KTU NOTES

The learning companion.

KTU STUDY MATERIALS | SYLLABUS | LIVE NOTIFICATIONS | SOLVED QUESTION PAPERS

Website: www.ktunotes.in

MODULE 5

POWER TRANSMISSION, HYDRAULIC MACHINES, REFRIGERATION AND AIR CONDITIONING

Power transmission

Power transmission is a process required in almost every piece of machinery. Power transmission methods are used to transmit power from the prime mover to the driven machinery for its function. The shaft from which power is transmitted is called driver shaft and the shaft to which power is transmitted is called driven shaft. Mechanical power can be transmitted from one shaft to another by following methods

- Belt drive
- Rope drive
- Chain drive
- Gear drive

Belt drive

A belt is a thin inextensible band made of leather, rubber, steel, canvas or balata. Belts are used to transmit power between two parallel shafts, which are at a considerable distance apart (large distance). A belt is a continuous band of flexible material passing over pulleys to transmit motion from one shaft to another. Belts are made endless to run over the pulleys mounted on the shafts. Friction between the belt and the pulley is responsible for transmitting power from one pulley to other. Belt drive is a friction drive and it is not a positive drive, since there is always some possibility of slipping between the belt and pulley. Amount of power transmitted depends on the velocity of the belt, the tension with which the belt is placed under the pulleys, the arc of contact between the belt and the smaller pulley.

Classification of belts (Type of belts)

1. Flat belts
2. V-belts
3. Timing belts
4. Round belt

1. Flat belts

Flat belts are belts with a narrow rectangular cross section and they run on flat pulleys. Flat belts are used for their simplicity and because they are subjected to minimum bending stress on the pulleys. The load capacity of flat belt is varied by varying their width and only one belt is used in each drive. They are used for moderate power transmission and are used in sawmills, conveyors, electrical generators etc.

Advantages

- Simple in construction, smooth operation,
- Low maintenance and long life
- Flexible

Disadvantages

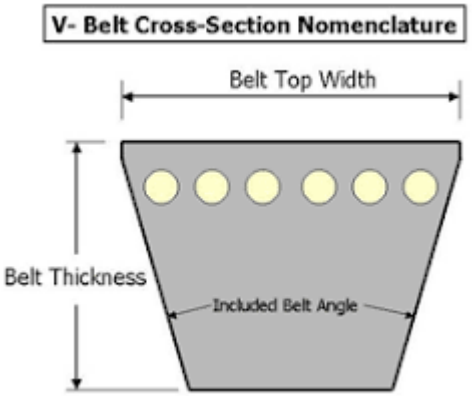
- Not positive drives
- Less efficient
- Not suitable for short distances

2. V-Belts

A V-belt is a belt of trapezoidal cross section running on pulleys with grooves cut to match the belt (V-grooved pulleys). The normal angle between the sides of the groove is 40 deg. They are usually made of fabric coated with rubber. They are silent and resilient. They are used when the distance between the shafts is too short for flat belt drives. Due to the wedge between the belt and the sides of the grooves in the pulley action (shape of belt and grooves in pulley), the V-belts are less likely to slip, hence more power can be transmitted for the same belt tension. Multiple V belts are used when the power to be transmitted is large for a single belt. V belts are used in automotives and in agricultural purposes.

Advantages

- Transmits higher torque than flat belts
- Suitable for short distance
- Easily installed and removed
- Slip is negligible
- Operation is quiet
- Suitable for large speeds
- No possibility of belt coming out of grooves
- Capable of absorbing high shock.



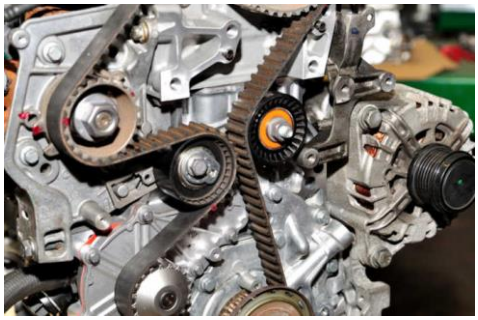
Disadvantages

- Not suitable for large distances
- Costly
- V belts cannot be repaired
- Construction is complicated

Comparison between V-Belt and Flat Belt

V Belt	Flat Belt
Suitable for shorter distance	Suitable for longer distance
Trapezoidal section	Rectangular section
Frictional grip is more	Frictional grip is less
Power transmitted is more	Power transmitted is less
Velocity ratio is high	Velocity ratio is low
Occurrence of slip is seldom possible	Slip occurs easily

3**. Timing Belt: Timing belts are toothed belts that use their teeth for power transmission, as opposed to friction.** This configuration results in **no slippage**, and therefore, the driving and driven shafts remain synchronized. It's more expensive to manufacture due to complexity of the belt and pulley shapes.



4. **Round belts**: Round belts are generally made of rubber. This type of belt is generally used for light loads, such as in a sewing machine or a vacuum cleaner.

Belt Drives

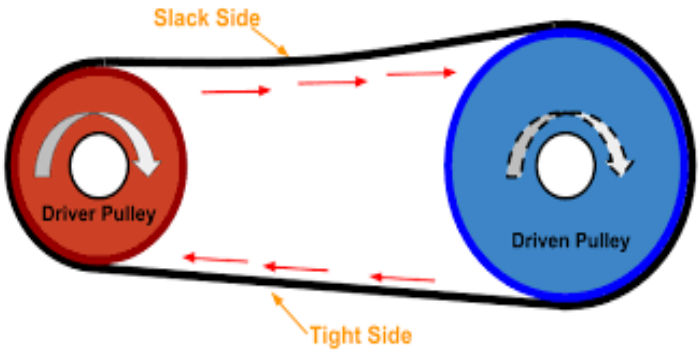
A belt drive consists of the driving and driven pulleys and the belt which is mounted on the pulleys with a certain amount of tension and transmits power by frictional force between belt and pulleys.

Belt drives can be categorised into:

1) Open belt drives
2) Cross belt drives
3) Belt drives with Idler pulleys
4) Compound belt drives
5) Stepped or Cone pulley drives

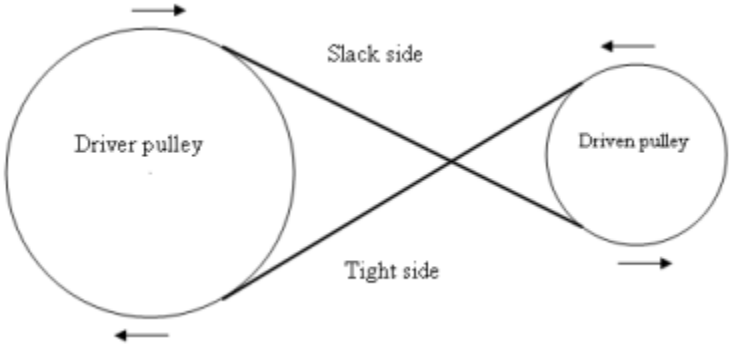
1. Open belt drives

It is used to transmit power when the distance between the shafts is large and both shafts are parallel. In open belt drives both the shafts rotates in the same direction. When the driver rotates in the clockwise direction, the lower side of the belt is tight and the upper side is slack. Upper side of the belt is called the slack side and the lower side of the belt is called the tight side.



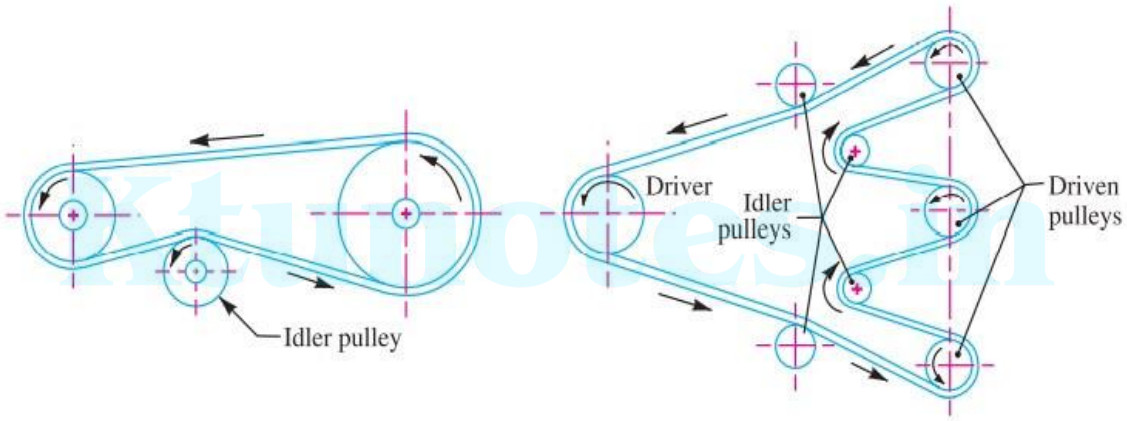
2. Cross belt drives

In cross belt drives the power is transmitted between parallel shafts rotating in opposite direction. Since the angle of contact in this type of drive is more, it can transmit more power than open belt drives. At the point where the belt crosses, it rubs against itself and wear and tear occurs. The drive should operate at low velocity.



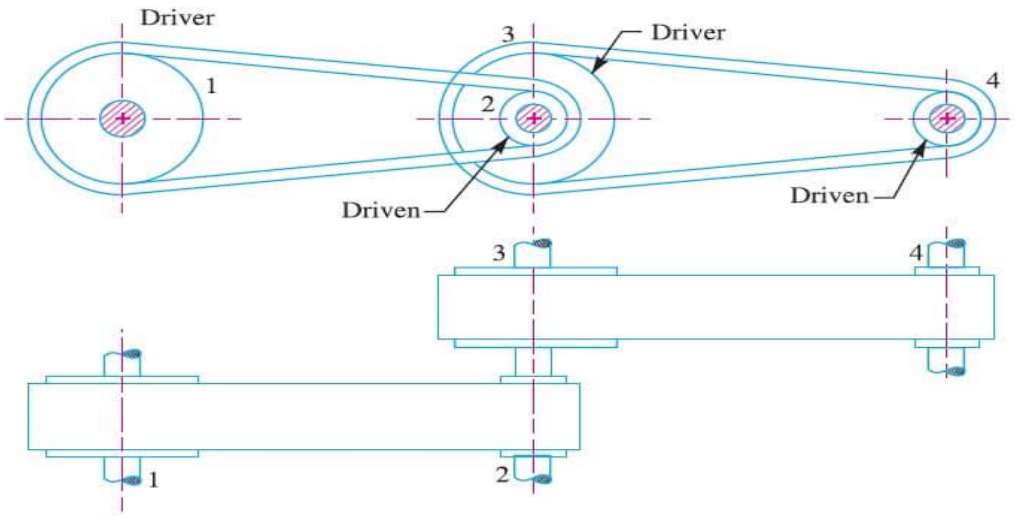
Belt drives with Idler pulleys

In this drive, a small pulley called idler pulley is placed on the slack side of the belt and nearer to the driven pulley. Idler pulley increases the angle of contact between belt and driver & driven pulleys. The shafts arranged in parallel and rotating in same direction and this drive is provided to deliver high velocity. Idler pulley reduces slip and increases the power transmission efficiency, but reduces belt life.



