## Q. What is enthalpy? [BPUT 2nd SEM 2018-19]

**ENTHALPY**

The enthalpy of a substance, h, is defined as

$$h=u+pv \quad \text{(i)}$$

It is an intensive property of a system (kJ/kg).

For a constant pressure process, the heat transfer is given as

$$dQ=du+pdv$$

At constant pressure

$$Pdv+d(pv)$$

$$(dQ)_p=du+d(pv)$$

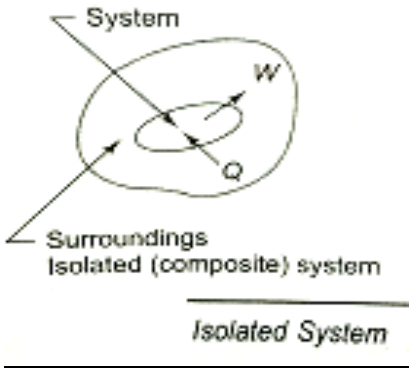
Or $$(dQ)_p=d(u+pv)$$

Or $$(dQ)_p=dh \quad \text{(ii)}$$

Where h=u+pv is the specific enthalpy , a property of the system. Heat transferred at constant pressure increases the enthalpy of a system.

## Q. Show that the entropy of universe is increasing. [BPUT 2nd SEM 2018-19]

**ENTROPY PRINCIPLE**




For any infinitesimal process undergone by a system, we have for the total mass,

$$dS \geq \frac{dQ}{T}$$

For an isolated system which does not undergo any energy interaction with the surroundings dQ=0.

Therefore, for an isolated system

$$dS_{iso} \geq 0$$

For a reversible process.

$$dS_{iso} = 0$$

Or S=constant

For an irreversible process

$$dS_{iso} > 0$$

It is thus proved that the entropy of an isolated system can never decrease. It always increases and remains constant only when the process is reversible.

This is known as the principle of increase of entropy, or simply the entropy principle. It is the quantitative general statement of second law from the macroscopic view point.

An isolated system can always be formed by including any system and its surroundings within a single boundary. Sometimes the original system which is then only a part of the isolated system is called a 'subsystem'.

The system and the surroundings together( the universe or the isolated system) include everything which is affected by the process.

For all possible processes that a system in the given surroundings can undergo

$$dS_{univ} \geq 0$$

Or $$dS_{sys} + dS_{surr} \geq 0$$

Entropy may decrease locally at some region within the isolated system, but it must be compensated by a greater increase of entropy somewhere within the system so that the net effect of an irreversible process is an entropy increase of the whole system.

The entropy increase of an isolated system is a measure of the extent of irreversibility of the process undergone by the system.

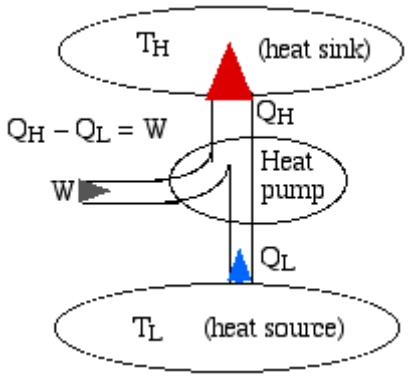
## Q. What is heat pump? Relate COP of heat pump to COP of refrigerator.

**[BPUT 2nd SEM 2018-19]**

## Heat Pumps

• A device that transfers heat from a low-temperature medium to a high-temperature one is the heat pump

• The objective of a heat pump, however, is to maintain a heated space at a high temperature. This is accomplished by absorbing heat from a low-temperature source, such as well water or cold outside air in winter, and supplying this heat to the high-temperature medium such as a house



**Relationship between Coefficient of Performance of a Refrigerator ($COP_R$) and a Heat Pump ($COP_{HP}$).**

$$COP_{HP} = \frac{Q_H}{W_{net,in}} = \frac{Q_H}{Q_H - Q_L} = \frac{W_{net,in} + Q_L}{Q_H - Q_L}$$

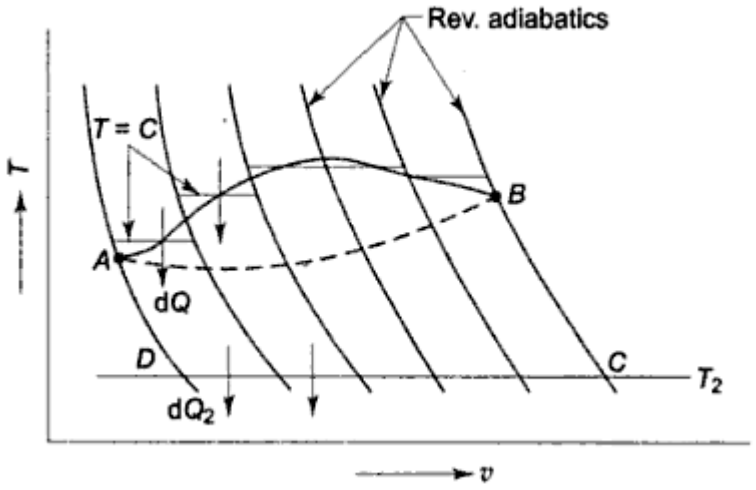
$$COP_{HP} = \frac{W_{net,in}}{Q_H - Q_L} + \frac{Q_L}{Q_H - Q_L} = 1 + COP_R$$

$$\boxed{COP_{HP} = 1 + COP_R}$$

26

**Q. State Clausius law of inequality.** **[BPUT 2nd SEM 2018-19]**

**THE INEQUALITY OF CLAUSIUS**




- Let us consider a cycle ABCD as shown in the figure. Let AB be a general process, either reversible or irreversible, while the other processes in the cycle are reversible.
- Let the cycle be divided into a number of elementary cycles, as shown. For one of these elementary cycles

$$\eta = 1 - \frac{dQ_2}{dQ}$$

Where dQ is the heat supplied at T , and $dQ_2$ the heat rejected at $T_2$.

- Now, the efficiency of a general cycle will be equal to or less than the efficiency of a reversible cycle.

Hence, $$1 - \frac{dQ_2}{dQ} \le \left(1 - \frac{dQ_2}{dQ}\right)_{rev}$$

Or $$\frac{dQ_2}{dQ} \ge \left(\frac{dQ_2}{dQ}\right)_{rev}$$

Or $$\frac{dQ}{dQ_2} \le \left(\frac{dQ}{dQ_2}\right)_{rev}$$

Since $$\left(\frac{dQ}{dQ_2}\right)_{rev} = \frac{T}{T_2}$$

Hence $$\frac{dQ}{dQ_2} \le \frac{T}{T_2}$$

Or $$\frac{dQ}{T} \le \frac{dQ_2}{T_2}$$ , for any process AB , reversible or irreversible.

- For a reversible process

$$ds = \frac{dQ_{rev}}{T} = \frac{dQ_2}{T_2}$$

Hence, for any process AB

$$\frac{dQ}{T} \le ds$$

Then for any cycle

$$\oint \frac{dQ}{T} \leq \oint ds$$

Since entropy is a property and the cyclic integral of any property is zero

$$\oint \frac{dQ}{T} \leq 0$$

This equation is known as the inequality of Clausius. It provides the criterion of the reversibility of a cycle.

- If $\oint \frac{dQ}{T} = 0$, the cycle is reversible

  $\oint \frac{dQ}{T} < 0$, the cycle is irreversible and possible

  $\oint \frac{dQ}{T} > 0$, the cycle is impossible, since it violates the second law

## Q. Name the components of steam power plant with their function.

**[BPUT 2nd SEM 2018-19]**

**STEAM POWER PLANT**

The function of a steam power plant is to convert the chemical energy in fossil fuel(coal , oil ,gas etc) into mechanical or electrical energy through the expansion of steam from a high pressure to low pressure in a suitable prime mover.

**Components Details**

**(i) Steam generator( Boiler) with their accessories**

A steam generator or boiler is usually, a closed vessel made of steel. Its function is to transfer the heat produced by the combustion of fuel to water , and ultimately to generate steam.

**Accessories**

**(a) Superheater-** The superheater is situated at the hottest part of the boiler. It is meant to raise the steam temperature above the saturation temperature (superheated steam) by absorbing heat from the flue gases.

**(b)** **Economiser**- The function of an economizer in a boiler is to absorb heat from the outgoing flue gases ( waste gases from the chimney) , to raise the temperature of the feed water coming from the condenser, before it enters the evaporative section.

**(c)** **Air Preheater**- The function of the air preheater in a boiler is to raise the temperature of air with the help of outgoing flue gases, before the air is led to the furnace for the combustion of fuel.

**(ii) Steam Turbine**

The function of a turbine is to convert the heat energy in the steam into rotational power of the shaft on which the turbine is mounted.

(iii) **Generator**

The generator which is directly coupled to the turbine shaft , converts mechanical energy of the turbine shaft into electrical energy.

(iv) **Condenser**

The function of the condenser is to condense the steam which has been discharged from low pressure turbine. The condenser is a large vessel containing a large number of brass tubes through which the cold water is circulated continuously for condensing the steam flowing outside the surface of the tubes. The hot condensate flows back to the boiler to be converted into steam.

(v) **Feed Pump**

A boiler feed pump is like a heart to the steam power plant. Its aim is to supply feed water ( coming from condenser) to the boiler at a high pressure than atmospheric pressure.

**(vi) Chimney**

The flue gases from the boiler, after removal of the fly ash in the precipitators, are let off to atmosphere through the chimney.

## Q. Classify the air compressors. [BPUT 1st SEM 2018-19]

**AIR COMPRESSORS**

Air compressors are used to compress the air and to raise its pressure. It sucks the air to the cylinder from atmosphere, compresses it and then delivers the same under a high pressure.

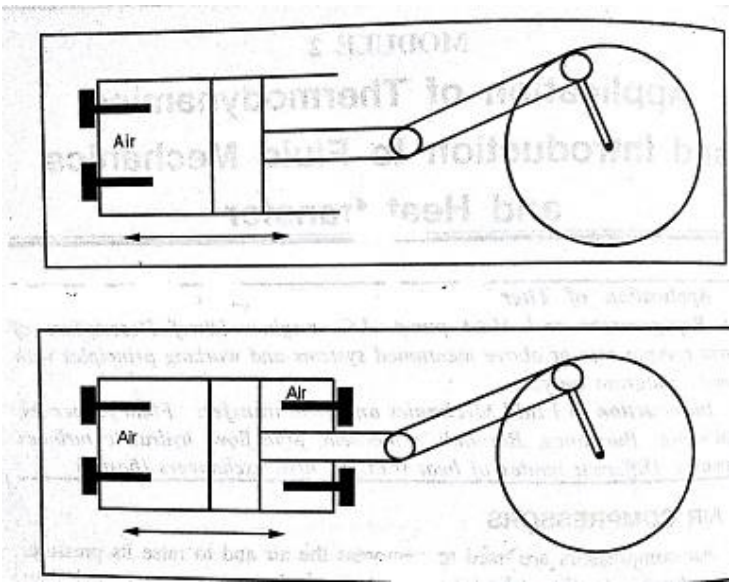
**RECIPROCATING AIR COMPRESSORS**

1. **Single acting air compressor**

In single acting air compressor, only one side of the piston is used to suck the air. Here both the suction and the compression takes place on the one side of the cylinder.

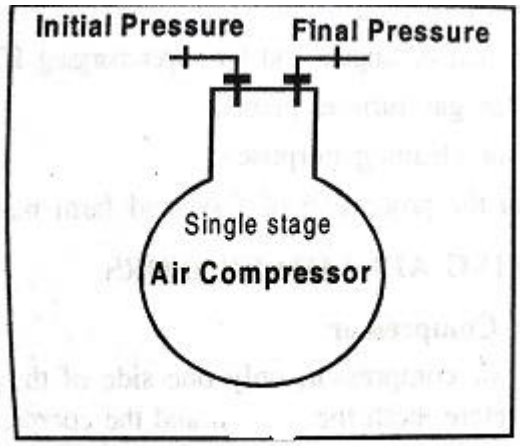
2. **Double acting air compressor**

In this compressor, both sides of the piston are used to suck the air. When suction is occurs in one side, compression and delivery will be taken on the other side. So simultaneously, two cycles will be completed in one revolution of the crank.



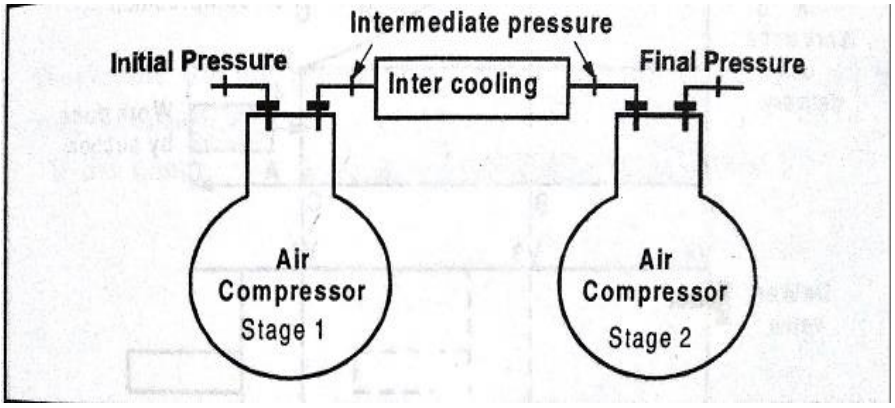

3. **Single stage compressor**

The compression of air from initial pressure to final pressure is carried out in one cylinder.




4. **Multi stage compressor**

The compression of initial pressure to final pressure is carried out in more than one cylinder.




**ROTARY COMPRESSORS**

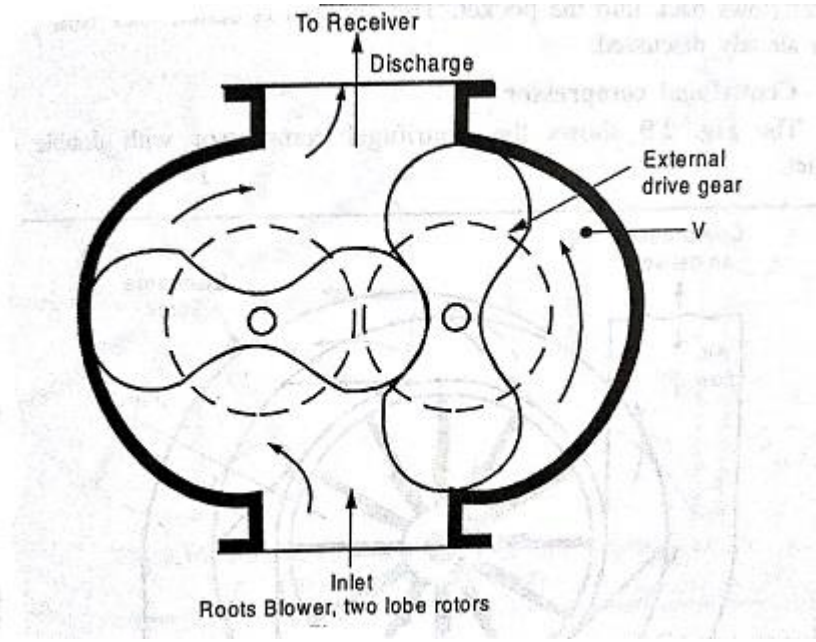
Rotary compressors are used to compress large quantity of air at a relatively low pressure . In rotary air compressor , the air is trapped in between two sets of engaging surfaces (lobes) and the pressure of air is increased by squeezing action or back flow of air.

**Different types of rotary compressors**

1. Roots blower compressor

2. Vane type blower compressor
3. Centrifugal compressor
4. Axial flow compressor

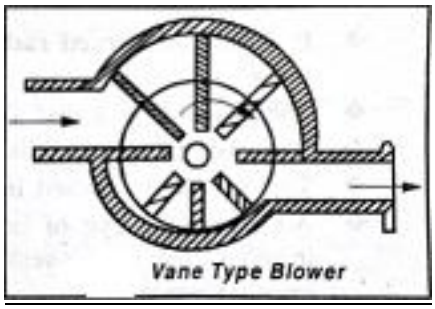
**Roots Blower**



Roots Blower, two lobe rotors

Roots blower compressor consists of two rotors with lobes . These lobes are rotating in air tight casing. It has inlet and outlet port. The shape of the lobes is epicycloid or hypocycloid or involute. During the rotation , volume of air at atmospheric pressure is trapped between left hand lobe and casing. The further rotary motion of the lobes delivers the entrapped air into the receiver. So more and more flow of air into the receiver increases its pressure.

**Vane type Blower Compressor**

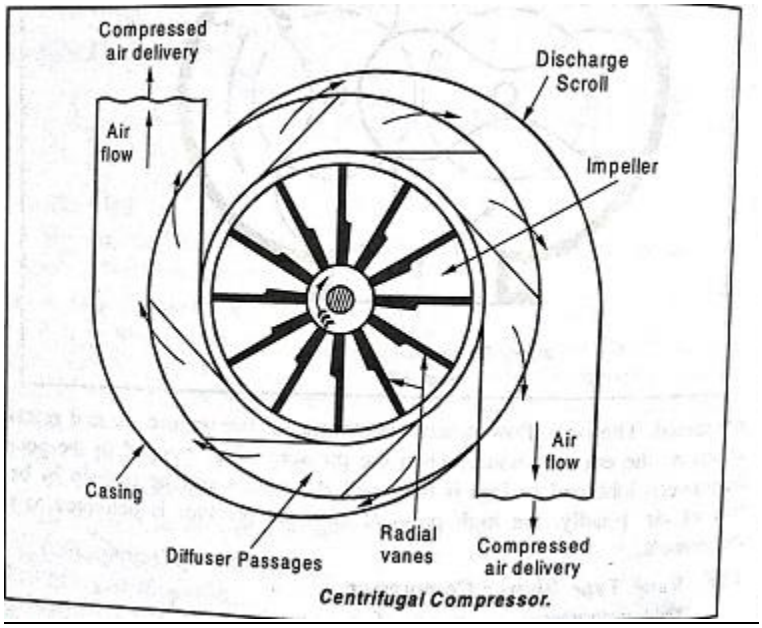



This compressor comprises of a disk rotating eccentrically in an air tight casing. It has inlet and outlet port. The disc has many number of vanes. When the rotor rotates , the air is trapped in the pockets formed between the vanes and casing.

