MODULE *3*

Content:

***Fundamentals of IC Engines**: Review of Internal Combustion Engines, 2-Strokes and 4-Strokes engines, Components and working principles, Application of IC Engines in Power Generation, Agriculture, Marine and Aircraft Propulsion, Automobile.*

***Insight into future mobility technology:** Electric and Hybrid Vehicles, Components of Electric and Hybrid Vehicles, Drives and Transmission. Advantages and disadvantages of EVs and Hybrid vehicles.*

***Refrigeration and Air-Conditioning:** Principle of refrigeration, Refrigeration effect, Ton of Refrigeration, COP, Refrigerants, and their desirable properties. Principles and Operation of Vapor Compression and Vapor absorption refrigeration. Domestic and Industrial Applications of Refrigerator. Working Principles of Air Conditioning, Classification, and Applications of Air Conditioners. Concept and operation of Centralized air conditioning system.*

Fundamentals of IC engines:

Engine: It is a device which converts heat energy liberated by combustion of fuel into mechanical energy.

Types of engines:

1)External combustion engine:

Here the combustion takes place outside the engine cylinder and the combustion products are supplied to the engine cylinder to convert heat energy into mechanical energy.

2) Internal combustion engine:

In this type of engine, the combustion takes place inside the engine cylinder itself.

Classification of I.C engines:

1) Based on fuel used
   - a) Petrol engine
   - b) Diesel engine
   - c) Gas engine
   - d) Bi-fuel engine

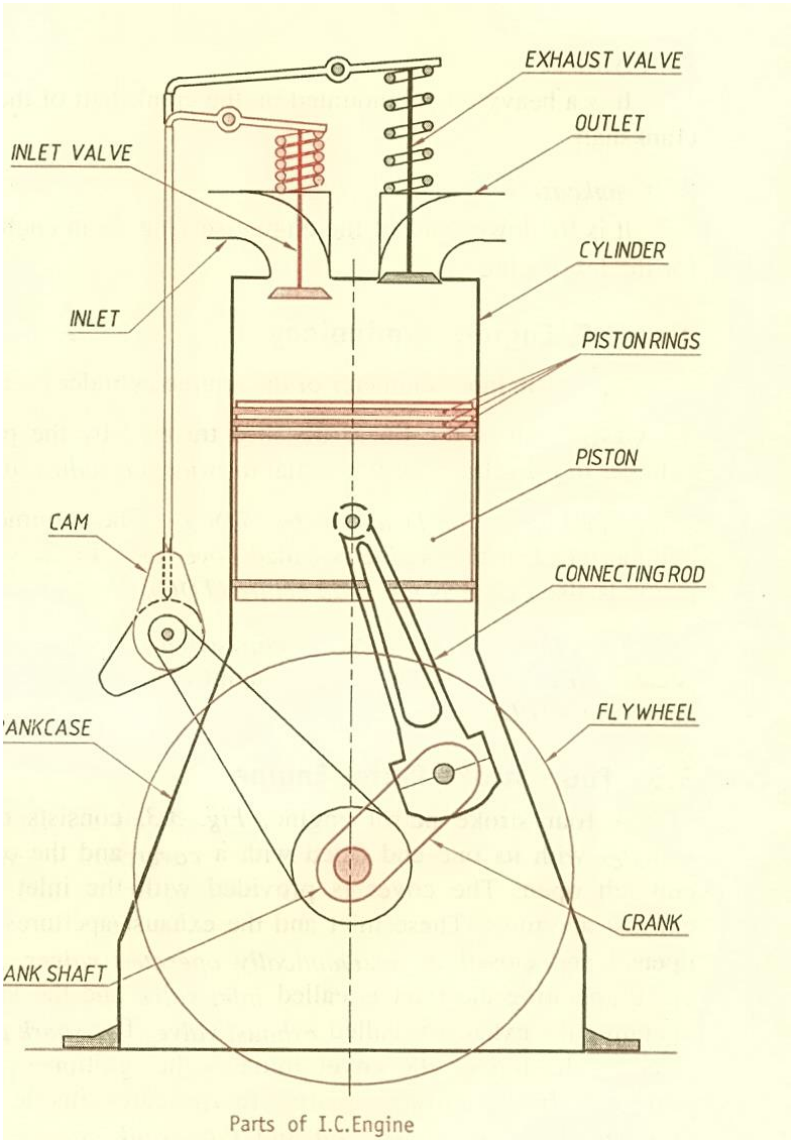
2) Based on thermodynamic cycle
   - a) Otto cycle engine
   - b) Diesel cycle engine
   - c) Dual combustion cycle engine

3) Based on strokes
   - a) 4 stroke engine
   - b) 2 stroke engine

4) Based on method of ignition
   - a) Spark ignition or S.I engine
   - b) Compression ignition or C.I engine

5) Based on number of cylinders as
   a) Single cylinder engine
   b) Multi cylinder engine
6) Based on position of cylinder as
   a) Horizontal engine
   b) Vertical engine
   c) Vee – engine
   d) Opposed cylinder engine
   e) Radial engine
7) Based on method of cooling as
   a) Air cooled engine
   b) Water cooled engine

Parts of I.C engine:



Parts of I.C.Engine

1. Cylinder: The heart of the engine is the cylinder in which the fuel is burnt and the power is developed. The inside diameter is called bore. To prevent the wearing of cylinder block, a sleeve will be fitted tightly in the cylinder. The piston reciprocates inside the cylinder.
2. Piston: The piston is a close fitting hollow cylindrical plunger moving to-and-fro in the cylinder. The power developed by the combustion of the fuel is transmitted by the piston to the crankshaft through the connecting rod.
3. Piston rings: The piston rings are the metallic rings inserted into the circumferential grooves provided at the top end of the piston. These rings maintain a gas-tight joint between the piston and the cylinder while the piston is reciprocating in the cylinder. They also help in conducting the heat from the piston to the cylinder.
4. Connecting rod: It is a link that connects the piston and the crankshaft by means of pin joints. It converts the rectilinear motion of the piston into rotary motion of the crankshaft.
5. Crank and crankshaft: The crank is lever that is connected to the end of the connecting rod by a pin joint with its other end rigidly connected to a shaft called crankshaft. It rotates about the axis of the crankshaft and causes the connecting rod to oscillate.
6. Crank case: It is the lower part of the engine serving as an enclosure for the crankshaft and sump for the lubricating oil.
7. Valves: The valves are the devices which controls the flow of the intake and the exhaust gas to and from the cylinder. They are also called poppet valves. These valves are operated by means of cams driven by crankshaft through a timing gear and chain.
8. Fly wheel: It is a heavy wheel mounted on the crankshaft of the engine to maintain uniform rotation of the crankshaft.

I.C engine terminology:

1. Stroke: It is the distance travelled by the piston from the cover end to the crank end or from crank end to the cover end. It is denoted by L.
2. Bore: It is the diameter of the cylinder or outer diameter of the piston. It is denoted by D.
3. Top Dead Centre (TDC) or cover end: It is the extreme position of the piston, when the piston is near cylinder head.
4. Bottom Dead Centre (BDC) or crank end: It is the extreme position of the piston, when the piston is near the crankshaft end.
5. Swept Volume (Vs): It is the volume covered by the piston when the piston moves from TDC to BDC. It is denoted by Vs and is given by,

$$Vs = (\prod D2/4)*L$$

6. Clearance Volume (Vc): It is the volume occupied by the charge at the end of compression stroke when the piston is at TDC.
7. Compression Ratio (C.R): It is the ratio of total volume of the cylinder to the clearance volume.

i.e., CR or r= Total volume/clearance volume = VT/Vc = (Vs+ Vc)/Vc

8. Piston speed: The total linear distance travelled by the piston per unit time is called piston speed. It is expressed in m/min and is given by,

Piston speed=2LN m/min

L= length of stroke in m

N= speed of the engine in rpm.

FOUR STROKE PETROL ENGINE:

Features:

It consists of a cylinder with its one end fitted a cover and the other end open.

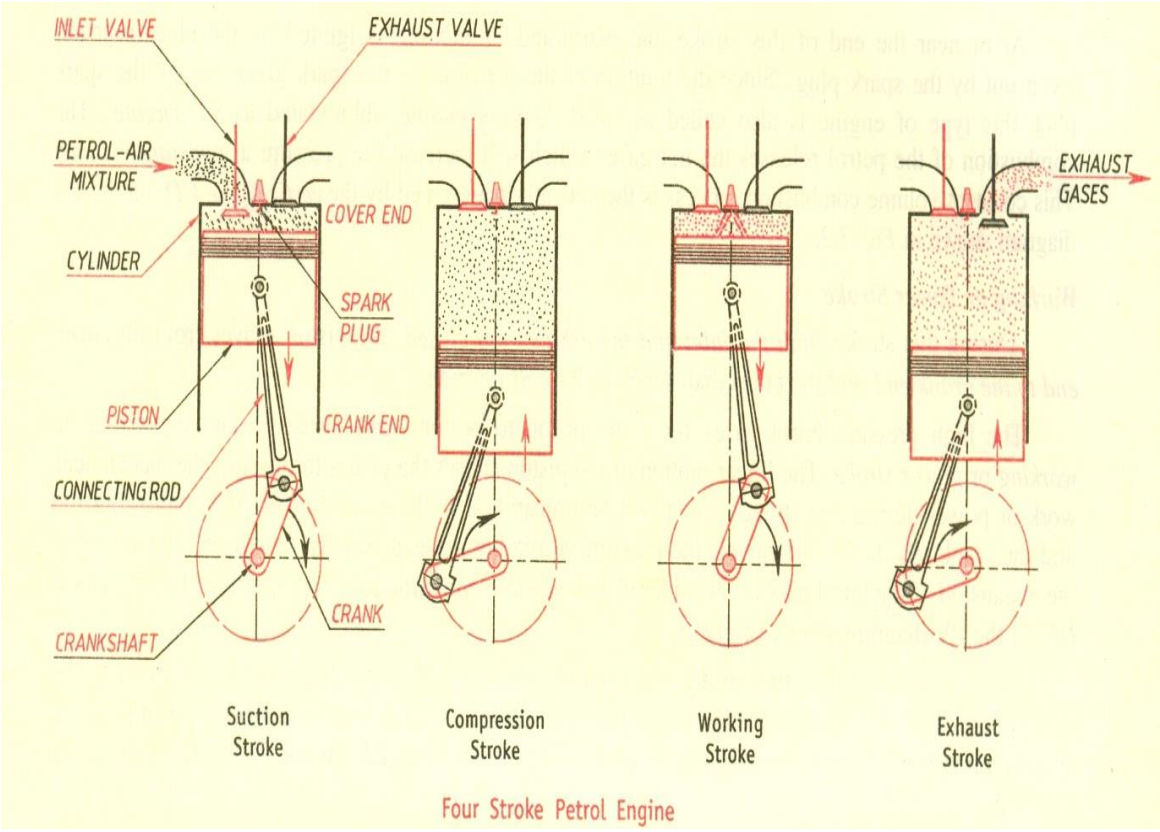
The cover is provided with inlet and exhaust apertures which are mechanically operated by valves called inlet and exhaust valve, respectively.

