MODULE-III:REFRIGERATION AND AIR CONDITIONING AND IC ENGINES

REFRIGERATION:

Refrigeration may be defined as a method of reducing the temperature of a system below that of the surroundings & maintaining at that lower temperature by continuously abstracting the heat from it. The device is used to produce the refrigeration effect is known as refrigerator.

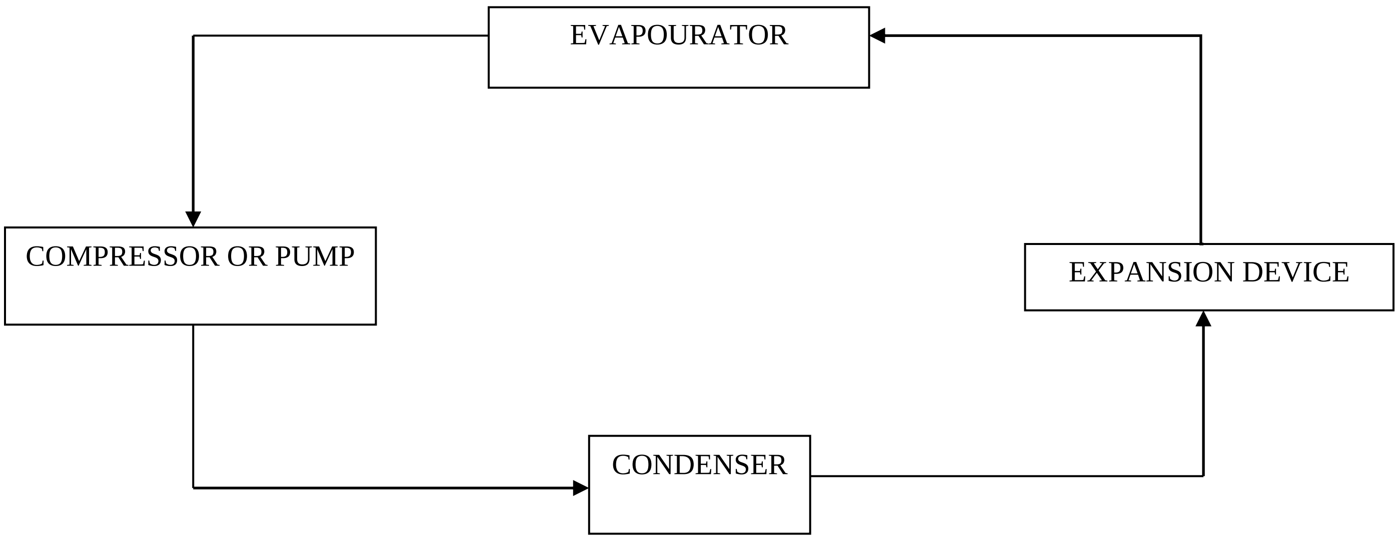
Concepts of refrigeration:

1. Heat is always transferring from body at a high temperature region to the body at a low temperature region.
2. Heat transfer is possible from a lower temperature system to higher temperature surroundings by some external means as per the 2^{nd} law of thermodynamics.
3. The working fluid changes from vapour phase to liquid phase after heat rejection and from liquid phase to vapour phase after heat absorption.
4. The change of phase of the working fluid from liquid phase to vapour phase results in cooling effect.

Principle of Refrigeration:

It is based on 2^{nd} law of thermo dynamics. As per Clausius Statement, heat cannot flow from a body at a lower temperature to a body at a higher temperature unless assisted by some external means. In refrigeration, heat is continuously removed from the system at a lower temperature and same heat is rejected to the surroundings at a higher temperature. This is done by using an external source like a compressor (or) a pump. Heat from a system at lower temperature is abstracted by using a working fluid/medium called refrigerant. The refrigerant rejects the heat to the high temperature surroundings. The refrigerant may be Freon, Ammonia, CO_2, SO_2, hydrocarbon refrigerant, methylene chloride, Ethylene, Ethane, Air, and Water.

Parts of a Refrigerator:



1. Compressor (or) Pump:

To compress and circulate the low temperature and low pressure working fluid into high temperature and high-pressure vapour. They are power absorbing mechanical devices and need input power. An electrical motor supplies power to these drives.

2. Condenser:

The high pressure, high temperature refrigerant entering from the compressor rejects its heat to the surrounding atmosphere in the condenser. It consists of a series of coils in the form of U – tubes. The latent heat of the refrigerant is given to the surrounding atmosphere, which results in change of phase of the refrigerant.

3. Expansion Value:

The high pressure and temperature liquid refrigerant expands in the expansion valve to low pressure & low temperature two-phase mixture. The temperature of the refrigerant drops in the expansion valve due to partial evaporation.

4. Evaporator:

It has cooling coils arranges in form of U – tubes. The function of the evaporator is to reduce the temperature of the refrigerator cabinet. The low temperature two phase mixture of refrigerant passing through the evaporator coils absorbs heat from the cabinet and changes into vapour phase.

Refrigeration Definitions:

1. Refrigeration Effect:

It is the amount of cooling produced by a refrigeration system.

It is defined as the rate at which the heat is removed from the space (or system) to be cooled in a cycle. It is also called *'capacity of refrigerator'*. It is expressed in ***kW or kJ/s.***

2. Ton of Refrigeration or Units of Refrigeration:

The unit of refrigeration is expressed in terms of 'ton of refrigeration'.

It is defined as the amount of heat absorbed in order to produce one ton of ice in 24 hours from water, whose initial temperature is 0°c.

In S.I. units the value of 1Ton of refrigeration =**210 kJ/min or 3.5 kW**

3. Ice Making Capacity:

Ice making capacity is the ability of a refrigerating system to make ice. In other words, it is the capacity of a refrigerating system to remove heat from water to make ice.

4. Co-efficient of Performance:

The performance of a refrigerator is measured by a factor known as Co-efficient Of Performance (COP). It is defined as the ratio or the amount of heat removed from a given space to the work supplied to achieve the heat removal.

$$COP = \frac{Heat\ extracted\ (absorbed)\ from\ the\ refrigerator}{Work\ supplied\ to\ the\ system}$$

or

$$COP = \frac{Heat\ absorbed}{Heat\ rejected - Heat\ absorbed} = \frac{Q}{W} = \frac{T_2}{T_1 - T_2}$$

Where, Q = heat removed in kJ/s and W = work supplied or work done in kJ/s

5. Relative COP:

It is defined as the ratio of actual COP to the theoretical COP of a refrigerator.

$$\text{Relative COP} = \frac{\text{Actual COP}}{\text{Theoretical COP}}$$

Properties of a good refrigerant:

1. It should have very low boiling point and very low freezing point.
2. It should have high enthalpy of evaporation and low specific volume.
3. It should have high latent heat of evaporation so that minimum amount of refrigerant can accomplish the work.
4. It should have low saturation pressure.
5. It should have good thermal conductivity for rapid heat transfer.
6. It should be non-toxic.
7. It should be non-inflammable.
8. It should be non-corrosive to the working parts.
9. It should be economical for both in initial cost and maintenance cost.
10. It should be chemically stable for temperature variations and neutral for lubricating oil.

List of Commonly Used Refrigerants:

The following represent some of the commonly used refrigerant**.**

No.	Refrigerant	Properties
1	**Ammonia (NH3)**	▪ It is the most widely used refrigerant in vapour absorption system. It has a normal boiling point temperature of -33.3°C. ▪ It is highly inflammable, irritating and corrosive. Hence, these food-destroying properties make it unsuitable for domestic refrigerator. ▪ But this refrigerant is used where its toxic nature is not considered seriously. It is used in large industries for cold storage, ice manufacturing plant packaging plants etc.
2	**Carbon dioxide (CO2)**	▪ It is non-toxic and non-flammable. ▪ Its normal boiling point is -77.6°C ▪ Due to its low specific volume the plant size is compact. ▪ It is used in ships where space consideration is more important.