The compression is occurred due to decreasing volume and back flow of air.

First of all , the rotary motion of the vanes compresses the air. Next when the rotating vane uncovers the exit port, the high pressure air from receiver flows back into the pocket. This process is called back flow process .

**Centrifugal compressor**

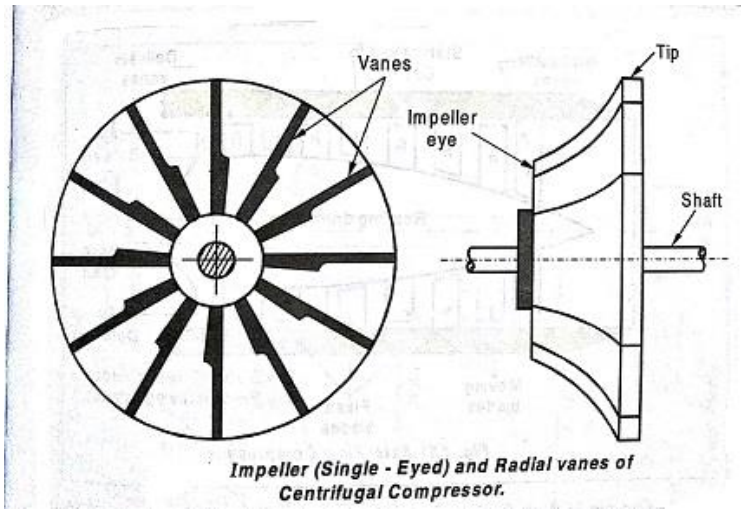


It consists of curved radial vanes which are attached to the shaft and rotate. The impeller is a disc fitted with radial vanes. The casing is surrounding the rotating impeller. The diffuser is housed in a radial portion of the housing.

Air enters the eye of impeller . Due to the centrifugal action of impeller, the air moves radially outwards with the guidance of impeller vanes. The impeller transfers energy to air by increasing its pressure rise.

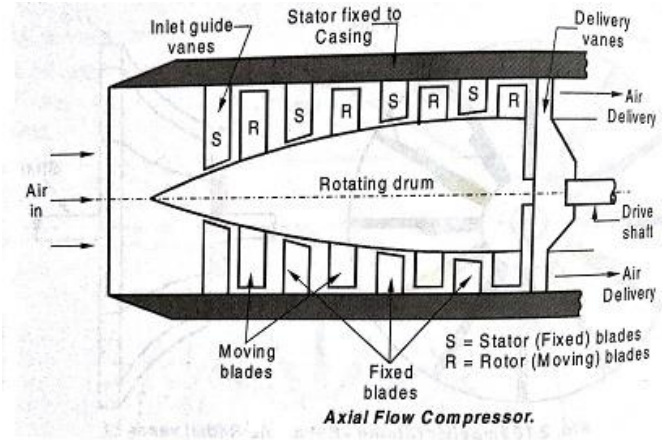
Then the air enters diverging portion called diffuser. Here , the kinetic energy is converted into pressure rise further. Nearly half the pressure rise is achieved by impeller and remaining by diffuser.

A pressure ratio of 5:1 is obtained by single stage centrifugal compressor and for higher pressure ratio multi stage compressors are used.




*Impeller (Single - Eyed) and Radial vanes of Centrifugal Compressor.*

**Axial Flow Compressor**




*Axial Flow Compressor.*

In this axial flow compressor , air is flowing parallel to the axis of compressor. It consists of stators( fixed blades) and rotars ( rotating blades) in an alternate rows

The rotars are fixed with rotating drum and stators are fixed to the casing. One stage of compressor means one row of stator blades with one row of rotar blades.

The work energy of moving blades is transferred to air to accelerate. The blades are so arranged that the space between the blades forms diffuser passage and hence air pressure is increased at the expense of velocity.

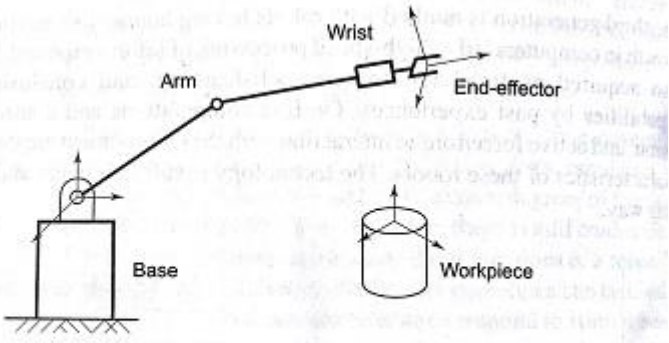
The air is then further flows through stator blades and gets diffused and its pressure is further increased. After air gets pressure rise in one stage , it will be allowed to pass second stage and pressure is continuously raised.

The annular area is normally reduced from inlet to outlet of the compressor to keep the flow velocity constant.

The stator blades serve to convert a part of kinetic energy in to pressure energy and to guide air from one stage to next stage without shock.

## Q. Specify robot anatomy. [BPUT 1st SEM 2018-19]

**ROBOT ANATOMY**




*The base, arm, wrist, and end-effector forming the mechanical structure of a manipulator*

1. **Base-** The base may be fixed or mobile.

2. **Manipulator arm-** Mechanical unit, arm that does the actual work of a robot , it consists of mechanical linkage and joint with actuators to drive the mechanism directly or indirectly through gears, chains or ball screw.

3. **Feedback devices-** Transducer that sense the position of various linkages and joints and transmit those informatios to the controller in either digital or analog form.

4. **End effectors-** Robot end-effector is the gripper or end of arm tooling mounted on the wrist of the robot manipulator arm. A robot performs a variety of tasks for which various tooling and special grippers are required to be designed.

   The wide range of gripping methods include:

(i) Mechanical clamping,

(ii) Magnetic gripping,

(iii) Vacuum (suction) gripping.

5. **Controller-**The brain of system that directs the movement of manipulator. In higher level robots, computers are used as controllers. The function of controller is to initiate and terminate the position , store data for position and motion sequence.

6. **Power supply-** Drives are electric, hydraulic and pneumatic end effectors used to provide and regulate energy needed for their manipulator and actuators.

7. **Job controller parts-**Interfaces in the outside world that may be in other machine or human being.

## Q. What is the use of clutch? [BPUT 1st SEM 2018-19]

A clutch is a device used to engage and disengage the driving shaft to the driver shaft according to the requirement. In case of automobiles, the clutch is required during changing of gears. By operating a lever, the clutch engages and disengages the driver and driven shafts. While changing gears, the driven shaft should be disengaged from the driving shaft.

**Working principle of friction clutch**

The principle of transmission of power is by contacting friction surfaces, to develop frictional force and this frictional force is used to start the driven shaft from rest and gradually increases the speed without slipping. In case of automobiles , the friction clutch is used to engage the engine shaft to the driven shaft.

## Q. Why couplings are used in machines? [BPUT 1st SEM 2018-19]

**COUPLINGS**

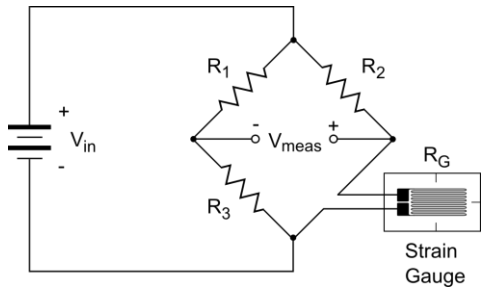
Couplings are used to connect sections of long transmission shafts. Couplings are also used to connect the driving shaft to the driven shaft.

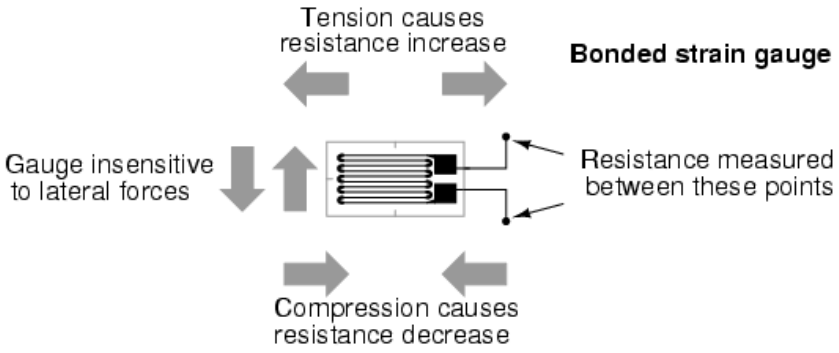
- Couplings are permanent connections.
- Couplings permit easy and quick engagement and disengagement of two shafts.

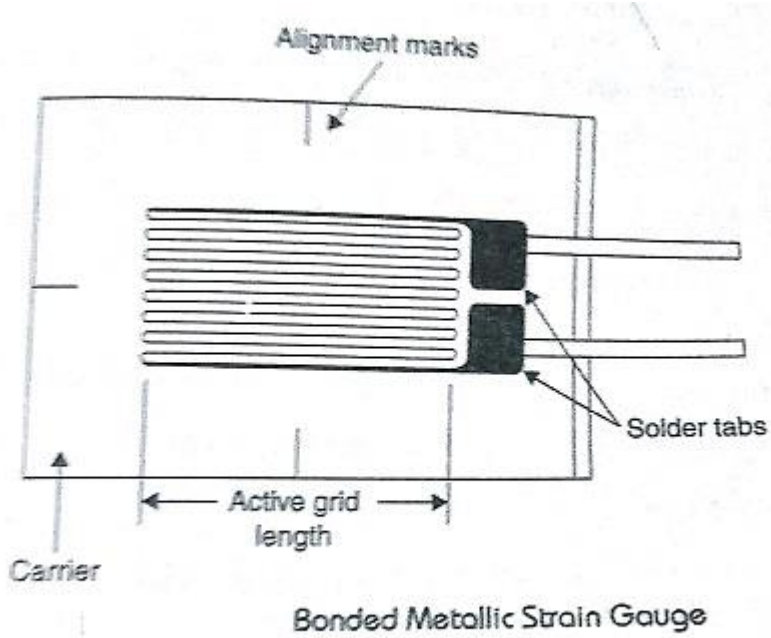
## Q. What is the principle of strain gauge? [BPUT 1st SEM 2017-18]

**STRAIN GAUGE**

- There are several methods of measuring strain; the most common is a strain gauge, a device whose electrical resistance varies in proportion to the amount of strain produced in the device.
- The most widely used gauge is the bonded metallic strain gauge. The metallic strain gauge consists of a very fine wire or more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction.






Bonded Metallic Strain Gauge

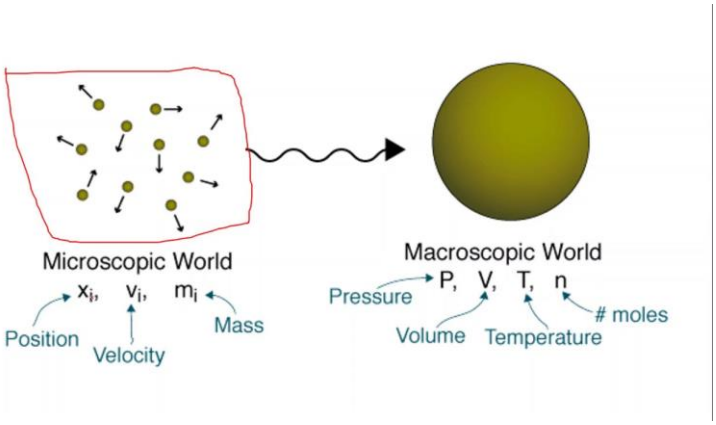
- The cross-sectional area of the grid is minimized to reduce the effect of shear strain and Poisson strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen.
- Therefore, the strain experienced by the test specimen is transferred directly to the strain gauge, which responds with a linear change in electrical resistance.

## Q. What is the difference between macroscopic and microscopic approach?

**[BPUT 2nd SEM 2017-18]**

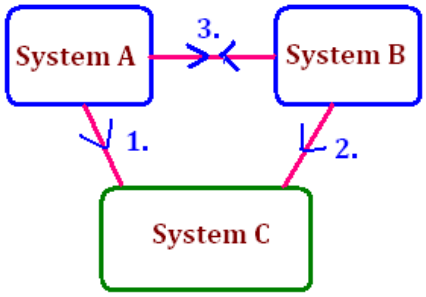
**MACROSCOPIC VERSUS MICROSCOPIC VIEW POINT**

- There are two points of view from which the behavior of matter can be studied: the macroscopic and the microscopic.
- In the macroscopic approach, a certain quantity of matter is considered, without the events occurring at the molecular level being taken into account. From the microscopic point of view , matter is composed of myriads of molecules .
- If it is a gas , each molecule at a given instant has a certain position, velocity and energy and for each molecule these change vary frequently as a result of collisions. The behavior of the gas is described by summing up the behavior of each molecule. Such a study is made in microscopic or statistical thermodynamics.
- Macroscopic thermodynamics is only concerned with the effects of the action of many molecules and these effects can be perceived by human senses.
- For example, the macroscopic quantity, pressure, is the average rate of change of momentum due to all the molecular collisions made on a unit area. The effect of pressure can be felt. The macroscopic point of view is not concerned with the action of individual molecules and the force on a given unit area can be measured by using a pressure gauge.
- These macroscopic observations are completely independent of the assumptions regarding the nature of matter.
- All the results of classical or macroscopic thermodynamics can, however, are derived from the microscopic and statistical study of matter.




## Q. Explain zeroth law of thermodynamics. [BPUT 2nd SEM 2017-18]

- If two systems (say A and B) are in thermal equilibrium with a third system (say C) separately (that is A and C are in thermal equilibrium; B and C are in thermal equilibrium) then they are in thermal equilibrium themselves (that is A and B will be in thermal equilibrium. This is known as Zeroth law of thermodynamics.




1. A & C are in thermal equilibrium
2. B & C are in thermal equilibrium

then

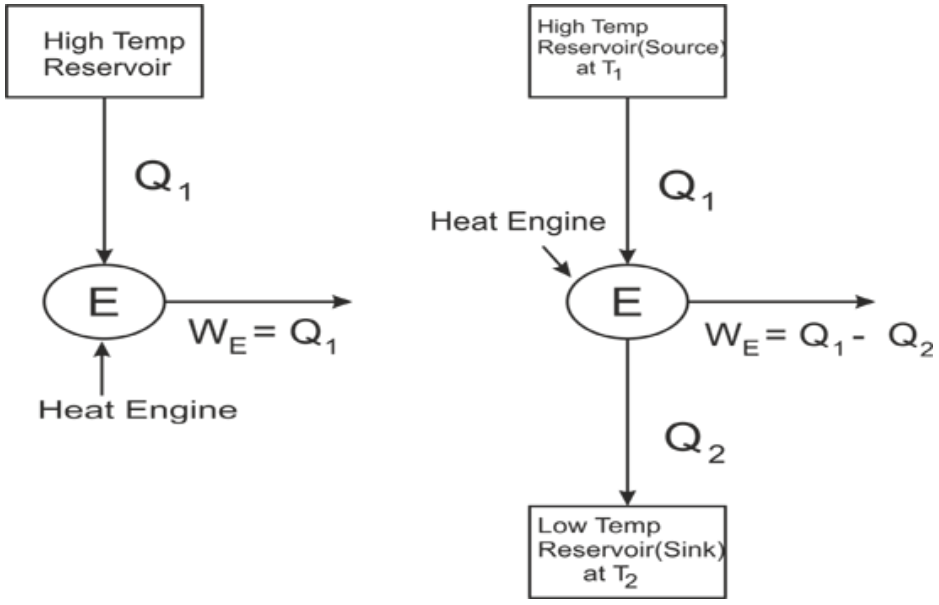
3. A & B are also in thermal equilibrium with each other

## Q. What is meant by PMM2 and why it is not possible? [BPUT 2nd SEM 2017-18]

- The efficiency of a heat engine is given by

$$\eta = \frac{W_{net}}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

- Experience shows that $W_{net} < Q_1$, since heat $Q_1$ transferred to a system cannot be completely converted to work in a cycle . Therefore ,η is less than unity.A heat engine can never be 100% efficient.
- Therefore, $Q_2 > 0$, i.e. there has always to be a heat rejection. To produce net work in a thermodynamic cycle, a heat engine has thus to exchange heat with two reservoirs, the source and the sink.
- The Kelvin-Planck statement of the second law states; it is impossible for a heat engine to produce net work in a complete cycle if it exchanges heat only with bodies at a single fixed temperature.
- If $Q_2 = 0$ , the heat engine will produce net work in a complete cycle by exchanging heat with only one reservoir, thus violating the Kelvin-Planck statement as shown in the figure below. Such a heat engine is called a perpetual motion machine of the second kind, A PMM2.
- A PMM2 is impossible, because it violates Kelvin-Planck statement of second law.



## Q. What is the difference between isentropic process and adiabatic process?

**[BPUT 2nd SEM 2017-18]**

- Adiabatic process is defined as a process in which there is no heat transfer.
- The infinitesimal change in entropy dS due to reversible heat transfer dQ at temperature T is

$$dS = \frac{dQ_{rev}}{T}$$

- If $dQ_{rev}=0$ , i.e., the process is reversible and adiabatic

$$dS=0$$

Or $$S=\text{constant}$$

A reversible adiabatic process is , therefore, an isentropic process.

## Q. What do you mean by gear train? [BPUT 2nd SEM 2017-18]

## Gear Trains

Gear trains are various types of combination of gears to transfer power from one shaft to another.

