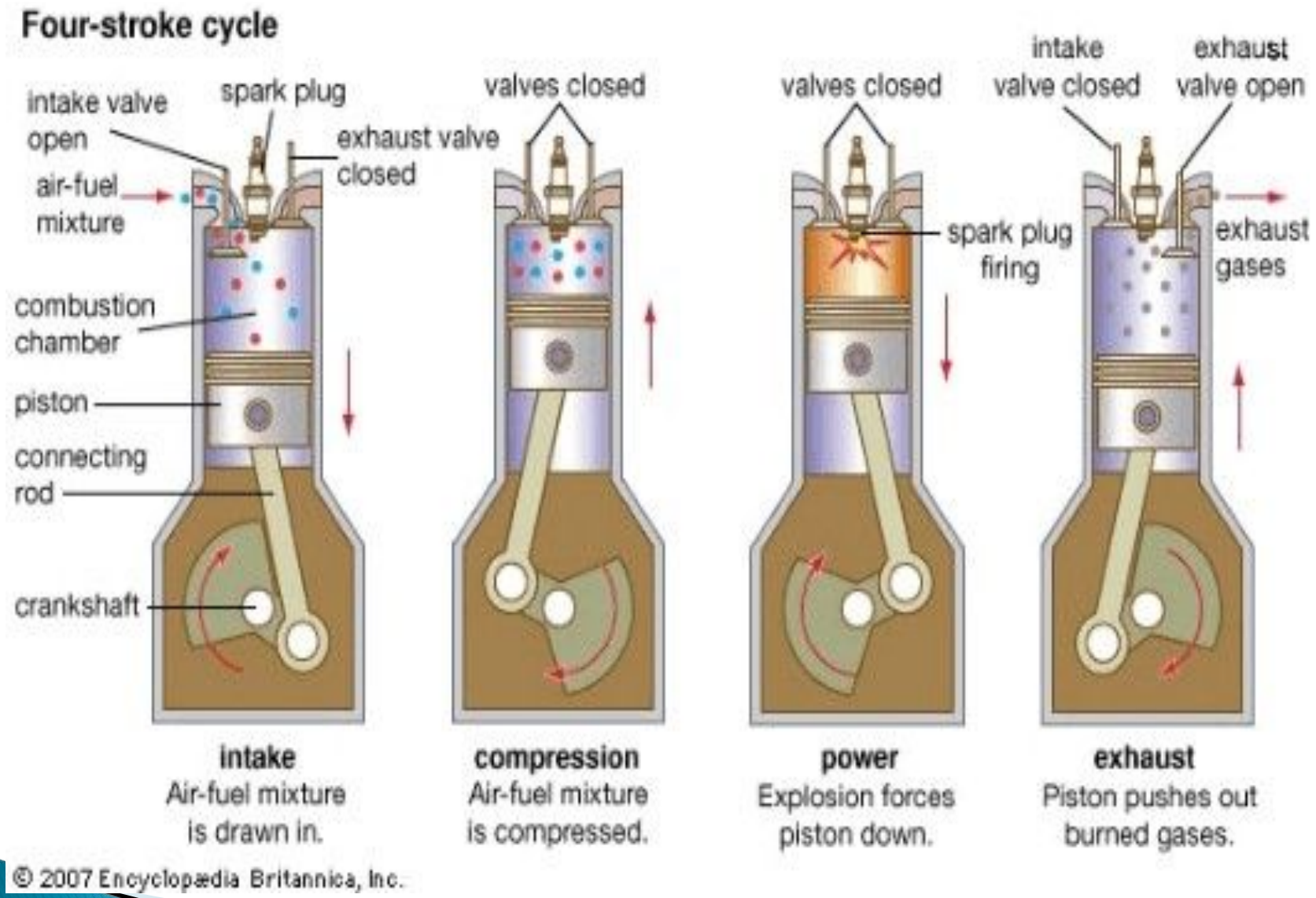
Otto four stroke cycle

- The four stroke petrol engines works on the principle of theoretical Otto cycle. also known as constant volume cycle. shown in Fig below