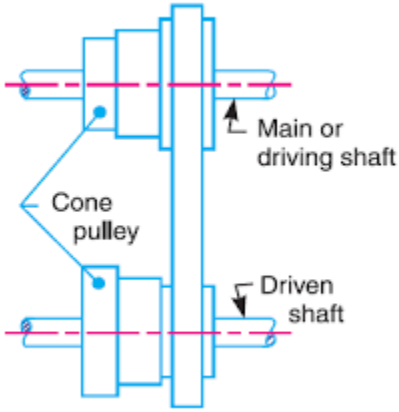
4. Compound belt drives

It is used when power is transmitted from one shaft to another through a number of pulleys. A single intermediate shaft may contain more than two pulleys.



5. Stepped or Cone pulley drives

In case of a stepped pulley system, a single pulley is made in three steps as shown in Fig. 9.6(a). It is made of cast iron. Two such pulleys are mounted on two parallel shafts as shown in Fig. It is used for changing the speed of driven shaft while the driving shaft is maintained at constant speed.



Applications of Belt drives

(i) To transmit power from low or medium capacity electric motors to operative machines.

(ii) To transmit power from small prime movers (IC Engines) to electric generators, agricultural and other machinery.

Advantages of Belt Drives

(i) They are simple and economical.

(ii) They can transmit power over a medium distance.

(iii) They give smooth operation (Noise and vibrations are damped out)

(iv) They can operate at high speeds of rotation.

(v) They are lubricant free and their maintenance cost is relatively low.

Disadvantages of Belt Drives

(i) Their considerable overall size, usually several times larger than toothed gearing.

(ii) Slip occurs in the belt drives.

(iii) The necessity of belt tensioning devices.

(iv) The necessity to keep oil from getting on the belt.

(v) The relatively short service life in high speed drives.

(vi) Heat build-up occurs. Speed is limited to usually 35 meters per second. Power transmission is limited to 370 kilowatts.

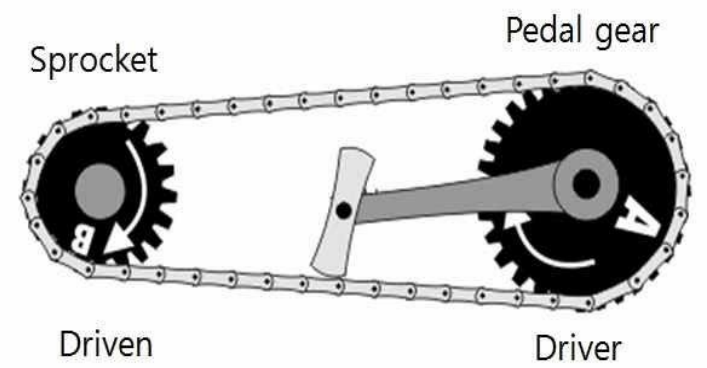
(vii) Operating temperatures are usually restricted to –35 to 85°C.

(viii) Stretching of belt after some time.

Chain Drive

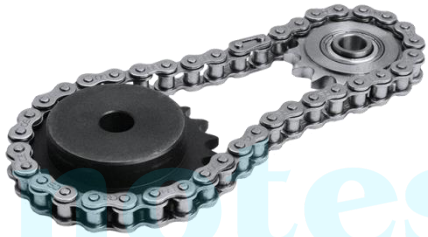
Chain drive is a way of transmitting mechanical power from one place to another using chains and sprocket. It is often used to convey power to the wheels of a vehicle, particularly bicycles and motorcycles. Chain drive consists of an endless chain running over special profile toothed wheels called sprockets. One of the sprockets will be the driver and the other driven. Smaller sprocket is called pinion and the bigger one is called wheel.

In belt or rope drive we see there is some percent of slip occurs, but in the chain, there will be no slip. But this does not mean that 100% power is transmitted from one to another device. Due to friction, loss some amount of power lost. A chain is made by a number of links and those are connected by the help of a pin. Chains are run over a wheel named sprocket which has several amounts of teeth around the circumference of that to grip the chain.



Main applications of chain drives are; (i) Motor cycles (ii) Bicycles (iii) Conveyers (iv) Agricultural machinery (v) Machine tools (vi) Automobiles etc.

There are two principal types of chain drives :
1) Roller chain drive



2) Inverted tooth or silent chain drive.

Advantages of chain drives:

- Low maintenance.
- Greater efficiency up to 97 percent.
- Slipping is negligible
- Chain drive can operate in wet conditions too.
- It can withstand abrasive conditions.
- The chain drive is easy to install.
- Chain drive requires less space and it is more compact than belt drive.
- It produces less stress on the shaft because the sprockets are lighter than pulleys.
- Transmit higher power compared to belt drive.
- It can be operated at a high temperature Like a belt which cants not operate at high temperatures.

Disadvantages of chain drives:

- The major disadvantages are here it requires more and frequent lubrication otherwise rust problem comes.
- We can't keep chain drive-in open. It needs housing or covering.
- It is noisy and therefore there is a problem of vibration too.
- The installation or initial cost is more.

Rope Drive

The rope drive is widely used where a large amount of power is to be transmitted, from one pulley to another, over a considerable distance. Rope drives use a number of circular section ropes, rather than a single flat or v belt.

The rope drive uses the following two types of ropes:

1. Fibre Ropes
2. Wire ropes.

Fibre Ropes

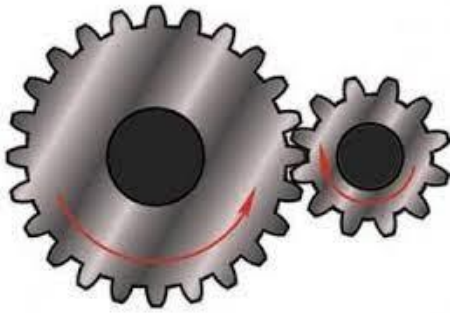
The ropes for transmitting power are usually made from fibrous, materials such as hemp, manila and cotton. Since the hemp and manila fibres are rough, Therefore the ropes made from these fibres are not very flexible and possesses poor mechanical properties. The fibre ropes operate successfully when the pulleys are about 60 metres apart.

Wire Ropes

When a large amount of power is to be transmitted over long distances from one pulley to another (i.e.when the pulleys are up to 150 metres apart), then wire ropes are used.The wire ropes are widely used in elevators, mine hoists, cranes, conveyors, hauling devices and suspension bridges.

Gear Drive

A gear is simply a toothed wheel. It is a wheel provided with teeth which mesh with the teeth on another wheel, or on to a rack, so as to give a positive transmission of power from one component to another. One gear is mounted on the driving shaft and another one on the driven shaft and their teeth is meshing with each other.
Gear drive is a positive drive (no slip) and the axes of the shafts may be parallel or non-parallel. When two gears of different sizes mesh, the smaller one is called pinion and the larger one is called gear. When pinion (smaller gear) is the driver, output speed (driver speed) decreases and torque increases. When the gear (larger gear) is the driver, output speed (driver speed) increases and torque decreases.



Advantages of gear drives

1) High efficiency
2) Long service life.
3) High reliability.
4) More compact.
5) Can operate at high speeds.
6) Can be used where precise timing is required.
7) Large power can be transmitted.
8) Constant speed ratio owing to absence of slipping.
9) Possibility of being applied for a wide range of torques, speeds and speed ratios.

Disadvantages of gear drives

1) Special equipment and tools are required to manufacture the gears.
2) When one wheel gets damaged the whole set up is affected.
3) Noisy in operation at considerable speeds.
4) Needs lubrication
5) Maintenance cost is high
6) Production cost is high

Classification of gears

1. Spur gears

Spur gears are those which have teeth cut parallel to the axis of the shaft. Spur gears are used to transmit power between parallel shafts. They are used in high speed and high load applications. This is the simplest form of geared drive.

2. Helical gears

In helical gear, the teeth cut on the periphery are of helical screw form. Helical tooth is inclined at an angle to the axis of the shaft. Helical gears are used to transmit power between parallel shafts and the shafts rotate in opposite directions.

3. Herringbone Gear or Double-Helical Gears

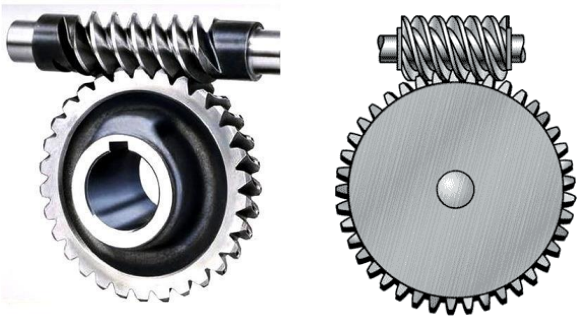
Herringbone gears have opposing helical teeth which nullify two axial thrusts. Load carrying capacity is very high and these gears are used to transmit power between two parallel shafts at high speeds. The two shafts rotate in opposite directions.

4. Bevel Gear

Bevel gears are used to connect two non-parallel shafts with intersecting axes. Teeth of these gears are formed on a conical surface. These gears are used to transmit power between two shafts at any angle, generally the shafts are at right angles. They are used to slow speed applications.

5. Worm Gear

Worm gears are used for power transmission between non-intersecting shafts that are generally at right angles to each other. Worm gearing consists of worm and worm wheel. Worm is a threaded screw and is used as the driver and worm wheel is a toothed wheel. Teeth of the worm wheel remain engaged with the threads of the worm. Worm gearing is smooth and quiet.