The spark plug fitted at the top of the cover initiates the ignition of the petrol, hence the name spark ignition engine.

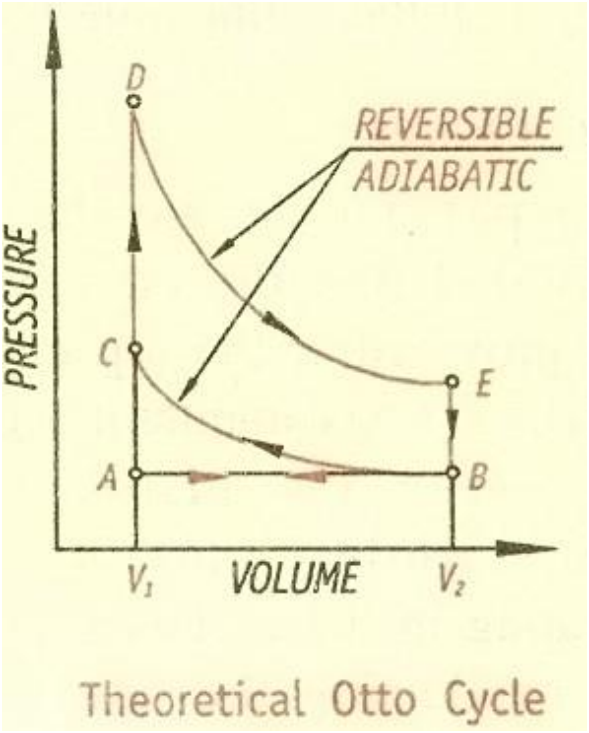
A freely moving piston reciprocates inside the cylinder. The connecting rod and the crank convert the reciprocating motion of the piston into the rotary motion.

The petrol engines work on the principle of theoretical OTTO cycle, also known as constant volume heat addition cycle.

The piston performs 4 strokes to complete one working cycle, hence the name 4S engine.



Four Stroke Petrol Engine



Theoretical Otto Cycle

The four different strokes are,

i) Suction stroke
ii) Compression stroke
iii) Working or power stroke
iv) Exhaust stroke.

SUCTION STROKE:

- Inlet is open and the exhaust is closed.
- The piston moves from the cover end to the crank end. Crankshaft revolves by half rotation.
- The volume in the cylinder increases, the pressure decreases.
- This sets up a pressure differential between the atmosphere and the inside of the cylinder.
- Due to this pressure differential the petrol & air mixture will be drawn into the cylinder through the carburetor.

COMPRESSION STROKE:

- Both the inlet and exhaust are closed.
- Piston moves from crank end to cover end.
- Crankshaft revolves next half revolution.
- The petrol and air mixture contained in the cylinder is compressed.
- The compression ratio of petrol engine varies from 7:1 to 11:1.
- At the end of the stroke the high temperature and pressure petrol-air mixture is ignited by electric spark produced by spark plug.

WORKING OR POWER OR EXPANSION STROKE:

- Both inlet and exhaust are closed.

- Piston moves from cover end to crank end.
- Crank revolves by half revolution.
- The high pressure of the burnt gases forces the piston downwards performing power stroke.
- The linear motion of the piston is converted to rotary motion of the crankshaft by connecting rod.
- At the end of the stroke exhaust valve opens.

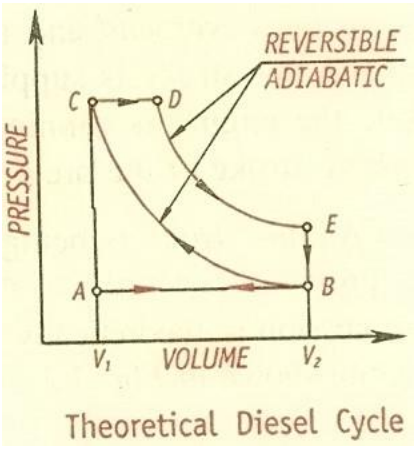
EXHAUST STROKE:

- Exhaust is open and inlet is closed.
- Piston moves from crank end to cover end.
- Crank revolves by half rotation.
- The burnt gases are expelled from cylinder at atmospheric pressure.

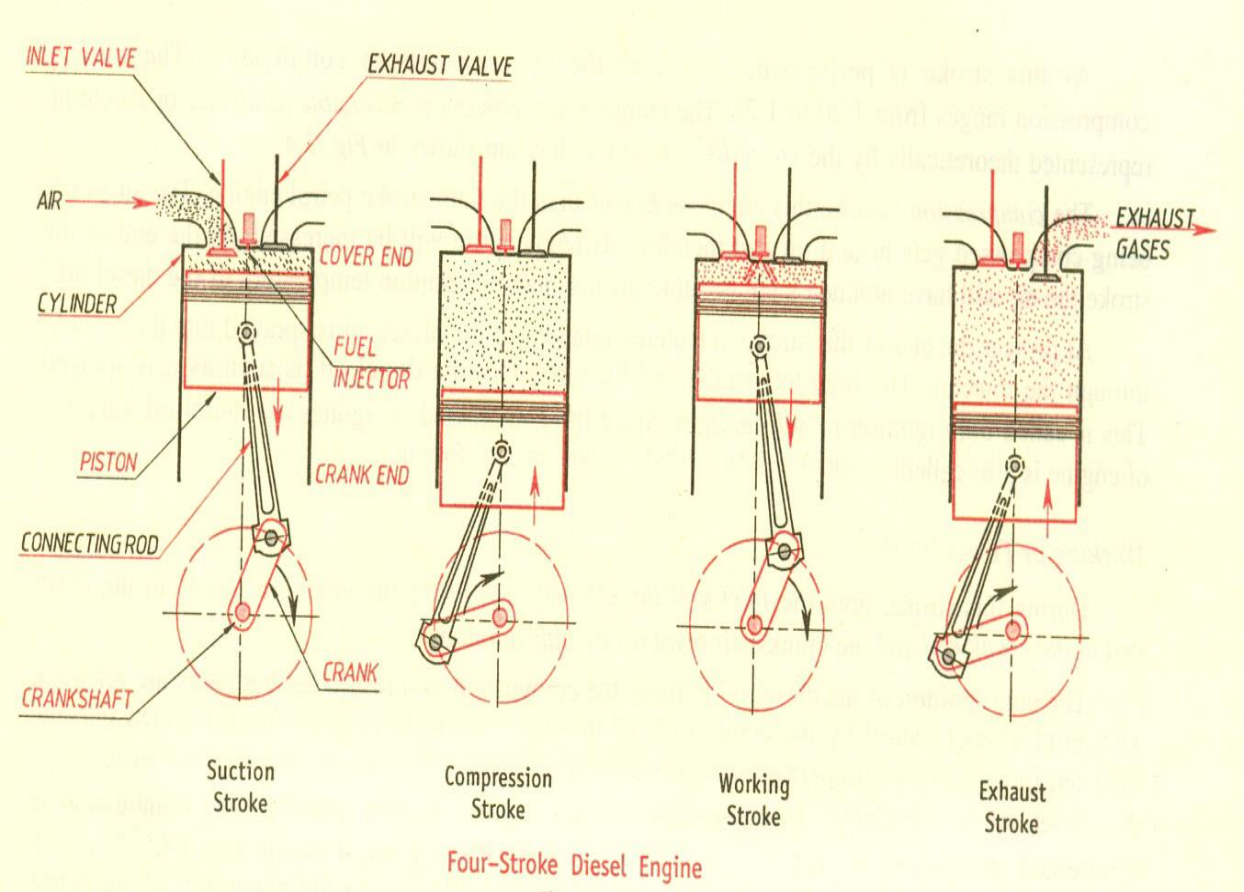
FOUR STROKE DIESEL ENGINE:

Features:

- It consists of a cylinder with its one end fitted a cover and the other end open. The cover is provided with inlet and exhaust apertures which are mechanically operated by valves called inlet and exhaust valve, respectively.
- The fuel injector mounted in its place injects Diesel fuel supplied by the fuel pump.
- A freely moving piston reciprocates inside the cylinder. The connecting rod and the crank convert the reciprocating motion of the piston into the rotary motion.
- The diesel engines work on the principle of theoretical DIESEL cycle, also known as constant pressure heat addition cycle.
- The compressed air ignites the diesel oil in the engine, hence the name compression ignition engine.
- The piston performs 4 strokes to complete one working cycle, hence the name 4S engine.