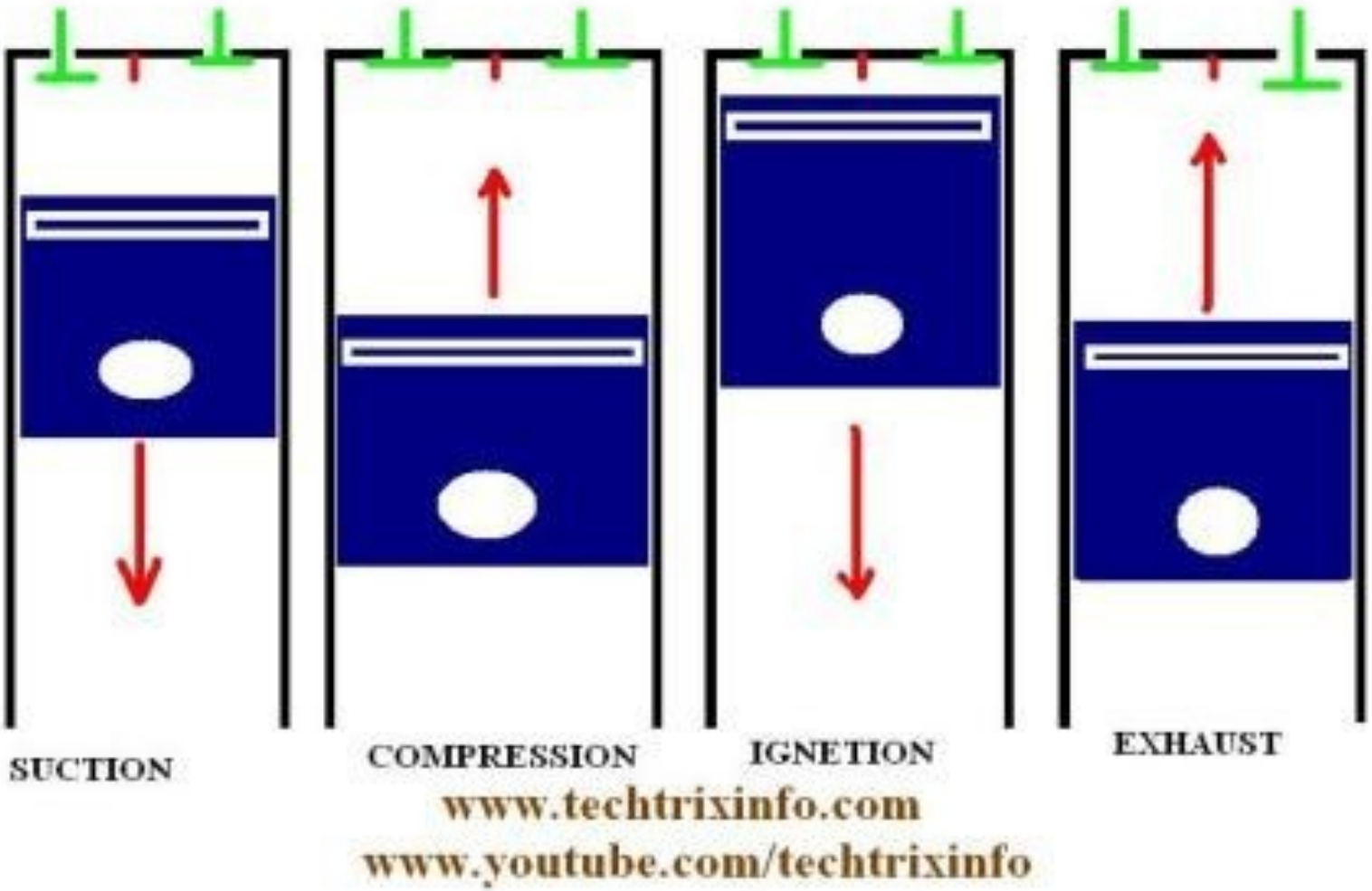


- In four stroke Petrol engine the vale operating for inlet is called inlet valve and the valve operating for exhaust is called Exhaust valve. In Petrol engine SPARK plug fitted at the top of cylinder head initiates the ignition of the air fuel mixture.
- The piston performs four strokes to complete one working cycle.The four different strokes are ; (1) SUCTION STROKE (2) COMPRESSION STROKE (3) POWER STROKE (4) EXHAUST STROKE.