6. Rack and Pinion

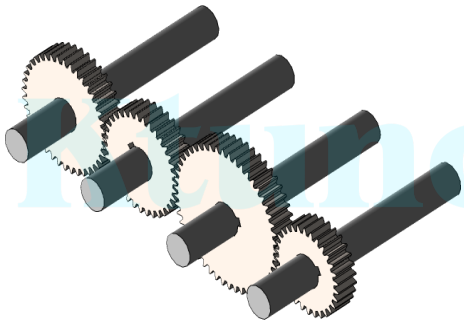
A rack is a spur gear of infinite diameter, thus it assumes the shape of a straight gear. Rack and pinion gears are used to convert rotation (pinion) into linear motion(rack) or vice versa.

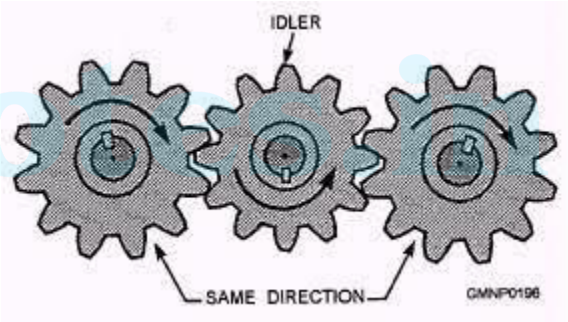
Types of Gear Trains

A gear train is a power transmission system made up of two or more gears. The gear to which the force is first applied is called the driver and the final gear on the train to which the force is transmitted is called the driven gear. Any gears between the driver and the driven gears are called the idlers. Conventionally, the smaller gear is the Pinion and the larger one is the gear. The gear trains are of the following types

1. Simple gear train

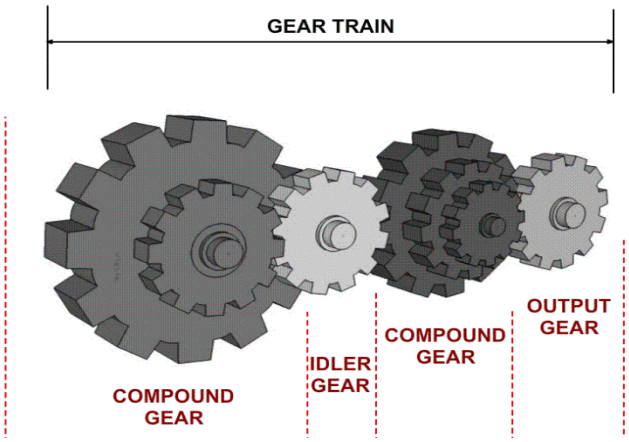
Simple gear trains have only one gear per shaft. The simple gear train is used where there is a large distance to be covered between the input shaft and the output shaft.

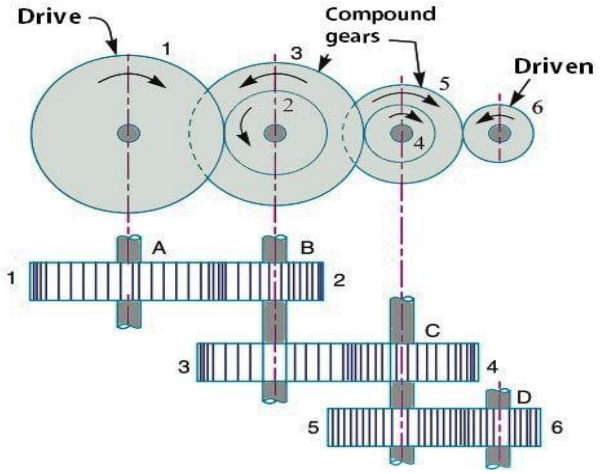




2. Compound gear train

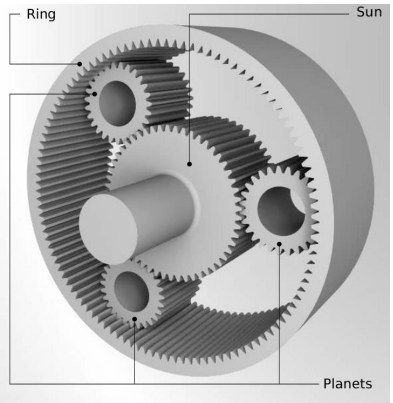
In a compound gear train at least one of the shafts in the train must hold two gears. Compound gear trains are used when large changes in speed or power output are needed and there is only a small space between the input and output shafts. When a series of gears are connected in such a way that two or more gear rotates about an axis with the same angular velocity, ii is known as compound gear train.

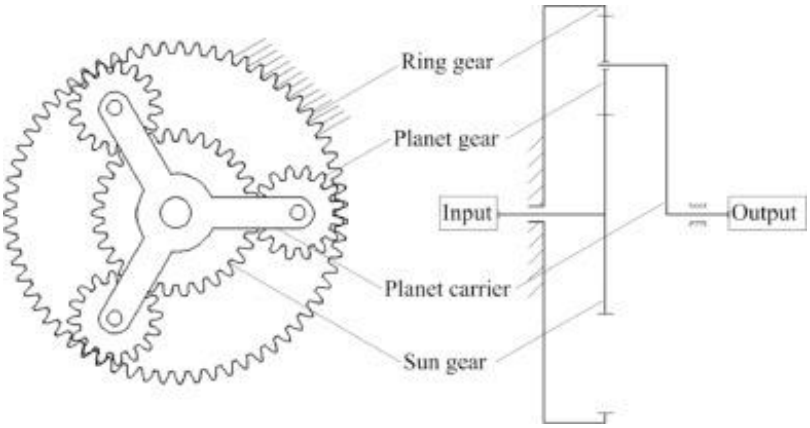




3. Planetary or Epicyclic gear train

A planetary transmission system (or Epicyclic system as it is also known), consists normally of a centrally pivoted sun gear, a ring gear and several planet gears which rotate between these. This assembly concept explains the term planetary transmission, as the planet gears rotate around the sun gear as in the astronomical sense the planets rotate around our sun. in an epicyclic gear train the axis of the shaft on which the gears are mounted may move relative to a fixed axis.



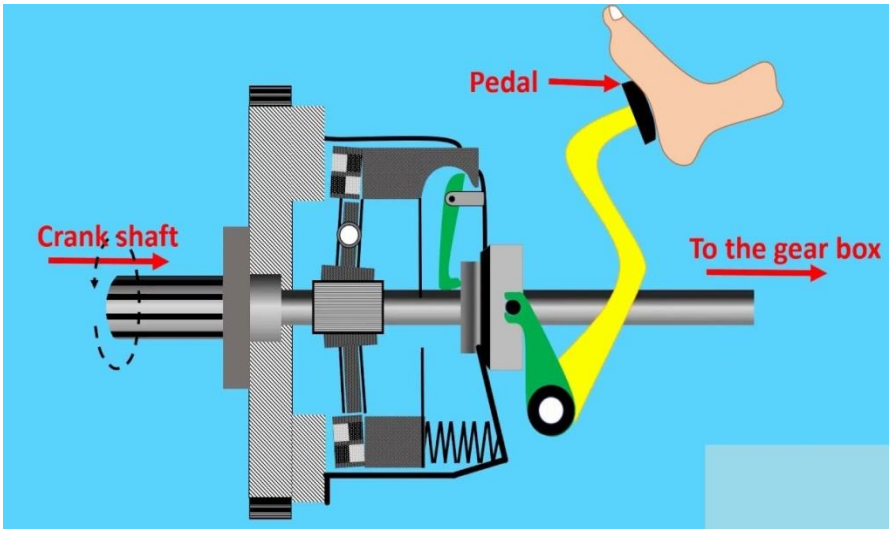


Clutch

Clutch is mechanical device which is used to transmit rotating motion or torque from one shaft to another shaft when required. Clutch provides a temporary connection between input and output shaft. Clutch lies between the engine and the gear box. In the simplest application, clutches connect and disconnect two rotating shafts. In these devices, one shaft is typically attached to an engine or other power unit (driving member) while the other shaft (the driven member). When clutch is in engaged position, the engine power flows to the gear box through clutch and from gear box power flows to the wheels. When clutch is in disengaged position, the engine power does not reach to gear box.

Purpose

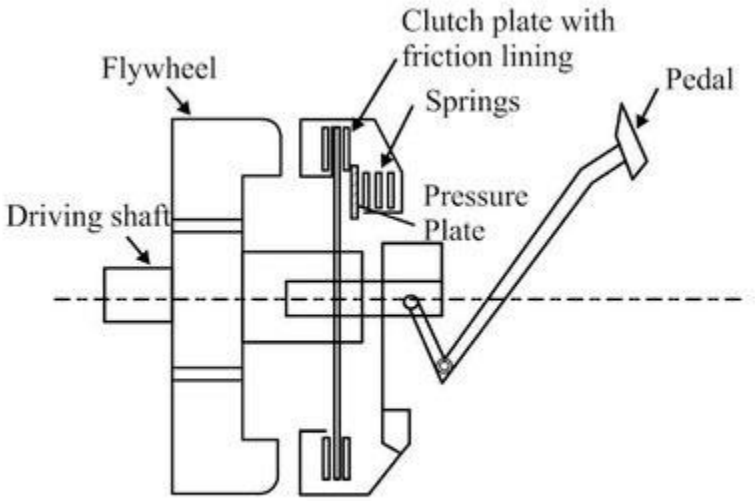
- Allows the vehicle to come to a stop while the transmission remains in gear
- Allows the driver to smoothly take off from a dead stop
- Allows the driver to smoothly change gears
- Must be able to transmit power and torque without slipping



Single Plate Clutch

Single plate clutch is a friction clutch in which Single plate with friction surface is connected to a driven shaft. It consists of

1) A driving member,
2) A driven member, and
3) An operating member



Single plate clutch

Driving member has a flywheel which is mounted on the engine crankshaft. The driven member is a disc called clutch plate. This plate can slide freely to and fro on the clutch shaft. The operating member consists of a pedal or lever which can be pressed to disengaged the driving and driven plate.