3	**Sulphur dioxide ($S0_2$)**	▪ It is Colourless, suffocating and possesses irritating odour. ▪ It has a high boiling point of-10°C. ▪ This refrigerant was used in house hold refrigerator in olden days.
4	**Freon-12**	▪ It is non-flammable, non-explosive, non corrosive and odourless. ▪ Hence it is a widely accepted refrigerant for various applications. ▪ It has a boiling point of -29.8°C. ▪ It is used in small capacity equipment such as domestic refrigerators, water coolers, air-conditioner etc.
5	**Freon-22**	▪ It has a normal boiling point of -40.8°C that is about 10° less than that of Freon-l2. ▪ It is therefore, a comparatively high-pressure refrigerant. ▪ Freon-22 is employed for air-conditioners in large capacity plants, food freezing, freeze drying etc.

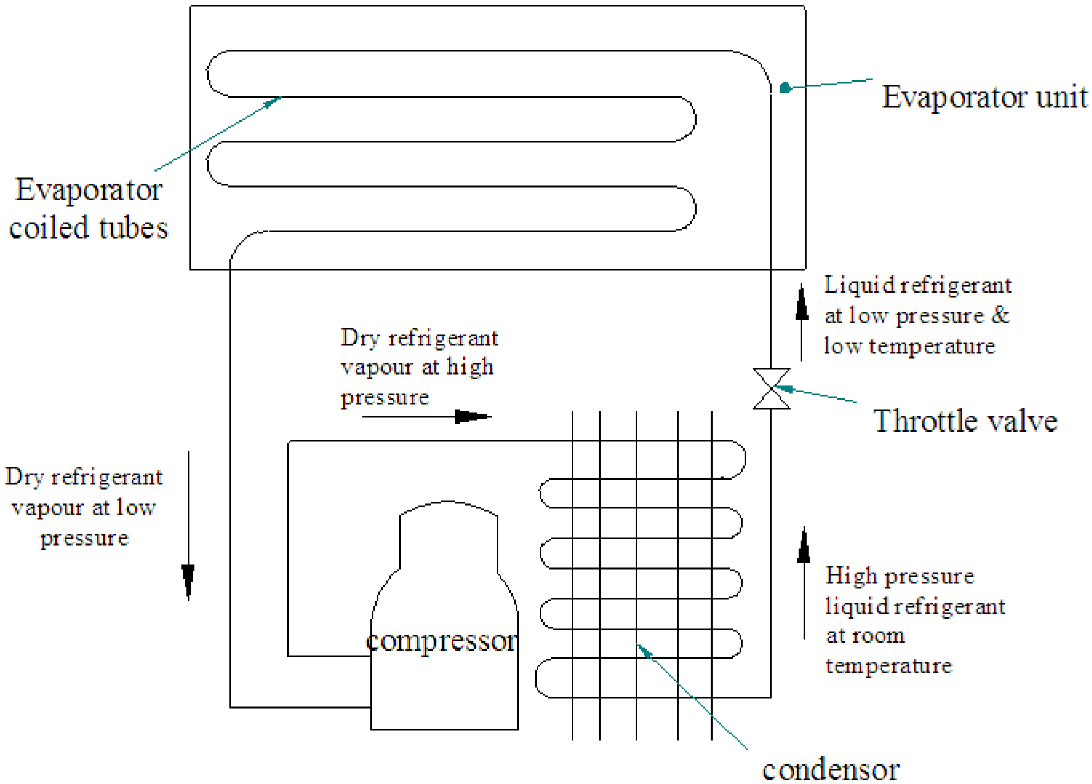
Refrigeration System:

There are three types of Mechanical Refrigerator systems. They are

1. Vapour Compression Refrigerator.
2. Vapour Absorption Refrigerator.

1. Vapour Compression Refrigerator:

➢ In Vapour Compression Refrigerator vapour refrigerant (Freon-12) is compressed as shown in the following figure.



From the fig, the arrangement consist of

1. *Evaporator*
2. *Compressor*
3. *Condenser and*
4. *An Expansion valve*.

- The liquid refrigerant in the *evaporator* absorbs the latent heat from the system (cabinet/refrigerated space) which is to be cooled and undergoes a change of phase from liquid to vapour.
- The vapour refrigerant at low temperature and pressure is drawn into the *compressor* where it is compressed to a high pressure and temperature.
- The compressed vapour refrigerant then enters the *condenser*, where it is cooled and condensed to liquid phase by giving its latent heat to the surrounding medium (atmosphere or water).
- The high-pressure liquid refrigerant leaves the condenser and passes through the *expansion valve* where it is expanded to low pressure and temperature, which will be less than that of the temperature & pressure of the refrigerated space.

- The low pressure-low temperature refrigerant again enters the *evaporator* where it absorbs the latent heat from the system and evaporates.
- The low pressure-low temperature vapour is drawn into the compressor and the cycle repeats.
- Thus heat is continuously extracted from the system, thereby keeping the system at the required lower temperature.

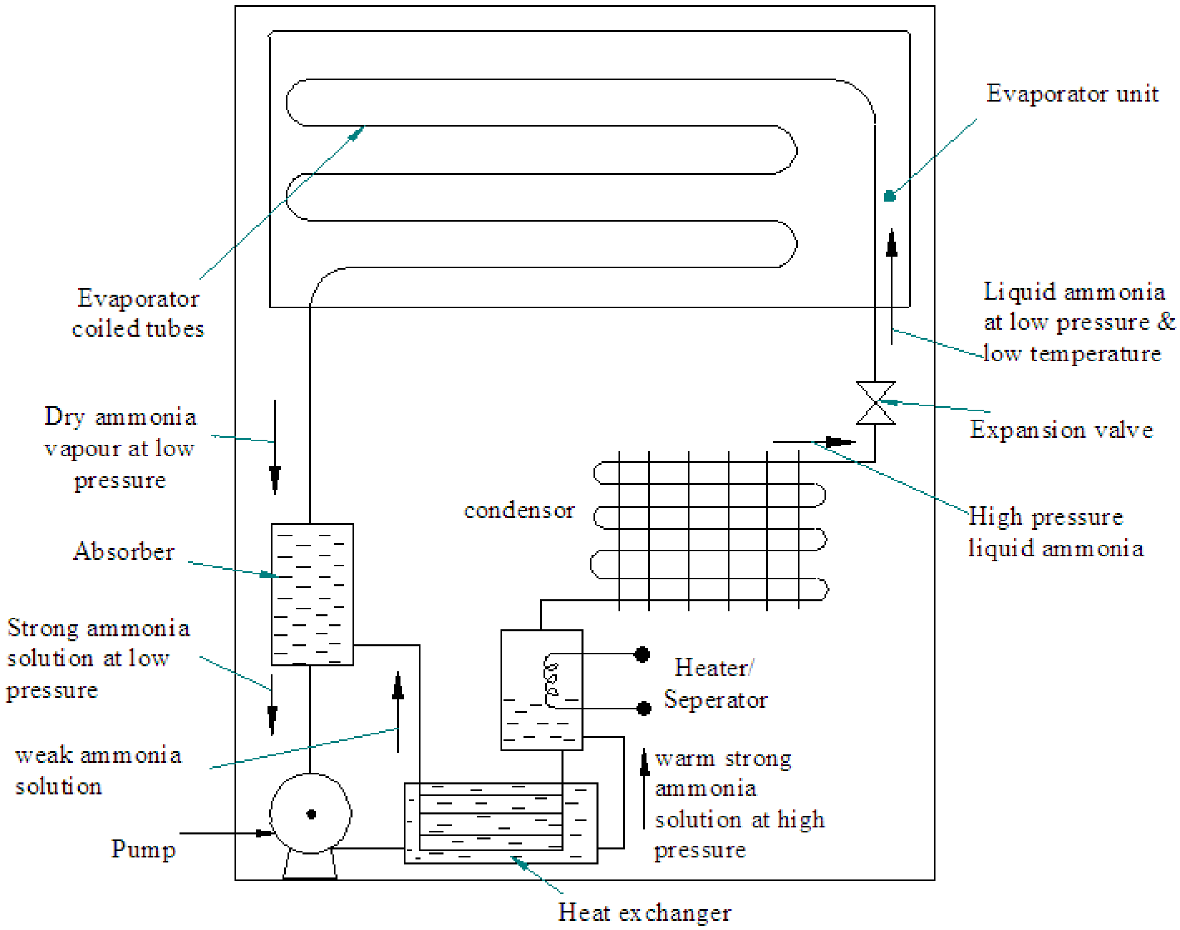
2. Vapour Absorption Refrigerator:

The compressor in the vapour compression refrigeration system consumes lot of energy. To avoid this, the vapour absorption refrigeration system has been developed. In this system, the compression process of vapour compression cycle is eliminated. Instead of that the three following process are introduced.

•Ammonia vapour is absorbed into water

•This mixture is pumped into a high pressure cycle

•This solution is heated to produce ammonia vapour.



The vapour absorption refrigeration system consists of Evaporator, Compressor, Condenser, an Expansion valve, Absorber, Circulating pump, Heat exchanger &Heater-Separator

- The liquid refrigerant (ammonia) in the evaporator absorbs the latent heat from the system (cabinet/refrigerated space) that is to be cooled and it undergoes a change of phase form liquid to vapour. The low pressure vapour refrigerant is then passed to the absorber.
- In the absorber, the low pressure vapour refrigerant (NH_3) is dissolved in the weak ammonia solution producing strong ammonia solution at low pressure.
- The strong ammonia solution is then pumped to a generator through the heat exchanger at high pressure.
- While passing through the heat exchanger, the strong ammonia solution is warmed up by the hot weak ammonia solution flowing from the generator to the absorber.

- This warm strong ammonia solution is heated by an external source in the generator, due to this heating, the weak ammonia solution in turn flows back to the heat exchanger & the high pressure ammonia vapour from the heater-separator passes to a condenser, where it is condensed to liquid phase.
- The high pressure liquid ammonia then passes through the expansion valve where it is expanded to low pressure and temperature.
- The low pressure-low temperature ammonia liquid again enters the evaporator where it absorbs the heat from the system and the cycle repeats.

Comparison between Vapour compression system & Vapour absorption system:

The following table illustrates comparison between Vapour compression system & Vapour absorption system:

Sl No.	Principle	Vapour compression system	Vapour absorption system
1	**Working method**	Refrigerant vapour is compressed	Refrigerant vapour is absorbed.
2	**Type of energy supplied**	Works solely on Mechanical energy	Works solely on Heat energy
3	**Mechanical work done**	More due the compressor used.	Less due the pump used.
4	**Refrigerant used**	Freon-12	Ammonia
5	**Capacity**	Limited to 1000 tons of refrigeration.	More than 1000 tons of refrigeration can be produced.
6	**Noise**	More due the compressor used.	Almost quiet in operation.
7	**Maintenance**	High due the compressor.	Less.
8	**Operating cost**	More	Less
9	**Leakage of Refrigerant**	Is a major problem	Almost no Leakage problem.
10	**COP**	Relatively higher but reduces at part loads.	Relatively lower but increases at part or full loads.

AIR CONDITIONING:

Air conditioning may be defined as the process of simultaneous control of temperature, humidity, cleanliness and air-motion of the confined space.

Principle of Air conditioning:

An Air conditioner is a machine which continuously draws the air from an indoor space (to be cooled) & cools it by refrigeration principles & discharge back into the same indoor space. Such continuous draw and re-circulation of cooled air keeps the indoor space at the required low temperature.

Applications of Air Conditioners:

Air conditioning provides comfort for human beings and also a controlled environment for industrial activities. Hence, applications of air conditioning can be broadly divided into

1. Comfort applications
2. Process applications.

1. Comfort applications:

Aim to provide an indoor environment that remains relatively constant in a range (preferred by humans) despite changes in external weather conditions or in internal heat loads, some of the applications are:

- In Residential buildings - single house and apartments.
- Institutional buildings - offices, hospitals, large complex buildings etc.
- Commercial buildings - shopping centers, malls etc.
- Transportation - in aircrafts, automobiles, ships etc.

2. Process applications:

Aim to provide a suitable environment for a process being carried out, regardless of internal heat loads and external weather conditions, some of the applications are

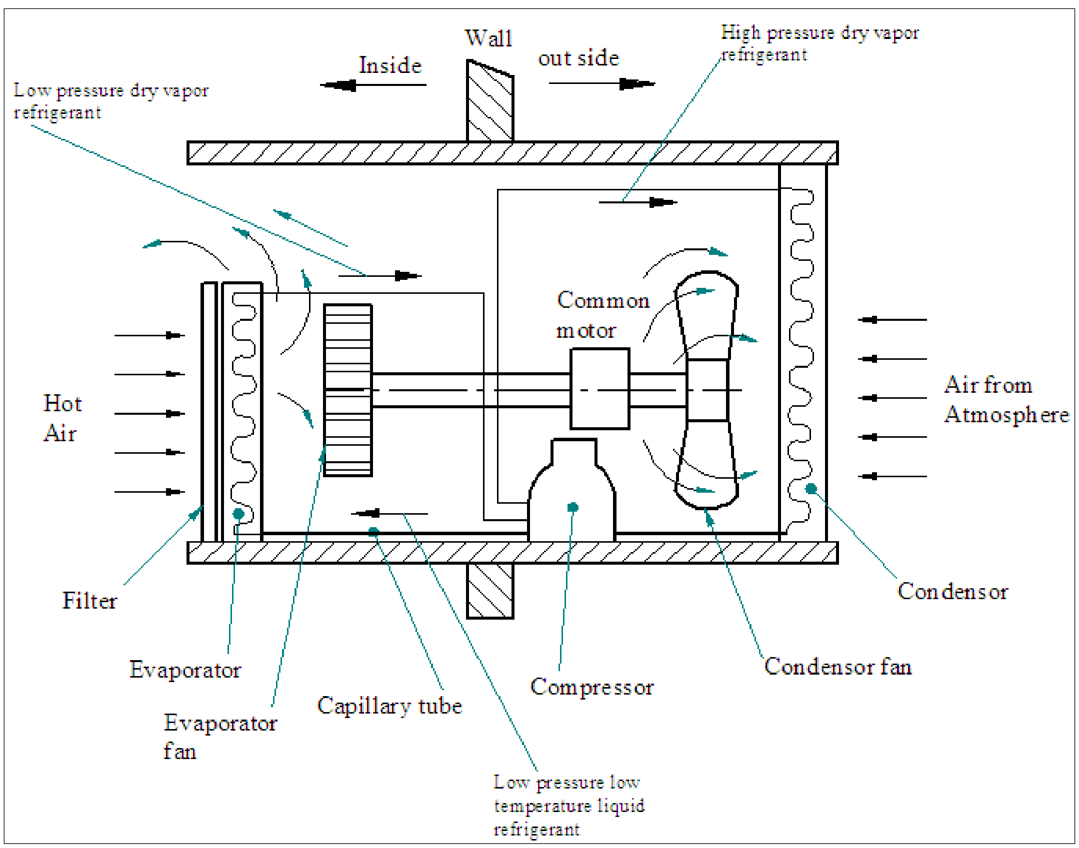
- Hospitals - in operation theatres (to reduce infection risk, to limit patient dehydration)
- Clean rooms - for production of integrated circuits,

- Pharmaceuticals and the like in which very high cleanliness and control of temperature and humidity are required.
- For breeding laboratory animals.
- Nuclear facilities
- Food cooking and processing areas
- Data processing centers etc.