Four stroke Petrol Engine

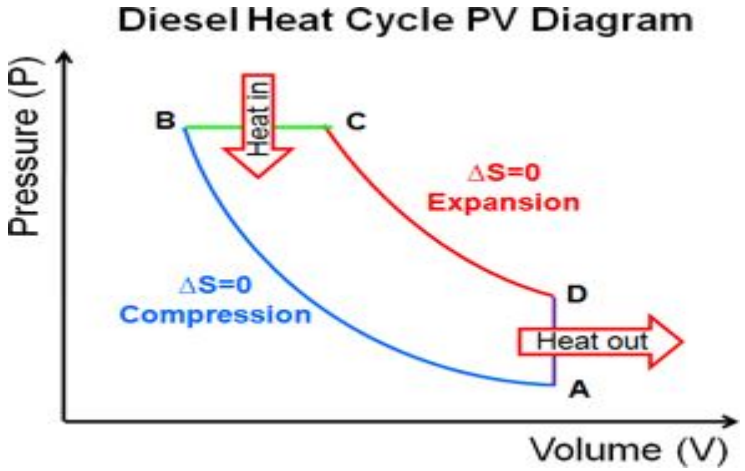


Pistons Position During The Four Stroke Cycle



Diesel four stroke cycle

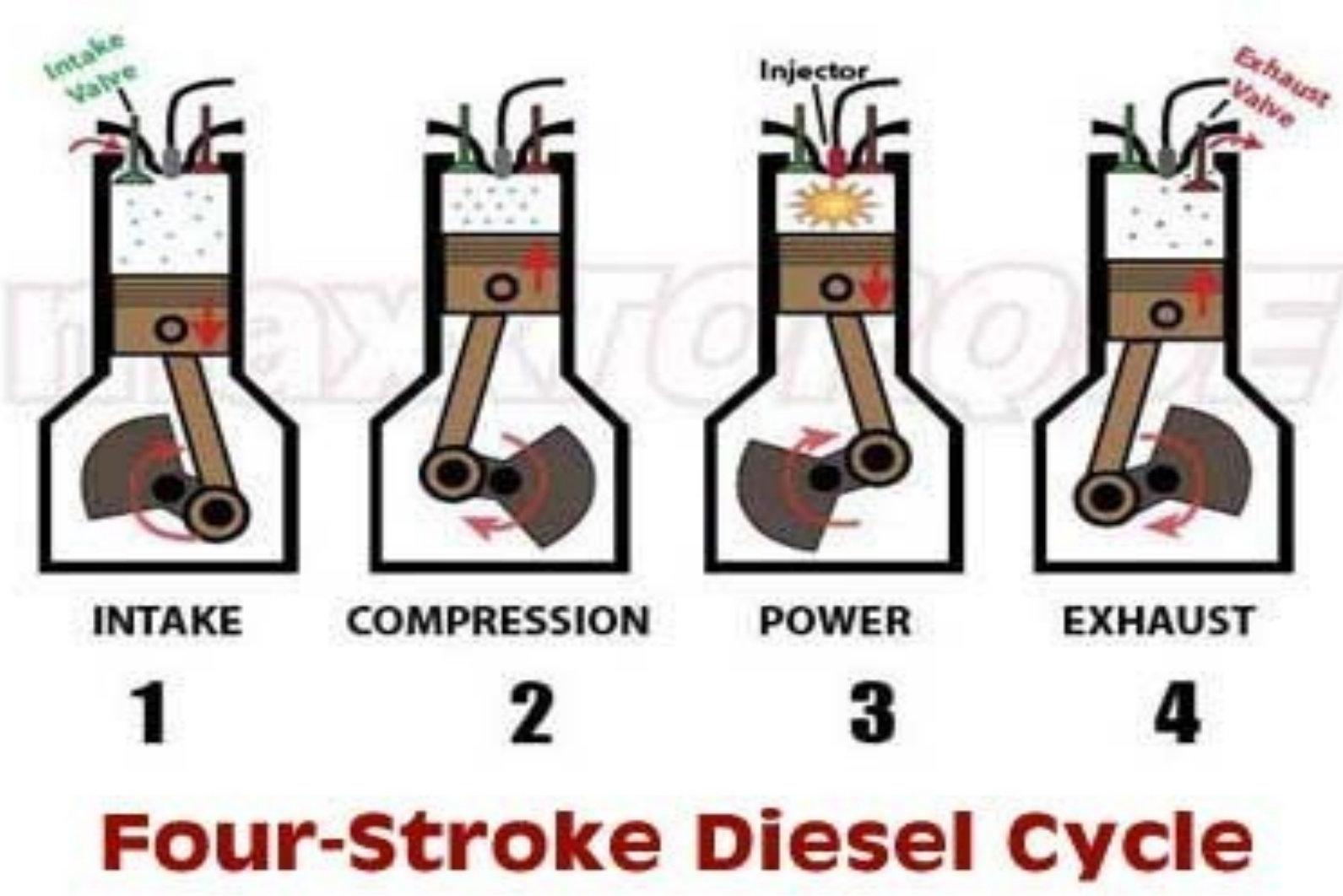
- The four stroke Diesel Engine works on the principle of Diesel Cycle , also called CONSTANT PRESSURE HEAT ADDITION PROCESS shown in Fig.