Theoretical Diesel Cycle



The four different strokes are,

i) Suction stroke
ii) Compression stroke
iii) Working or power stroke
iv) Exhaust stroke.

SUCTION STROKE:

- Inlet is open and the exhaust is closed.
- The piston moves from the cover end to the crank end. Crankshaft revolves by half rotation.
- The volume in the cylinder increases, the pressure decreases.
- This sets up a pressure differential between the atmosphere and the inside of the cylinder.
- Due to this pressure differential, only the atmospheric air will be drawn into the cylinder.

COMPRESSION STROKE:

- Both the inlet and exhaust are closed.
- Piston moves from crank end to cover end.
- Crankshaft revolves next half revolution.
- The air in the cylinder is compressed.

- The compression ratio of diesel engine varies from 16:1 to 22:1.
- The process of compression is reversible adiabatic or isentropic. At the end of the stroke a metered quantity of diesel oil is sprayed into the cylinder through the injector.
- The high temperature of the air ignites the diesel as soon as it is sprayed and is called self-ignition or auto ignition.

WORKING OR POWER OR EXPANSION STROKE:

- Both inlet and exhaust are closed.
- Piston moves from cover end to crank end.
- Crank revolves by half revolution.
- The auto ignition of diesel takes place almost at constant pressure till the injection is completed.
- The high pressure of the burnt gases forces the piston downwards initially and later by expansion of burnt gases performing power stroke.

EXHAUST STROKE:

- Exhaust is open and inlet is closed. Piston moves from crank end to cover end.
- Crank revolves by half rotation.
- The burnt gases are expelled from cylinder at atmospheric pressure.
- In 4 stroke engines, the 4 stroke constitute one cycle, hence the name 4 stroke cycle engine.
- Crankshaft makes two revolutions to complete one cycle.
- The power is developed in every alternate revolution of the crankshaft.
- 4S diesel engines produce higher power than 4S petrol engines.

TWO STROKE ENGINE:

Features:

- A 2-stroke engine performs only TWO strokes to complete one cycle.
- Here suction and exhaust strokes are eliminated & are performed while compression and expansion are in progress.
- Crankshaft makes only one revolution to complete the cycle.
- The power is developed in every revolution of the crankshaft.

IMPORTANT POINTS:

- The cylinder is fitted with a cover at one end & a hermetically sealed crank case at the other end.
- The inlet & outlet openings are provided on the circumference of the cylinder & are called ports.
- The lower port is called admission port or inlet port & the upper port is called the exhaust port.

- A transfer port is provided diametrically opposite to the exhaust port but slightly at a lower level, serves as the passage for the transfer of charge from the crankcase to the cylinder.
- These ports are opened and closed or uncovered and covered by the reciprocating piston.
- The connecting rod and the crank convert the reciprocating motion of the piston into the rotary motion.

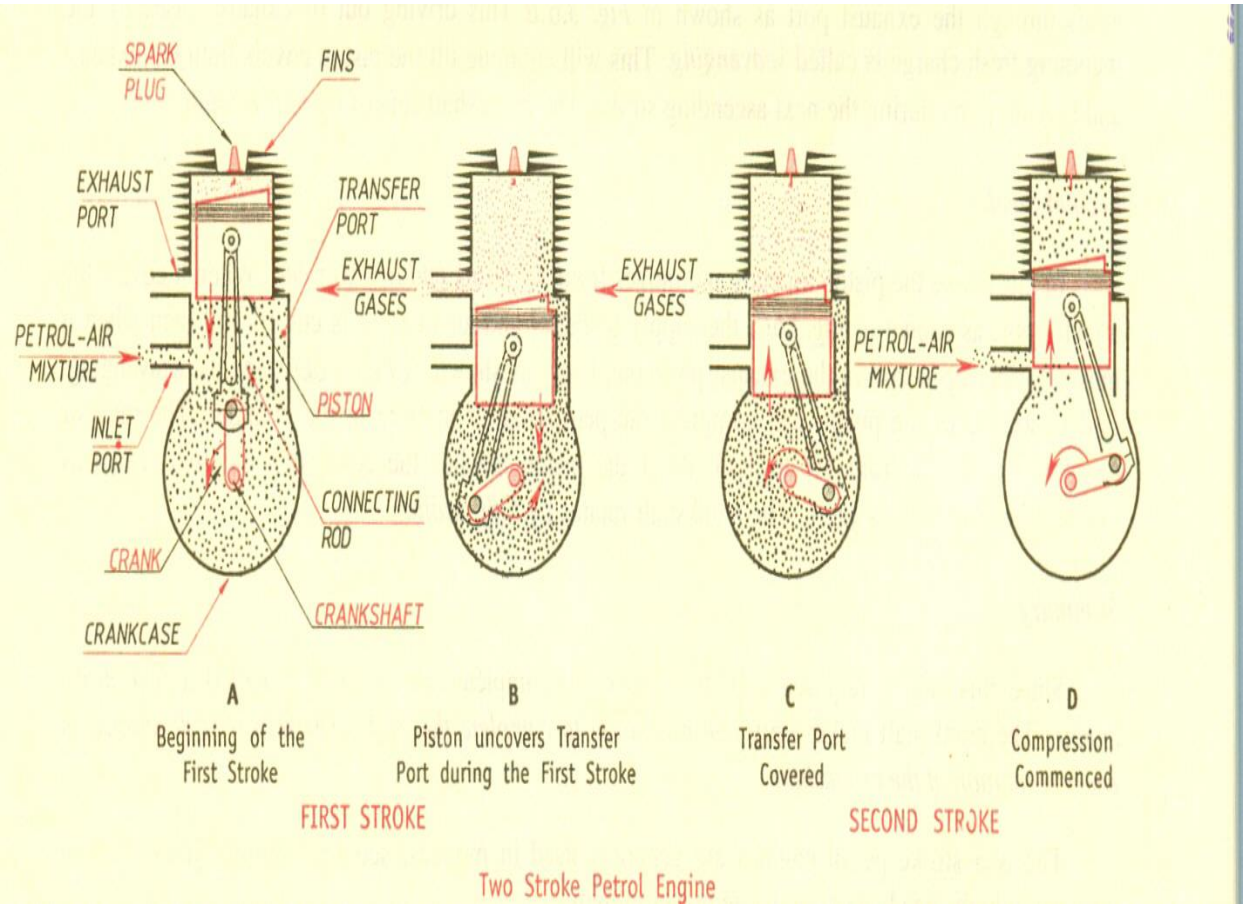
TWO STROKE PETROL ENGINE:

The drawing of petrol and air mixture:

- When the piston ascends a partial vacuum is created in the crankcase until its lower edge uncovers the inlet port.

The pressure difference between atmosphere and crankcase will draw the petrol-air mixture into the crankcase. The process will continue till the inlet port is covered by the piston during its next descent stroke.

- Further descent of piston compresses the mixture in the crankcase and as soon as the top edge of the piston uncovers transfer port the compressed charge flows from the crankcase through the transfer port into the cylinder. This will continue till the piston covers the transfer port in the next ascending stroke.



Two Stroke Petrol Engine

FIRST STROKE:

- Piston moves from cover end to crank end. The spark plug ignites the compressed petrol and air mixture.
- The hot gases are released during combustion increases the pressure in the cylinder which forces the piston downwards.
- The piston performs the power stroke till it uncovers the exhaust port.
- The combustion gases which are still at high pressure escape through the exhaust port.
- As soon as the top edge of the piston uncovers the transfer port fresh charge flows from crankcase into the cylinder.
- This fresh charge entering the cylinder drives out spent burnt gases through the exhaust port and the process is called scavenging.
- This process is continued till the piston covers both exhaust & transfer port during the next ascending stroke.
- The crankshaft rotates by half rotation.

SECOND STROKE:

- Piston moves from crank end to cover end.
- When it covers transfer port the supply of petrol & air mixture is cut-off.
- Further upward movement covers exhaust port & stops scavenging.
- Further ascend of piston will compress the petrol and air mixture in the cylinder.
- The compression ratio ranges from 7:1 to 11:1.
- After piston reaches cover end first stroke repeats again.
- The crank rotates by half rotation.

TWO STROKE DIESEL ENGINE:

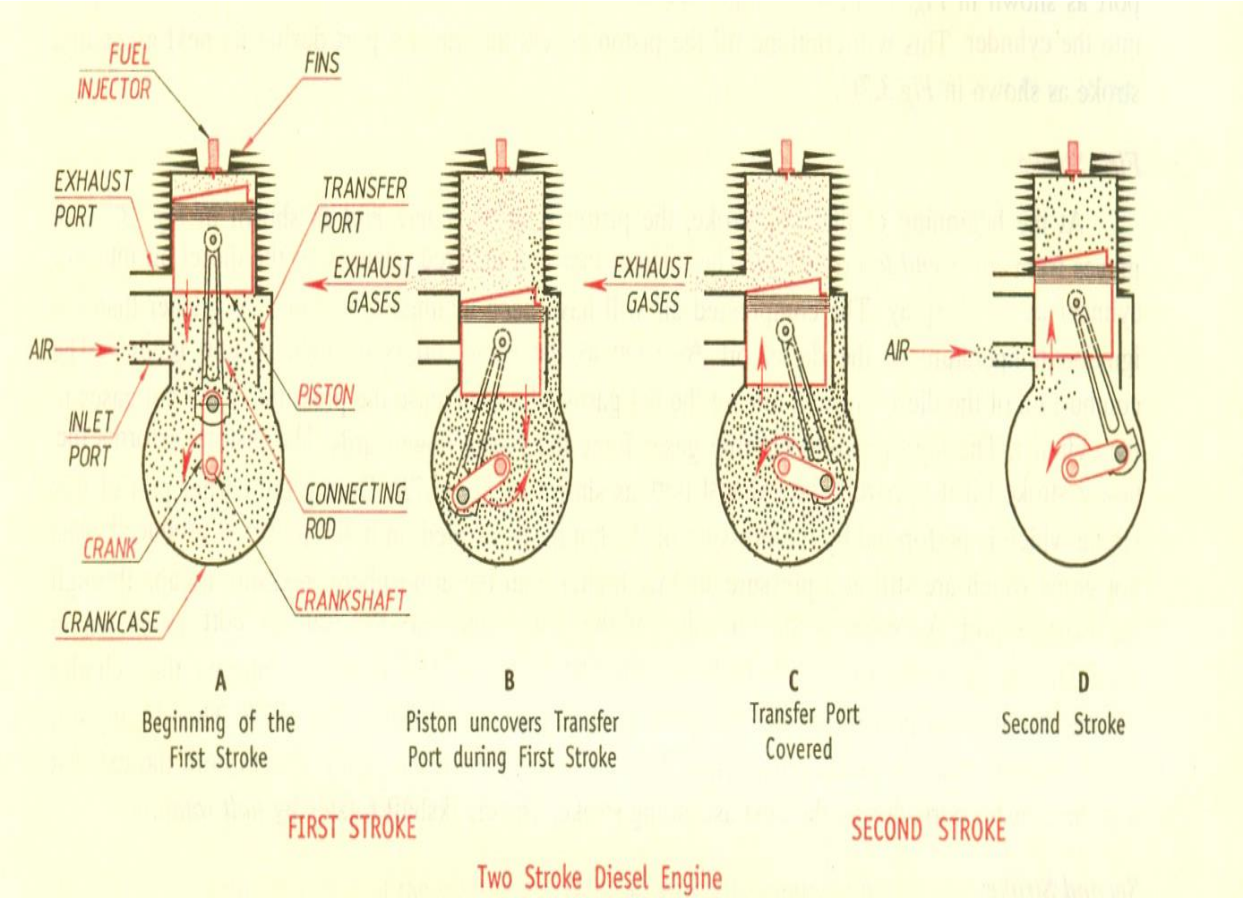
The drawing of air:

- When the piston ascends a partial vacuum is created in the crankcase until its lower edge uncovers the inlet port.
- The pressure difference between atmosphere and crankcase will draw only air into the crankcase. The process will continue till the inlet port is covered by the piston during its next descent stroke.
- Further descent of piston compresses the air in the crankcase and as soon as the top edge of the piston uncovers transfer port the compressed air flows from the crankcase through the transfer port into the cylinder. This will continue till the piston covers the transfer port in the next ascending stroke.

FIRST STROKE:

- Piston moves from cover end to crank end.

- The injector injects a metered quantity of the diesel oil into the cylinder as a fine spray.
- The high temperature of compressed air ignites the injected diesel oil.
- The hot gases are released during combustion increases the pressure in the cylinder which forces the piston downwards.
- The piston performs the power stroke till it uncovers the exhaust port.
- The combustion gases which are still at high pressure escape through the exhaust port.
- As soon as the top edge of the piston uncovers the transfer port fresh charge flows from crankcase into the cylinder.
- This fresh charge entering the cylinder drives out spent burnt gases through the exhaust port and the process is called scavenging.
- This process is continued till the piston covers both exhaust & transfer port during the next ascending stroke.
- The crankshaft rotates by half rotation.



Two Stroke Diesel Engine

SECOND STROKE:

- Piston moves from crank end to cover end.
- When it covers transfer port the supply of air is cut-off.

- Further upward movement covers exhaust port & stops scavenging.
- Further ascend of piston will compress the air in the cylinder.
- The compression ratio ranges from 16:1 to 22:1.
- After piston reaches cover end first stroke repeats again.
- The crank rotates by half rotation.

COMPARISON OF PETROL AND DIESEL ENGINE:

PRINCIPLE	PETROL	DIESEL
1. Cycle of operation	**Otto cycle**	**Diesel cycle**
2. Fuel used	Petrol	diesel
3. Admission of fuel	Air & petrol during suction	Diesel oil by injector at the end of compression stroke.
4. Charge drawn during suction	Air and petrol mixture	Only air
5. Compression ratio	7:1 to 12:1	16:1 to 22:1
6. Ignition of fuel	Spark ignition	Compression or auto ignition
7. Governing	Quantitative	Qualitative
8. Engine speed	High about 7000rpm	Low from 500 to 3000rpm
9. Power output capacity	Less	More
10. Thermal efficiency	Less	High
11. Noise & vibration	Almost nil	High
12. Weight of the engine	Less	high
13. Initial cost	Less	More
14. Operating cost	High	Less
15. Maintenance cost	Less	Slightly higher
16. Starting of the engine	Easily started	Difficult to start in cold weather
17. Exhaust gas pollution	More	Less
18. Uses	Scooter, motorcycle, car, etc.,	Trucks, tractors, buses, etc.,

COMPARISON OF 4 STROKE AND 2 STROKE ENGINE:

PRINCIPLE	4 STROKES	2 STROKES
1. Number of strokes per cycle	Four	Two
2. Number of cycles per minute	Half of the speed of the engine	Equal to the speed of the engine

3. Power	Developed in every alternate revolution of the crankshaft	Developed in every revolution of the crankshaft
4. Flywheel	Heavier flywheel is required	Lighter flywheel is required
5. Admission of charge	Directly admitted to the engine cylinder	First admitted to the crankcase & then transferred to the engine cylinder
6. Exhaust gases	Driven through the outlet during exhaust stroke	Driven out by scavenging operation
7. Valves	Opened & closed by mechanical valves	Opened & closed by piston
8. crankcase	Not hermetically sealed	Hermetically sealed
9. Direction of rotation of crankshaft	Rotates only in one direction	Can rotate in either direction
10. Lubricating oil consumption	Less	More
11. Fuel consumption	Less	More
12. Mechanical efficiency	Low	High
13. Noise	Less	High
14. Uses	Slow speed & high-power applications like cars, trucks, tractors, jeeps, buses, etc.,	High speed & low power applications like mopeds, scooters, motorcycles, etc.,

Advantages of TWO stroke engine over a FOUR stroke engine:

- A two-stroke engine has twice the number of power strokes than a four-stroke engine at the same speed. Hence theoretically a two-stroke engine develops double the power output per cubic meter of the swept volume than a 4S engine running at same speed.
- The weight of a 2S stroke engine is less than the 4S engine because of the lighter flywheel due to more uniform torque on the crankshaft.
- The scavenging is more complete in slow speed 2S engines, since exhaust gases are not left in the clearance volume as in the 4S engine.
- Since there are only 2 strokes in a cycle, the work required to overcome of the suction and the exhaust stroke is saved.
- Since there are no mechanical valves and gears, the construction of a 2S engine is simple which reduces initial cost.
- A 2S engine can be easily reversed by a simple reversing gear mechanism.
- A 2S engine can be easily started than a 4S engine.
- A 2S engine occupies less space.
- A lighter foundation will be sufficient for 2S engines.

- A 2S engine has less maintenance cost since it has a smaller number of moving parts.
- Since the engine is light in weight and its speed is high, 2S engines are preferred in motorcycles, scooters etc.
- Since there are 2S per cycle, the frictional losses are less.

Disadvantages of 2S engine over a 4S engine:

- Since the firing takes place in every revolution, the time available for cooling will be less than a 4S engine, which results in overheating of the piston and other engine parts.
- Incomplete scavenging results in mixing of the exhaust gases with the fresh charge which will dilute it, hence less power output and low thermal efficiency.
- Since the transfer port is kept open only during a short period, it is likely that less quantity of the charge may be admitted into the cylinder which will reduce the power output.
- Since both the exhaust and the transfer ports are kept open during the same period, there is a possibility of the escape of the fresh charge through the exhaust port which will also reduce its thermal efficiency.
- For a given stroke and clearance volume, the effective compression stroke is less than in a 4S engine.
- A 2S engine needs better cooling arrangement because of high operating temperature.
- A 2S engine consumes more lubricating oil.
- The exhaust in a 2S engine is noisy due to the sudden release of the burnt gases.

Application of IC engines in agriculture:

There is no doubt that engines are vital to the agricultural industry today. Many aspects would be less efficient and reliable year to year if engines were not available. Engines allow faster production, more food to be grown and harvested, and superior procedures concerning countless tasks.

Farm Equipment

- Farm equipment and machinery are at the heart of the agricultural industry. Tractors, planters, and combines are all powered with engines to plant and harvest crops. Balers are used to cut and harvest hay for animals. Tractors with bush hogs are used to mow grass and cut down brush and weeds on parts of the farm and in ditches next to fields.

Trucks for Transportation

- Along with the farm machinery that is needed to grow and harvest crops, trucks are required to transport these products. During harvest, semi-trailers are filled

from the combines with product ready to go to market. These semi-trucks then transport the product to the intended destination.

- Trucks and tractor trailers are also used to transport fertilizer, herbicides and pesticides, and even water to fields to help prepare them for planting and keeping the crop healthy while it is growing. This job would be immensely harder if not for engine-powered machinery.

Application of IC engines in marine:

- Marine engines on ships are responsible for propulsion of the vessel from one port to another. Whether it's of a small ship plying in the coastal areas or of a massive one voyaging international waters. A marine engine of either 4-stroke or 2-stroke is fitted onboard ship for the propulsion purpose.

The two basic types of marine diesel engines are –

- 4 stroke engine
- 2 stroke engine

A 4-stroke engine can be installed on the ship to produce electrical power and to propel the ship (usually in small size vessel). This engine takes 4 cycles to complete the transfer of power from the combustion chamber to the crankshaft.

Application of IC engines in aircraft propulsion:

An aircraft engine, often referred to as an aero engine, is the power component of an aircraft propulsion system. Most aircraft engines are either piston engines or gas turbines, although a few have been rocket powered and in recent years many small UAVs have used electric motors.