Room air conditioner:

The Air conditioning system consist of

- A vapour compression refrigeration system
- An air filter &
- A double shaft motor that drives a fan at one end and a blower at the other end.
- The room side and the outdoor side of the unit are separated by an insulated partition wall within the casing.



Working:

- The blower sucks the warm air from the room through the air filter and the evaporator.
- The air from the interior passing over the evaporator coils is cooled by the refrigerant, which consequently evaporates by absorbing the heat from the air.
- The high temperature evaporated refrigerant from the evaporator is drawn by the suction of the compressor, which compresses it & delivers it to the condenser.
- The high-pressure-temperature refrigerant vapour now flows through the condenser coils.
- The condenser fan draws the atmospheric air from the exposed side-portions of the air conditioner which is projecting outside the building into the space behind it & discharges to pass through the center section of the condenser unit over the condenser coils.
- The high-pressure-temperature refrigerant passing inside the condenser coils condenses by giving off the heat to the atmospheric air.
- The cooled high pressure refrigerant from the condenser passes through the capillary tube, where it undergoes expansion & is again re-circulated to repeat the cycle continuously.

IC ENGINES:

Heat engines are thermal prime movers which converts the chemical energy contained in the fuel into heat energy by the combustion, further utilizes this heat energy to produce useful mechanical work. Heat engines are classified as

a) **Internal combustion Engine (IC Engine**): are those in which combustion of fuel takes place inside the engine cylinder. ***Example:*** *Petrol engines, Diesel engines, Gas engines, etc.*

b) **External combustion Engine (EC Engine):** are those in which combustion of fuel takes place outside the engine cylinder. ***Example:*** *Steam engines, Steam turbines.*

CLASSIFICATION OF I.C. ENGINES

I.C Engines can be classified into the following types:

(i)According to the type of fuel used

a) Petrol engines - fuel used in these engines is petrol.
b) Diesel engines - fuel used is Diesel.

(ii)According to the number of strokes

a) 4-strokeengine - the working cycle is completed in four different strokes.
b) 2-strokeengine - the working cycle is completed in two different strokes.

(iii) According to the method of ignition

a) Spark ignition engine (S.I engine) - Fuel is ignited by an electric spark.
b) Compression ignition engine (C.I. engine) – Ignition takes place due to high compression.

(iv) According to the cycle of combustion

a) Otto cycle engine – Combustion of fuel takes place at constant volume.
b) Diesel cycle engine - Combustion of fuel takes place at constant pressure.

(v) According to the number of cylinders

a) Single cylinder engine – These engines consist of only one cylinder.
b) Multi-cylinder engine - It consists of 2,3,4,6 or 8 cylinders.

(vi) According to the arrangement of cylinders

a) Inline or parallel engines - Cylinders are arranged in a line.
b) Radial engines – Cylinders are arranged radially.
c) V-engines – the arrangement of two cylinders are at an angle.
d) Opposed type engine - Cylinders are arranged opposite to each other.

(vii) According to the method of cooling

a) Air cooled engines – the cooling of the engine is done by air. Example: bike
b) Water cooled engines – the cooling of the engine is done by water, here a radiator is used for cooling purpose. Example: cars

IC ENGINE PARTS:

The following figure illustrate major parts of an IC Engine

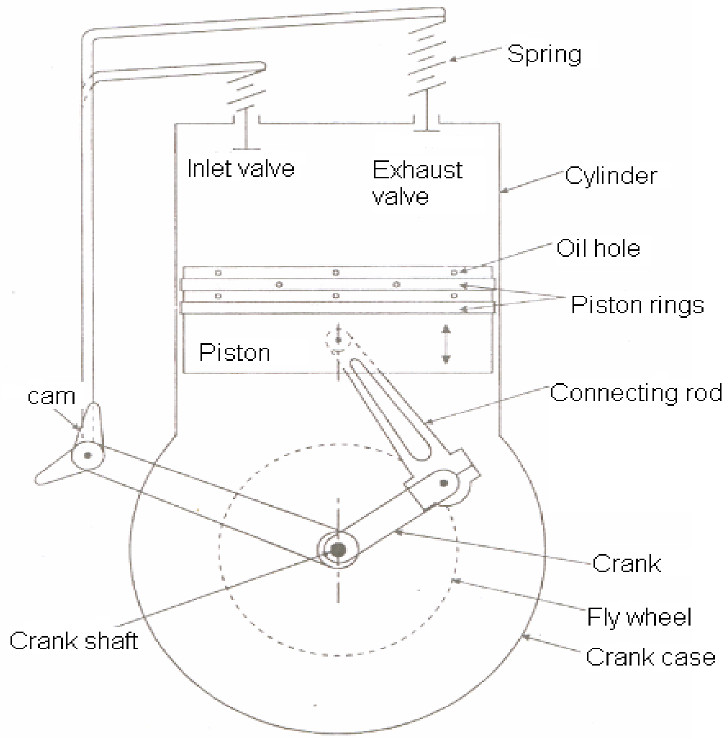


Fig: Parts of IC Engine

The parts of internal combustion engines are Cylinder, head, piston, piston rings (compression rings and oil control ring), connecting rod and crankshaft.

Functions of IC engine parts:

Cylinder (cylinder block): The cylinder is the main part of an engine. The combustion takes place in the combustion chamber and these gases exert pressure on the piston, due to high gas pressures the piston reciprocates in the cylinder block. The cylinder is designed to with stand high gas pressure. The temperature in the combustion chamber (cylinder block) will reach up to 2800^0 C. The cylinder has to be cooled properly either by air cooling or water cooling. In case of air cooled engines fins are provided around the cylinder block (Scooter and bikes) in water cooled engines water jackets are provided for the circulation of water to carry away the heat around the cylinder block. The cylinder block material is grey cast iron.

Cylinder head: The head is fitted on the top of the cylinder block and is provided with the inlet valve, exhaust valve and spark plug/fuel injector. There is a gasket is provided between cylinder and cylinder head in order to prevent the leakage of high pressure gases. The material used for cylinder head is grey cast iron and for gasket is copper and asbestos.

Piston: The piston is a cylindrical plug, which converts heat energy in to mechanical energy. A two stroke piston is fitted with only compression ring. In four-stroke engine both compression ring and oil control rings are fitted. The piston is connecting to the small end of the connecting rod. The piston is made of aluminium alloy. Functions of piston are

i) The piston will act as a seal

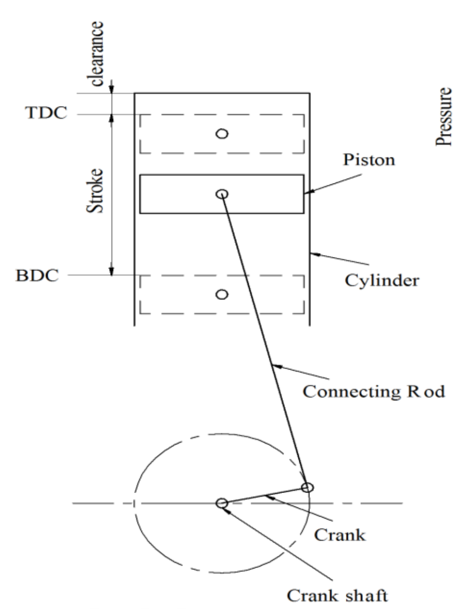
ii) To provide the passage for heat flow from piston to cylinder block through rings.

iii) It transmits the force of explosion to the crankshaft through connecting rod.