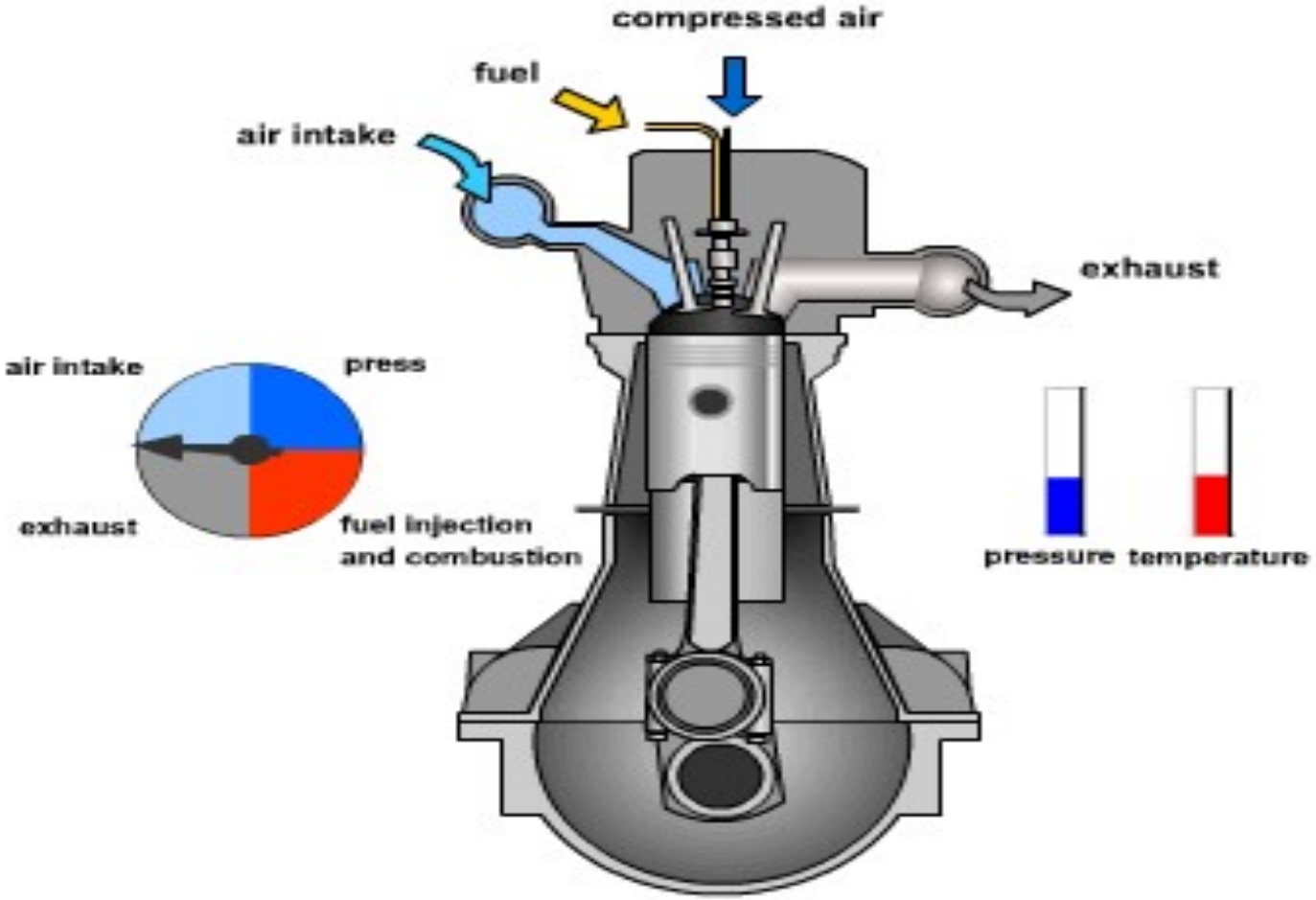
- The four stroke Diesel engine is also consists of SUCTION,COMPRESSION,POWER and EXHAUST strokes.

- The basic construction of a four stroke diesel engine is same as that of four stroke petrol engine, except instead of spark plug, a fuel injector is mounted in its place .

Four Stroke Diesel Engine



Working of four stroke Engine



Difference between Petrol and Diesel Engine

The basic differences between Petrol and Diesel Engine given below .

PETROL ENGINE	DIESEL ENGINE
Works on Otto cycle .	Works on Diesel Cycle .
Petrol is used as fuel .	Diesel is used as fuel .
Air and fuel mixture enters in cylinder during suction stroke .	Only Air is drawn during the suction stroke .
Low compression ratio ranging from 6 to 10 .	High compression ratio ranging from14 to 20 .
The compressed charge is ignited by the spark plug.	The fuel injector is used in Diesel engine.
High engine speed of about 3000 RPM .	Low to medium engine speed ranging from 500 to 1500 RPM.
The Thermal efficiency is lower due to lower Compression ratio .	The Thermal efficiency is higher due to high Compression ratio .
Lighter in weight because maximum pressure and Temperature is less .	Heavier in Weight because maximum pressure and temperature is high .
Less Costlier .	More Costlier .
Maintanence cost is Less .	Maintanence cost is Slightly higher .
Easier starting even in cold weather .	Difficult to start in cold weather .
Running cost Higher because petrol is Costlier .	Running cost is Less because diesel is Cheaper .

Two Stroke Cycle Engines

As the name itself implies, all the processes in two stroke cycle engine are completed in two strokes.