Working

When the clutch is engaged, the clutch plate is gripped between the flywheel and pressure plate. The friction linings are on both sides of clutch plate. Due to friction between flywheel, clutch plate and pressure plate, the clutch plate revolves with the flywheel. As clutch plate revolves the clutch shaft also revolves. Thus, engine power is transmitted to the clutch shaft. When the clutch pedal is pressed the pressure plate moves back against the spring force and clutch plate becomes free between flywheel and pressure plate. Thus flywheel remains rotating as long as the clutch pedal is pressed, the clutch is said to be disengaged and clutch shaft speed reduces slowly and finally it stops rotating.

Advantages:

- The working of the single plate clutch is smooth i.e. the engagement and disengagement is very smooth in operation.
- Less slip occurs in it.
- Power losses are very less.
- Less heat generates because only single plate is used.
- Single plate clutches have quick operation and respond fast.

Disadvantages:

- It has less torque transmitting capacity
- It has bigger in size even for transmitting less torque.
- It requires high maintenance because they are dry clutches and it is necessary to prevent them from moisture or any leakage of lubricant/oil in machinery.

Hydraulic Machines

Hydraulic machines are machinery and tools that use liquid fluid power to do simple work, operated by the use of hydraulics, where a liquid is the powering medium.

Hydraulic Pumps

Pumps are hydraulic machines which convert the mechanical energy into hydraulic energy. Pump is generally used for raising liquid from low level to high level. Hydraulic pumps can be classified into two

1) Centrifugal pump
2) Reciprocating pump

Centrifugal pump

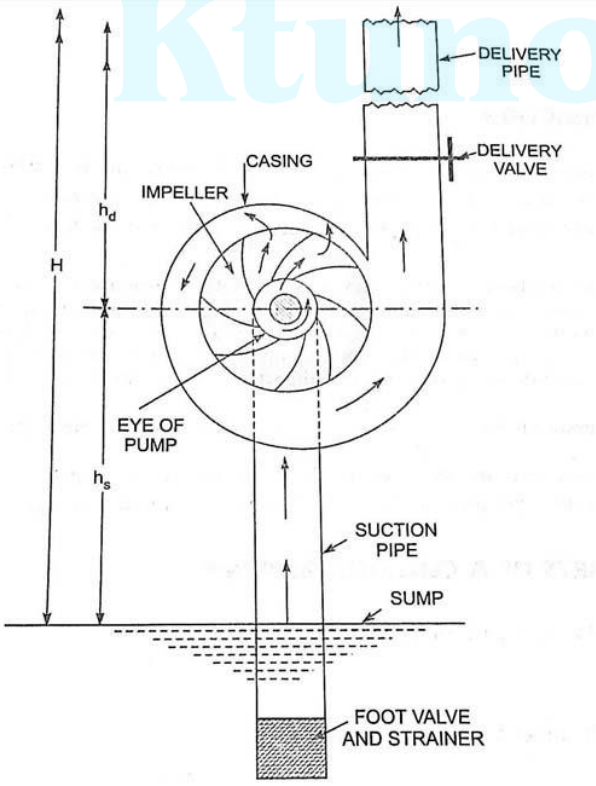
A centrifugal pump is a roto dynamic pump that uses a rotating impeller to create flow by the addition of energy to a fluid.

The main parts of a centrifugal pump are

1. Impeller: Rotating solid disc with curved blades. Impeller is mounted on a shaft connected to the shaft of an electric motor. As the impeller rotates, fluid is drawn into the impeller inlet (eye of pump) is accelerated as it is forced radially outwards.

2. Casing: Air tight passage around the impeller.

3. Suction pipe and delivery pipe: Pipe whose one end is connected to the inlet of pump and other end dipped in a sump is known as suction pipe. Pipe whose one end is connected to the outlet of the pump and the other end delivers the working fluid at a required height is known as delivery pipe.



Working of a centrifugal pump

Working fluid enters the pump at the centre of a rotating impeller. Impeller imparts centrifugal force on the liquid entrapped in the impeller and throws the liquid towards the outer periphery of the impeller. Outward movement of liquid in the impeller creates a partial vacuum near the eye of the impeller. Consequently, liquid from the sump is sucked in towards the impeller eye and enters through the inlet tip of impeller vanes. Thus, there is a continuous flow of liquid from the sump to the casing. The liquid leaving the impeller vanes is at a higher pressure and velocity. The velocity head is converted to pressure head in the casing.

Reciprocating pump

Reciprocating pump is a positive displacement pump. It creates the lift and pressure by displacing the liquid using a moving mechanical element called plunger (piston) inside a cylinder.

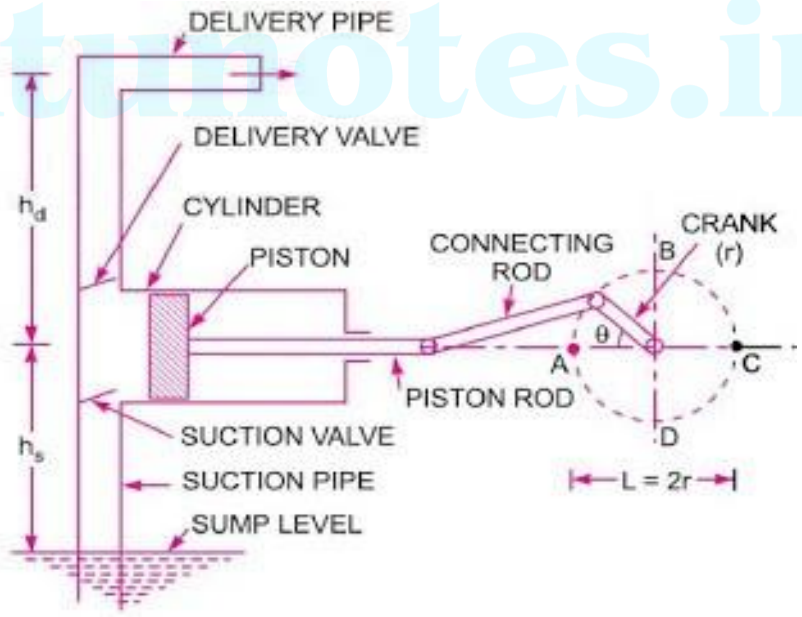
The main parts of a reciprocating pump are

1. Cylinder with valves at inlet and delivery: Suction and delivery pipes with suction valve and delivery valve are connected to the cylinder. The suction and delivery valves are one-way valves or non-return valves, which allow the water to flow in one direction only.

2. Plunger or piston: Piston reciprocates in the closely fitted cylinder.

3. Connecting rod and crank mechanism: Crank and connecting rod mechanism is operated by a power source.

4. Suction and delivery pipe with one way valve: One end of suction pipe remains dip in the liquid and other end attached to the inlet of the cylinder. One end of delivery pipe attached with delivery part and other end at discharge point.



Working of Reciprocating pump

Working of reciprocating pump is similar to that of reciprocating engines. Piston moves from left to right (crank moves from A to C) creates a vacuum inside the cylinder and atmospheric pressure forces the liquid up through the suction pipe (suction valve is opened when crank is at B) into the cylinder. Delivery valve will be closed during this stroke. During the return stroke (crank moves from C to A), the pressure developed in the fluid opens the delivery valve (when crank is at D), closes the inlet valve and pushes the fluid through the delivery valve. This pump is suitable for high heads and low discharge.

Hydraulic Turbines

A hydraulic turbine is a rotary machine that converts kinetic energy and potential energy of water (hydraulic energy or hydro-potential) into mechanical work. Mechanical energy developed by turbines is used to run electric generators coupled to the shaft of turbines. Hydroelectric power is the cheapest source of power generation.

Flowing liquid, mostly water, when pass through the Hydraulic Turbine it strikes the blades of the turbine and makes the shaft rotate. There are different forms of Hydraulic Turbines in use depending on the operational requirements. For every specific use a particular type of Hydraulic Turbine provides the optimum output.

Classification of turbines

Turbines can be classified on the basis of:

1. Head and quantity of water available

a) High head turbine: Head is more than 250m, low discharge, eg. Pelton turbine

b) Medium head turbine: 60m to 250m, medium discharge types, eg. Francis turbine

c) Low head turbine: Head will be below 60m, high discharge, eg. Kaplan turbine

2. Action of water on moving blades

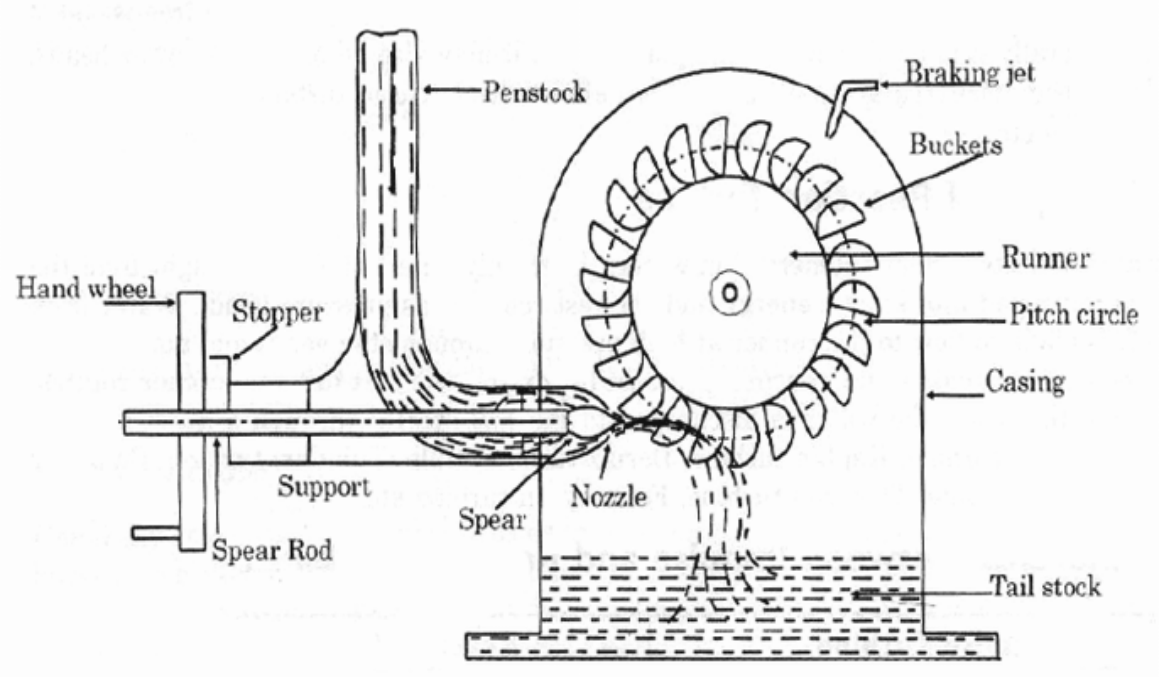
a) Impulse turbine: Water possess only kinetic energy at the inlet of the turbine, eg. Pelton turbine.

b) Reaction turbine: Water possess both kinetic energy and pressure energy at the inlet, eg. Francis and Kaplan turbine.