The operation of aerospace propulsion engines rests on the foundation of Newton's laws of motion. The second of these laws explains that the change in momentum of the fluid passing through an engine is equal to the force acting on the fluid. The third law states that the force acting on the fluid exerts a reaction, an equal and opposite force, on the boundaries separating the fluid and the engine. Indeed, such engines are often referred to as reaction motors.

In general, aerospace propulsion engines may be thought of as idealized flow machines in which fluid within the machine has work and/or heat added to it prior to its exit from the machine as a jet, thereby producing thrust according to the reaction principle described above. The fluid may enter the machine from the surroundings or may be carried entirely within the machine prior to being processed. The former engines are usually called airbreathing engines and the latter, rockets. Of primary interest is the magnitude of the thrust produced and the efficiency with which the heat and power is used in generating thrust.

Application of IC engines in automobile:

IC engines are used in Road vehicles like scooters, motorcycles, cars, buses trucks etc.

Insight to future mobility technology:

Electric and Hybrid vehicles:

Why Electric Vehicles (EV)?

There are many reasons why people are moving to Electric Vehicles (EV) to get them to the places they need to be. These include:

- EVs are fun to drive because they are fast and smooth.
- Many studies show that the emissions from burning fossil fuels such as gasoline produce harmful greenhouse gases. EV's produce no smelly fumes or harmful greenhouse gases.
- EVs are innovative and cool.
- EVs only cost approximately $360 a year to operate compared to $3600 for a gasoline vehicle.
- EVs are a smart and convenient choice.

There are 3 types of electric vehicle: Battery Electric Vehicle (BEV), Plugin Hybrid Electric Vehicle (PHEV) and Hybrid Electric Vehicle (HEV).

Battery Electric Vehicle (BEV)

A battery electric vehicle (BEV) runs entirely using an electric motor and battery, without the support of a traditional internal combustion engine, and must be plugged into an external source of electricity to recharge its battery. Like all electric vehicles, BEVs can also recharge their batteries through a process known as regenerative braking, which uses the vehicle's electric motor to assist in slowing the vehicle, and to recover some of the energy normally converted to heat by the brakes.

Pros

- No emissions
- No gasoline or oil changes
- Ability to conveniently charge at home
- Fast and smooth acceleration
- Low cost of operation - about $30 a month.

Cons

- Shorter range than gasoline vehicles, although most people drive well within the range of today's BEV and could rent a hybrid for the rare long trips.
- Slightly more expensive than their gasoline equivalent although the gasoline savings pay off the difference in typically 2-3 years.

Plug-in Hybrid Electric Vehicle (PHEV)

Plug-in hybrids (PHEVs) use an electric motor and battery that can be plugged into the power grid to charge the battery, but also has the support of an internal combustion engine that may be used to recharge the vehicle's battery and/or to replace the electric motor when the battery is low. Because Plug-in Hybrids use electricity from the power grid, they often realize more savings in fuel costs than tradition hybrid electric vehicles (HEV).

Pros

- Longer range than BEV
- Less fuel consumption than fuel only vehicle
- Fewer emissions
- Very simple mechanics, less to go wrong.

Cons

- Produces tailpipe emissions
- Needs fuel and oil changes
- More expensive to operate than Battery Electric Vehicle (BEV) but less than traditional hybrid vehicle (HEV).

Hybrid Electric Vehicles (HEVs)

Hybrid Electric Vehicles (HEVs) have two complementary drive systems: a gasoline engine with a fuel tank; and an electric motor with a battery. Both the engine and the electric motor can turn the transmission at the same time, and the transmission then turns the wheels. HEVs cannot be recharged from the electricity grid – all their energy comes from gasoline and from regenerative braking.

Pros

- Longer range than BEV
- Less gas consumption than gas only vehicle
- Fewer emissions than gas only vehicle

Cons

- Still produces emissions
- Complex mechanics – Gasoline + Electric
- Expensive to operate (8-10 times more expensive than BEV) but less than traditional gasoline vehicle.
- No ability to conveniently charge at home.

Components of an Electric vehicle:

Electric Motor

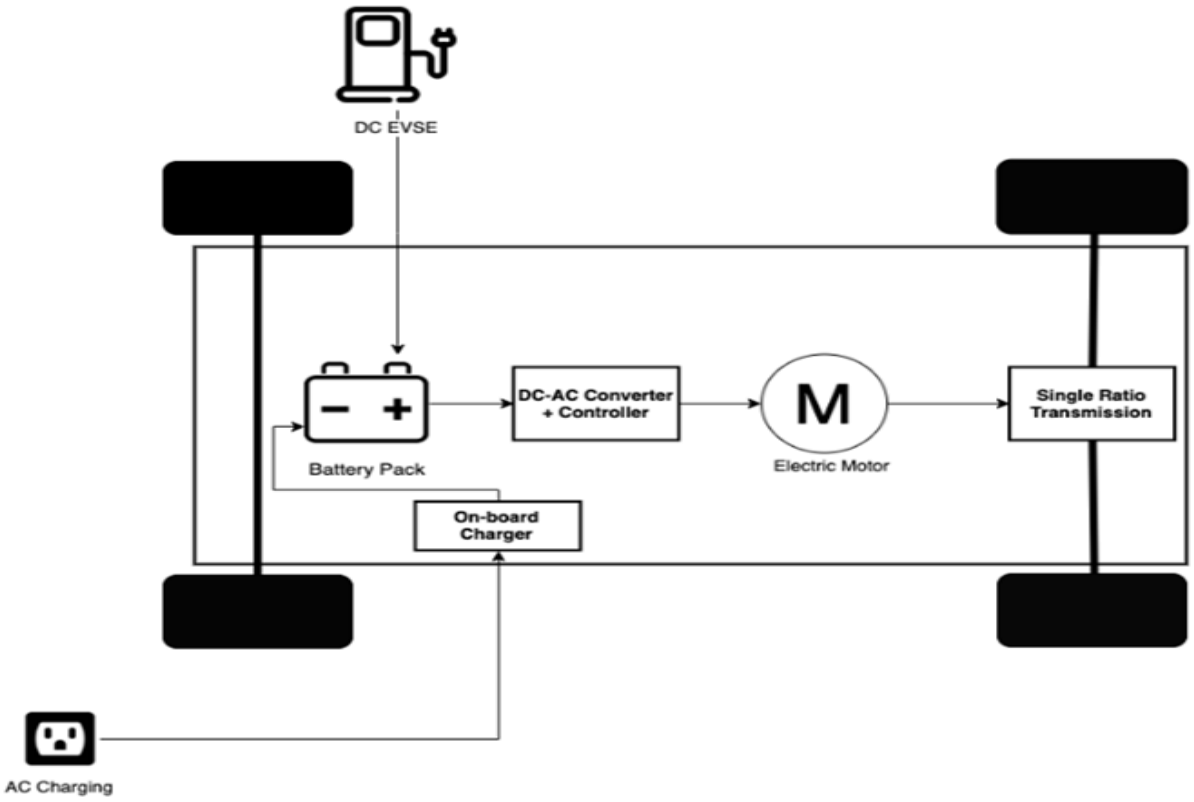
Converts electrical energy to mechanical energy, that is delivered to the wheels via single ratio transmission

DC-AC Converter

The DC supplied by battery pack is converted to AC and supplied to the electric motor. This power transfer is managed by a sophisticated "motor control mechanism" that controls the frequency and magnitude of the voltage supplied to the electric motor to manage the speed.

Battery pack

The battery pack is made up of multiple lithium-ion cells and stores the energy needed to run the vehicle. Battery packs provide DC output.



On-Board Charger-

Converts AC received through charge port to DC and controls the amount of current flowing into the battery pack.

Apart from the core parts, there are multiple hardware and software components in an EV powertrain. Electronic Control Units (ECU'S) are basically software programs integrated with the powertrain components to help data exchange and processing

Battery Management system (BMS) –

A BMS continuously monitors the state of the battery and is responsible for taking necessary measures in case of a malfunction. BMS performs cell balancing to deliver maximum efficiency from the battery pack.

DC-DC Converter –

A battery pack delivers a fixed voltage, but the requirement of other accessories like wipers, lights, infotainment systems, mirror control in EV would vary. This converter

helps to distribute power to different systems by converting the power from battery pack to the expected level

Thermal Management system –

Responsible for maintaining optimum operating temperature range for powertrain components.