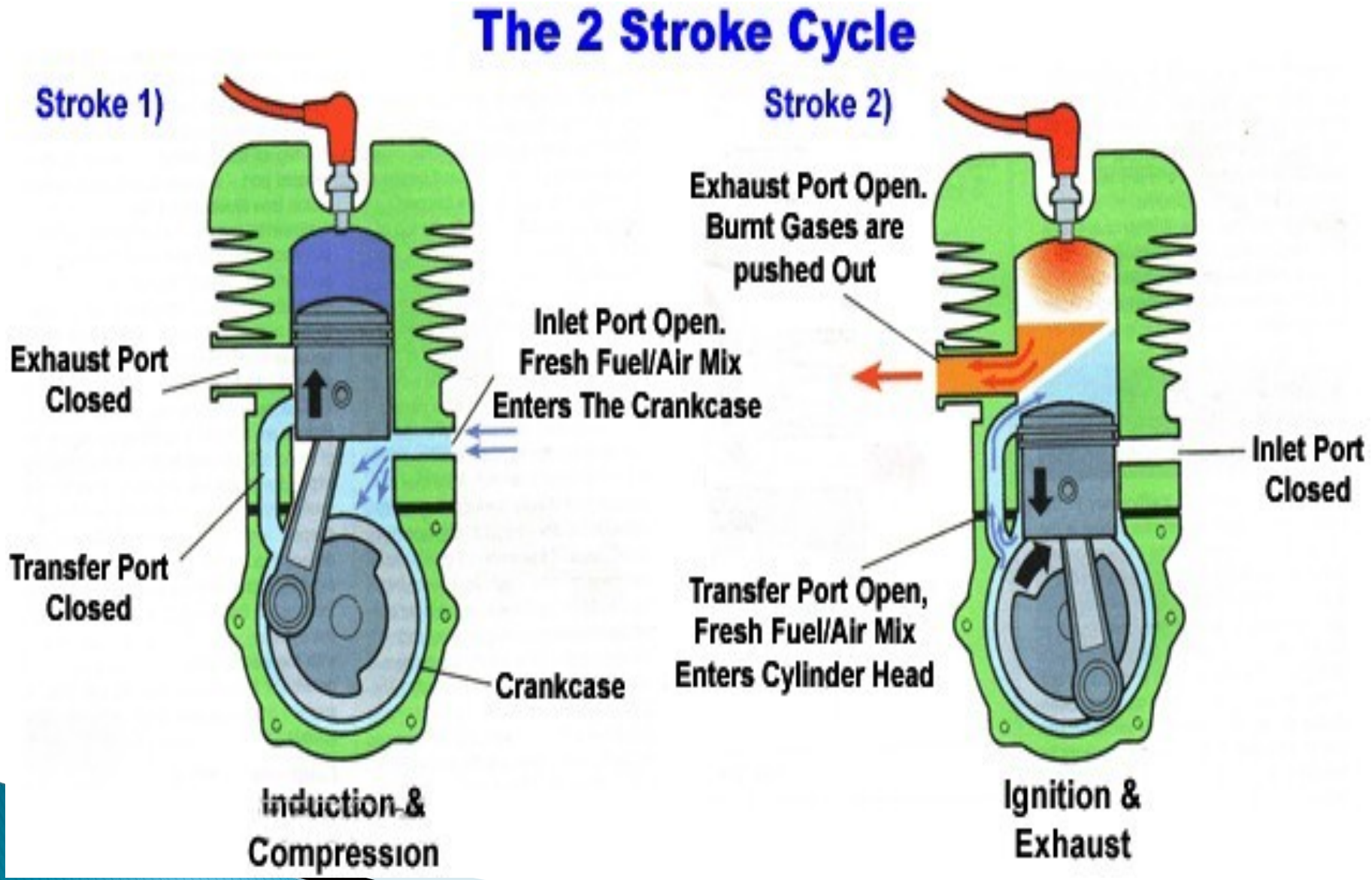
In four stroke engine cycle Two complete revolutions of crank shaft is required for completing one cycle .

In two stroke Engine cycle Operations Suction , Compression , Expansion and Exhaust are completed in One Complete revolution of the crank shaft in two stroke Engines.