Pelton Wheel

A Pelton wheel is an impulse-type water turbine invented by Lester Allan Pelton in the 1870s. The Pelton wheel extracts energy from the impulse of moving water. Nozzles direct forceful, high-speed streams of water against a series of spoon-shaped buckets, also known as impulse blades, which are mounted around the outer rim of a drive wheel - also called a runner. Main Parts of a Pelton Turbine are

1. **Nozzle and flow regulating arrangement**
2. **Runner and buckets:** Runner is a circular disc on the periphery of which a number of buckets are fixed.
3. **Casing:** Prevent the splashing of water.
4. **Brake jet:** Used to stop the runner.



Working

Nozzle directs the water against buckets mounted around the runner. When the water jet strikes the bucket, the impulse energy of the water jet exerts torque (pressure) on the bucket-and-wheel system, spinning the wheel (runner). In the process, the water jet's momentum is transferred to the wheel and hence to a turbine. The runner shaft is connected with the generator, thus the electricity is produced.

Francis Turbine

The Francis turbine is a type of water turbine that was developed by James B. Francis. It is an inward-flow reaction turbine that combines radial and axial flow concepts. Francis turbines are the most common water turbine in use today. They operate in a water head from 40 to 600 m (130 to 2,000 ft) and are primarily used for electrical power production.

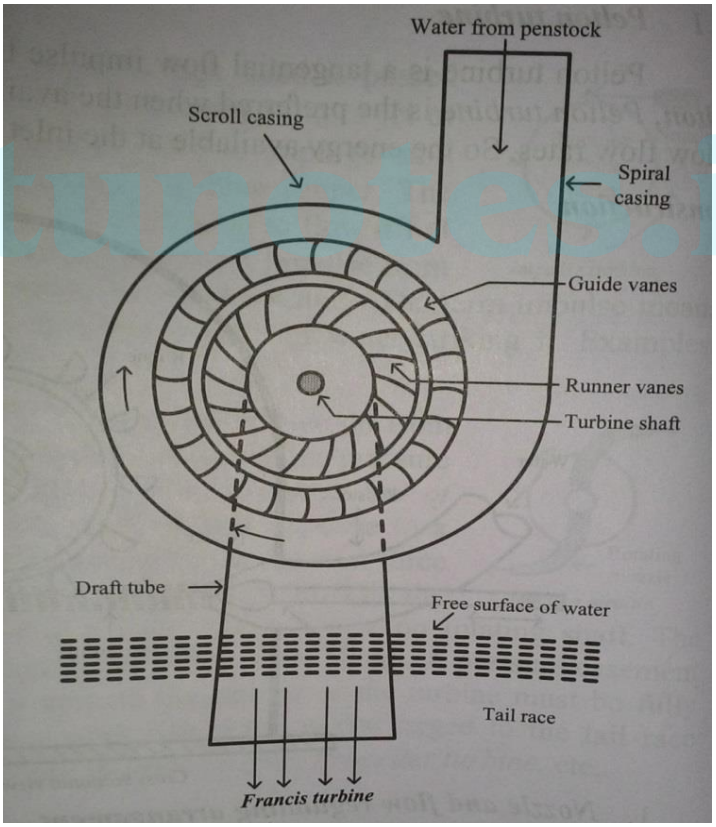
Main parts of Francis Turbine

1. Spiral casing: Maintain a uniform velocity around the guide vanes.

2. Guide vanes: Around the circumference of the runner. It acts like a nozzle to increase the velocity of water. It also regulates the amount of water inlet to the turbine.

3. Runner and runner vanes: Runner vanes have aerofoil like structure. Pressure difference on the blades causes the rotation.

4. Draft tube: Water flows from runner outlet to tail race through draft tube.



Working

The Francis turbine is a type of reaction turbine, a category of turbine in which the working fluid comes to the turbine under immense pressure and the energy is extracted by the turbine blades from the working fluid.

The water is allowed to enter the spiral casing of the turbine, which lead the water through the stay vanes and guide vanes. Water enters the runner from the guide vanes towards the centre in radial direction and discharges out of the runner axially. The impulse and reaction force of water rotates the runner and the runner shaft is connected with the generator, thus the electricity is produced.

Kaplan turbine

The Kaplan turbine is a propeller-type water turbine which has adjustable blades. It was developed in 1913 by Austrian professor Viktor Kaplan. Kaplan turbines are now widely used throughout the world in high-flow, low-head power production. They cover the lowest head hydro sites and are especially suited for high flow conditions. The design combines features of radial and axial turbines.

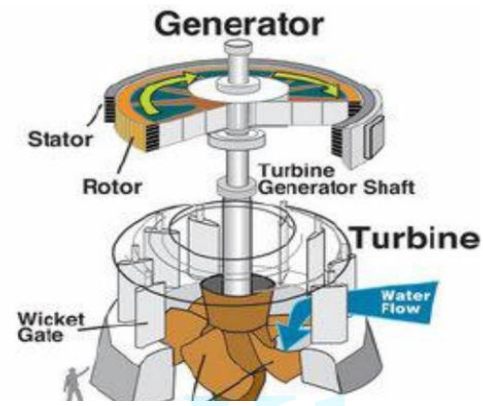
Main parts of a Kaplan Turbine

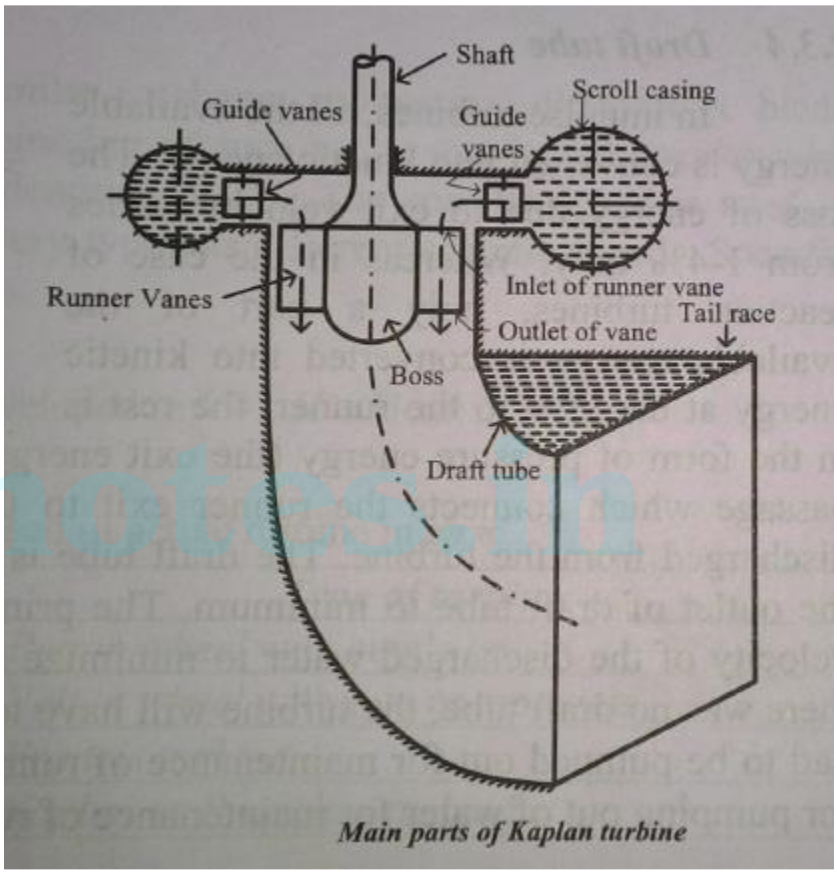
1. Scroll casing

2. Guide vanes: Used to turn the water through 900

3. Hub and vanes: Vanes are fixed to hub. Vanes are adjustable. Vanes are adjusted according to the flow rate. Vanes are aerofoil shaped profile

4. Draft tube





Working

The Kaplan turbine is an inward flow reaction turbine, which means that the working fluid changes pressure as it moves through the turbine and gives up its energy. Power is recovered from both the hydrostatic head and from the kinetic energy of the flowing water. The inlet is a scroll-shaped tube that wraps around the turbine's guide vane. Water is directed tangentially through the guide vane and spirals on to a propeller shaped runner, causing it to spin. The runner rotates the generator producing power. The outlet is a specially shaped draft tube that helps decelerate the water and recover kinetic energy.

Problems of hydraulic machines

Q1. Estimate the shaft power and motor power requirement to pump 200,000 kg/hr of water available at 250C and atmospheric pressure from a storage tank. The rated differential head requirement is 30 m. Assume the mechanical efficiency of the pump to be 70%. Assume the motor efficiency to be 90%.