Connecting rod: The small end of the connecting rod is connected to the piston and the big end of the connecting rod is connecting to the crankshaft. The connecting rod converts the reciprocating motion of piston in to rotary motion of crankshaft. The connecting rod is made of I-beam cross section to provide maximum rigidity with minimum weight.

Crankshaft: The big end of the connecting rod is connected to the crankshaft. The power transmission starts from the crankshaft. The crankshaft is rigidly fixed in the crankcase. The other end of the crankshaft is connected to a clutch.

Crankcase: Crankcase is fitted at the bottom of the cylinder block. Two-stroke engine crankcase is properly sealed and made airtight. Four stroke engine crankcase will serve as a reservoir, filled with sufficient quantity of lubricating oil. This oil lubricates the main bearings of crankshaft, big end bearings of connecting rod, lubricates the cylinder liner, piston and piston rings.



IC Engine Terminology:

1) **Bore:** The nominal inside diameter of the engine cylinder is known as Bore.

2) **Stroke:** It is the linear distance, measured parallel to the axis of the cylinder, between extreme upper and lower positions of the piston.

3) **Top Dead Centre (TDC):** TDC in vertical engine is the extreme position of the piston nearer to the cylinder head. The cylinder volume is minimum at TDC. In case of horizontal engine this position is known as inner dead center (IDC).

4) **Bottom Dead Centre (BDC):** BDC in vertical engine is the extreme position of the piston towards the crank end. The cylinder volume will be maximum. In case of horizontal engine. This position is known as outer dead center (ODC).

5) **Clearance volume:** the volume contained in the cylinder above the top of the piston When the piston is at TDC is known as clearance volume and it is denoted by V_c

6) **Swept volume**: The volume swept by piston while traveling from TDC to BDC in known as swept volume and is denoted by V_s.

$V_s = (\pi D^2 / 4)\, L \quad m^3$

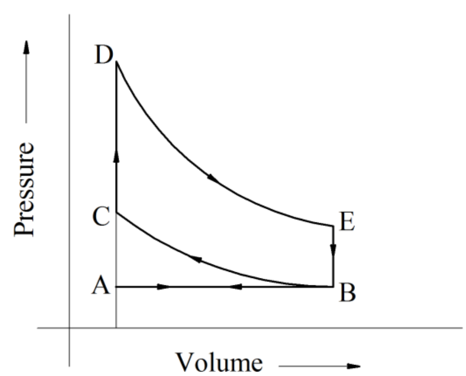
7) **Compression ratio**: It is the ratio of total volume of cylinder (V_s+V_c) to the clearance volume (V_c). It is denoted 'r'.

$$r = (V_s+V_c) / Vc$$

The compression ratio of petrol engine varies from 7:1 to 12:1.

The compression ratio of diesel engine varies from 16:1 to 22:1

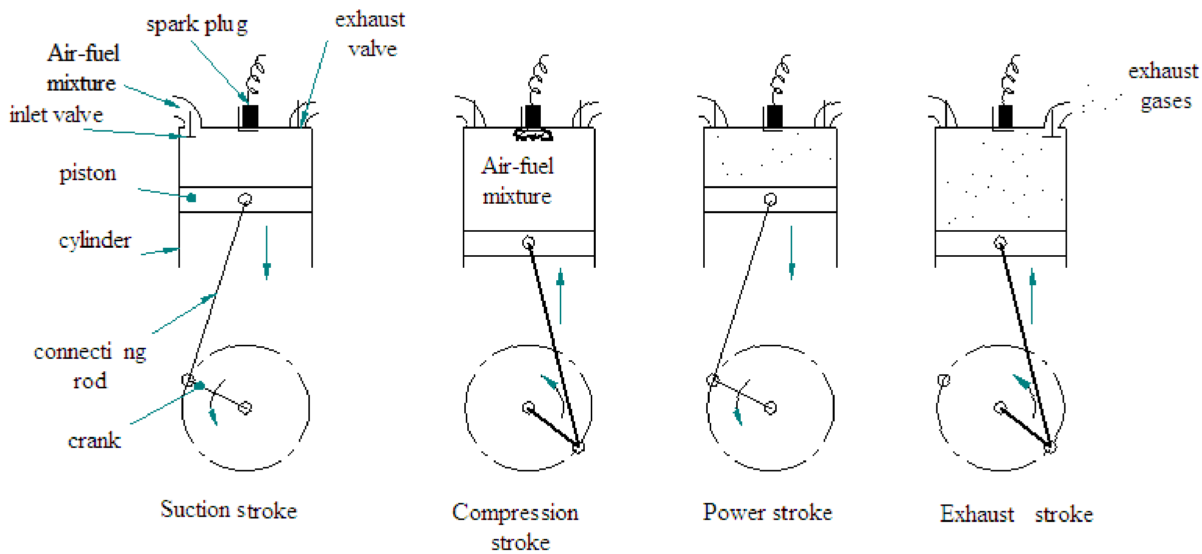
4-Stroke Petrol Engine:



The four-stroke petrol engine works on the principle of Otto (constant volume) cycle. As heat addition takes place at constant volume, this cycle is known as constant volume cycle. The parts of four-stroke petrol engine are cylinder, piston, head, crankcase, connecting rod, crankshaft, spark plug, and inlet and exhaust valve. The four-stroke petrol engine may be air-cooled or water-cooled. The piston performs four strokes to complete one cycle. The four different strokes are

i) Suction stroke ii) Compression stroke iii) Power or Expansion stroke iv) Exhaust stroke

Since the ignition in these engines is due to the spark of a spark plug, it is very commonly known as spark ignition engines (S.I Engines).



1. **Suction stroke**: The suction stroke is completed by rotating the crankshaft from 0^o to 180^o. During suction stroke the inlet valve opens and exhaust valve should kept in closed condition. When the piston starts moving from TDC to BDC, The volume above the piston increases, results in decrease in pressure (vacuum), This decrease in pressure draws the petrol and air mixture from the carburetor and delivered it to the cylinder, this process is continuous till the pressure inside the cylinder becomes equal to atmosphere. At the end of suction stroke the cylinder is completely filled with petrol and air mixture. At the end of suction stroke the inlet valve closes. The line AB in the PV diagram represents suction stroke (volume of mixture filled in the cylinder).

2. Compression stroke:

- During the compression stroke both inlet and exhaust valves are closed and the piston travels from the BDC to TDC & the crankshaft revolves further by half rotation, causing the compression of air and fuel mixture.
- This stroke is represented by a line **BC** on the (Pressure -Volume) P-V diagram.
- At the end of this stroke a spark is produced by a sparkplug, resulting in the combustion of the fuel and air & is represented by a line **CD** on P-V diagram.