Gear trains can be classified as follows;

- Simple gear train
- Compound gear train
- Reverted gear train
- Planetary gear train
- Sun and planet gear

**Simple Gear Train**

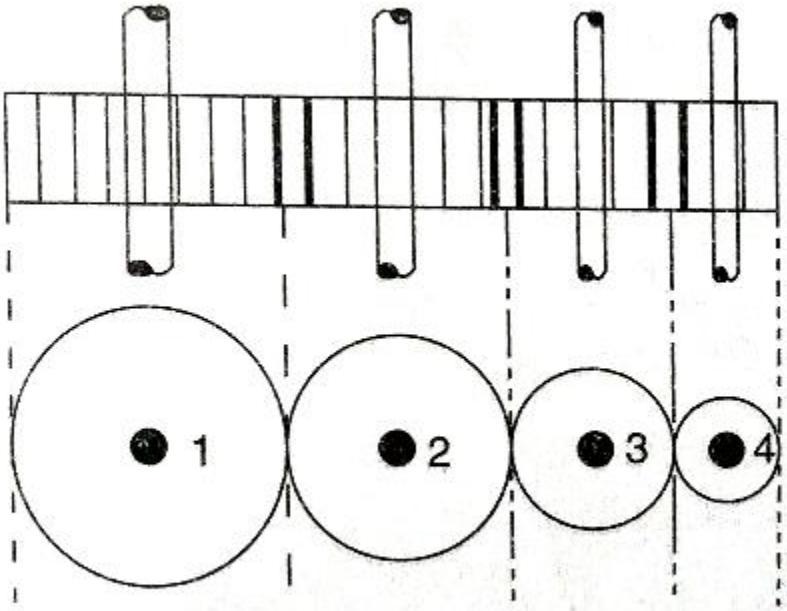



Figure Simple Gear Train

In this gear train , all the gears are mounted on their separate shafts and the gear axes remain fixed in a frame. All the paired gears are moved in opposite directions .

**Compound Gear Train**

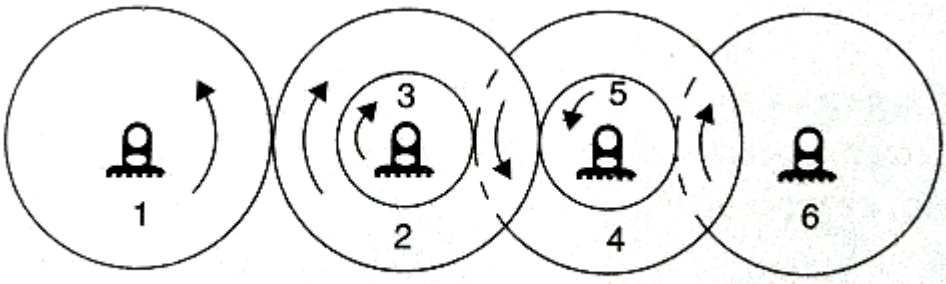



Figure Compound Gear Train

When two or more gears rotate about same axis and have same angular velocity, it is known as compound gear train.

**Reverted Gear Train**

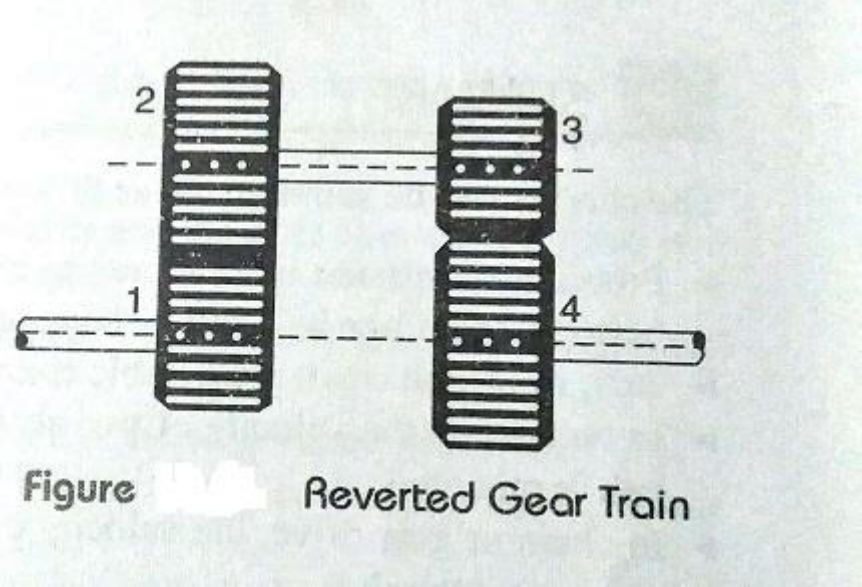



Figure Reverted Gear Train

If axes of the first and the last wheels of a compound gear coincide , it is called reverted gear train.

**Planetary or Epicyclic Gear Train**

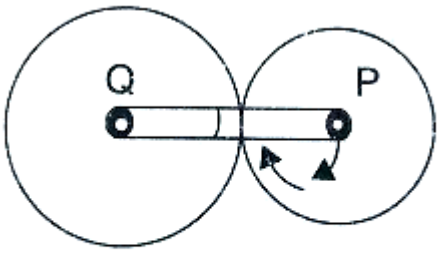



Figure Epicyclic Gear Train

If the axis of at least one gear in gear train moves relative to fixed axis or frame , such type of gear train is known as epicyclic gear train. In this gear train, one gear rotates over pitch circle of other gear as shown in the figure.

Consider two gear wheels P and Q , the axes of which are connected by an arm ‘a’ is fixed. The wheels P and Q constitute a simple gear train.

However, if the wheel Q is fixed so that the arm can rotate about the axes of Q , the wheel P would also move around Q. Thus, it is epicyclic gear train.

**Sun and Planet Gear**

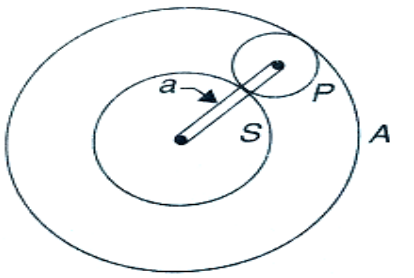



Figure Sun and Planet Gear

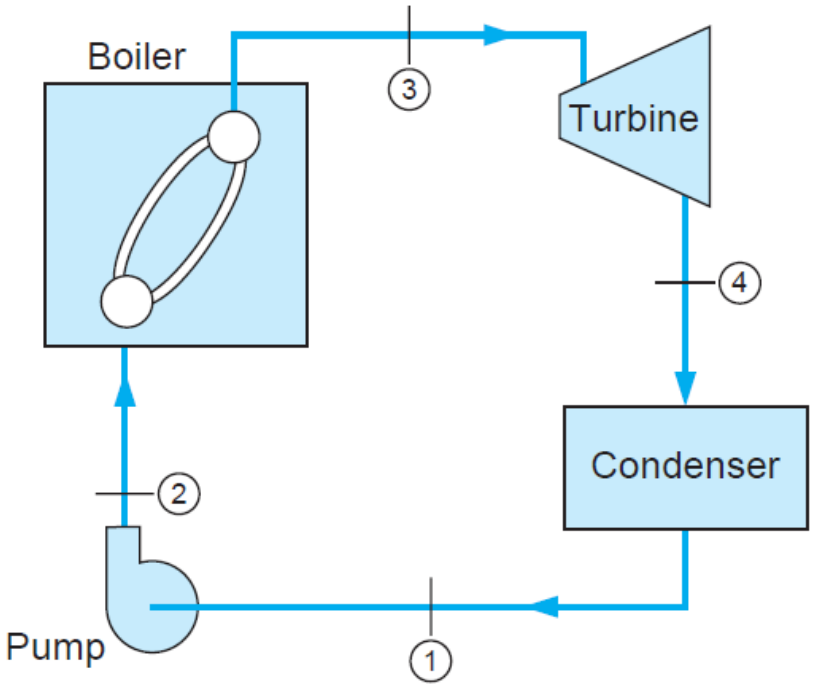
When an annular gear A is used in epicyclic gear train, it is known as sun and planet gear teain.The annular wheel meshes with wheel P and rotates as sun and planet gear as shown inth figure. The wheel S and P are , generally called the sun and the planet wheels , respectively due to similarity of motion of a planet around the sun.

## Q. Explain second law of thermodynamics. [BPUT 2nd SEM 2018-19]

**SECOND LAW OF THERMODYNAMICS**

**CYCLIC HEAT ENGINE**

- A heat engine cycle is a thermodynamic cycle in which there is a net heat transfer to the system and a net work transfer from the system. The system which executes a heat engine cycle is called a heat engine.




- In figure above heat $Q_1$ is transferred from the furnace to the water in the boiler to form steam which then works on the turbine rotor to produce work $W_T$ , then the steam is condensed to water in the condenser in which an amount of heat $Q_2$ is rejected from the system, and finally work $W_P$ is done on the system(water) to pump it to the boiler. The system repeats the cycle.
- The net heat transfer in a cycle

  $Q_{net}= Q_1-Q_2$

  The net work transfer in a cycle

  $W_{net}=W_T-W_P$
- By the first law of thermodynamics, we have

  $$\sum_{cycle} Q = \sum_{cycle} W$$

  Or $Q_{net}=W_{net}$

  Or $Q_1-Q_2= W_T-W_P$

- The function of a heat engine cycle is to produce work continuously at the expense of heat input to the system. So the net work $W_{net}$ and heat input $Q_1$ referred to the cycle are of primary interest.
- The efficiency of a heat engine or a heat engine cycle is defined as follows:

$$\eta = \frac{Networkoutputofthecycle}{Totalheatinputtothecycle}$$

$$= \frac{W_{net}}{Q_1}$$

Or $$\eta = \frac{W_{net}}{Q_1} = \frac{W_T - W_P}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

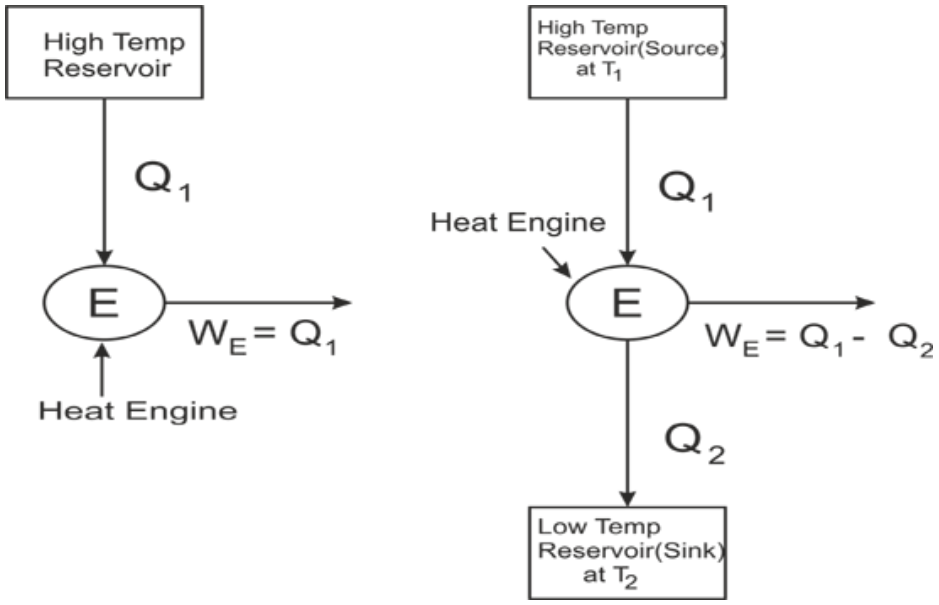
- This is also known as the thermal efficiency of a heat engine cycle.

**KELVIN-PLANCK STATEMENT OF SECOND LAW**

- The efficiency of a heat engine is given by

$$\eta = \frac{W_{net}}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

- Experience shows that $W_{net}<Q_1$, since heat $Q_1$ transferred to a system cannot be completely converted to work in a cycle . Therefore ,η is less than unity.A heat engine can never be 100% efficient.
- Therefore, $Q_2>0$, i.e. there has always to be a heat rejection. To produce net work in a thermodynamic cycle, a heat engine has thus to exchange heat with two reservoirs, the source and the sink.
- **The Kelvin-Planck statement of the second law states**; it is impossible for a heat engine to produce net work in a complete cycle if it exchanges heat only with bodies at a single fixed temperature.
- If $Q_2 =0$ , the heat engine will produce net work in a complete cycle by exchanging heat with only one reservoir, thus violating the Kelvin-Planck statement as shown in the figure below. Such a heat engine is called a perpetual motion machine of the second kind, A PMM2.
- A PMM2 is impossible.




**CLAUSIUS' STATEMENT OF THE SECOND LAW**

- Heat always flows from a body at a higher temperature to a body at a lower temperature. The reverse process never occurs spontaneously.
- **Clausius' statement of the second law** gives; It is impossible to construct a device which, operating in a cycle, will produce no effect other than the transfer of heat from a cooler to a hotter body.

## Q. Compare the belt drive with gear drive. [BPUT 2nd SEM 2018-19]

**Belt Drives**

A belt is a loop of flexible material used to link two or more rotating shafts mechanically, most often parallel. Belts are looped over pulleys and may have a twist between the pulleys and the shafts need not be parallel.

• Friction between the belt and the pulley is responsible for transmitting power from one pulley to other
• It's a friction drive

• 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

• Velocity of the belt

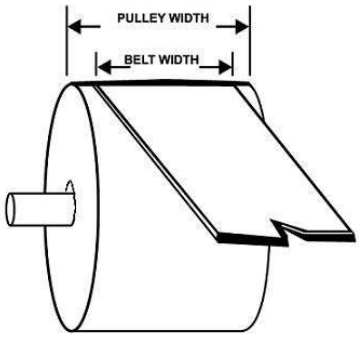
• The tension with which the belt is placed under the pulleys

• The arc of contact between the belt and the smaller pulley

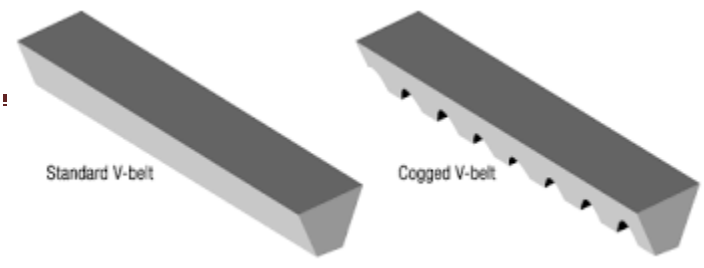
**Types of belts**

There are many types of belts. The general and important types of belts are

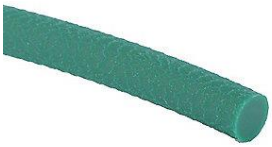
(1)Flat belt: These are mostly used in factories and workshops, where moderate amount of power is required to be transmitted and when the two pulleys are not more than 8 meters apart.



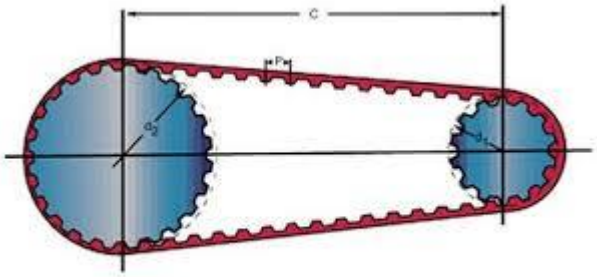

(2)V-belt: In V belts the V shaped cross-section prevents belt from slipping off. These pulleys are used when the two pulleys are very nearer to each other and greater amount of power is required to be transmitted.



(3)Round belt: Round belt are generally made of rubber. This type of belt is generally used for light loads, such as in sewing machine.

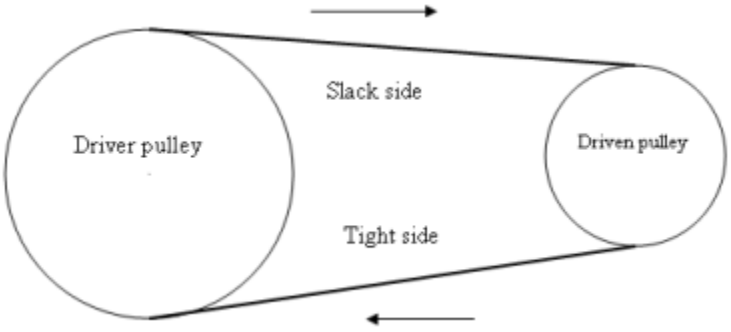


(4)Toothed belts: Toothed belts use their teeth for power transmission, as opposed to friction. This results in no slippage. It is more expensive to manufacture.



**Types of belt drives**

(i) Open belt drive: An open belt drive is used to rotate the driven pulley in the same direction of driving pulley.




• It is used to transmit power when the distance between the shafts is large

• Both shafts are in parallel

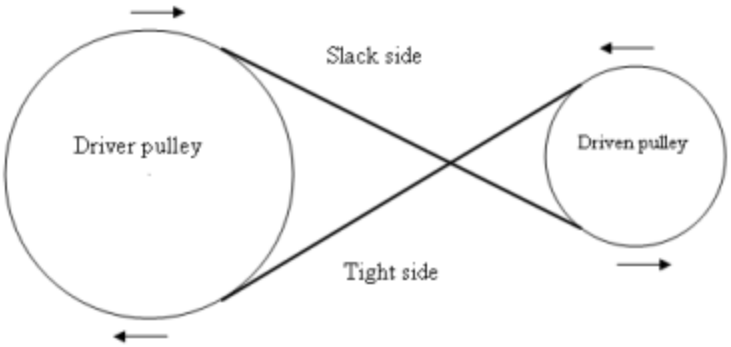
• Both shafts rotates in the same direction

• 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

• Lower side of the belt is called the tight side

(ii) Crossed belt drive: It is used to rotate driven pulley in the opposite direction of the driving pulley.