Advantages and disadvantages of an Electric vehicle:

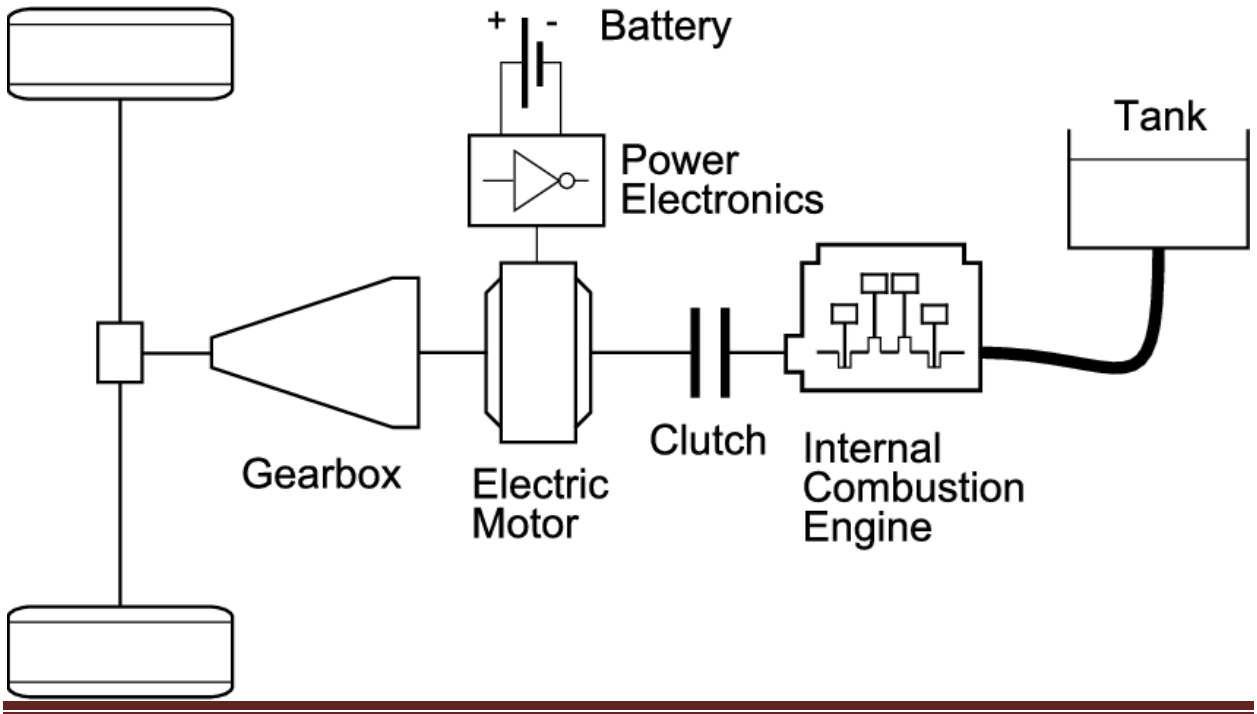
ADVANTAGES

- They are easier on the environment without any harmful emissions
- Electricity is cheaper than gasoline. Long term savings in fuel cost
- Convenience of charging the car at home
- Maintenance is less frequent and less expensive
- They are very quiet. Hence ride comfort is better
- Buyers can claim tax benefits
- Easy driving with the absence of clutch and gear box

DISADVANTAGES

- Non availability of many recharges' stations
- Initial investment of the vehicle is high
- Short driving range and speed
- Longer recharge times
- Not suitable for cities facing shortage of power
- Battery replacement and disposal issues.

Components of Hybrid vehicle:



Hybrid vehicles (HVs) : A hybrid car uses more than one means of energy, combining a petrol or diesel engine with an electric motor, and the two systems work with each other to move the vehicle.

- This allows the car to burn less gasoline, achieving better fuel efficiency than a traditional engine that solely uses fuel.
- Hybrids, except for plug-in hybrids, charge the battery through its internal system, so they do not need recharging.

These greener vehicles allow drivers to experience their more improved fuel economy than conventional cars."

Advantages and disadvantages of Hybrid vehicle:

ADVANTAGES

1) Environmental friendliness: Hybrid cars house a gasoline engine and an electric motor, resulting in less dependence on fossil fuels, and producing low CO2 emissions.
2) Financial benefits: Many tax credits and incentives are available to make hybrid cars more affordable.
3) Regenerative braking system: The energy from the motion of applying the brake is captured and used to recharge the battery. Such a system allows you to eliminate the amount of time for regularly recharging the battery.
4) Higher resale value: With the growing popularity, hybrids' resale value is higher than the average.

DISADVANTAGES

1) Higher costs: A hybrid car is comparatively expensive than a regular gasoline car, and its technology requires higher costs for maintenance.
2) Less power: The power of a combination of a gasoline engine and an electric motor in hybrid cars is less than that of a gasoline powered engine in many cases.
3) Poorer handling: Hybrid vehicles have more machinery than regular cars do. Manufacturers' attempts to avoid extra weight in vehicles result in smaller motor and battery in addition to reduced support in the suspension and body.
4) High voltage batteries: In case of an accident, the presence of the high voltage increases the risk of the passengers being electrocuted and makes the rescuers' task more difficult.

Advantages of EVs and Hybrid vehicles over Internal combustion engines:

1. If electricity is generated from renewable energy sources, the electric car is advantageous since it produces less emissions.
2. If the electricity is generated from fossil fuels, the electric car remains competitive only if the electricity is generated onboard.

3. If the electricity is generated with an efficiency of 50–60% by a gas turbine engine connected to a high-capacity battery and electric motor, the electric car is superior in many respects.
4. EVs are fast and smooth.
5. EV's produce no smelly fumes or harmful greenhouse gases.
6. EV's no gas or oil change is required.
7. EV's can be charged conveniently at homes/ charging points.
8. Running cost of EVs are less since electricity is used as compared to Internal combustion engine where petrol or diesel is used.

Disadvantages of EVs and Hybrid vehicles over Internal combustion engines:

1. Shorter range than internal combustion engine vehicles.
2. Slightly more expensive than their internal combustion engine vehicle equivalent although the petrol/diesel fuel savings pay off the difference in typically 2-3 years.
3. Complex mechanisms for Hybrid vehicle which have both IC engine and Electric power.

Refrigeration and Air-Conditioning:

REFRIGERATION

It is defined as a method of reducing temperature of a system below that of the surroundings and maintaining it at the lower temperature by continuously abstracting the heat from it.

REFRIGERATOR

The machine which effects refrigeration is called refrigerator.

PRINCIPLE OF REFRIGERATION

The principle of operation of refrigeration is based on second law of thermodynamics, which states that heat can be removed continuously from a system at lower temperature and transferred to the surroundings at higher temperature only with the aid of external work.

REFRIGERANT

The medium or working substance that continuously extracts heat from the space within the refrigerator which is to be kept cool at temperature less than atmospheric by rejecting heat to atmosphere is called refrigerant.

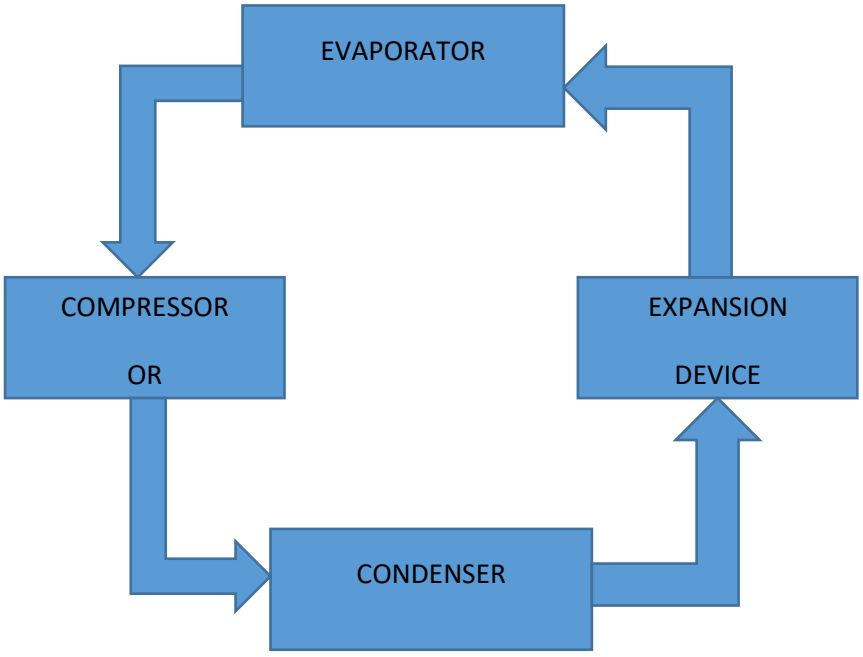
REFRIGERATION CONCEPTS

1. Heat flows from a system at higher temperature to a system at lower temperature.
2. Fluids absorb heat, change from liquid phase to vapor phase and condenses back to liquid while by giving off heat.
3. The boiling and freezing temperatures of fluid depends on its pressure.
4. Heat can flow from a system at lower temperature to a system at higher temperature only with the aid of external work.

PARTS OF REFRIGERATOR

A refrigerator consists of following main parts:

1. Evaporator
2. Circulating System
3. Condenser
4. Expansion Device



1. Evaporator: Here the liquid refrigerant evaporates by absorbing heat from the refrigerator cabinet in which the substances must be cooled are kept. It consists of metal tubes surrounding around the freezing or cooling compartment to produce the cooling effect. It is also called as cooling coil or freezing coil.
2. Circulating System: It consists of mechanical devices such as compressors and pumps necessary to circulate the refrigerant to undergo refrigeration cycle. They increase pressure and temperature of the refrigerant. They are driven by electrical motors which are the energy input to the refrigerators.

3. Condenser: It is a device wherein the refrigerant vapor gives off its latent heat to the atmospheric air and condenses into liquid so that it can be recirculated in the refrigeration cycle.
4. Expansion Device: It is a device which reduces pressure and temperature of the liquid refrigerant before it passes to the evaporator. An expansion valve serves the purpose.

REFRIGERATING EFFECT

The rate at which the heat is absorbed in a cycle from the interior space to be cooled is called refrigerating effect.

UNIT OF REFRIGERATION

The capacity of refrigeration system is expressed in tons of refrigeration.

A ton of refrigeration is defined as the quantity of heat absorbed in order to form one ton of ice in 24hours from water at 0^0C.

In S.I System

1 ton of refrigeration = 907.185X335/(24X60)

= 211 kJ/min

= 3.5 kW

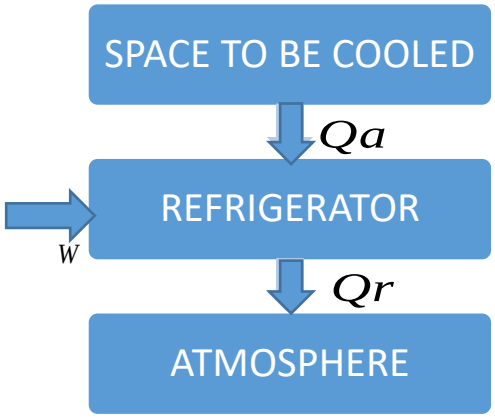
COEFFICIENT OF PERFORMANCE

The coefficient of performance (COP) of a refrigeration system is defined as the ratio of the refrigerating effect (heat absorbed or removed) to the work supplied.