3. Power stroke / Expansion stroke / Working stroke:

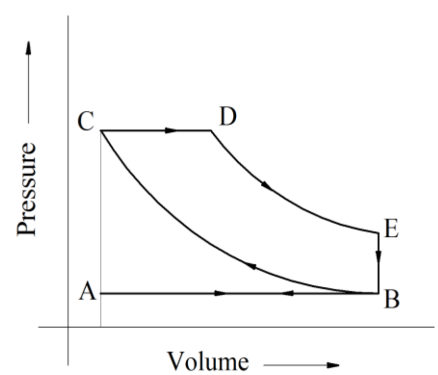
- In this stroke the piston travels from TDC to BDC with both the valves remain closed & the crankshaft revolves half rotation.
- The piston is forced due to the expansion of the burnt gases .This linear motion of the piston is transmitted to the crankshaft through the connecting rod to produce Mechanical power. This stroke is called as power stroke as the Mechanical power is produced during this stroke.
- It is represented by the curve **DE** on a P-V diagram.
- As the piston moves further, the pressure of the hot gases gradually decreases at constant volume as represented by the line **EB** in PV diagram.

4. Exhaust stroke:

- During Exhaust stroke the exhaust valve opens with inlet valve closed and the piston travels from BDC to TDC, causing the exhaust of burnt gases from the cylinder & the crankshaft revolves half rotation.
- This stroke is represented by a line **BA** on the (Pressure -Volume) P-V diagram.

4-Stroke Diesel Engine:

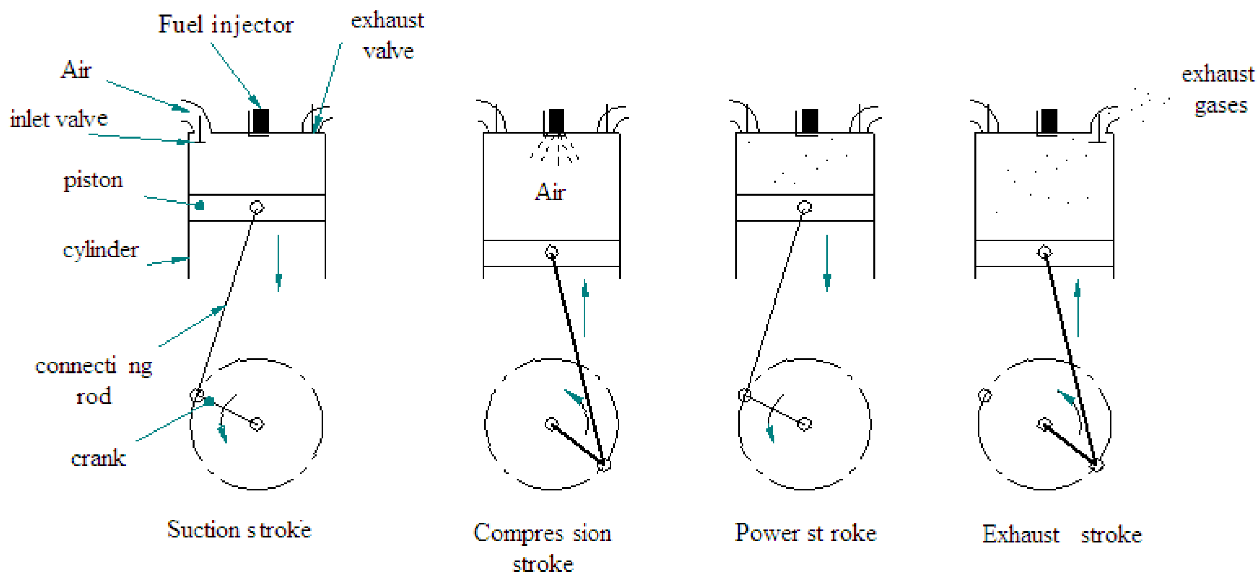
The working principle of a 4-stroke Diesel engine is based on Diesel cycle (constant pressure cycle). Hence, it is also called as constant pressure cycle engine. Since the ignition in these engines is due to high compression of air, it is very commonly known as Compression Ignition engines (C.I Engines).



The four strokes that are performed are,

1. Suction stroke
2. Compression stroke
3. Working stroke or Power stroke or Expansion stroke &
4. Exhaust stroke

The following figure represent working principle of 4-stroke Diesel engine with Theoretical Diesel-cycle.



1. Suction stroke:

- During suction stroke the inlet valve opens with outlet valve closed & the piston travels from (Top Dead Center) TDC to (Bottom Dead Center) BDC & the crankshaft revolves by half rotation, causing the suction of pure air.
- The energy required to perform this stroke is supplied by ‘cranking’ only during the first cycle at the time of starting, while running, the flywheel supplies the mechanical energy.
- This stroke is represented by a line **AB** on the (Pressure -Volume) P-V diagram.

2. Compression stroke:

- During the compression stroke both inlet and exhaust valves are closed and the piston travels from the BDC to TDC & the crankshaft revolves further by half rotation, causing the compression of air.
- This stroke is represented by a line **BC** on the (Pressure -Volume) P-V diagram.
- At the end of this stroke a metered quantity of fuel is injected through the fuel injector, the high temperature of the air ignites the fuel as soon as it is injected. This is called Auto-ignition or Self-ignition

3. Power stroke / Expansion stroke / Working stroke:

- In this stroke the piston travels from TDC to BDC with both the valves remain closed & the crankshaft revolves half rotation.
- The burnt gases released by the combustion of the fuel that is continuously injected into the cylinder, force the piston to perform earlier part of this stroke at constant pressure till the injection of the fuel is completed. This constant pressure expansion with simultaneous combustion is represented by the line **CD** on PV diagram.
- The piston is forced further during the remaining part of this stroke due to the expansion of the burnt gases .This linear motion of the piston is transmitted to the crankshaft through the connecting rod to produce Mechanical power. This stroke is called as power stroke as the Mechanical power is produced during this stroke.
- It is represented by the curve **DE** on a P-V diagram.
- As the piston moves further, the pressure of the hot gases gradually decreases at constant volume as represented by the line **EB** in PV diagram.

4. Exhaust stroke:

- During Exhaust stroke the exhaust valve opens with inlet valve closed and the piston travels from BDC to TDC, causing the exhaust of burnt gases from the cylinder & the crankshaft revolves half rotation.
- This stroke is represented by a line **BA** on the (Pressure -Volume) P-V diagram.

2-Stroke Petrol Engine:

One cycle is completed in 2 strokes of the piston in one revolution of the crankshaft. It has only ports at the cylinder walls and has no valves. These ports are covered and uncovered by the upward and downward movement of the piston

Scavenging: The exhaust gases are removed from the cylinder with the help of fresh compressed charge. This process of removing exhaust gases is called scavenging.

Deflector: In order To prevent the loss of incoming charge and helps for exhausting hot gases piston is provided with a deflector at its top. It is mainly used in scooters and motor cycles. It is having 3 ports.

1. Inlet Port: Through this inlet port only, Fresh charge from the carburetor is taken into the cylinder.
2. Transfer port: Through this Transfer port only, fresh charge entering into the cylinder from the crankcase.
3. Exhaust port: The Hot exhaust gases are pushed out from the combustion chamber. The cycle beginning at the point when the piston reaches TDC at the end of the compression stroke. When the piston is at TDC the exhaust and transfer ports are covered and inlet port is uncovered. When the piston is at BDC the exhaust and transfer ports are uncovered and inlet port is covered.

The following figure represent working principle of 2-stroke Petrol engine.