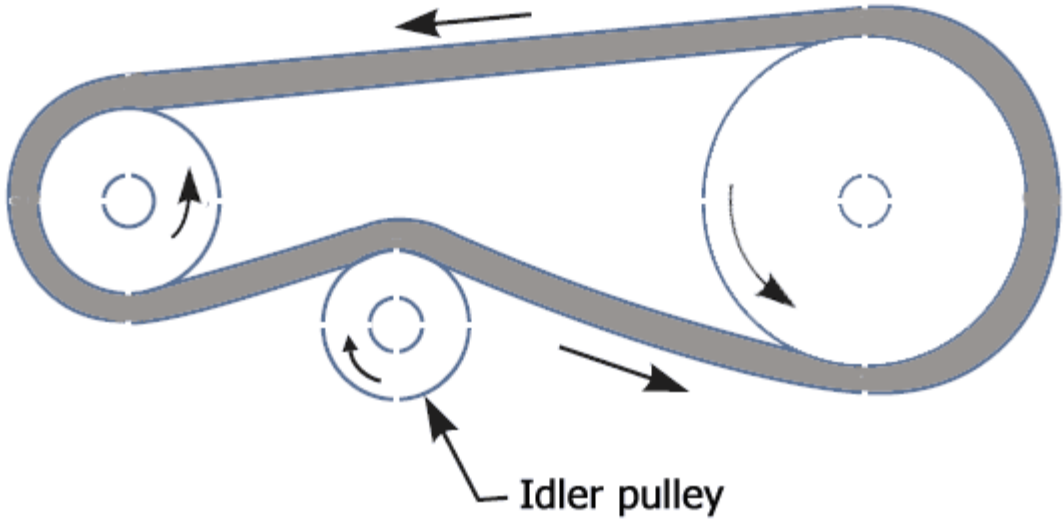



• Shafts are parallel and rotating in the opposite directions

• At the point where the belt crosses, it rubs against itself and wears

• The drive should operate at low velocity

(iii)Belt Drive With Idler Pulleys



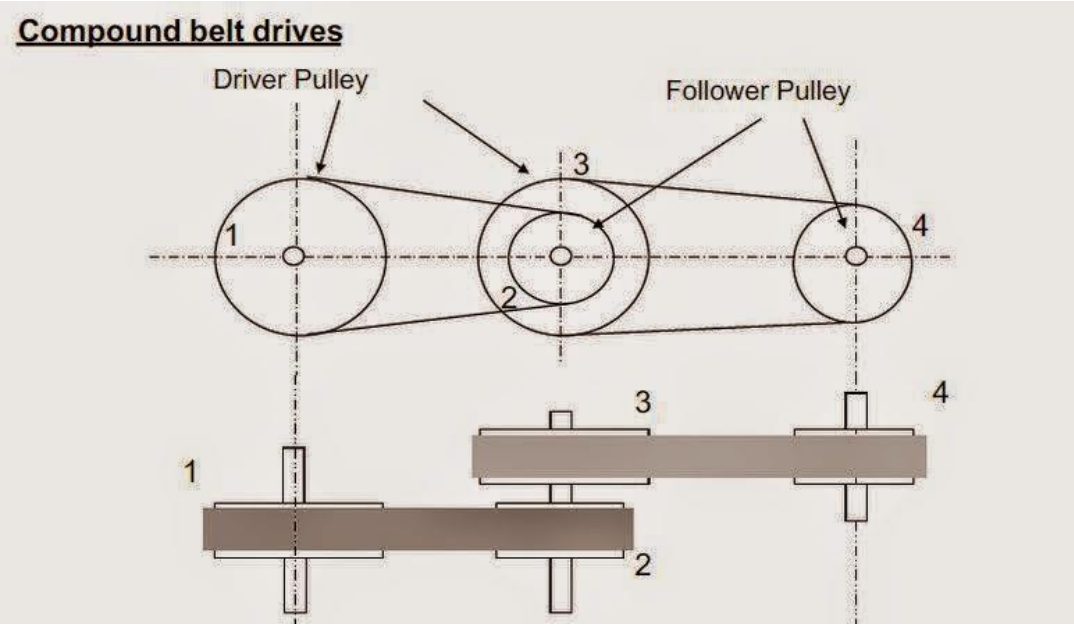

• Shafts arranged in parallel and rotating in same direction

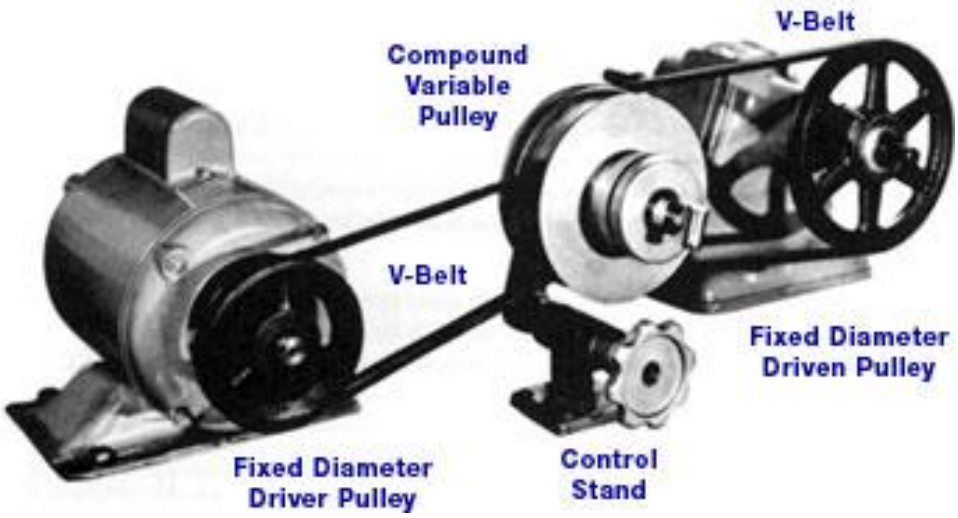
• This drive is provided to deliver high velocity

• Idler pulley increases the angle of contact between belt and shaft

(iv)Compound Belt Drive

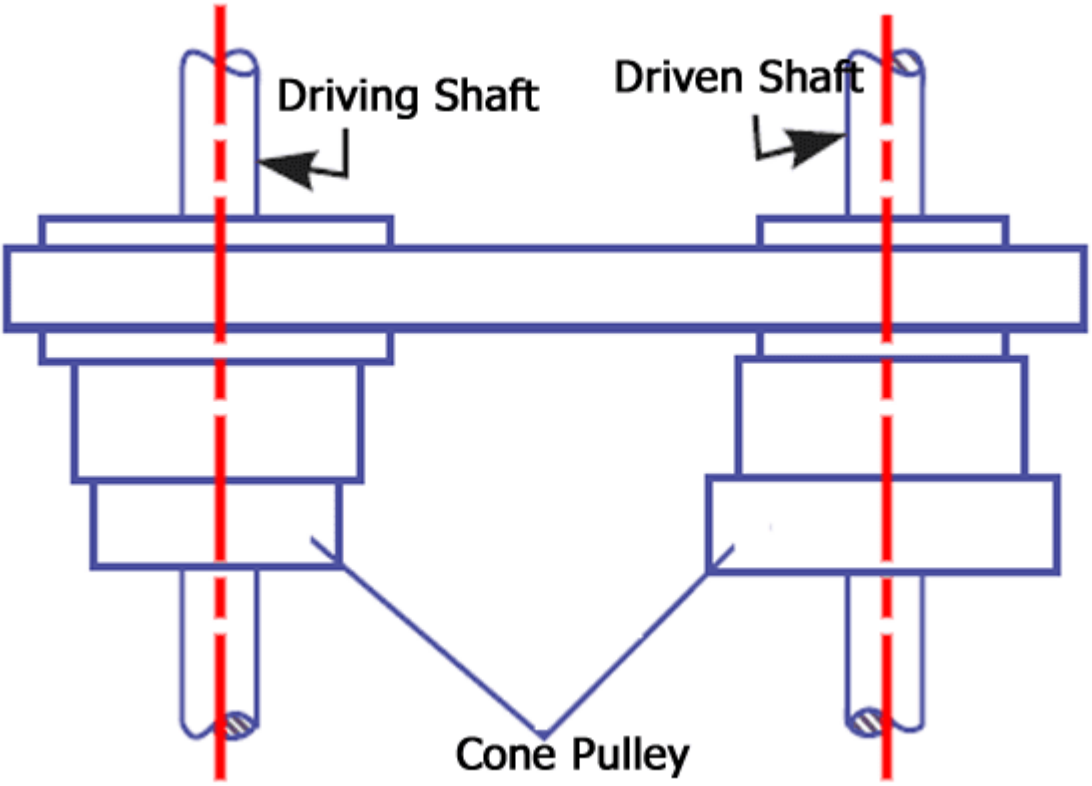
It is used when power is transmitted from one shaft to another through a number of pulleys

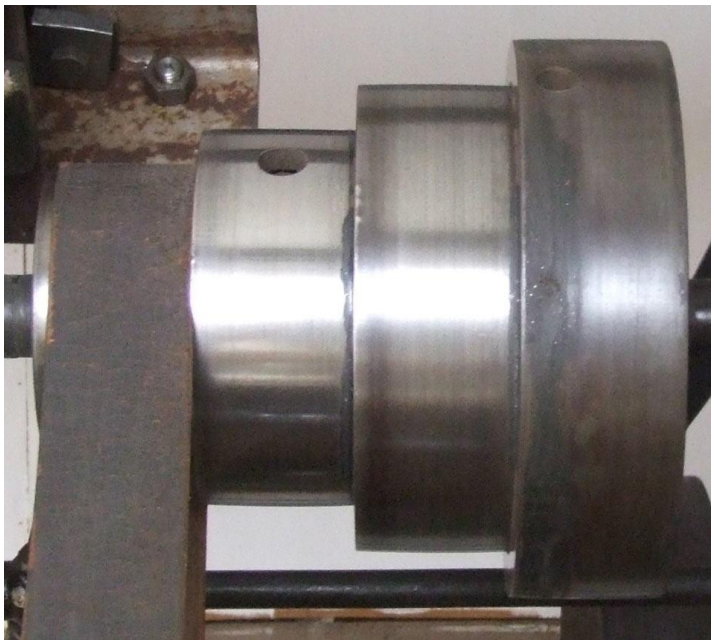



(v)Stepped or Cone Pulley Drive

- Used for changing the speed of driven shaft while the driving shaft is maintained at constant speed


Driving Shaft
Driven Shaft
Cone Pulley



## GEAR DRIVE

• A gear is a toothed wheel

• One gear is mounted on the driving shaft and another one on the driven shaft, their teeth meshing with each other

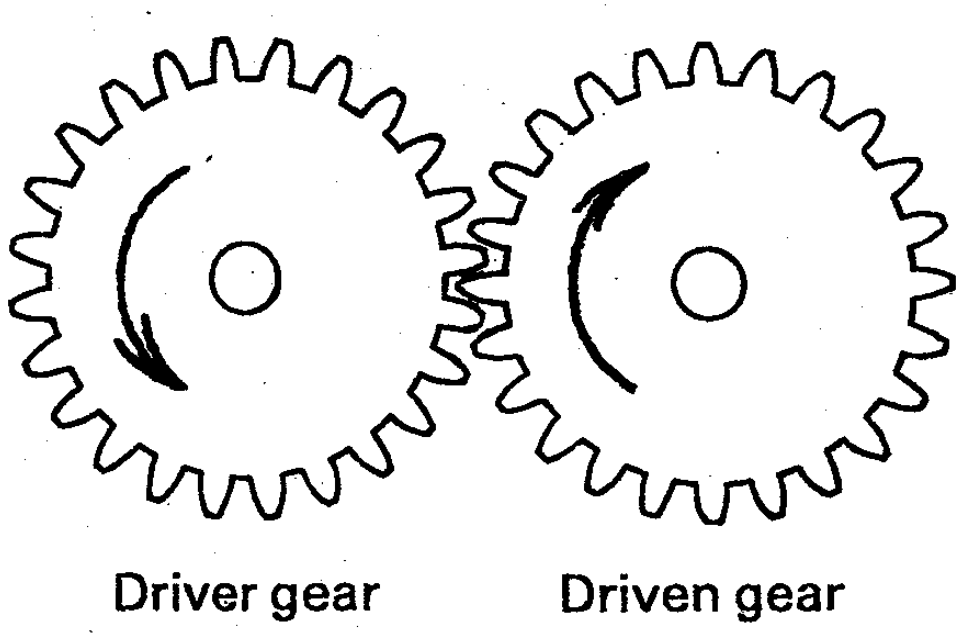
• It is a positive drive(no slip)

• 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




## 1.SPUR GEAR

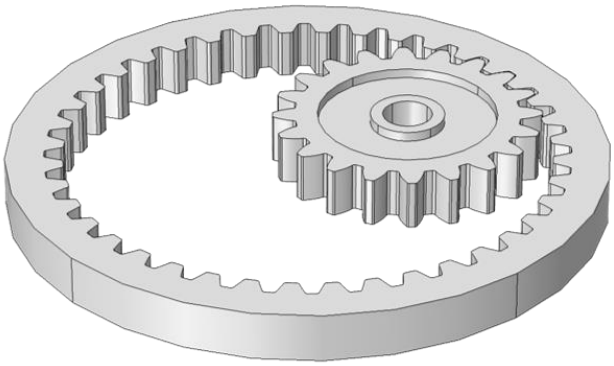
• SPUR gears are those which have teeth cut parallel to the axis of the shaft

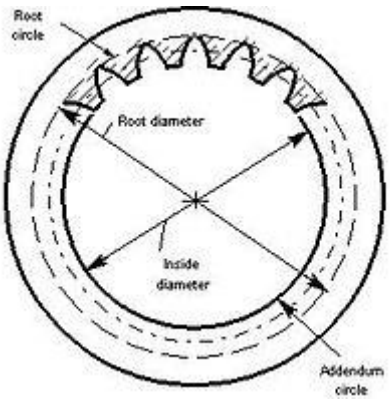
• Spur gears are used to transmit power between parallel shafts

• They are used in high speed and high load applications

Two types : External gear and internal gear

## Internal Spur Gear





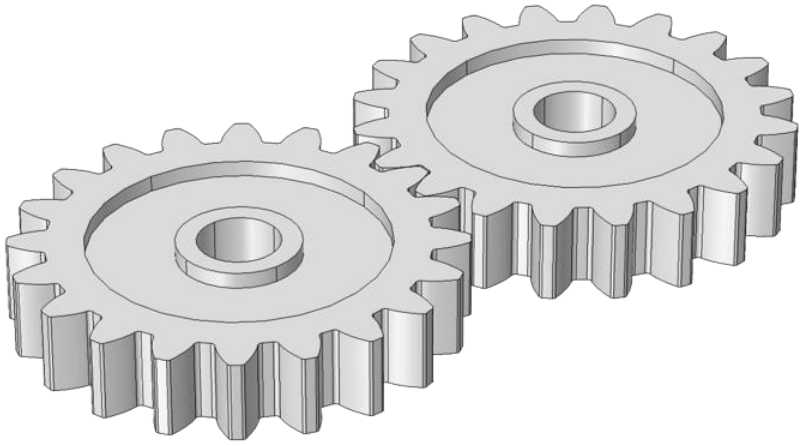

• Internal gears have teeth on the inner periphery

• Two gears rotate in same direction

• Pinion or smaller gear is inside the spur gear

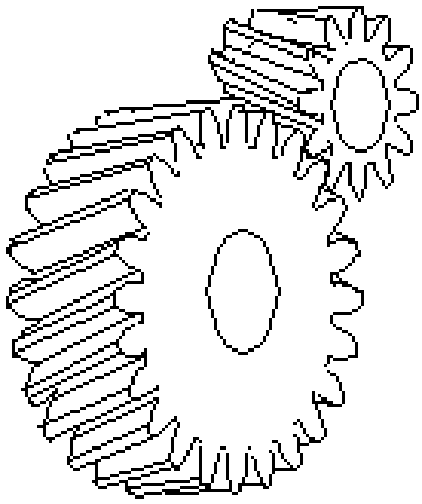
• Internal gears are used in heavy duty tractors, where much torque is required

## External Spur Gear



External gears have teeth on the outer surfaces and the two shafts rotate in opposite directions

## 2.HELICAL GEAR



• 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

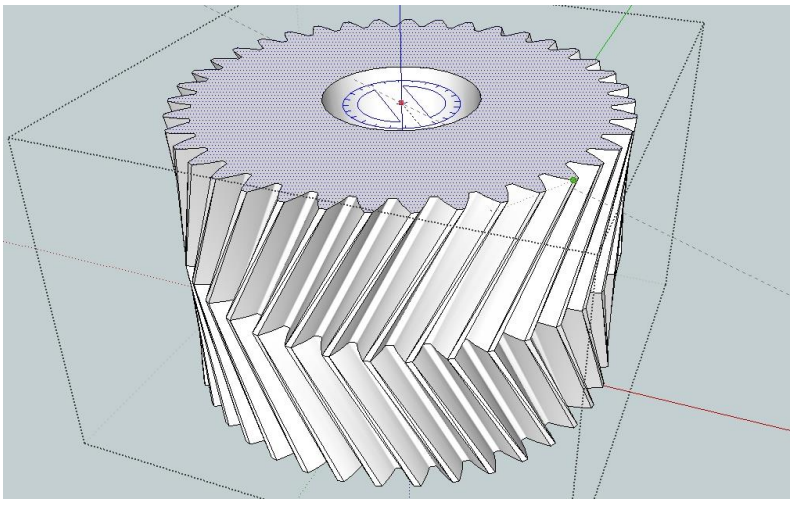
• Helical gears are used to transmit power between parallel shafts

• The two shafts rotate in opposite directions

• They have higher load carrying capacity

• They operate smoother and quieter than spur gears

## 3.Herringbone Gear or Double-Helical Gears



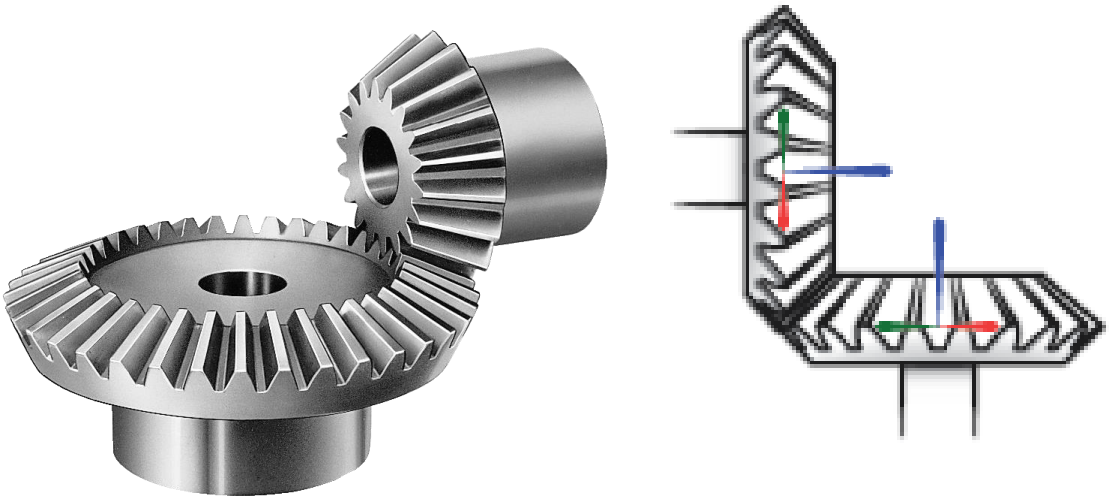
• Herringbone gears have opposing helical teeth which nullify two axial thrusts