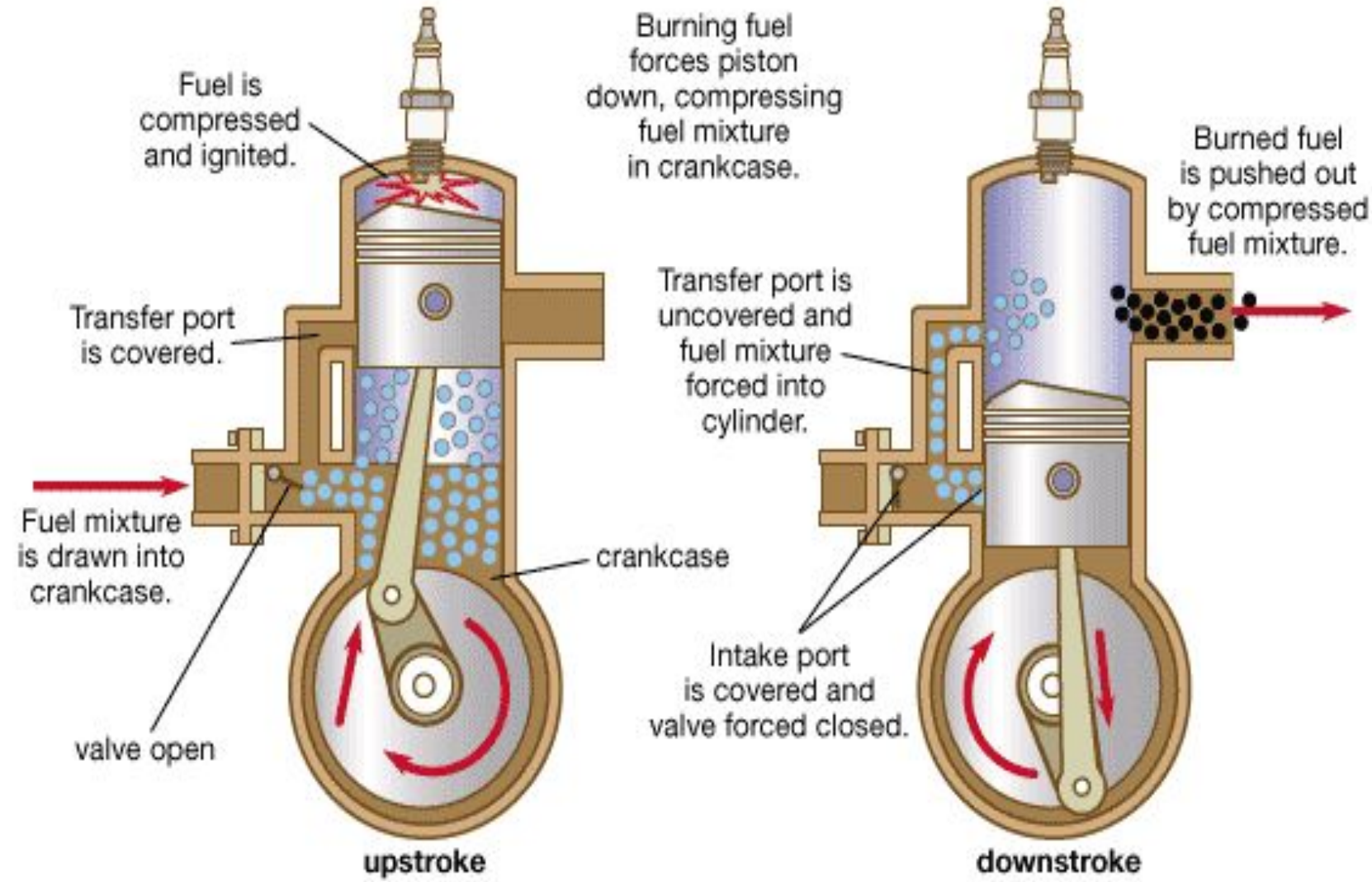
These engines have one Power stroke per revolution of the crank shaft. In two stroke engines there is two openings called PORTS are provided in place of valves of four stroke engines.

These Ports are opened and closed by Reciprocating Motion of the Piston in the Cylinder. One port is known as INLET PORT and another port is known as EXHAUST PORT .

Two Stroke Petrol Engine



Two Stroke Diesel Engine



Difference Between Two Stroke and Four Stroke Engines

FOUR STROKE ENGINE	TWO STROKE ENGINE
Four piston strokes require to complete one cycle .	Only two piston strokes required to complete one cycle .
Two complete revolutions of crank shaft is required to complete one cycle.	Only one complete revolution of crank shaft is required to complete one cycle .
Equal to half of the speed of engine crank shaft . Number of power stroke/min. n=N/2	Equal to the speed of engine crank shaft . Number of power stroke/min. n=N
Power is developed in every alternate revolution of crank shaft .	Power is also developed in every revolution of crank shaft hence for same cylinder.
The power is developed in every alternate revolution, hence heavy fly wheel is required .	The power is developed in every revolution , hence lighter flywheel is required .
These engines are Heavier, larger and required more space.	These engine are lighter more compact and require less space.
The inlet and exhaust valve are require and they are operated by valve operated by valve operating mechanism.	In place of valve, ports are used which opens and close by motion of piston itself.
Lubricating oil consumption is less .	Lubricating oil consumption is more because lubricating oil is mixed with fuel
Thermal efficiency is higher .	Less Thermal efficiency.
Mechanical efficiency is Low because of more number of moving parts .	Mechanical efficiency is High because of less number of moving parts .
These Engines are used basically in High Power Application Where more space is available like Cars , Truck, Tractors , Buses etc .	These Engines are used basically in Low Power Application Where less space is available like Mopeds ,Scooters ,Motor cycle etc .

Efficiencies

- **Mechanical Efficiency** : It is defined as the ratio of the break power and the Indicated power .

$$\eta_{mech} = \frac{B.P.}{I.P.}$$

- **Thermal Efficiency** : It is the efficiency of conversion of the heat energy produced by the actual combustion of the fuel into the power output of the engine . It is the ratio of work done to heat supplied by fuel .

- (1) Indicated Thermal Efficiency $\eta_{it} = \frac{I.P.}{m_f \times C.V}$

  where , m_f = mass of fuel supplied , C.V = calorific value of fuel , J/kg

(2) Break Thermal Efficiency $\eta_{bt} = \frac{B.P.}{m_f \times C.V}$

- **Relative Efficiency** : It is the ratio of Indicated Thermal Efficiency of an engine to air standard cycle Efficiency cycle Efficiency .