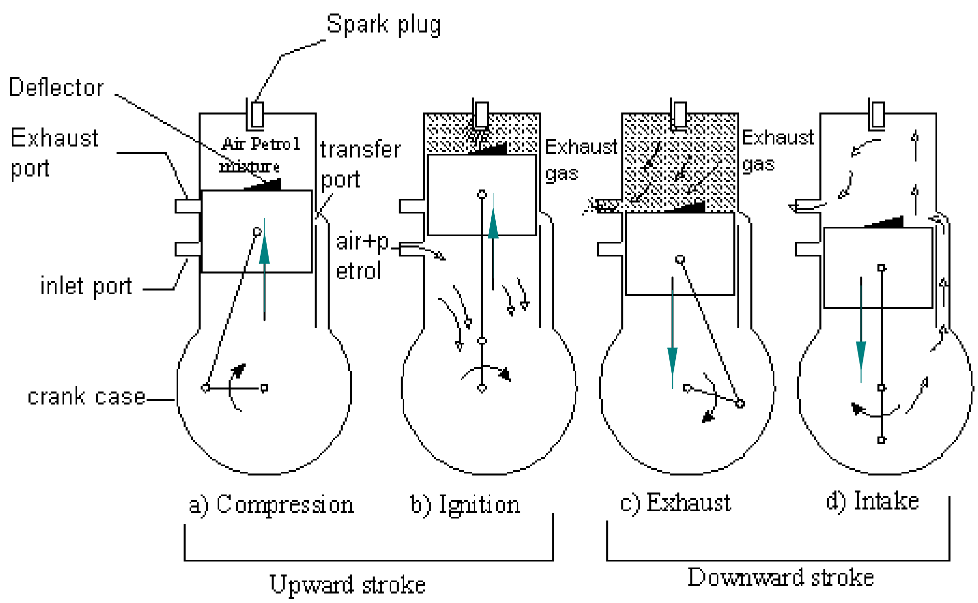


Fig: 2-Stroke Petrol Engine

A 2-stroke petrol engine works on the principle of Otto cycle & involves the following two strokes.

1. Upward stroke &
2. **Downward** stroke

1. Upward Stroke:

- During upward stroke the piston moves from BDC to TDC & the crankshaft revolves by half rotation, causing the compression of air and fuel mixture.
- Due to this upward movement of the piston, a partial vacuum is created in the crankcase & fresh air and fuel mixture is drawn from the inlet port to the crank case .As the piston moves upward, the exhaust port and the transfer port are covered by the piston.
- At the end of this upward stroke, the compressed charge is ignited in the combustion chamber by a spark plug.

2. Downward Stroke:

- During this stroke, as soon as the charge is ignited, the hot gases force the piston to move from TDC to BDC & the crankshaft revolves by half rotation.
- This linear motion of the piston is transmitted to the crankshaft through the connecting rod to produce Mechanical power.

- Further downward movement of the piston uncovers first the exhaust port & then the transfer port.
- The burnt gases escape through the exhaust port & the compressed charge from the crankcase flows into the cylinder through the transfer port. Here deflectors are used, so that the fresh air and fuel should not mix up with the burnt gases as shown in figure (d).

Comparison between Petrol Engine & Diesel Engine:

Sl No	**SI Engines** (Petrol engine)	**CI Engines** (Diesel engine)
1	Ignition of the fuel by spark plug	Ignition of the fuel by spraying fuel to compressed air at high temperature
2	Works on theoretical Otto cycle	Works on theoretical Diesel cycle
3	Fuel used is petrol	Fuel used is diesel
4	A mixture of air and petrol is drawn during suction stroke	Only air is drawn during suction stroke
5	Combustion is at constant volume	Combustion is at constant pressure
6	Low compression ratio ranging from 7:1 to 12:1	High compression ratio ranging from 16:1 to 22:1
7	Fuel cost is high	Fuel cost is low
8	Power output will be less	Power output will be more

Comparison between 2-stroke & 4-stroke IC Engine:

Sl No	Two-stroke Engines	Four-stroke Engines
1	One cycle is completed in two strokes of the piston	One cycle is completed in four strokes of the piston
2	Power is developed during each revolution of the crank	Power is developed during every alternate revolution of crank
3	Flywheel not essential but small flywheel can be provided for smooth operation	Flywheel is essential
4	Ports are used	Valves are used
5	Charge is admitted first into crank case and then to cylinder	Charge is admitted directly into cylinder
6	Construction is simple	Construction is complicated
7	Exhaust gases are driven out by the piston during the exhaust stroke	Exhaust gases are driven out by the incoming fresh charge

Performance parameters of IC engines:

i) **Mean effective pressure (p_m)**:

It is defined as the average pressure is acting on the piston during the entire expansion (power stroke) stroke.

p_m = Mean effective pressure **N / m²**

$$P_m = \frac{Net\ area\ of\ the\ indicator\ diagram \times spring\ cons\tan t}{Length\ of\ the\ indictor\ diagram}$$

$$P_m = \frac{a \times s}{l}$$

P_m is the hypothetical pressure acting on the piston throughout the power stroke.

ii) Indicated power (IP):

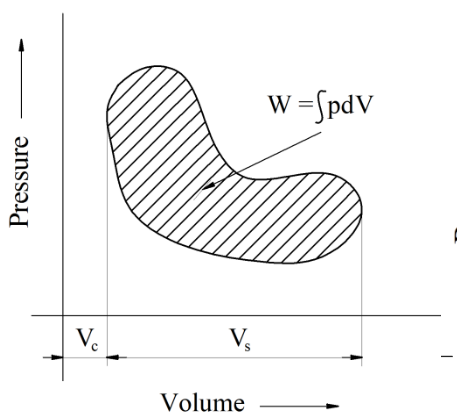
The power developed within the piston –cylinder arrangement by the combustion of fuel is known as the indicated power. The pressure acting on the piston varies throughout the working cycle. To record the variation of pressure for one cycle of operation, a device called piston indicator is mounted by drilling a small hole on the cylinder cover. It mainly consists of a small plunger and a cylinder. The plunger displacement is proportional to the pressure acting on it from inside against the spring force on the other side. The movement of the plunger transmitted to a stylus through linkages. The stylus traces out a graph on a recording drum, which rotates at a constant speed. The graph thus obtained is called the indicator diagram. The area of the indicator diagram is proportional to the work done in a cycle.

Mean effective pressure (p_m):

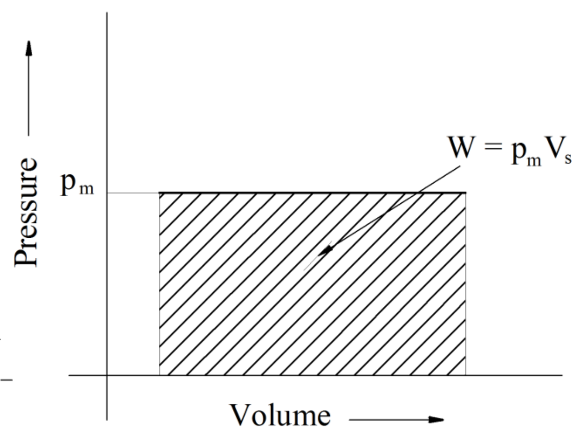
The work done on the piston for one cycle of operation is given by

$$W = \int pdV,$$

Where the integration is carried out for one cycle,



Indicator diagram.



Mean effective pressure.

The right hand side of the equation is nothing but the area within the loop on the pressure-volume diagram.

The mean effective pressure is defined as the equivalent constant pressure which has to be acting on the piston during the expansion stroke, to give the same work output as the varying pressure, in one cycle.

From the indicator diagram, the mean effective pressure can e calculated as,

$p_m = s.a/l$.