• Load carrying capacity is very high

• These gears are used to transmit power between two parallel shafts at high speeds

• The two shafts rotate in opposite directions

## 4.BEVEL GEAR



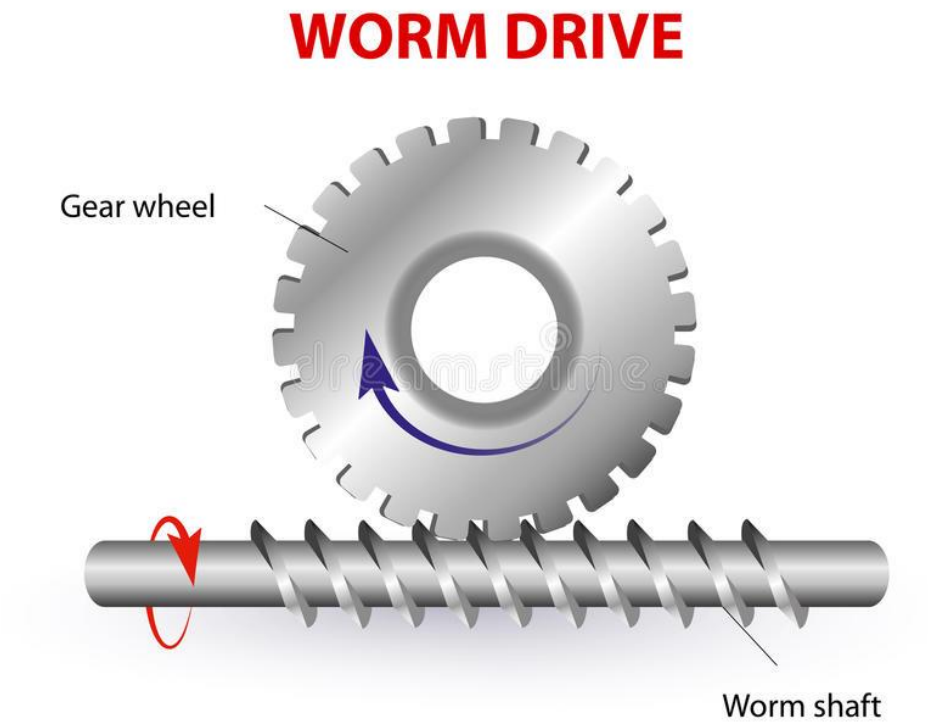
• Bevel gears are used to connect two non-parallel shafts with intersecting axes

• 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

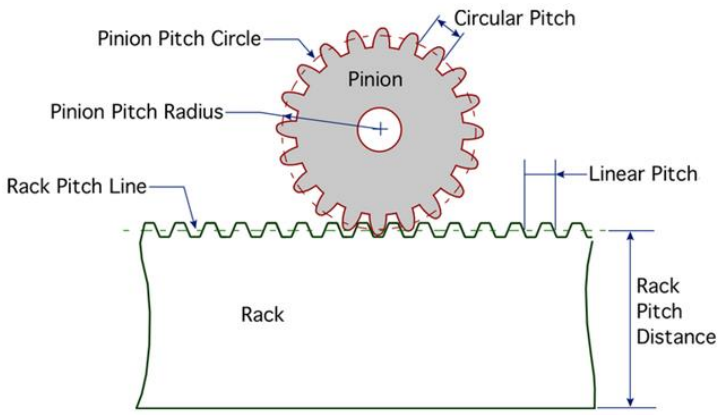
• Worm gearing consists of worm and worm wheel

• Worm is a threaded screw and is used as the driver

• Worm wheel is a toothed wheel

• Teeth of the worm wheel remain engaged with the threads of the worm

## 6.RACK AND PINION




Rack and pinion gears are used to convert rotation(pinion) into linear motion(rack) or vice versa

Advantages of gear drive

- Smooth and reliable
- Transmits more power

Disadvantages

- Not suitable for large distances
- Needs lubrication
- Maintenance cost is high
- Power loss due to friction
- Production cost is high

## Q. Describe the torque measurements method (any one).

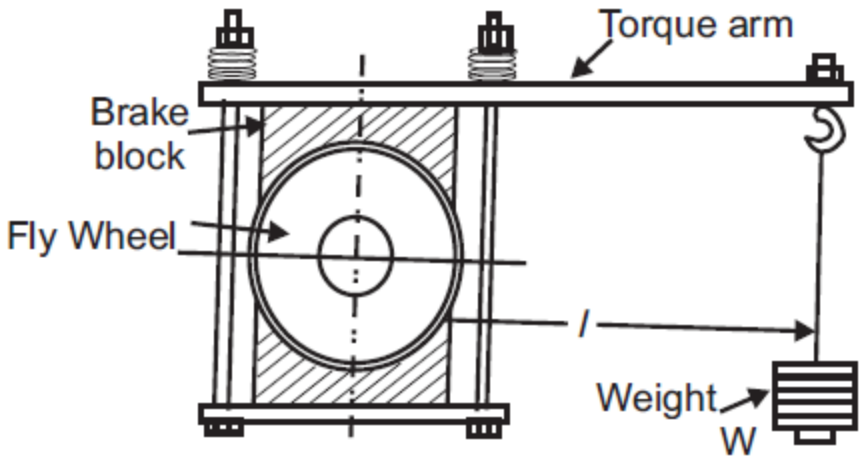
**[BPUT 2nd SEM 2018-19]**

**TORQUE MEASUREMENT**

**PRONY BRAKE DYNAMOMETER**

- A prony brake develops mechanical friction on the periphery of a rotating pulley by means of brake blocks that are squeezed against the wheel by tightening the bolts until the friction torque F.R balances the torque W.L.

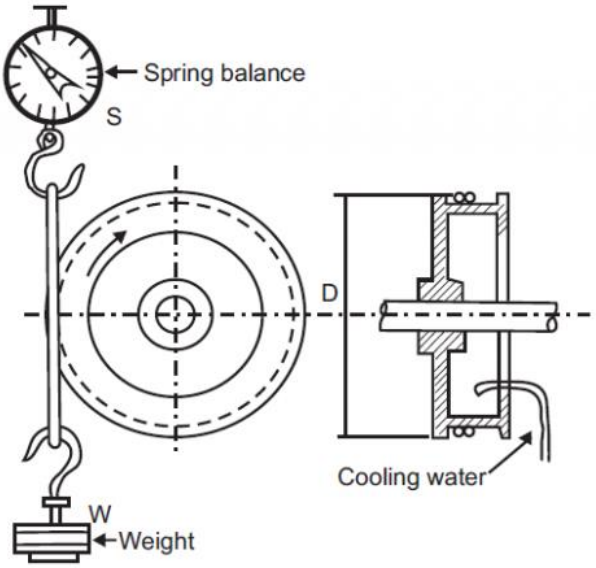
- Torque, T=F X R=W X L




**ROPE BRAKE DYNAMOMETER**

Rope brake dynamometer consists of a rope wound round the rim of the pulley fixed to the shaft of the engine whose torque is to be measured. The upper end of the rope is attached with a spring balance of stiffness S and lower end of the rope is attached with a load W as shown in the figure below. If the diameters of pulley and ropes be D and d, respectively, the toque can be measured as

$$T = (W-S)\frac{D+d}{2}$$




**HYDRAULIC DYNAMOMETER**

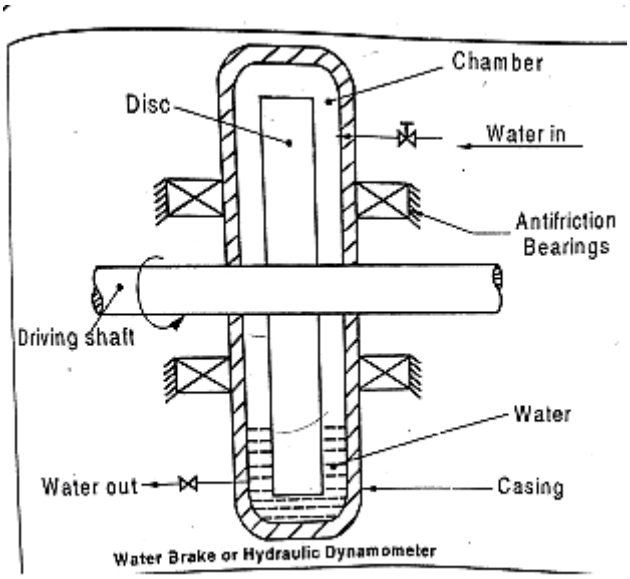
The water brake is of hydraulic nature and it is the simplest example for hydraulic dynamometer. Generally the water brake is used for large capacity systems as compared to prony brake system, because large amount of heat is dissipated to the water in water brke system.

This device uses fluid friction and not dry friction.

**DESCRIPTION**

The main parts of this system are shown in the figure.

- A rotating disk is fixed to the driving shaft semi-elliptical grooves are provided on the disc through which a stream of water flows.
- A casing is stationary in which the disc rotates.
- The casing is mounted on anti friction bearings and it carries a braking arm and a balance system. Therefore, the casing can rotate freely , but its movement can be restricted by the arm.



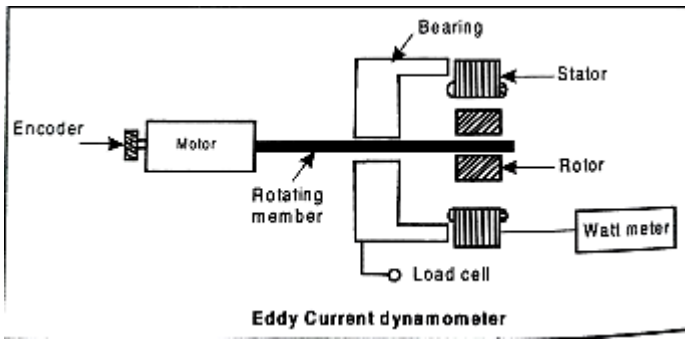

**OPERATION**

- When the driving shaft rotates, water flows in a helical path in the chamber. Due to vortices and eddy-current set up in the water, the casing tends to rotate in the same direction as the driving shaft.
- By varying the amount of water and its pressure, the braking action can be initiated . Braking can also be provided by varying the distance between the rotating disk and the casing.
- Power absorption is approximately the cube of rotational speed and the fifth power of disc diameter.
- The housing is constrained by a force-measuring load cell placed at the end of the arm of radius r.

Torque T= F.r , where F=force measured at radius r

Power (P)= $\frac{2\pi NT}{60}$

**EDDY CURRENT DYNAMOMETER**




It is an absorption type dynamometer. The eddy current dynamometer setup is shown in the figure and it cosists of motor, stator, rotor bearing and load cell etc.

Stator is the fixed member and rotor is the rotating member.

The rotating member is connected to one side of the motor and the other side consists of bearing , stator-rotor arrangement. Due to the magnetic flux produced, the rotating member will rotate. Therefore eddy currents will be generated, when the rotating member rotates.

By measuring eddy current , the torque can be measured.

## Q. Explain (in detail with line diagram) the working of a four stroke and two stroke petrol engines. [BPUT 2nd SEM 2018-19]

**Four stroke engine:**

- Cycle of operation completed in four strokes of the piston or two revolution of the piston.

(i) Suction stroke (suction valve open, exhaust valve closed)-charge consisting of fresh air mixed with the fuel is drawn into the cylinder due to the vacuum pressure created by the movement of the piston from TDC to BDC.

(ii) Compression stroke (both valves closed)-fresh charge is compressed into clearance volume by the return stroke of the piston and ignited by the spark for combustion. Hence pressure and temperature is increased due to the combustion of fuel

(iii) Expansion stroke (both valves closed)-high pressure of the burnt gases force the piston towards BDC and hence power is obtained at the crankshaft.

(iv) Exhaust stroke (exhaust valve open, suction valve closed)- burned gases expel out due to the movement of piston from BDC to TDC.

Figure  show the cycle of operation of four stroke engine.

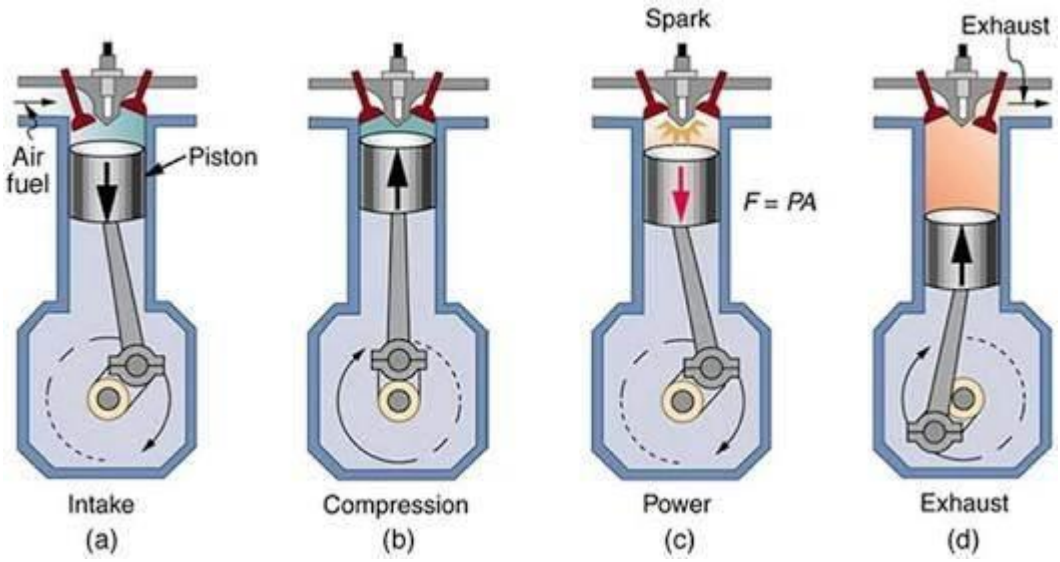



Fig.  Cycle of operation in four stroke engine

**Two stroke engine:**

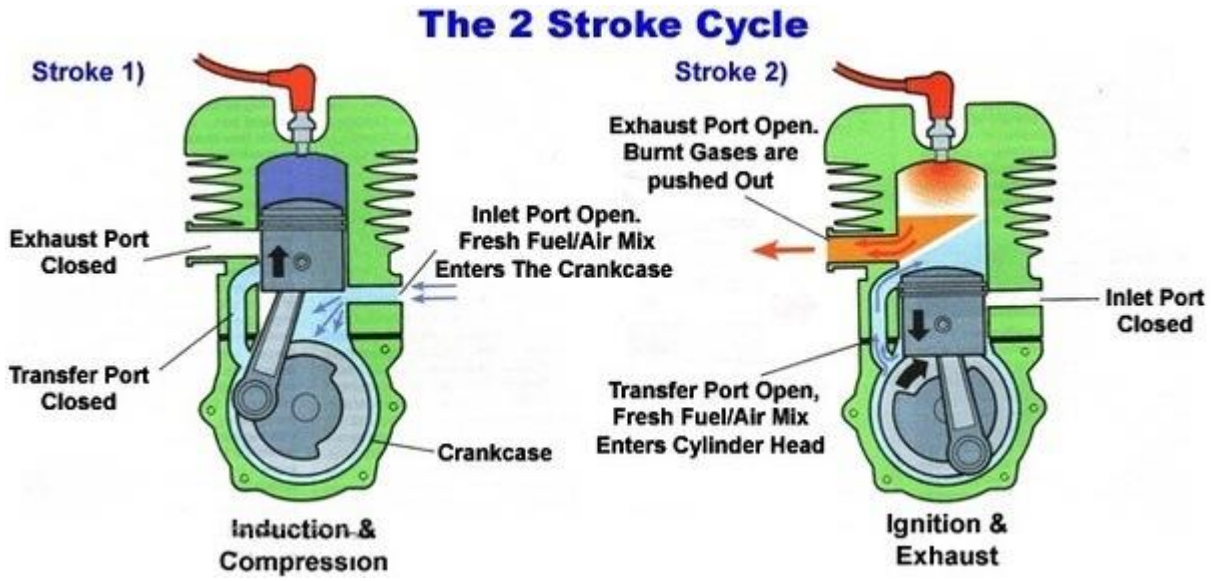
-No piston stroke for suction and exhaust operations

-Suction is accomplished by air compressed in crankcase or by a blower

-Induction of compressed air removes the products of combustion through exhaust ports

-Transfer port is there to supply the fresh charge into combustion chamber

Figure  represents operation of two stroke engine




Comparison of Four-stroke and two-stroke engine:

| Four-stroke engine | Two-stroke engine |
|---|---|
| *Four stroke of the piston and two revolution of crankshaft<br>*One power stroke in every two revolution of crankshaft<br>*Heavier flywheel due to non-uniform turning movement<br>*Power produce is less<br><br>*Heavy and bulky<br><br>*Lesser cooling and lubrication requirements<br>*Lesser rate of wear and tear<br>*Contains valve and valve mechanism<br><br>*Higher initial cost<br><br>*It is used where efficiency is important.<br>Ex-cars, buses, trucks, tractors, industrial engines, aero planes, power generation etc. | *Two stroke of the piston and one revolution of crankshaft<br>*One power stroke in each revolution of crankshaft<br>*Lighter flywheel due to more uniform turning movement<br>*Theoretically power produce is twice than the four stroke engine for same size<br>*Light and compact<br><br>*Greater cooling and lubrication requirements<br>*Higher rate of wear and tear<br>*Contains ports arrangement<br><br>*Cheaper initial cost<br><br>*It is used where low cost, compactness and light weight are important.<br>Ex-lawn mowers, scooters, motor cycles, mopeds, propulsion ship etc. |

## Q. Explain the function of a clutch and different types of clutches with their relative advantages and disadvantages. [BPUT 2nd SEM 2018-19]

**CLUTCH-BASICS**

A clutch is a device used to engage and disengage the driving shaft to the driver shaft according to the requirement. In case of automobiles, the clutch is required during changing of gears. By operating a lever, the clutch engages and disengages the driver and driven shafts. While changing gears, the driven shaft should be disengaged from the driving shaft.