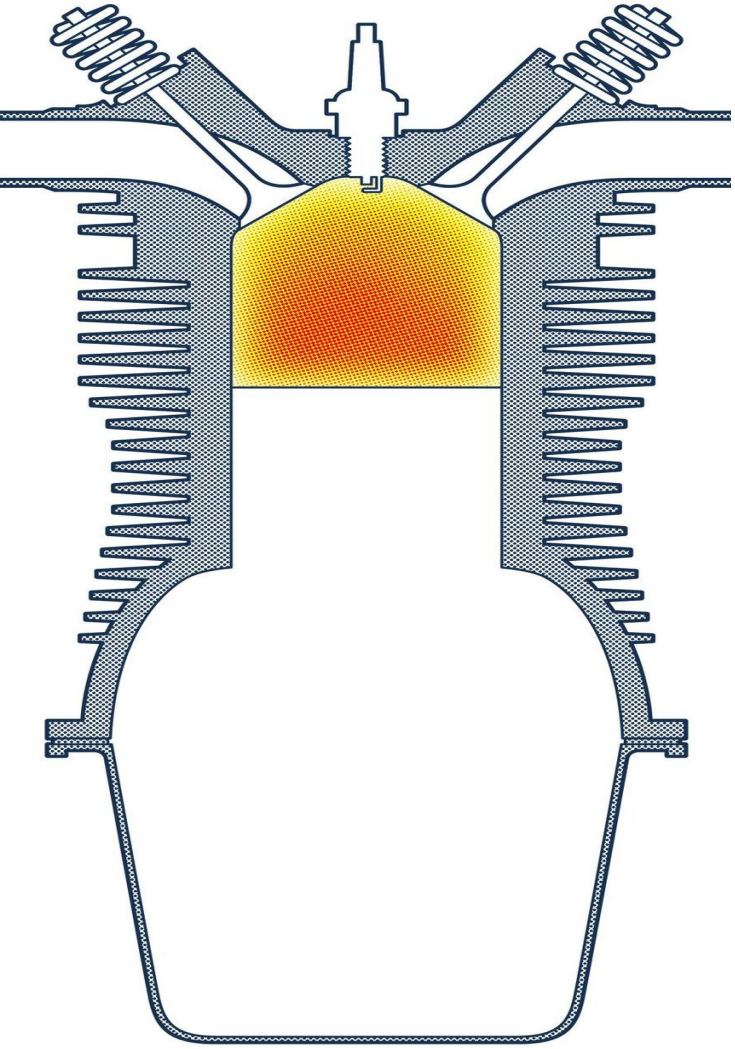
$$\eta_{rel} = \frac{\eta_{it}}{\eta_{air}}$$

- Air standard Efficiency : It is

COOLING SYSTEMS OF IC ENGINES

- We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500°C.
- This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same.
- So, this temperature must be reduced to about 150-200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature.

- It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling.
- It is also to be noted that : (a) About 20-25% of total heat generated is used for producing brake power (useful work). (b) Cooling system is designed to remove 30-35% of total heat. (c) Remaining heat is lost in friction and carried away by exhaust gases.



Air Cooled System

- Air cooled system is generally used in small engines say up to 15-20 kW and in aero plane engines. In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc. Heat generated due to combustion in the engine cylinder will be conducted to the fins and when the air flows over the fins, heat will be dissipated to air. The amount of heat dissipated to air depends upon : (a) Amount of air flowing through the fins. (b) Fin surface area. (c) Thermal conductivity of metal used for fins.

- **Advantages of Air Cooled System**

Following are the advantages of air cooled system :

(a) Radiator/pump is absent hence the system is light.

(b) In case of water cooling system there are leakages, but in this case there are no leakages.

(c) Coolant and antifreeze solutions are not required.

(d) This system can be used in cold climates, where if water is used it may freeze.

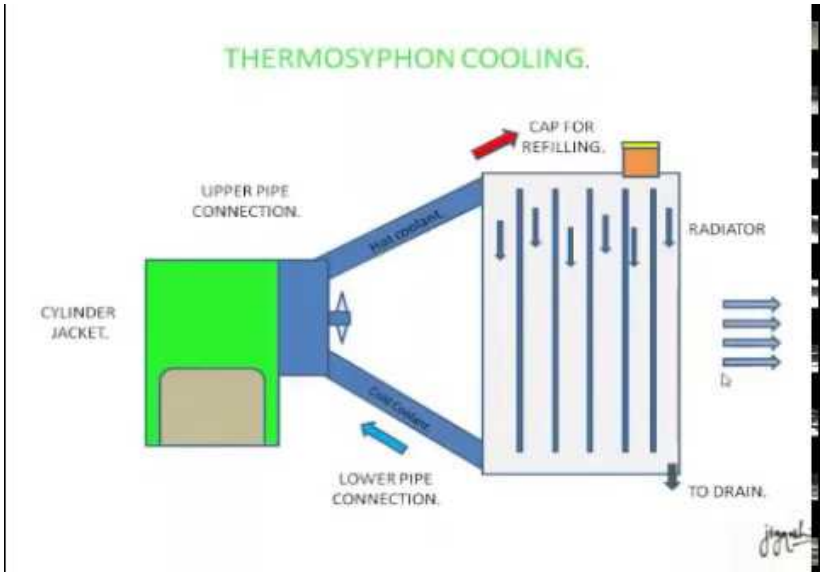
- **Disadvantages of Air Cooled System**

(a) Comparatively it is less efficient.