Where,

s = spring constant of the spring used in the piston indicator,

l = length of the indicator diagram,

a = area of the indicator diagram.

$$IP = \frac{p_m\, L\, A\, n}{60 \times 1000}\ \textbf{kW}$$

Where,

p_m = mean effective pressure,

L = stroke length,

A = area of cross-section of the piston,

n = number of cycles per minute,

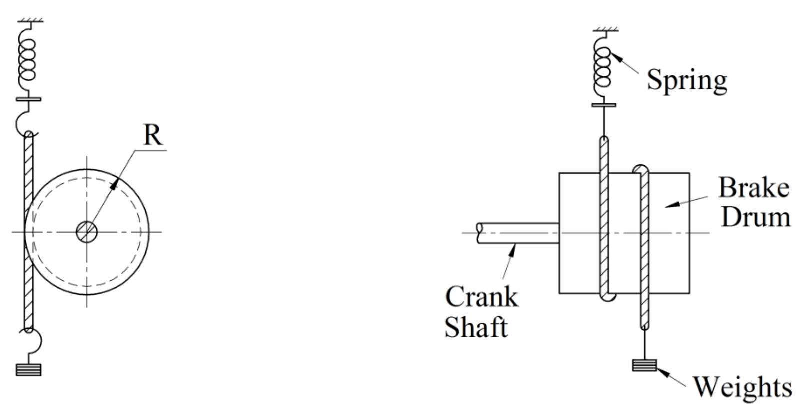
= N/2 for a four stroke engine,

= N for a two stroke engine.

N = crank shaft speed, rpm.

iii) Brake power (BP):

The power available at the crank shaft is always less than the power developed within the piston-cylinder arrangement because of frictional losses in the moving parts. The power actually available at the crank shaft is called the brake power. It can be measured using dynamometers. One such dynamometer is the brake-drum dynamometer.



It consists of a drum, which is mounted on the crankshaft. A rope is wound on the drum. One end of the rope is connected to a spring balance, and the other end, to a weight-loading device.

The torque on the brake drum is given by,

$T = (W - S) \times R$ Where, W = weight on the rope, N.

S = spring balance reading, N.

R = mean radius of brake drum, m.

Brake power is given by,

$$BP = \frac{2\,\pi\,N\,T}{60 \times 1000} \quad \textbf{kW}$$

iv) Frictional power(FP):

The difference between indicated power and brake power is known as frictional power

$$FP = IP - BP \quad \textbf{kW}$$

v) Mechanical efficiency:

It is defined as the ratio of brake power to indicated power

$$\eta_{mech} = \frac{\text{Brake power}}{\text{Indicated power}}$$

vi) Thermal efficiency:

In IC engines, energy is supplied to the engine by burning fuel. But all of the energy that is supplied is not converted into useful mechanical work. Some of the energy supplied is lost through hot exhaust gases, some due to the cooling of the engine and some through radiation and convection heat losses. The fraction of the energy supplied that is available as useful work determines the thermal efficiency of the engine. The thermal efficiency can be calculated either for the indicated power, or for the brake power. Accordingly they are referred to as indicated thermal efficiency, and brake thermal efficiency.

Heat supplied to the engine per sec = mass of fuel burnt x calorific value.

$$\eta_{\text{indicated thermal}} = \frac{\text{Indicated power}}{m_f \times CV}$$

$$\eta_{\text{brake thermal}} = \frac{\text{Brake power}}{m_f \times CV}$$

Where,

m_f = Mass of fuel used in **kg / sec**.

CV = Calorific value of fuel **kJ / kg**

vii) Specific fuel consumption (SFC):

It is the mass of fuel supplied per hour in order to get unit power output.

$$SFC = \frac{m_f}{\text{Power}} \text{ kg/kW-hr}$$

SFC can be calculated on indicated power basis or on brake power basis.

Problems:

1. A single cylinder two stroke cycle I.C engine has a piston diameter of 105mm & stroke length 120mm. The mean effective pressure is 6bar .If the crankshaft speed is 1500rpm, calculate the indicated power of the engine.

2. A two stroke Diesel engine has a piston diameter of 200mm & a stroke of 300mm .It has mean pressure of 2.8 bar & a speed of 400rpm. The diameter of the brake drum is 1m & the effective brake load is 64kg. Find the indicated power, the brake power, the Mechanical efficiency of the engine & the average piston speed.

3. A four stroke I.C engine running at 450rpm has a bore diameter of 100mm & stroke length 120mm. The indicated diagram details are;

Area of the diagram = 4cm^2

Length of indicator diagram = 6.5cm

Spring value of the spring used = 10bar/cm

Calculate the indicated power of the engine. Also find the average piston speed.

4. Find the indicated power of a four stroke petrol engine of swept volume of 6ltrs & running at 1000rpm. The mean effective pressure is 600 kN/m^2

5. The following readings were taken on a four stroke I.C engine

Diameter of the brakedrum = 1.5m

Spring balnce reading = 5kg

Diameter of the rope = 10mm

Crankshaft speed = 200rpm

Load suspended on the brakedrum = 100 kg.

Determine the brakepower of the engine?

6. The following data refers to a single cylinder four stroke petrol engine

Cylinder diameter = 20cm;

Stroke of piston = 40cm,

Engine speed = 400 rpm;

Indicated mean effective pressure = 7bar,

Fuel consumption = 10 liters/hr;

Calorific value of the fuel = 45000kj/kg, S

pecific gravity of the fuel = 0.8.

Find indicated thermal efficiency?

7. A four stroke petrol engine of 100mm bore & 150mm stroke consumes 1kg of fuel/hr. The mean effective pressure is 7bar & its indicated thermal efficiency is 30%. The calorific value of the fuel is 40x10^3 kJ/kg. Find the crankshaft speed?

8. The following are the details of a 4-stroke petrol engine. (i) Diameter of brake drum=60.03cm, (ii) full brake load on drum=250N, (iii) brake drum speed = 450 rpm, (iv)

Calorific value of petrol = 40MJ/kg, (v) brake thermal efficiency=32%, (vi) mechanical efficiency=80%, specific gravity of petrol=0.82. Determine (i) brake power, (ii) indicated power, (iii) fuel consumption in liter per second, and (iv) indicated thermal efficiency.

9. The following observations were recorded during a test on a 4-stroke engine. Bore = 25cm, stroke=40cm, crank speed=250 rpm, net load on the brake drum=700N, diameter of brake drum=2m, indicated mean effective pressure=6bar, fuel consumption=0.0013kg/s, specific gravity of fuel=0.78, calorific value of fuel=43900kJ/kg. Determine (i) BP, (ii) IP, (iii) FP, and (iv) mechanical efficiency (v) indicated and brake thermal efficiency**.**

10. A petrol car which consists of four-cylinder engine develops Brake power of 30kW at 2500 rpm. The mean effective pressure on each piston is 8bar, and mechanical efficiency is 80%. Calculate the diameter and stroke of each cylinder, stroke to bore ratio is 1.5. Also calculate the fuel consumption if brake thermal efficiency is 28%. Consider the engine is 2-stroke engine and calorific value of petrol is 47300kJ/kg.

11. A 10 wheeler Truck when it is running with engine speed of 3700rpm it produces misfires. Which consists of 4-stroke 6 cylinders develops 50Kw of indicated power at mean effective pressure of 7 bars. The bore & stroke of the engine cylinder is 70mm & 100mm respectively. Find the average misfires per minute.

12. A Bajaj Pulsar 200CC bike when its engine running at 1000rpm it produces 60kW Brake power and also the following observations were recorded during the same speed and power.

The mean effective pressure=6bar,

Petrol consumption=0.0013kg/s,

Calorific value of petrol=47300kJ/kg.

Determine power developed inside the cylinder, mechanical efficiency, indicated and brake thermal efficiency**.**

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