Ans:
Flow rate (Q) = 200000kg/hr = 0.055m^3/s
Differential head (H) = 30m
Efficiency of pump = 70% = .7
Efficiency of motor = 90% = .9
Shaft power P in watt = ρ g Q H / efficiency of pump
= 1000x9.81x0.055x30/(.7)
= 23123.57 W = 23.12 kW
Motor power requirement = Pump shaft power / motor efficiency
= 23123.57/.9
= 25692 W = 25.69 kW

Q.2 A centrifugal pump using 1kw of electric motor of pumping water against 3m suction head and 7m delivery head. The discharge of the pump is 100litres/minute. Find the efficiency of pump?
Ans:
Electric power supplied, P = 1kw =1000 W
Total head, H = suction head + delivery head = 3m+7m =10m
Discharge of the pump, Q =100L/min =0.1/60 m^3/s
Density of water, ρ = 1000kg/m^3
Efficiency of the pump, η = ρ g Q H / P
= (1000 x 9.81 x 0.1 x 10) / (1000 x 60)
= 0.1635 = 16.35%

Q.3 To find the power that can be developed by the hydraulic turbine of input power 1000kw, assume an overall efficiency of 0.85
Ans:
Overall efficiency of turbine = 0.85
Input power = 1000*10^3 W= 10^6 W
Efficiency = output power/input power
Output power = 0.85*10^6 W
= 850 kW

Q.4 A turbine is working at a head of 250m and the discharge through the penstock is 2m^3/s. If the efficiency of the turbine is 55%, find the power developed by the turbine?
Ans:
Head of the turbine, H = 250m Discharge of water, Q = 2m^3/s
Efficiency of the turbine, η = 0.55 Density of water, ρ = 1000 kg/m^3
Efficiency of the turbine, η = Power available at the turbine shaft / ρ g Q H
Power developed by the shaft = ρ g Q H x η
= 1000 x 9.81 x 2 x 250 x 0.55
= 2697750 W = 2697.750 Kw

Refrigeration

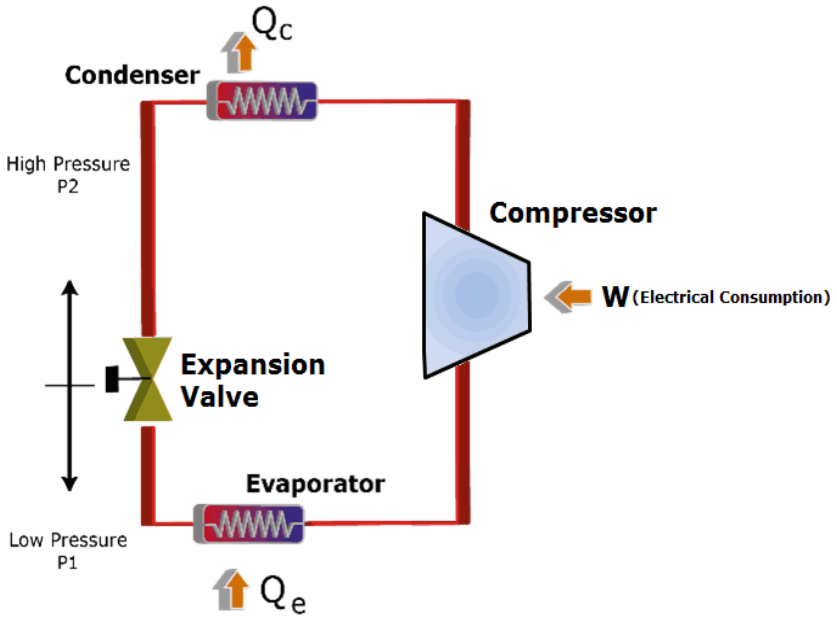
Refrigeration can also be defined as the process of cooling of bodies or fluids to temperatures lower than the surrounding. Refrigeration is therefore the science of moving heat from low temperature to high temperature Ex. Refrigerator. A refrigerator removes heat from the food products and rejects the heat to the atmosphere. The equipment used to maintain a lower temperature inside the system than its surroundings is known as refrigerating system and the working fluid inside the system is known as refrigerant. Freon, CFC, ammonia etc are commonly used refrigerants. Chemical stability, non flammability, availability, low specific heat, high critical temperature, cheapness etc are the desirable properties of refrigerants. The region that is maintained at a temperature lower than its surrounding is known as refrigerated space.

Applications

- Long preservation of food items without spoiling.
- Textile manufacture greatly depends on moisture content.
- Dry air is required in steel manufacture as it improves the quality of steel.
- Print Industry: Some colour printing presses have one press for each colour. The paper passes from one press to another press. The ink of one colour must get dried before it reaches the second press, so that the colours do not smudge.
- Pharmaceutical industry needs refrigeration to reduce air borne bacteria and dirt to preserve products
- Farm animals: The yield of Jersey cows decreases drastically during summer months. Low temperature results in more efficient digestion of food and increase in weight of cow and the milk yield.
- Computer Rooms/Server Rooms: These require control of temperature, humidity and cleanliness. The temperature of around 25 C and relative humidity of 50% is maintained in these rooms.
- Laboratories: This may involve precision measurement to performance testing of materials, equipment and processes at controlled temperature and relative humidity.
- Manufacturing of Precision Parts: If the metal parts are maintained at uniform temperature during manufacturing process, these will neither expand nor shrink, maintaining close tolerances.

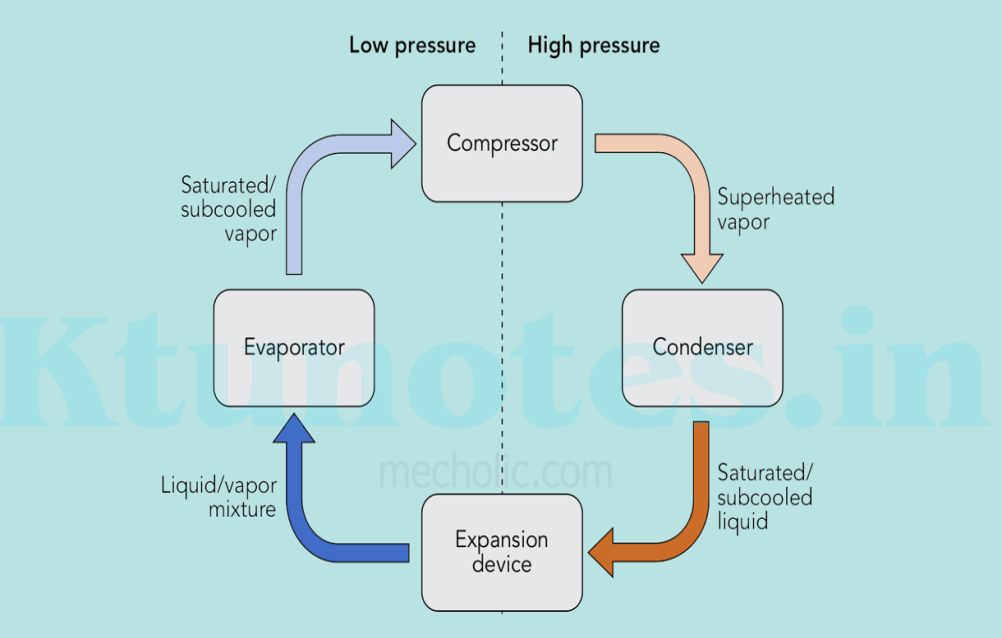
VAPOUR COMPRESSION REFRIGERATION SYSTEM

In vapour compression refrigeration system, the working fluid (Refrigerant) undergoes phase change (Liquid to vapour and vice versa) and refrigeration effect is due to the vaporisation of refrigerant liquid. This system is used in Refrigerators, Air conditioning systems etc…The major components of vapour compression refrigeration system are



Compressor: The function of the compressor is to compress the vapour refrigerant to high pressure.
Condensor: Condensor consists of coil of pipes and is used to condense the vapour refrigerant to liquid state by rejecting heat to the outside.
Throttle valve/Expansion Valve: It is used to reduce the pressure of the refrigerant (Which was compressed to high pressure at the compressor) and to control the flow of refrigerant in to the evaporator. During this process a very small quantity of liquid refrigerant get converted to its vapour state.
Evaporator: Here evaporation of the liquid refrigerant occurs. In evaporator liquid the refrigerant absorbs heat from the substance to be cooled or space to be cooled and converts to vapour state.

Refrigerant flows through the compressor, which raises the pressure of the refrigerant. Next the refrigerant flows through the condenser, where it condenses from vapor form to liquid form, giving off heat in the process. The heat given off is what makes the condenser "hot to the touch." After the condenser, the refrigerant goes through the expansion valve, where it experiences a pressure drop. Finally, the refrigerant goes to the evaporator. The refrigerant draws heat from the evaporator which causes the refrigerant to vaporize. The vaporized refrigerant goes back to the compressor to restart the cycle.



Unit of refrigeration
The unit of refrigeration is expressed in terms of ton of refrigeration (TR). One ton of refrigeration is defined as the amount of refrigeration effect (heat transfer rate) produced during uniform melting of one ton (1000kg) of ice at 0°C to the water at the 0°C in 24 hours.

Latent heat of ice is 335KJ/kg (heat absorbed during melting of one kg ice)
1 Ton of refrigeration, 1TR= 1000*335 in 24 hours
=(1000×335)/(24×60) in one minute
=232.6kJ/min

Theoretically one Ton of refrigeration taken as 232.6kJ/min, However in actual practice, it is taken as 210kJ/min. 1 ton of refrigeration approximately equal to 3.5kW.

Heat flows in direction of decreasing temperature, i.e., from high-temperature to low temperature regions. The transfer of heat from a low-temperature to high-temperature requires a refrigerator and/or heat pump. Refrigerators and heat pumps are essentially the same device; they only differ in their objectives. The performance of refrigerators and heat pumps is expressed in terms of coefficient of performance (COP):

General definition

$$CP = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_C} \Rightarrow \frac{T_H}{T_H - T_C}$$

Limit for ideal Carnot case

Ideal coefficient of performance

The coefficient of performance of refrigerator depends upon the two temperature values i.e. low temperature Tl and high temperature Th. For COP value to be high the low temperature Tl should be high while higher temperature Th should be small. The reverse Carnot cycle is the most efficient refrigeration cycle operating between two specified temperature levels. It sets the highest theoretical COP.

Reversed Carnot cycle

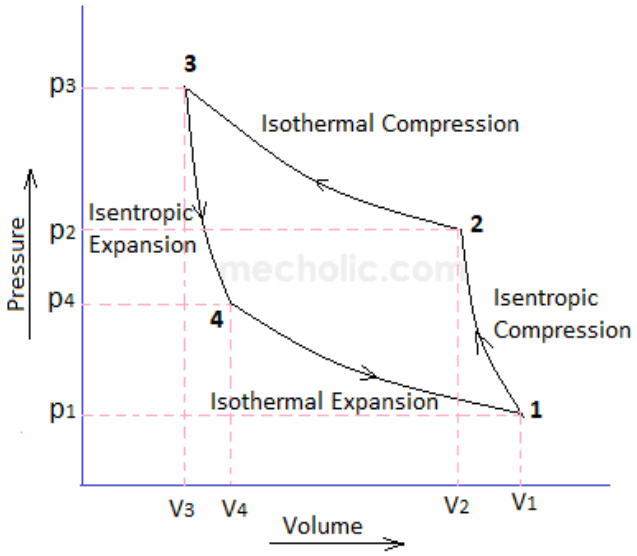
In the reverse Carnot cycle, work is done to extract heat from one system and expel it into another via four processes, two isothermal and two isentropic.