**Working principle of friction clutch**

The principle of transmission of power is by contacting friction surfaces, to develop frictional force and this frictional force is used to start the driven shaft from rest and gradually increases the speed without slipping. In case of automobiles, the friction clutch is used to engage the engine shaft to the driven shaft.

**Material for friction surface**

The materials used for lining of friction surfaces should have the following properties.

1. The material should have high coefficient of friction.
2. The material should withstand high temperatures caused during operation.
3. The material should have high heat conductivity, high resistance to wear and should not be affected by moisture or oil.

**Types of friction clutches**

1. Disc or plate clutches

   (a)Single disc clutch

   (b)Multiple disc clutch

2. Cone clutch.

3. Centrifugal clutches

**Advantages**

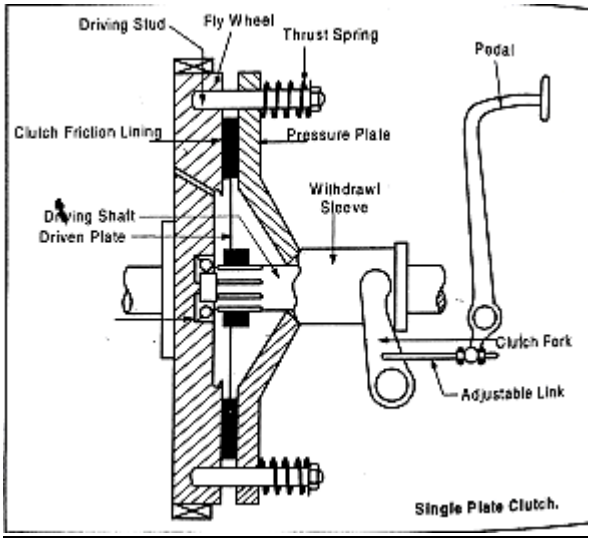
1. They have a very little shock during engagement as they can slip relative to each other
2. It can be used for high speed engagement applications.

**Limitations**

1. They are not suitable for application that require positive transmission because they do slip.
2. Replacement of friction material is often required as they wear out.
3. External cooling is required as they generate heat during engagement.

**Single plate clutch**

The most common type of clutch used is single plate coil spring dry clutch. This varies in size and number of coil springs according to the torque requirements. It consists of a single driven plate clamped between the flywheel and the pressure plate by a ring of coil springs which are held in compressed state by the clutch cover..




**Working of single plate clutch**

The flywheel which is bolted to the driving shaft and the pressure plate on the driven shaft are coaxial to each other and the pressure plate is free to move along the driven shaft due to splined connection.

During disengagement of the clutch , the contact lever keeps the pressure plate away from the flywheel thus the transmission is broken.

With the release of clutch pedal, the spring provides an actuating force to the pressure plate and force it to move towards the flywheel and finally makes contact with it and the clutch gets engaged. The driven

shaft starts rotating with a low speed due to low friction between the disks. When the pedal is fully released the spring provides required axial force and presses the plate against flywheel to get full speed.

When the clutch pedal is pressed down, a release bearing under hydraulic pressure , presses down on the center of the clutch cover and forces the pressure plate away from the clutch plate. This action allows the clutch plate to remain stationary between the revolving flywheel and clutch cover. Gears may now be selected , and the slow release of the clutch pedal gradually clamps the clutch plate to the flywheel, allowing the drive of power from crankshaft to the transmission. Torque is transmitted by means of frictional force between these plates.

**Applications of single plate clutch**

Cars use a single plate clutch as there is enough space to use the correct diameter plate to create the right amount of torque while motor bikes use multi-plate clutches as they have limited space and need to create more frictional surfaces to produce the required torque.

**Advantages of single plate clutch**

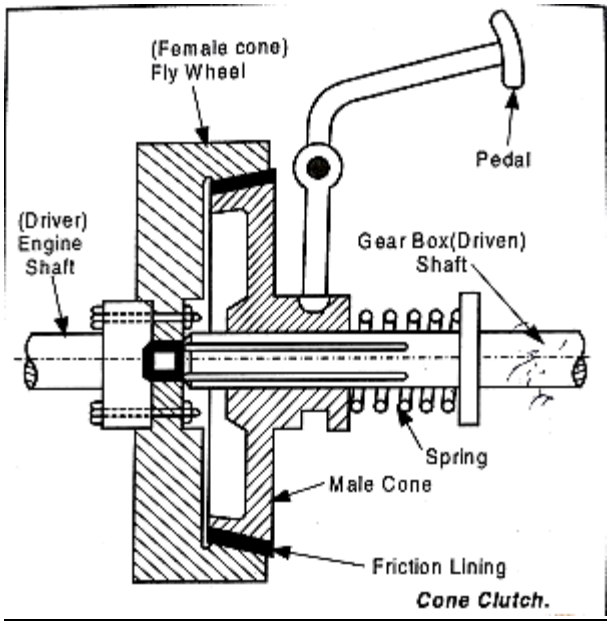
(i) It is is easy to repair.

(ii) Maintenance is easy.

(iii) Easy to transmit power.

**CONE CLUTCH**

The cone clutch uses two conical surfaces to transmit torque by friction. The cone transmits higher torque than plate or disc clutch of the same size due to wedging action and increased surface. The added advantage with this type of clutch is that the normal force acting on the friction surface is greater than the axial force, as compared with other types of clutches.



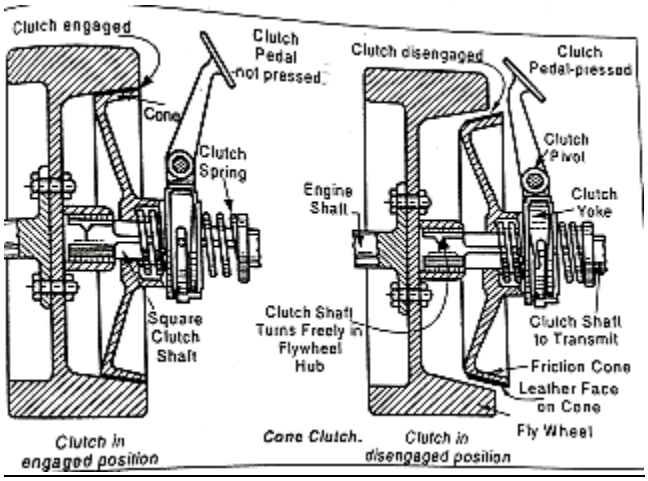

The cone clutch is practically obsolete nowadays due to some of its disadvantages.

(i) If the angle of cone is made smaller than $20^0$, the cone tends to bind with the flywheel (female cone) and it becomes difficult to disengage the clutch after it is removed.

(ii) A small amount of wear on the cone surfaces results in a considerable amount of axial movement of the male cone to engage which will not be possible.

**Construction of cone clutch**

Cone clutch consists of flywheel (female cone) and a male cone mounted on the driving shaft and driven shaft respectively. A friction lining is introduced between the cone and the flywheel which is made up of asbestos , or leather materials. A spring provides the necessary axial force to the male cone to press against the flywheel.




**Working**

In normal condition , the force exerted by the spring keeps the clutch always in engaged position , which makes an angle called semi-cone angle with the flywheel. To disengage the clutch cone from flywheel , a force has to be given against the spring by means of a lever mechanism , operated through the clutch pedal, for smooth shifting of gears.

**Applications**

Usually confined for very special transmissions like

(i) Race cars

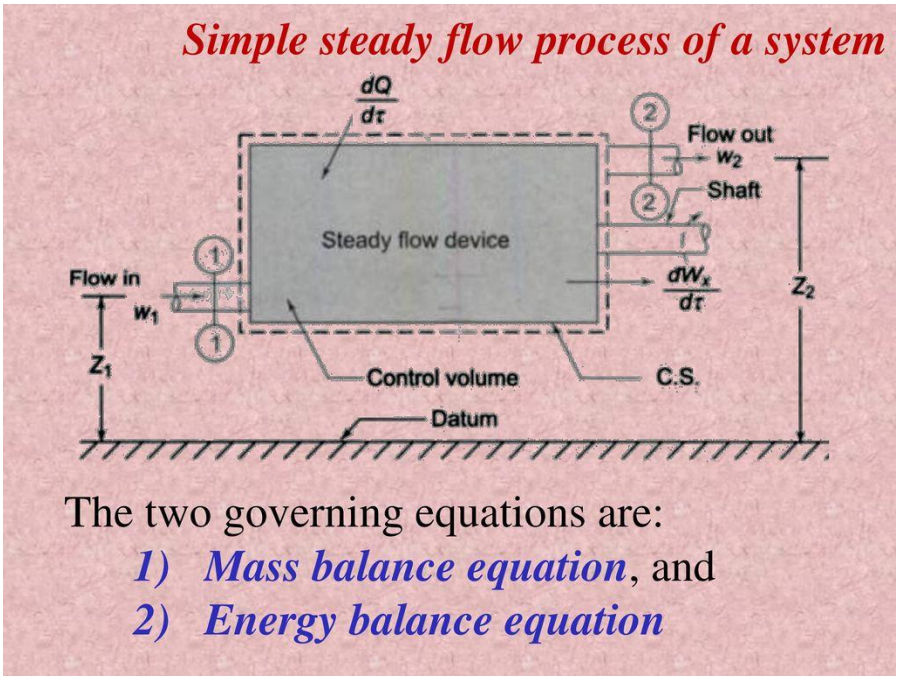
(ii) Off-road vehicles

(iii) Power boats

## Q. Derive mass continuity and SFEEE equation for the flow systems.

**[BPUT 1st SEM 2018-19]**

**MASS BALANCE AND ENERGY BALANCE IN A SIMPLE STEADY FLOW PROCESS**




In the above figure a steady flow system has been shown in which , one stream of fluid enters and an another stream leaves the control volume. There is no accumulation of mass or energy within the control volume, and the properties at any location within the control volume are steady with time. Sections 1 and 2 indicate respectively , the entrance and exit of the fluid across the control surface.The following quantities are defined with reference to the figure,

$A_1, A_2$ - cross-section of stream , $m^2$

$W_1, w_2$ – mass flow rate,kg/s

$P_1, P_2$ – pressure, absolute, $N/m^2$

$v_1, v_2$ –specific volume, $m^3/kg$

$u_1, u_2$ –specific internal energy,J/kg

$V_1, V_2$ –velocity, m/s

$Z_1, Z_2$ –elevation above arbitrary datum,m

$\frac{dQ}{d\tau}$ -net rate of heat transfer through the control surface, J/s

$\frac{dW_x}{d\tau}$ - net rate of work transfer through the control surface, J/s

τ- time, s.

Subscripts 1 and 2 refer to the inlet and exit sections.

**MASS BALANCE**

By the conservation of mass, if there is no accumulation of mass within the control volume, the mass flow rate entering must equal the mass flow rate leaving,or

$$w_1=w_2$$

Or $$(A_1V_1/v_1)=(A_2V_2/v_2) \quad \text{(i)}$$

This equation is known as the equation of continuity.

**ENERGY BALANCE**

- In a flow process , work transfer may be of two types; the external work and flow work. The external work refers to all the work transferacross the control surfaceother than that due to normal fluid forces.
- In engineering thermodynamics the only kinds of external of importance are shear(shaft or stirring) work and electrical work.
- In figure the only external work occurs in the form of shaft work, $W_x$.
- The flow work is the displacement work done by the fluid of mass $dm_1$ at the inlet section 1 and that of the mass $dm_2$ at the exit section 2, which are $(-p_1v_1dm_1)$ and $(+p_2v_2dm_2)$respectively.
- Therefore , the total work transfer is given by

$$W =W_x - p_1v_1dm_1+ p_2v_2dm_2 \quad \text{(ii)}$$

In the rate form

$$\frac{dW}{d\tau} = \frac{dW_x}{d\tau} - p_1 v_1 \frac{dm_1}{d\tau} + p_2 v_2 \frac{dm_2}{d\tau} \quad \text{(iii)}$$

Or $$\frac{dW}{d\tau} = \frac{dW_x}{d\tau} - w_1 p_1 v_1 + w_2 p_2 v_2 \quad \text{(iv)}$$

- Since there is no accumulation of energy , by the conservation of energy, the total rate of flow of all energy streams entering the control volume must equal the total rate of flow of all energy streams leaving the control volume.
- This may be expressed in thr following equation,

$$w_1 e_1 + \frac{dQ}{d\tau} = w_2 e_2 + \frac{dW}{d\tau}$$

Su+ ep bstituting for $\frac{dW}{d\tau}$ from equation –(iv)

$$w_1 e_1 + \frac{dQ}{d\tau} = w_2 e_2 + \frac{dW_x}{d\tau} - w_1 p_1 v_1 + w_2 p_2 v_2$$

Or $$w_1 e_1 + w_1 p_1 v_1 + \frac{dQ}{d\tau} = w_2 e_2 + w_2 p_2 v_2 + \frac{dW_x}{d\tau} \quad \text{(v)}$$

Where $e_1$ and $e_2$ refer to the energy carried into or out of the control volumewith uniy mass of fluid.

The specific energy e is given by

$e = e_k + e_p + u$

$= V^2/2 + Zg + u$ (vi)

Substituting the expression for e in equation –(v)

$$w_1\left(\frac{V_1^2}{2} + Z_1 g + u_1\right) + w_1 p_1 v_1 + \frac{dQ}{d\tau} = w_2\left(\frac{V_2^2}{2} + Z_2 g + u_2\right) + w_2 p_2 v_2 + \frac{dW_x}{d\tau}$$

Or $$w_1\left(h_1 + \frac{V_1^2}{2} + Z_1 g\right) + \frac{dQ}{d\tau} = w_2\left(h_2 + \frac{V_2^2}{2} + Z_2 g\right) + \frac{dW_x}{d\tau} \quad \text{(vii)}$$

Where h=u+pv

And since $w_1=w_2$, let $w=w_1=w_2=dm/d\tau$

Dividing equation (vii) by $dm/d\tau$

$$h_1 + \frac{V_1^2}{2} + Z_1 g + \frac{dQ}{dm} = h_2 + \frac{V_2^2}{2} + Z_2 g + \frac{dW_x}{dm} \qquad \text{(viii)}$$

Equation (vii) and(viii) are known as steady flow energy equations(S.F.E.E.)for a single stream of fluid entering and a single stream of fluid leaving the control volume.

## Q. Write down the different methodologies of temperature measurement.

**[BPUT 1st SEM 2018-19]**

**RESISTANCE TEMPERATURE DETECTORS(RTD)**

In 1821, Sir Humphery Dary announced that the resistivity of metals is dependent on temperature. Fifty years later, Sir William Siemens recommended that platinum can be used as an element in a resistance thermometer. Since then , platinum has been used as the primary element in all high-accuracy resistance thermometers. It is capable of withstanding high temperatures and also it can sustain excellent stability and exhibits good linearity.

**WORKING PRINCIPLE**

- An RTD a temperature sensor operates on the measurement principle that a material's electrical resistance changes with temperature. It means that the resistance of electrically conductive material is proportional to temperature. Hence, metals can be classified as per their positive temperature coefficient.
- When temperature measurement is performed by a resistance thermometer using metallic conductors, it is called as a resistance temperature detector(RTD), on the other hand , semiconductors used for temperature measurement are called thermistors.
- Many materials such as platinum, nickel, and copper are commonly used for making resistance thermometers.

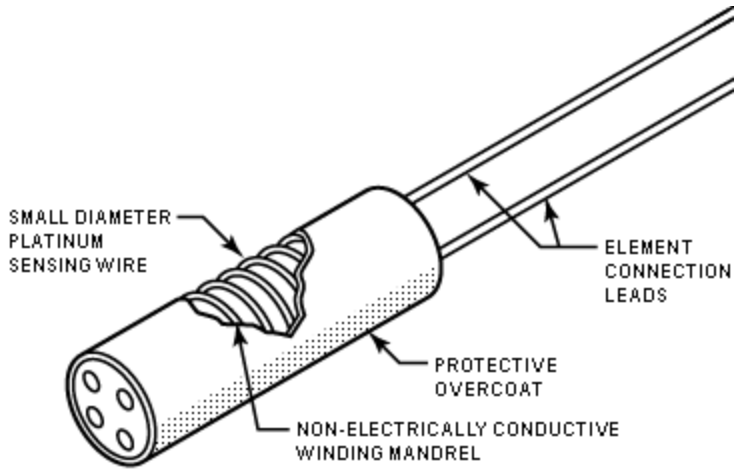
**ADVANTAGES**

- Good stability at high temperature.
- Speed response.

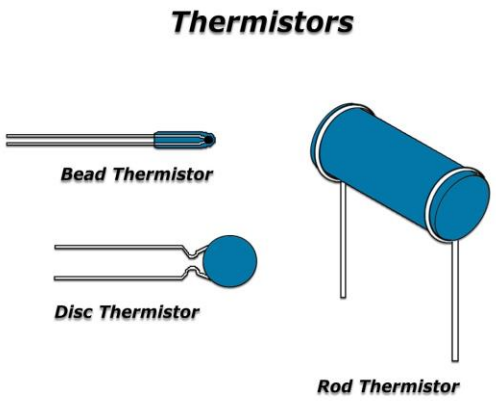
- High accuracy and good reproducibility.
- Interchangeable sensors.

**LIMITATION**

- More expensive.
- Affected by shock and vibration.
- Low sensitivity.
- Its bulb size is larger than thermocouple.
- Requires external electrical supply.




## THERMISTOR




- Thermistor are made up of solid semiconductor materials having a high coefficient of resistivity.
- When a termistor is employed for temperature measurement , its resistance decreases wuth increase in temperature. The valence electrons, which are mutually shared by the metal atoms, move continuously and freely through the metal during their movement from atom to atom.
- In case of themistors , the valence electrons are attached more firmly to the atoms; some of the electrons are detached and flow due to the increase in temperature, which decreases electrical resistance facilitating the easy flow of electrons.
- The relationship between temperature and resistance is given by the following equation

$$R = R_R.e^{\beta\left(\frac{1}{T}-\frac{1}{T_R}\right)}$$

Where , R –is the resistance at the measured temperature, T

$R_R$-is the resistance at the reference temperature, $T_R$

B- is the experimentally determined constant for a given thrmistor material.