If Q = Heat absorbed or removed, kW

W = Work supplied, kW

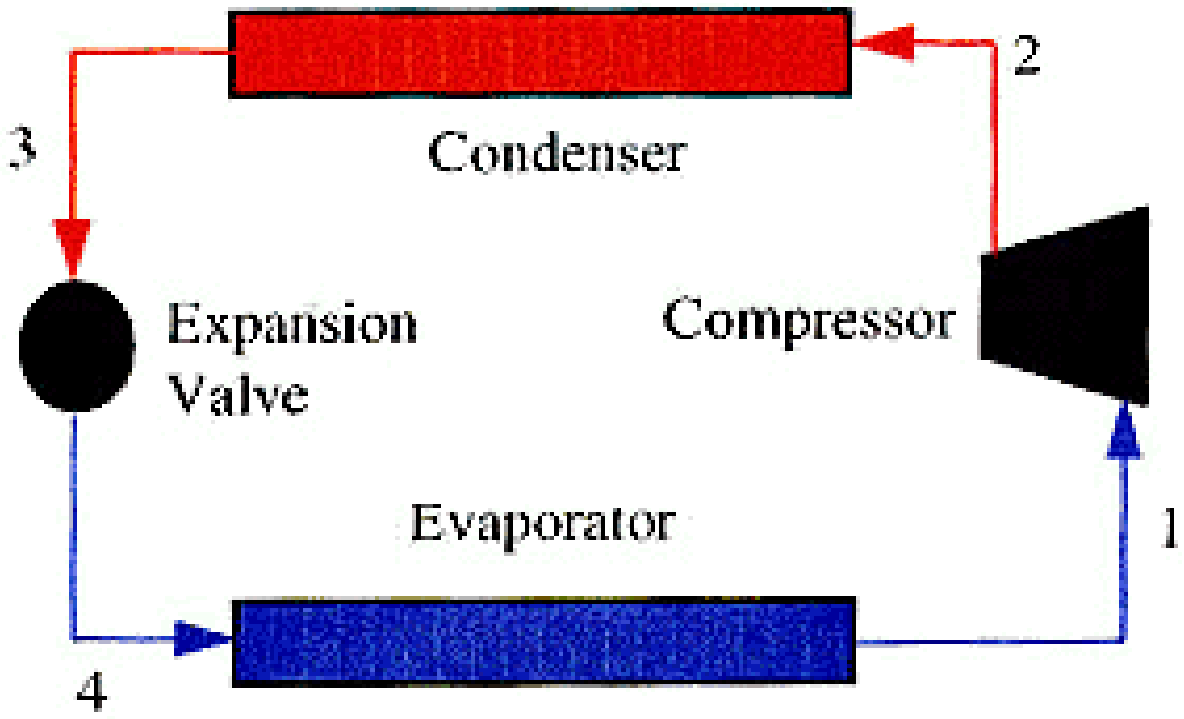
Then, COP = $\frac{Qa}{W}$



TYPES OF REFRIGERATION SYSTEMS:

Air refrigerator,
Vapor compression refrigerator,
Vapor absorption refrigerator.

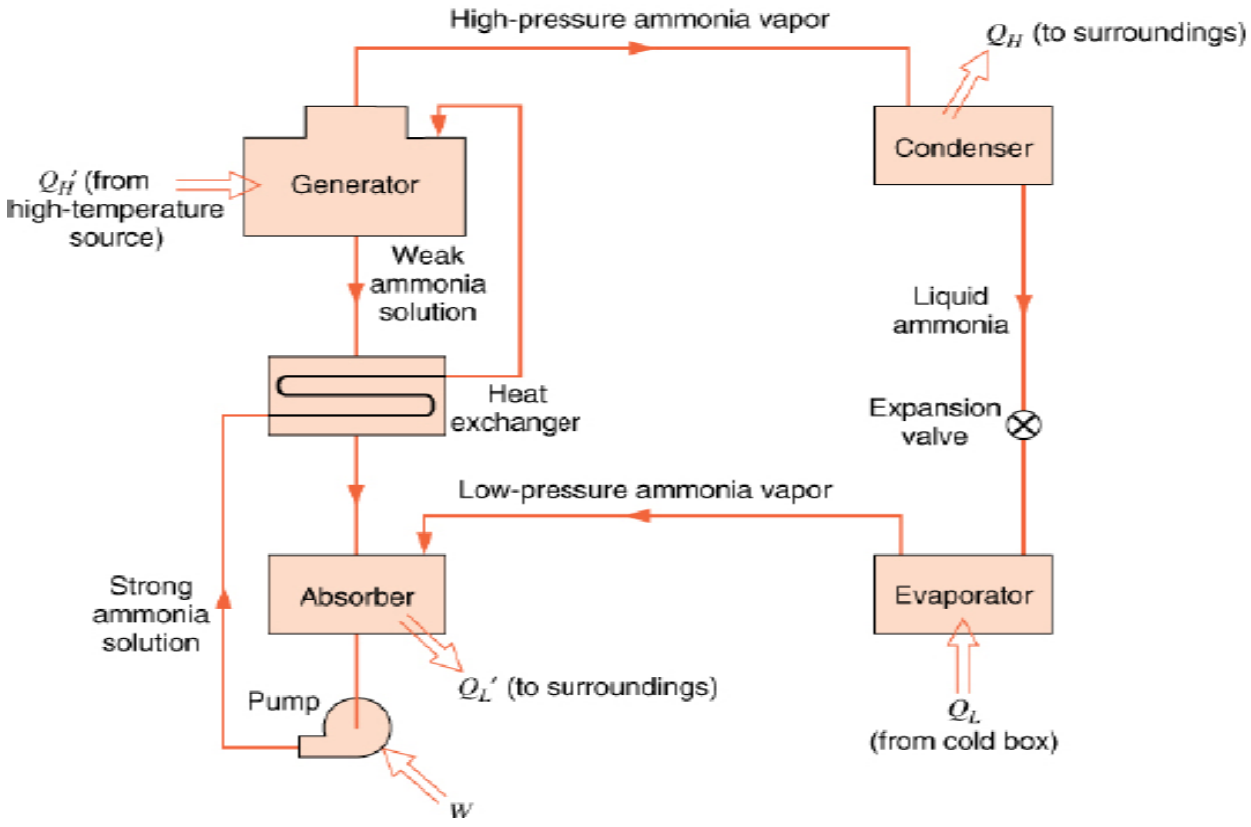
VAPOR COMPRESSION REFRIGERATOR



- It mainly consists of an evaporator made of coiled tubes installed in the freezing compartment of the refrigerator, a compressor, a throttle valve and a condenser.
- The liquid refrigerant at low pressure and temperature passing in the evaporator coiled tubes absorbs heat from the contents in the freezing compartment and evaporates.
- This lowers the temperature of freezing compartment. The vapor refrigerant at low pressure from evaporator is drawn by the compressor which compresses it to high pressure.
- This increase in pressure increases the saturation temperature of the refrigerant higher than the temperature of the cooling medium (atmospheric air) in the condenser so that vapor can reject heat in the condenser.
- The high pressure – high temperature vapor refrigerant from the compressor flows to the condenser where it gives off its latent heat to the atmosphere air.
- As a result of the loss of latent heat in the condenser, the refrigerant condenses to liquid.

- The high-pressure liquid refrigerant approximately at room temperature now flows to the throttle valve in which it expands to a low pressure and then passes to the evaporator coils for recirculation again.
- During throttling expansion, the pressure and temperature reduces, and refrigerant partly evaporates. The temperature reduces to -100C and vapor will be wet.
- This wet vapor now passes to the evaporator coils where it absorbs its latent heat and then re circulated to repeat the cycle continuously.
- Thus, heat is continuously removed from the contents of the refrigerator in the evaporator and rejected in the condenser to the atmospheric air.
- This will keep the contents of the refrigerator at lower temperature. The temperature is maintained by a thermostat switch which switches on and off as and when the temperature either falls below or rises above the required temperature.
- The most used refrigerant in vapor compression refrigerator is dichlorodifluoromethane popularly known as Freon 12 or R12.

VAPOR ABSORPTION REFRIGERATION SYSTEM



- This makes use of absorbent to absorb large volumes of the vapor of a refrigerant when cold and reduce it to a liquid and subsequently give off its vapors when heated.
- Ammonia is commonly used as the refrigerant and water as absorbent in this type of refrigerators.
- In this the ammonia refrigerant vaporizes in the evaporator coils absorbing the latent heat from the freezing compartment thus keeping it cool and rejects this heat in the condenser.
- This refrigerator mainly consists of an absorber, a circulating pump, heat exchanger, generator, expansion valve and evaporating coiled tubes.
- Dry ammonia vapor is dissolved in the cold water contained in the absorber, which will produce a strong ammonia solution.
- The strong ammonia solution from absorber is pumped to heat exchanger where it is warmed by the warm weak ammonia solution flowing back from the generator.
- The warm high pressure ammonia solution now passes to the generator where it is heated by heating coils.
- The heating will drive out the ammonia vapor from it. Now the solution in generator becomes weak and flows back to the heat exchanger where it warms up the strong ammonia solution passing through it.
- The high-pressure ammonia vapor from generator now passes to a condenser, where it is condensed.
- The high-pressure ammonia liquid is now expanded to low pressure and low temperature in the throttle valve.
- The low pressure condensed ammonia liquid at low temperature is passed onto the evaporator coils provided in the freezing compartment, where it absorbs the heat and evaporates. The low-pressure ammonia vapor from freezing compartment is passed again to the absorber.