Isentropic compression (1→2) - The gas is isentropically compressed, and there is no heat flow into or out of the refrigerator.

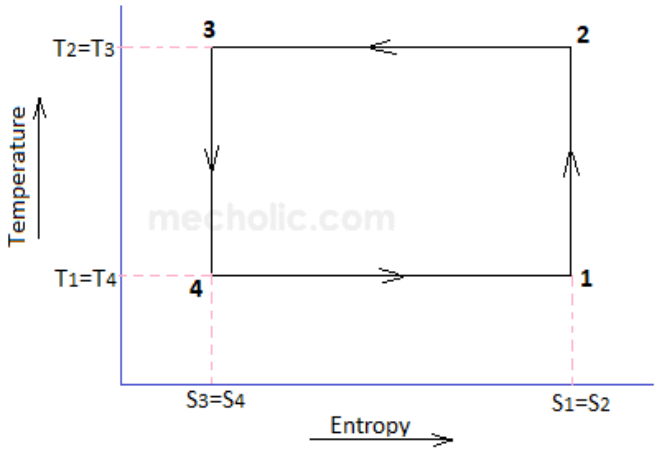
Isothermal compression (2→3) - Heat is expelled into the sink (e.g. outside air) isothermally ($T_2 = T_3$). The amount of heat ejected per unit mass of gas is $Q_C = T_2(S_2 - S_3)$.

Isentropic expansion (3→4) - The gas is isentropically expanded. The pressure and temperature decrease to P_4, T_4. Heat transfer at this stage is zero.

Isothermal expansion (4→1) - The gas expands isothermally ($T_4 = T_1$), extracting heat from the source (e.g. room). This is where the cooling takes place. The heat extracted from the source per unit mass of gas is $Q_H = T_1(S_1 - S_4) = T_1(S_2 - S_3)$



Fig(1) p-v diagram



Fig(2) T-s diagram

Air Conditioning

The science of air conditioning, deals with supplying and maintaining a desired internal atmospheric condition irrespective of external Conditions. Air conditioning is the process of controlling and maintaining the internal atmosphere in a confined space. It involves the control of temperature, humidity, motion of air and purity of atmosphere in the space of interest.

This involves the simultaneous control of air purity, air motion, temperature and humidity of the air inside an enclosed space.

- Air temperature is controlled by cooling or heating the air.
- Humidity is controlled by adding or removing water vapour to or from the air.
- Air motion is controlled by appropriate air distribution equipment
- Air purity is controlled by filtering and removing undesirable contaminants from the air.

Air conditioning applications are two types: comfort and industrial. Any air conditioning application having the primary intention of human health and comfort is called comfort air conditioning. Any air conditioning which is not primarily meant for human comfort is industrial air conditioning. Basically, the equipment and process involved in both types of air conditioning is the same.

PSYCHROMETRY

The properties, of moist air are called psychrometric properties and the subject which deals with the behaviour of moist air is known as psychrometry. Several special terms used in the study of psychrometry are defined below:

1. **Dry air:** Dry air is a mixture of oxygen, nitrogen, carbon - dioxide, hydrogen, argon, neon, helium etc with oxygen and nitrogen as its major constituents. The volumetric composition of air is 79 % nitrogen and 21 % oxygen.

2. Moist air: It is ordinary atmospheric air which is a mixture of dry air and water vapour.

3. Saturated air: It is the air which contains maximum amount of water vapour which the air can hold at a given temperature and pressure. The maximum quantity of water vapour that can be present in the air depends up on the temperature and pressure of air.

4. Specific or absolute humidity or humidity ratio: It is defined as the ratio of the mass of water vapour to the mass of dry air in a given volume of moist air. It is generally expressed as grams of water per kg of dry air.

5. Relative humidity: It is the ratio of mass of water vapour in a given volume of moist air at a given temperature to the mass of water vapour contained in the same volume of moist air at the same temperature when the air is saturated.

6. Dry bulb temperature: It is the temperature of air measured by an ordinary thermometer.

7. Wet bulb temperature: It is the temperature recorded by a thermometer, when its bulb is covered by a wet cloth and is exposed to a current of moving air.

The difference between the dry bulb temperature and wet bulb temperature is known as wet bulb depression If relative humidity is high, the rate of evaporation from the wet cloth is low and hence wet bulb depression will be low. When air is dry saturated the DBT and WBT are the same.

8. Dew point temperature: It is the temperature at which the condensation of moisture begins when the air is cooled at constant pressure. The difference between dry bulb temperature and dew point temperature is known as dew point depression.

9. Sensible heat of air: It is the heat that changes the temperature of a substance when added to or abstracted from it.

10. Latent Heat: It is the heat that does not affect the temperature but changes the state of substance when added to or abstracted from it.

Psychrometric chart

A psychrometric chart is the graphical representation of the various thermodynamic properties of moist air. The chart enables the properties of moist air to be read off directly.

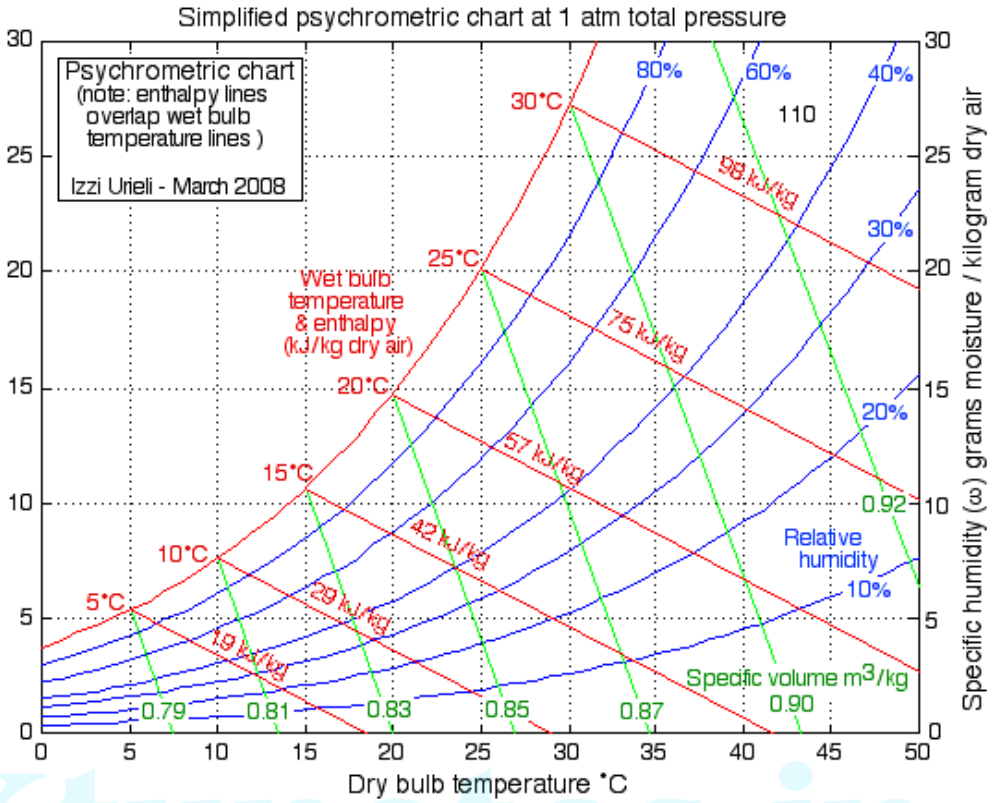


Fig. shows a typical psychrometric chart. The vertical scale of the chart is the specific humidity and the horizontal scale is the dry bulb temperature. In addition, it contains the following lines, Dry bulb temperature lines, Specific humidity lines, Wet bulb temperature lines, Relative humidity lines etc.

The various basic process involved in air conditioning are:

1. Sensible Heating(C): Increase the dry bulb temperature of air without change in its specific humidity(moisture content), using heating coil.

2. Sensible Cooling(G): Decreases dry bulb temperature of air without change in its specific humidity(moisture content), using cooling coil.

3. Humidification(A): Increase the specific humidity without change in dry bulb temperature, using humidifier.

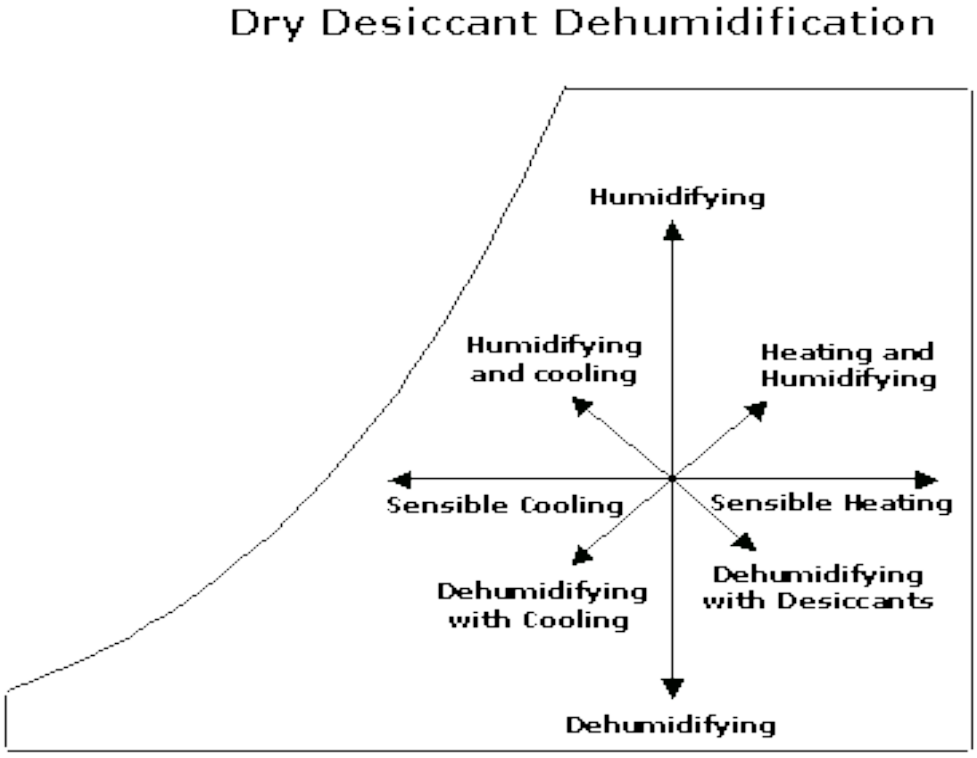
4. Dehumidification(E): Decreases the specific humidity without change in dry bulb temperature, using dehumidifier.