$T_R$-is the reference temperature generally taken as 298K($25^0$C).

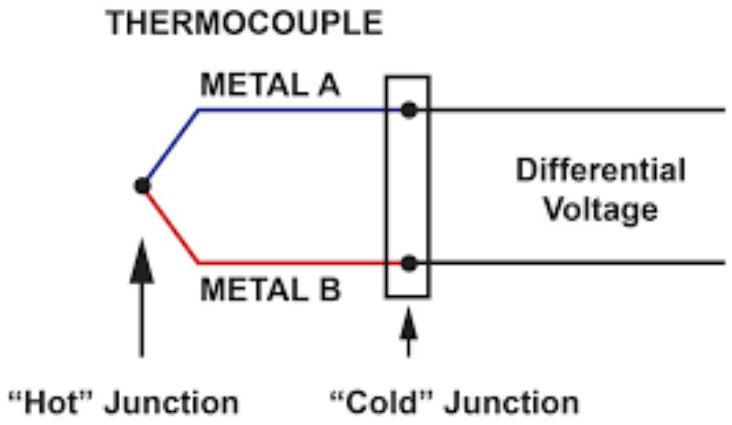
**THERMOCOUPLE**

A thermocouple is a device made of two different wires joined at one end, called junction end. The two wires are called thermoelements

The two thermoelements are distinguished as positive and negative ones. The one end of the thermocouple is called tail end or reference end. The junction end (hot junction) is placed in the environment whose temperature has to be measured. The tail end (cold junction)is held at a different temperature (at ambient temperature).

Because of the temperature difference between junction end and tail end, a voltage difference is produced and it can be measured at the tail end.

So the thermocouple is  a temperature-voltage transducer which was discovered by Thomas Seebeck in 1832. Hence this effect is called seebeck effect. All dissimilar metals exhibit this seebeck effect. The seebeck voltage is linearly proportional to small change in temperature.




**MEASURING THERMOCOUPLE VOLTAGE**

We can measure the seebeck voltage, by connecting a voltmeter to the thermocouple, and the voltmeter creats a new thermoelectric circuit.

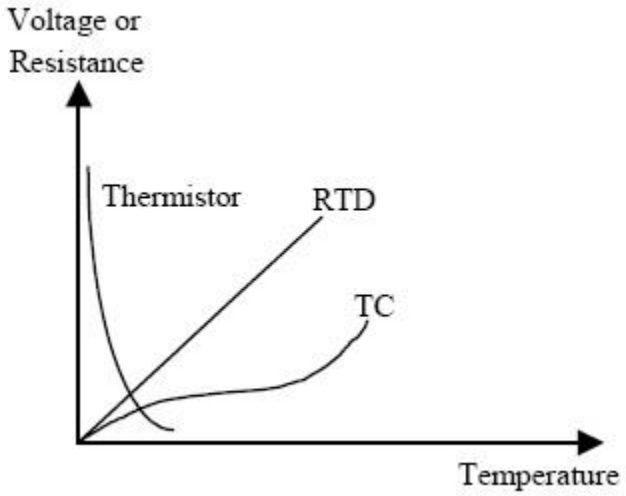
**ADVANTAGES**

- Rugged and inexpensive.
- Simple construction.

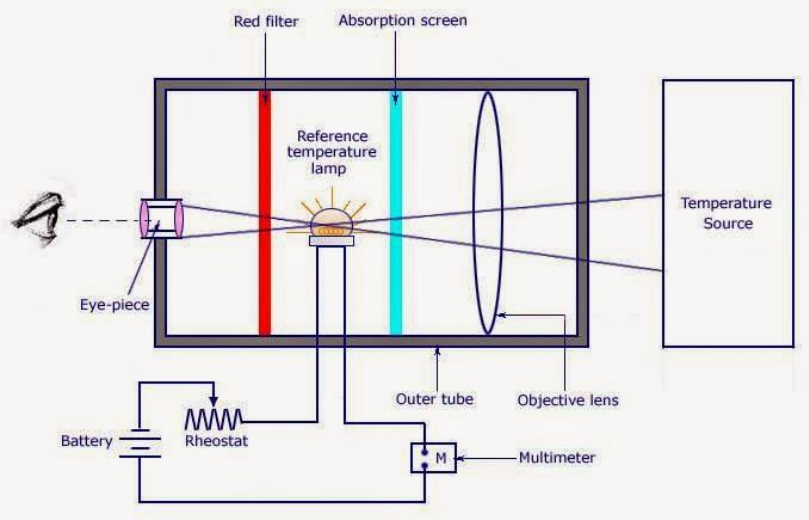
- Reasonably short response time.
- High accuracy.
- Used to measure the temperature ranges of $1000^0$C.

**LIMITATIONS**

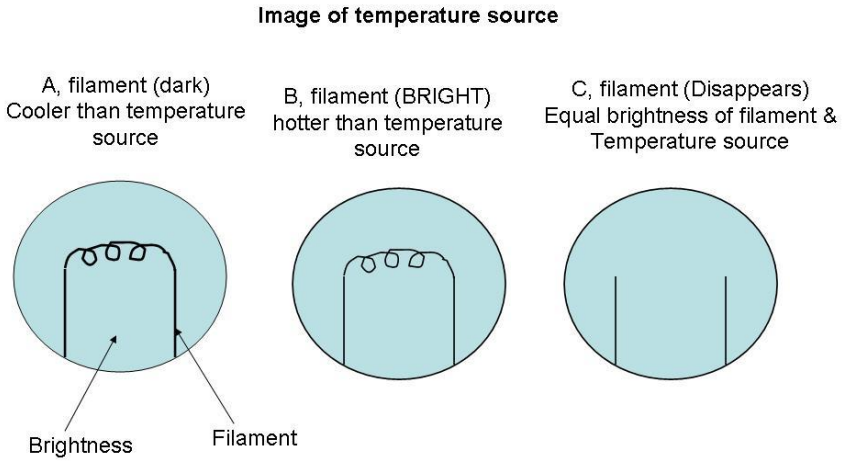
- Possible to get corroded because thermocouple is made with two different types of metal composition. It reduces the accuracy.
- The relationship between the process temperature and the thermocouple signal is not linear.



**PYROMETERS**




Optical Pyrometers work on the principle of using the human eye to match the brightness of the hot body to the brightness of a calibrated lamp filament inside the pyrometer.



The brightness of a lamp filament inside the device is adjusted to match the brightness of the target. At this time , amount of power required by the filament to match the brightness of the target is measured and the corresponding temperature is found out which is equal to the temperature of the object(hot body) to be measured. This is called filament disappearing method.

**CONSTRUCTION**

The construction of an optical thermometer is similar to a telescope . However a tungsten filament lamp is placed at the focus of the objective lens. The filament lamp acts as the standard source, so that the image of the hot target is on the plane of the filament. Due to this , the target image and filament lamp are superimposed on one another when viewed through the eyepiece. Atwo-volt battery with a multimeter and rheostat is connected in series with the lamp. The intensity of a filament lamp lights can be adjusted by adjusting the current using rheostat.

**WORKING**

- An operator views a hot body (target) and adjusts the lamp brightness until its image is seen in red. When the lamp filament is initially cooler than the target, its image appears as darker red or black spot superimposed on the target's image.
- If the lamp current is increased till the filament becomes hotter than the target, then the image of filament appears brighter red than the target.
- If the lamp current is adjusted so that the lamp filament's brightness is equal to that of the target, then the filaments image blends into the image of the target.

**ADVANTAGES**

- It shows lower temperature error.

**DISADVANTAGES**

- It is only suitable for spot measurement and it requires a skilled operator to use it.
- It is not suitable of quick response and is totally unsuitable for control purposes.
- Fragile: expensive-capability required.
- Emissivity correction.

## Q. Briefly discuss about the merits and demerits of rope drive and belt drive.

**[BPUT 1st SEM 2018-19]**

**Belt Drives**

A belt is a loop of flexible material used to link two or more rotating shafts mechanically, most often parallel. Belts are looped over pulleys and may have a twist between the pulleys and the shafts need not be parallel.

• Friction between the belt and the pulley is responsible for transmitting power from one pulley to other
• It's a friction drive

• 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

• Velocity of the belt

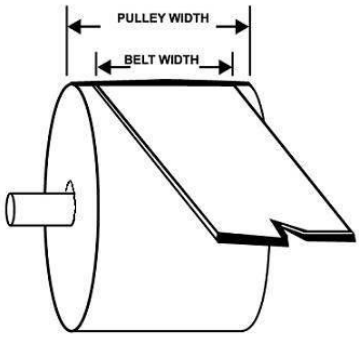
• The tension with which the belt is placed under the pulleys

• The arc of contact between the belt and the smaller pulley

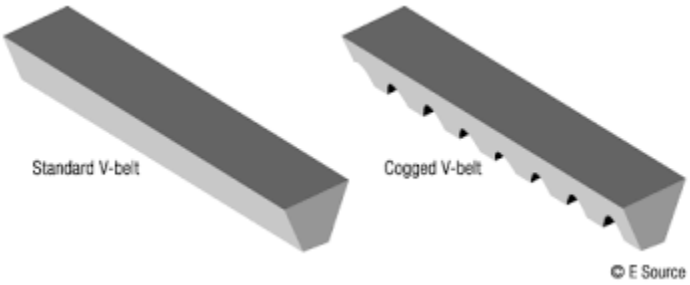
**Types of belts**

There are many types of belts. The general and important types of belts are

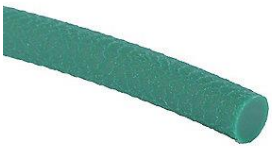
(1)Flat belt: These are mostly used in factories and workshops, where moderate amount of power is required to be transmitted and when the two pulleys are not more than 8 meters apart.



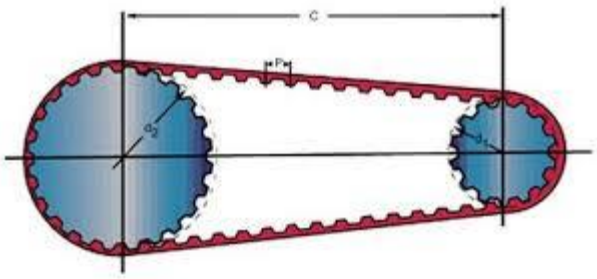
(2)V-belt: In V belts the V shaped cross-section prevents belt from slipping off. These pulleys are used when the two pulleys are very nearer to each other and greater amount of power is required to be transmitted.




(3)Round belt: Round belt are generally made of rubber. This type of belt is generally used for light loads, such as in sewing machine.



(4)Toothed belts: Toothed belts use their teeth for power transmission, as opposed to friction. This results in no slippage. It is more expensive to manufacture.



# Rope Drive

- The rope drives are widely used where a large amount of power is to be transmitted, from one pulley to another, over a considerable distance. It may be noted that the use of flat belts is limited for the transmission of moderate power from one pulley to another when the two pulleys are not more than 8 meters apart. If large amounts of power are to be transmitted by the flat belt, then it would result in excessive belt cross-section.
- frictional grip in case of rope drives is more than that in V-drive. One of the main advantage of rope drives is that a number of separate drives may be taken from the one driving pulley. For example, in many spinning mills, the line shaft on each floor is driven by ropes passing directly from the main engine pulley on the ground floor.
- The rope drives use the following two types of ropes :

  **1. Fibre ropes, and 2. Wire ropes.**
- The fibre ropes operate successfully when the pulleys are about 60 metres apart, while the wire ropes are used when the pulleys are upto 150 metres apart.

Advantages

- Smooth and silent operation
- Less weight
- Longer life
- Efficiency is high
- More reliable
- Low cost

## Q. Define the following, (i) $C_P$ (ii) $C_V$ (iii) H [BPUT 1st SEM 2018-19]

**SPECIFIC HEAT AT CONSTANT VOLUME**

The specific heat of a substance at constant volume $c_V$ is defined as the rate of change of specific internal energy with respect to temperature when the volume is held constant, i.e.

$$c_V = \left(\frac{\partial u}{\partial T}\right)_V \qquad \text{(i)}$$

For a constant volume process

$$(\Delta u)_V = \int_{T_1}^{T_2} c_V \, dT \qquad \text{(ii)}$$

The first law may be written for a closed stationary system composed of a unit mass of a pure substance

$$Q=\Delta u+W$$

Or $$dQ=du+dW$$

For a process in the absence of work other than pdV work

$$dW=pdV$$

$$dQ=du+pdV \qquad \text{(iii)}$$

When the volume is held constant

$$(Q)_V=(\Delta u)_V$$

$$(Q)_V=\int_{T_1}^{T_2} c_V \, dT \qquad \text{(iv)}$$

Hence heat transferred at constant volume increases the internal energy of the system. Since u,T, and v are properties, $c_V$ is a property of a substance. The product $mc_V=C_V$ is called the heat capacity at constant volume.

**ENTHALPY(H)**

The specific enthalpy of a substance, h, is defined as

$$h=u+pv \qquad \text{(i)}$$

It is an intensive property of a system (kJ/kg).

Total enthalpy H , is defined as

$$H=U+PV$$

Its unit is Joule or KJ.

For a constant pressure process, the heat transfer is given as

$$dQ=du+pdv$$

At constant pressure

$$Pdv+d(pv)$$

$$(dQ)_p=du+d(pv)$$

Or $(dQ)_p=d(u+pv)$

Or $(dQ)_p=dh$ (ii)

Where h=u+pv is the specific enthalpy , a property of the system. Heat transferred at constant pressure increases the enthalpy of a system.

**SPECIFIC HEAT AT CONSTANT PRESSURE**

The specific heat at constant pressure $c_p$ is defined as the rate of change of enthalpy with respect to temperature when the pressure is held constant.

$$c_p = \left( \frac{\partial h}{\partial T_p} \right) \quad \text{(i)}$$

Since h, T,and p are properties ,so $c_p$ is a property of the system.

For a constant pressure process

$$(\Delta h)_p = \int_{T_1}^{T_2} c_p dT \quad \text{(ii)}$$

The first law for a closed stationary system of unit mass

$$dQ=du+pdv$$

Again $h=u+pv$

$dh=du+pdv+vdp$

$=dQ+vdp$

$dQ=dh-vdp$ (iii)

$(dQ)_p=dh$

Or $(Q)_p=(\Delta h)_p$

Or $$(Q)_p = \int_{T_1}^{T_2} c_p dT$$

$C_p$ is a property of the system, just like $c_v$. The heat capacity at constant pressure $C_p$ is equal to $mc_p$(J/K).

## Q. Define critical point and triple point. [BPUT 1st SEM 2017-18]

The saturated liquid line with respect to vaporization and the saturated vapour line incline towards each other and form what is known as the saturation or vapour dome. The two lines meet at the critical state.

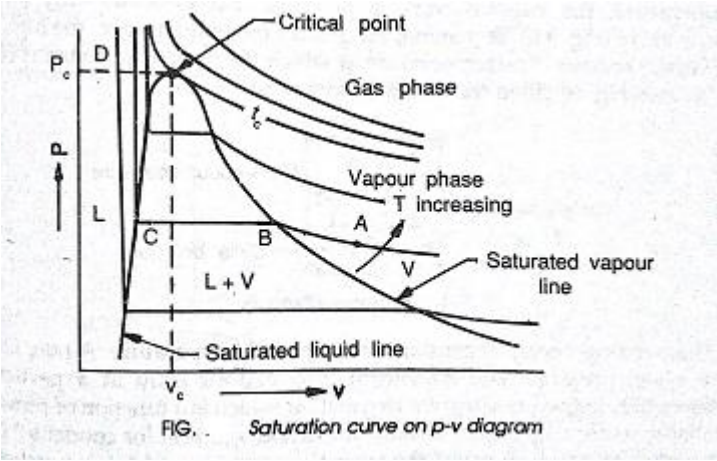



FIG. . *Saturation curve on p-v diagram*

As the temperature increases , the liquid-vapour transition , as represented by BC, decreases, and becomes zero at the critical point. Below the critical point only , there is a liquid-vapour transition zone, where a saturated liquid, on heating , absorbs the latent heat of vaporization, and becomes saturated vapour at a constant pressure and temperature.

Above critical point , a liquid, upon heating suddenly flashes into vapour, or a vapour , upon cooling , suddenly condenses into liquid. There is no distinct transition zone from liquid to vapour and vice versa. The isotherm passing through the critical point is called the critical isotherm, and the corresponding

temperature is known as the critical temperature($t_c$). The pressure and volume at the critical point are known as the critical pressure($p_c$) and the critical volume($v_c$)respectively. For water

$P_c$= 221.2 bar

$t_c$= 374.15$^0$C

$v_c$=0.00317 m$^3$/kg

**P-T DIAGRAM FOR A PURE SUBSTANCE**

The state changes of a pure substance , upon slow heating at different constant pressures , are already shown on the P-V plane . If these state changes are plotted on P-T coordinates, the diagram is shown in the figure below will be obtained.

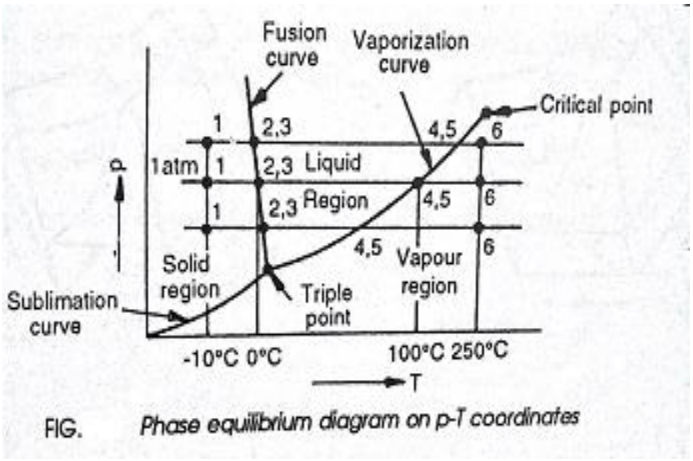



FIG. *Phase equilibrium diagram on p-T coordinates*

If the heating of ice at -10$^0$C to steam at 250$^0$C at the constant pressure of 1 atm is considered, 1-2 is the solid(ice) heating, 2-3 is the melting of ice at 0$^0$C, 3-4 is the liquid heating , 4-5 is the vaporization of water at 100$^0$C, and 5-6 is the heating in the vapour phase.