COMPARISON BETWEEN VAPOR COMPRESSION AND VAPOR ABSORPTION SYSTEMS:

Principle	Vapor compression	Vapor absorption
Working method	Refrigerant vapor is compressed	Refrigerant vapor is absorbed and heated
Type of energy supplied	Mechanical	Heat
Work or energy supplied	To compress refrigerant	To run the pump
COP	Higher and reduces at part loads	Relatively low & remains same
Capacity	Up to 1000 tons	Above 1000 tons
Noise	More	Almost quiet

Refrigerant	Freon-12	Ammonia
Leakage problem	Chances are more	No leakage
Maintenance	High	Less
Operating cost	High	Less

REFRIGERANTS COMMONLY USED

1. Ammonia – in vapor absorption refrigerator.
2. Carbon dioxide – in marine refrigerators.
3. Sulphur dioxide – in household refrigerators.
4. Methyl chloride – in small scale & domestic refrigerators.
5. Freon – 12 – in domestic vapor compression refrigerators.
6. Freon – 22 – in air conditioners.

Ammonia: Used in absorption refrigerator. High latent heat of 1300kJ/kg and low specific volume at -15^0 C. It is environmentally friendly, will not harm ozone layer. It is widely used in cold storage, ice making plants, etc. Its toxic, flammable, irritating and food destroying properties makes it unsuitable for domestic refrigerators. It is used in industrial refrigeration.

Carbon dioxide: It has low specific volume and hence the plant size is compact. It is used in ships where space considerations are more important. It is cheap, non-corrosive and non-flammable. It has a boiling point of 78.5^{0}C and low critical temperature of 31^{0}C.

Sulphur dioxide: It has a boiling point temperature of -25.6^{0}C and has a high critical temperature of 157.2^{0}C. It is highly toxic and corrosive in nature. It is used in small plants and domestic refrigerators.

Freon-12: It is colorless, odorless, and non-toxic in nature. It is mostly used in domestic refrigerators. It has low specific volume compared ammonia. It has a boiling point of -29.8^{0}C and critical temperature of 112.1^{0}C.

Freon-22: It is another refrigerant used from freon group. It has low specific volume. Its boiling point is -40.8^{0}C and critical temperature is 96.2^{0}C. It is used in small and medium commercial plants.

PROPERTIES OF GOOD REFRIGERANT

A. THERMODYNAMIC PROPERTIES:	**REQUIREMENT**
1. Boiling point	Must have low boiling point
2. Freezing point	Must have low freezing point
3. Evaporator & condenser pressure	Should be slightly above the atmospheric pressure
4. Latent heat of evaporation	Must be very high

B. PHYSICAL PROPERTIES	**REQUIREMENT**

1. Specific volume	Must be very low
2. Specific heat of liquid & vapor	Must be low in liquid state & high in vapor state
3. viscosity	Both liquid & vapor states must be low

C. SAFE WORKING PROPERTIES	**REQUIREMENT**
1. Toxicity	Should be non-toxic
2. Flammability	Should not be flammable
3. corrosiveness	Should be non-corrosive
4. Chemical stability	Should be stable & should not decompose

D. OTHER PROPERTIES	**REQUIREMENT**
1. COP	Must be high
2. Odour	Must be odourless
3. Leakage	Should be easily detectable
4. Action with lubricating oil	Must not react with lubricating oil

AIR CONDITIONING

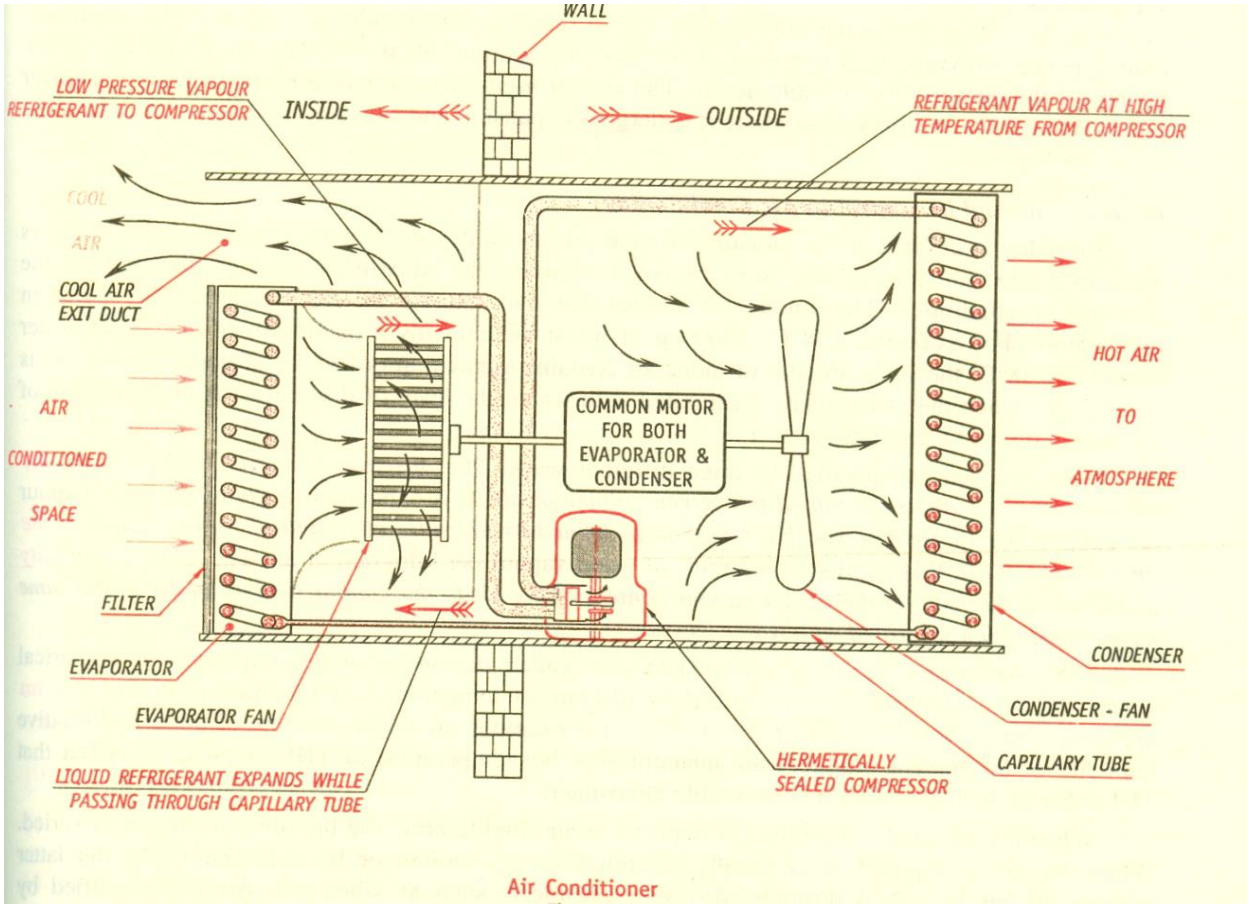
Providing a cool congenial indoor atmosphere by cooling, humidifying, or dehumidifying, cleaning, and recirculating the surrounding air is called air conditioning. The artificial cooling of air and conditioning it to provide maximum comfort to human beings is called comfort air conditioning.

The artificial cooling of air and conditioning it to provide a controlled atmosphere required in some engineering, manufacturing, and processing is called industrial air conditioning.

ROOM AIR CONDITIONER AND PRINCIPLES OF AIR CONDITIONING:

- An air conditioner continuously draws air from an indoor space to be cooled, cools it by the refrigeration principles and discharges back into the same indoor space that needs to be cooled.
- Both the comfort and industrial air conditioning work almost on the same basic principle, the working principle of a comfort air conditioner is explained below:
- It mainly consists of an evaporator, condenser, compressor, two fans one each for evaporator and condenser units usually driven by the single motor, capillary, etc. It is generally mounted on a windowsill such that the evaporator unit is inside the room and the condenser part projecting outside the building.
- The high pressure, high temperature liquid refrigerant from the condenser is passed to the evaporator coils through the capillary tube where it undergoes expansion.

- The refrigerant in evaporator coils absorbs heat from the air passing over it from the interior and evaporates.
- The high temperature evaporated refrigerant is compressed to high pressure by a compressor and delivered to the condenser, where it is cooled or condensed to liquid by giving off the heat to the atmospheric air passing over it.
- The cooled high-pressure refrigerant now passes through the capillary tube where it undergoes expansion and again re circulated to repeat the cycle continuously.



Air Conditioner

HUMIDITY AND ITS CONTROL IN AIR CONDITIONING

- Humidity is defined as the moisture content present in the atmosphere. It will be in the form vapour and the maximum amount depends on the atmospheric conditions.
- The amount of vapour that will saturate the air increases with the rise of temperature.
- As the atmosphere is saturated with water, the level of discomfort is high because of the evaporation of perspiration.

AIR CLEANING IN AIR CONDITIONING

- Along with controlling of temperature and humidity of the air supplied in Air Conditioning system it should be seen that air is free from dust.

- Therefore, air is cleaned by removing dust electrostatically by means of precipitators.

ABSOLUTE HUMIDITY: It is defined as ratio of water vapour contained in each volume of air.

SPECIFIC HUMIDITY: It is defined as the ratio of mass of water vapour to the total mass of air.

RELATIVE HUMIDITY: It is defined as the ratio of the actual vapour content of the air to the vapour content of the air at the same temperature when saturated with water vapour.

CENTRAL AIR CINDITIONING:

- These systems are widely used in theatres, offices, stores, restaurants, public buildings, etc.
- They provide controlled atmosphere by heating, cooling and ventilation.
- The system consists of refrigerating units, blowers, air ducts in which the air from the interior of the building is mixed with outside air.
- In these systems, cooling and dehumidification are done during summer and heating is done during winter.