(b) It is used in aero planes and motorcycle engines where the engines are exposed to air directly.

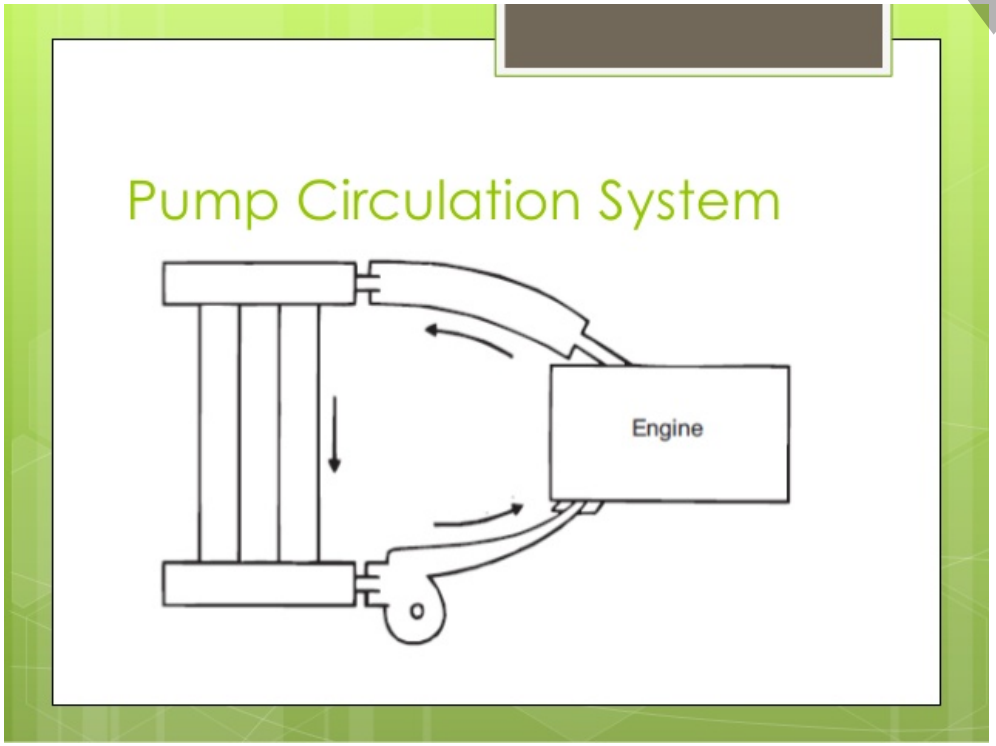
Water Cooled System

- In this method, cooling water jackets are provided around the cylinder, cylinder head, valve seats etc. The water when circulated through the jackets, it absorbs heat of combustion. This hot water will then be cooling in the radiator partially by a fan and partially by the flow developed by the forward motion of the vehicle. The cooled water is again recirculated through the water jackets.
- **Thermo Siphon System** In this system the circulation of water is due to difference in temperature (i.e. difference in densities) of water. So in this system pump is not required but water is circulated because of density difference only.



- **Pump Circulation System**

In this system circulation of water is obtained by a pump. This pump is driven by means of engine output shaft through V-belts.



- **Advantages**

(a) Uniform cooling of cylinder, cylinder head and valves.

(b) Specific fuel consumption of engine improves by using water cooling system.

(c) If we employ water cooling system, then engine need not be provided at the front end of moving vehicle.

(d) Engine is less noisy as compared with air cooled engines, as it has water for damping noise.

- **Disadvantages**

(a) It depends upon the supply of water.

(b) The water pump which circulates water absorbs considerable power.

(c) If the water cooling system fails then it will result in severe damage of engine.

(d) The water cooling system is costlier as it has more number of parts. Also it requires more maintenance and care for its parts.

Sl.no	Air Cooling System	Water Cooling System
1	The design of this system is simple and less costly.	The design of this system is complicated and more costly.
2	The weight of the cooling system (per B.H.P. of the engine) is very less.	The weight of the cooling system (per B.H.P. the engine) in much more.
3	The fuel consumption is more.	The fuel consumption is less.
4	Its installation and maintenance are very easy and less costly.	Its installation and maintenance in difficult and more costly.
5	There is no danger of leakage or freezing of the coolant.	There is a danger of leakage or freezing of the coolant.
6	It works smoothly and continuously. Moreover, it does not depend on any coolant.	If the system fails, it may cause serious damage to the engine within a short time.
7	Air cooling system is not suitable for multi cylinder engines	This system can be employed in multi cylinder engines satisfactorily