5. Heating with Humidification(B): Increases both dry bulb temperature and specific humidity of air, using high temperature steam.

6. Heating with Dehumidification(D): Increases the dry bulb temperature and decreases the specific humidity of air, using silica gel or alumina.

7. Cooling with Humidification(H): Decreases the dry bulb temperature and increases the specific humidity of air, using cold water.

8. Cooling with Dehumidification (F): Decreases both dry bulb temperature and specific humidity of air, using cooling coil with very low temperature



Air conditioning system

Factors affecting comfort air conditioning

1. Temperature of the air – A human feels comfortable when the air is at 220C – 260C. This is maintained by cooling or heating process.
2. Humidity of the air - Increasing or decreasing the humidity during winter and summer A/C system respectively. Relative humidity should not be less than 60% during summer air conditioning system whereas in winter air conditioning not less than 40 %.
3. Purity of air - People do not feel comfortable if the air is contaminated.
4. Motion of air - Equi-distribution of air throughout the room

Comfort air-conditioning

The comfort air conditioning intends to provide a comfortable environment for human beings round the year. Human beings are comfortable in wide range of relative humidity varying from 30 to 70%. The temperature range for human comfort is 22^0 C to 26^0 C.

Classification of air conditioning system

1. According to purpose

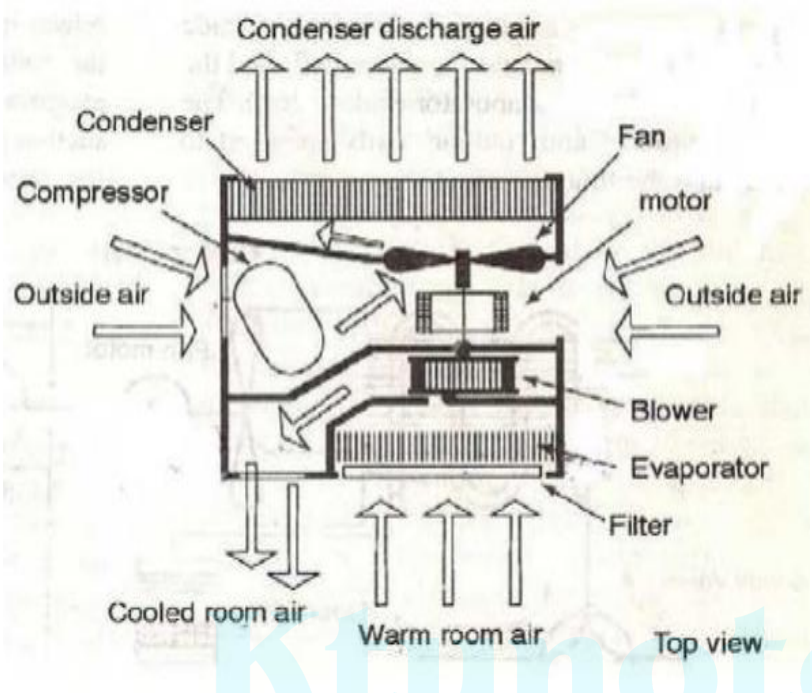
a. Comfort air conditioning
b. Industrial air conditioning

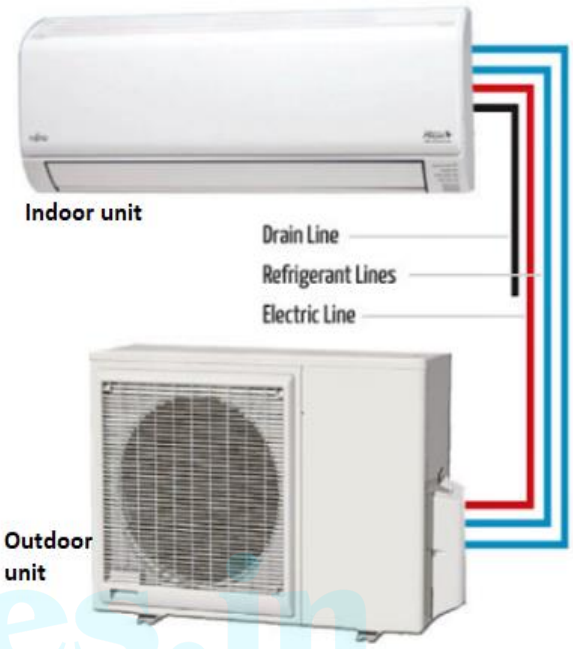
2. According to the arrangements of equipment's

a. Unitary air conditioning system
   Split air conditioning
b. Central air condition system

Unitary systems. (Unit air conditioners)

Window air conditioner is a type of unit air conditioner**.** Window Air-Conditioner is also called as room air conditioner, which is installed on the window of a room or wall opening. It works on principle of vapour compression refrigeration system. The refrigerant used is Freon-12(R -12) or Freon 22(R-22). A package unit is a self-contained unit because the complete unit including evaporator and condensing unit is all incorporated in a common enclosure. The normal capacity of such a unit is 1 and 1.5 TR. There are window mounting models which are normally capable of cooling, heating, cleaning and circulating the air.





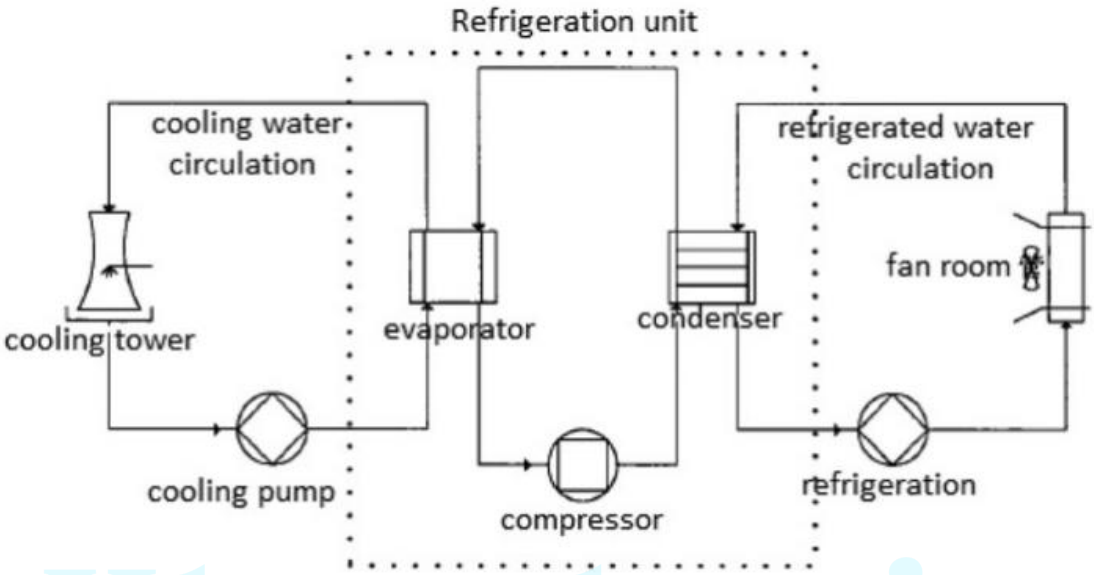
Working: Low pressure vapour refrigerant from the evaporator is sucked by compressor and is compressed to a high pressure & is delivered to the condenser. In the condenser, the refrigerant vapour is condensed to liquid by releasing latent heat of condensation to the surrounding air. Hot air formed is driven out using a fan. High pressure liquid refrigerant enters the capillary tube where the pressure is reduced. This low pressure liquid-vapour refrigerant enters the evaporator. Liquid refrigerant evaporates by absorbing latent heat of vaporization from the surrounding air. This cold air is delivered to the room using a fan. Direction of air flow can be changed using a damper. Low pressure vapour refrigerant is again sucked by compressor. Thus one cycle of operation is completed.

Advantages of unitary system

- There is saving in the installation and assembly labour charges.
- Zoning and duct work eliminated.
- In unitary system exact requirement of each separate room is met whereas in central system the individual needs of separate rooms cannot the met.
- Failure of the unit puts off conditioning in only one room whereas the failure of the central plant off-sets all the rooms to be served.
- Only those rooms which need cooling will have their units running, whereas the central plant will have to run all the time for the sake of only a few rooms.
- The specific feature of a unitary system is that there in individual room-temperature control

Central Air conditioning system

Central air conditioning systems are suitable for air conditioning large space such as big factory spaces, theatres, cinemas, exhibition halls, restaurants etc. where no sub division exists. The central systems are generally employed for the loads above 25T. In this system, equipments such as fans, coils, filters and their encasement are designed for assembly in the field. A central system serves different rooms, requires individual control of each room. The condenser, compressor, dampers, heating, cooling and humidifying coils and fan are located at one place. The conditioned air is carried to different rooms by means of supply ducts and returned back to the control plant through return ducts.



Working: Outdoor air enters from a intake and the air after passing through damper passes through filters. Filters may be of a mechanical cleaned type, replaceable cell type or may be electrostatic. The cleaned air then passes to the conditioning equipment in the following order: Tempering (Preheater) coil, Cooling coil, Humidifier (Air washer), Heating coil and finally fan. Tempering coil is used to preheat the cleaned air. Cooling and dehumidification is achieved by using cooling with chilled water. Air washer controls the humidity in the air. Eliminator is used to remove water droplets from the air and final reheating coil is used to heat the air to the required temperature.

Advantages of central system

- Low investment cost as compared to total cost of separate unit.
- Better accessibility for maintenance.
- The running cost is less per unit of refrigeration.
- Noise and vibration troubles are less to the people in air conditioned places as the air conditioning plant is far away from the air-conditioned places.