The fusion curve, the vaporization curve, and the sublimation curve meet at triple point.

The triple point of water is at 4.58 mm of Hg and 273.16 K, whereas that of $CO_2$ is at 3885 mm Hg (about 5 atm) and 216.55 K. So when solid $CO_2$ (dry ice) is exposed to 1 atm pressure , it gets transformed into vapour directly, absorbing the latent heat of sublimation from the surroundings , which gets cooled or refrigerated.

## Q. Classify types of steam. Or what is wet steam , dry steam and superheated steam? [BPUT 1st SEM 2018-19]

Quality or dryness fraction of steam (x) is defined as

$$x = \frac{m_v}{m_v + m_l}$$

Where $m_v$ and $m_l$ are the masses of vapour and liquid respectively in the mixture. The value of x varies between 0 and 1. For **saturated water**, when water just starts boiling , x=0, and for saturated vapour, when vaporization is complete, x=1, for which the vapour is said to be **dry saturated or dry steam.**

If 0<x<1 , then the mixture is partly liquid water and partly steam, and is known as **wet steam.**

If x=1 and temperature T is greater than saturated temperature $T_{sat}$ , then it is known as **superheated steam.**

For wet steam,

$$v = v_f + xv_{fg}$$

$$h = h_f + xh_{fg}$$

$$s = s_f + xs_{fg}$$

$$u = u_f + xu_{fg}$$

## Q. What is a coupling? Explain with neat sketch.

**COUPLINGS**

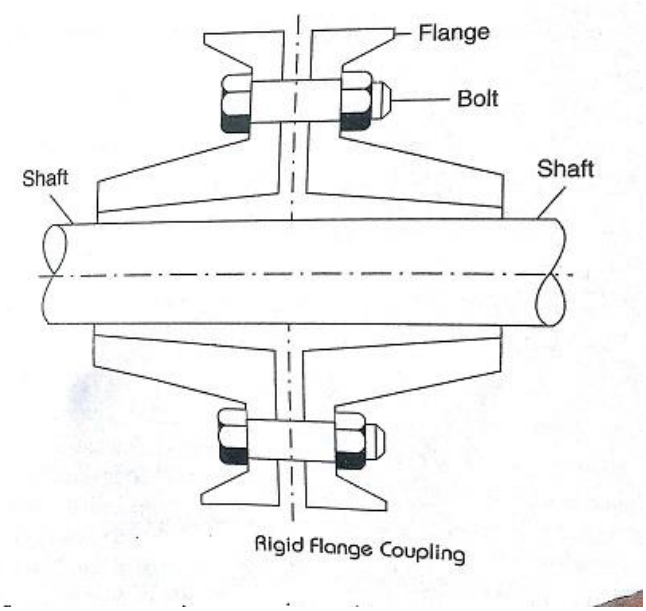
Couplings are used to connect sections of long transmission shafts. Couplings are also used to connect the driving shaft to the driven shaft

- Couplings are permanent connections.
- Couplings permit easy and quick engagement and disengagement of two shafts.

**COUPLINGS ARE CLASSIFIED AS**

**Rigid coupling:** It is used to connect two shafts which are perfectly aligned(collinear shafts). It consists of two cast iron flanges which are keyed to the shafts to be joined as shown in the figure. The flanges are

brought together and are bolted in the annular space between the hub and the protecting flange. The protective flange is provided to guard the projecting blot heads and nuts. The bolts are placed equispaced on a bolt circle diameter and the number of bolt depends on the shaft diameter d.



Rigid Flange Coupling

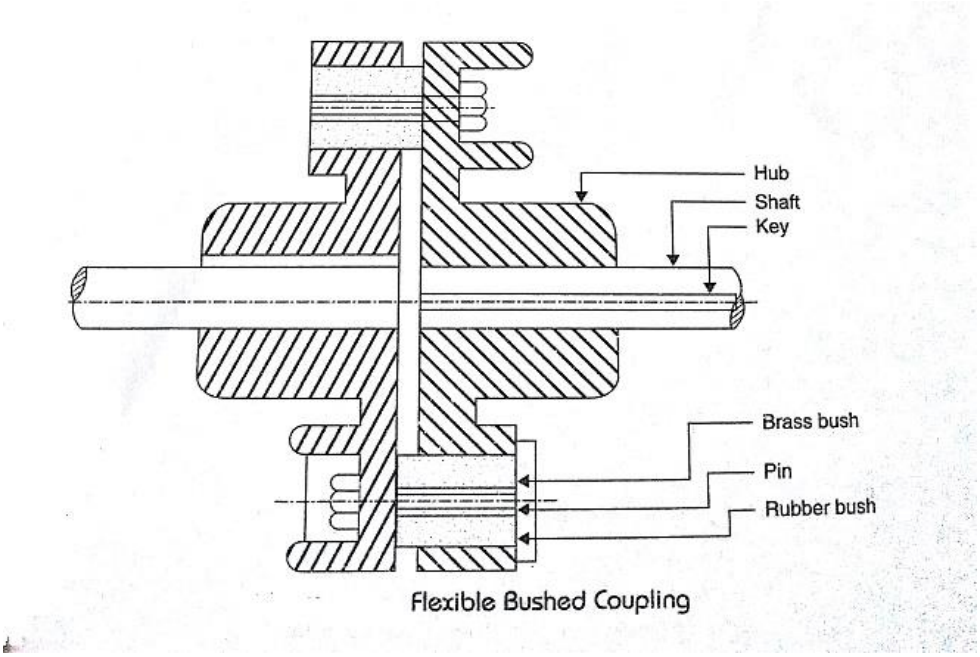
Advantages of rigid coupling

- It has high torque transmission capacity.
- It is easy to assemble and disassemble.
- It has simple design and is easy to manufacture.

Disadvantages of rigid coupling

- It cannot tolerate misalignment between two shaft.
- It can be used only where the motion is free from shocks and vibrations.
- It requires more space than that of other coupling like muff coupling.

**Flexible coupling:** It is used to connect two shafts which are having lateral and angular misalignment.



Flexible Bushed Coupling

Advantages of flexible bushed coupling

- It can bear 0.5 mm of lateral or axial misalignment and $1.5^0$ of angular misalignment.
- It prevents transmission of shock from one shaft to the other and absorbs vibrations.
- It is used for transmission of high torque.
- It is easy to assemble and disassemble due to simple design.

Disadvantages

- Its cost is higher than the rigid flange coupling.
- It rquires more radial space.

1. Rigid Coupling

   (a)Box or Muff coupling or Sleeve coupling.

   (b)Clamp or Compression coupling.

   (c) Flange coupling

2. Flexible Coupling

   (a)Bushed pin coupling.

(b) Oldhams coupling.

(c) Universal coupling.

**FEATURES OF SHAFT COUPLING**

A good shaft coupling has following features.

(i)It should be easy to connect and disconnect ,

(ii)It should provide perfect alignment of shafts,

(iii)It should avoid transmission of shock loads between shafts,

(iv)It should transmit full power between shafts without losses.

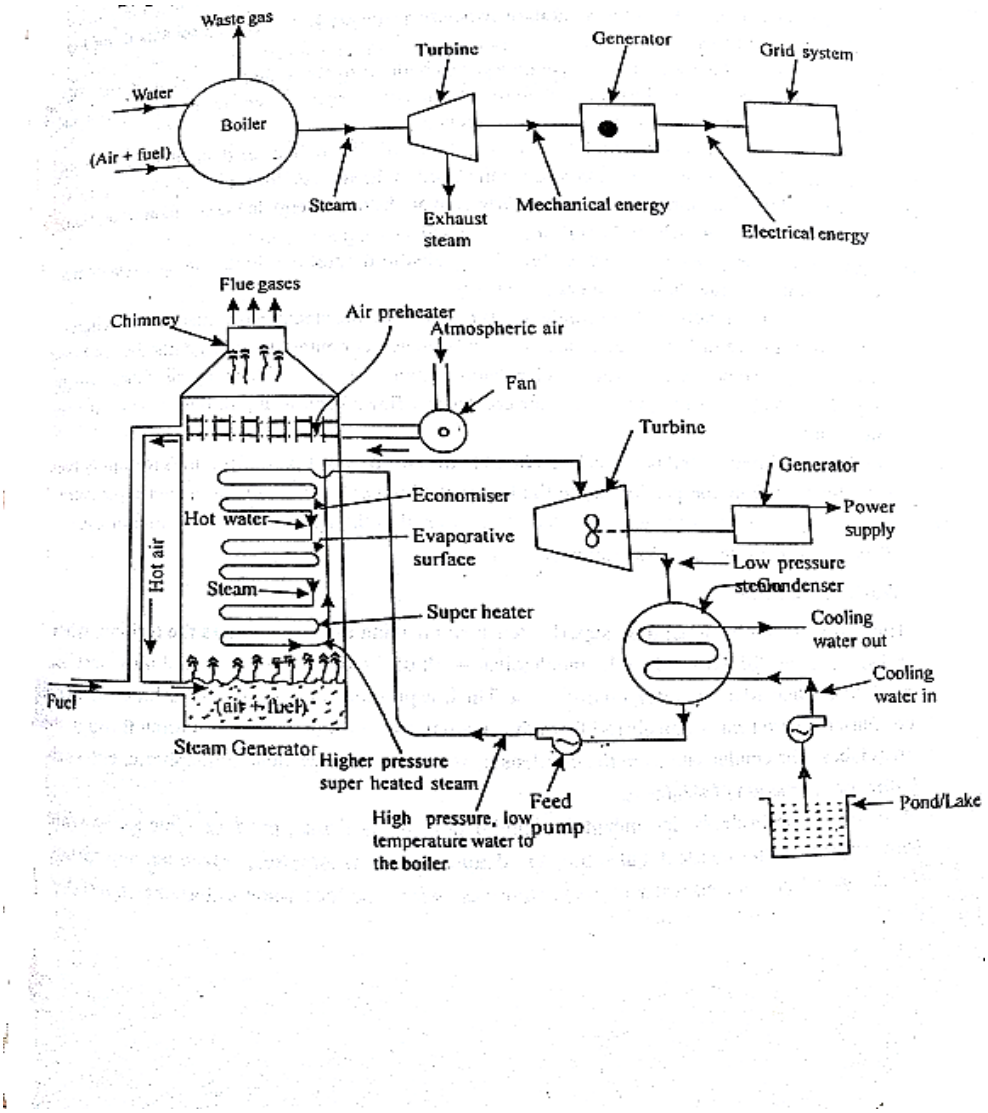
## Q. Explain the working of a steam power plant.

**[BPUT 2nd SEM 2017-18]**

**[BPUT 2nd SEM 2018-19]**

**STEAM POWER PLANT**

The function of a steam power plant is to convert the chemical energy in fossil fuel(coal , oil ,gas etc) into mechanical or electrical energy through the expansion of steam from a high pressure to low pressure in a suitable prime mover.



**Construction Details**

**(vii) Steam generator( Boiler) with their accessories**

A steam generator or boiler is usually, a closed vessel made of steel. Its function is to transfer the heat produced by the combustion of fuel to water , and ultimately to generate steam.

**Accessories**

**(d) Superheater-** The superheater is situated at the hottest part of the boiler. It is meant to raise the steam temperature above the saturation temperature (superheated steam) by absorbing heat from the flue gases.

**(e) Economiser**- The function of an economizer in a boiler is to absorb heat from the outgoing flue gases ( waste gases from the chimney) , to raise the temperature of the feed water coming from the condenser, before it enters the evaporative section.

**(f) Air Preheater**- The function of the air preheater in a boiler is to raise the temperature of air with the help of outgoing flue gases, before the air is led to the furnace for the combustion of fuel.

**(viii) Steam Turbine**

The function of a turbine is to convert the heat energy in the steam into rotational power of the shaft on which the turbine is mounted.

(ix) **Generator**

The generator which is directly coupled to the turbine shaft , converts mechanical energy of the turbine shaft into electrical energy.

(x) **Condenser**

The function of the condenser is to condense the steam which has been discharged from low pressure turbine. The condenser is a large vessel containing a large number of brass tubes through which the cold water is circulated continuously for condensing the steam flowing outside the surface of the tubes. The hot condensate flows back to the boiler to be converted into steam.

(xi) **Feed Pump**

A boiler feed pump is like a heart to the steam power plant. Its aim is to supply feed water ( coming from condenser) to the boiler at a high pressure than atmospheric pressure.

**(xii) Chimney**

The flue gases from the boiler, after removal of the fly ash in the precipitators, arelet off to atmosphere through the chimney.

**Working Principle**

High pressure , high temperature superheated steam leaving the boiler enters the turbine, where it does some useful work. Then the mechanical work of the turbine is converted into electrical work by the help of a generator, coupled to it. The low pressure steam from the turbine enters the condenser, where heat is transferred from the steam to the cooling water circulating through the brass tubes. The condensate from the condenser, at a pressure more than atmospheric , enters the boiler for production of steam. A furnace , beneath the boiler, meant for combustion of fossil fuel, produces flue gases which heat water and then superheated it at superheated zone. The exhaust gases, before leaving through the chimney heat the feed water in the economizer before the feed water enters the steam drum and then heat the air for combustion in a zone called air preheater. An induced draught fan is used to exhaust ash laden flue gaese through the interior of the boiler, an dust extracting equipment and to the chimney.

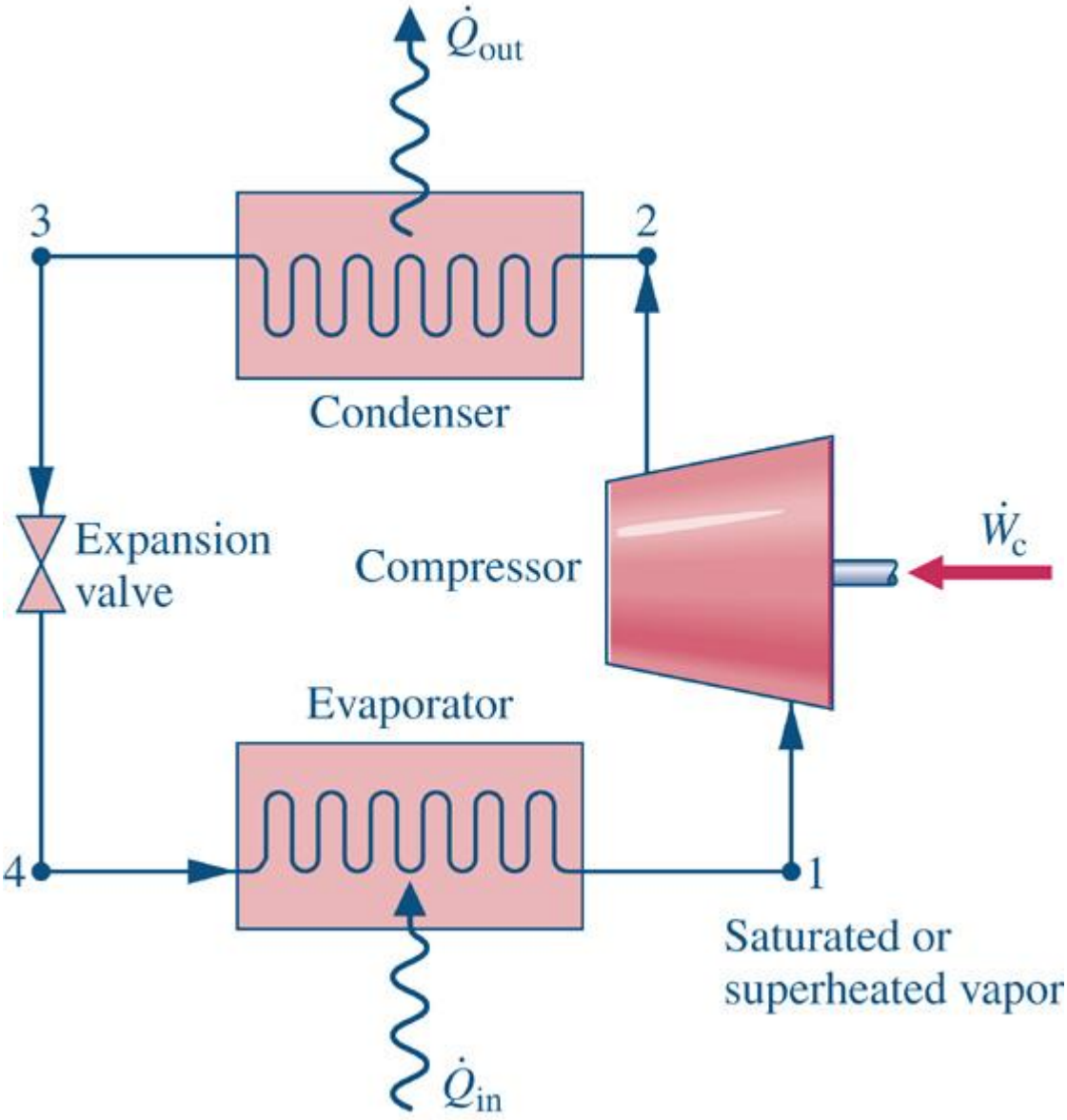
## Q. Explain the working of a refrigeration cycle with a schematic diagram. Represent the same on T-S diagram. [BPUT 1st SEM 2016-17]

## Vapour Compression Refrigeration System(VCRS)

• In this system, a liquid refrigerant is used which is alternately evaporates and condenses for absorbing heat from the refrigerated space and for rejecting heat to the surroundings

• During the evaporation process, it absorbs heat from and gets converted from liquid to vapour.

• During the condensing process, it rejects heat and gets condensed from vapour to liquid.




## Basic components of a VCR system

• Compressor: Suck the low temperature refrigerant vapour from the evaporator and to compress it to a high pressure and temperature

• Condenser: Condense the high pressure and temperature refrigerant vapour from the compressor, by rejecting its latent heat to the cooling water at ambient temperature( or rejects heats to ambient air)

• Expansion valve(Throttle valve): Throttle the liquid refrigerant from the condenser. By throttling, the pressure and temperature reduces and the refrigerant becomes partly liquid and partly vapour at the required low temperature. It also regulates the flow of liquid refrigerant to the evaporator

• Evaporator: To evaporate the liquid refrigerant by absorbing the latent heat of vapourization from the cold refrigerated space.

## Working Principle of VCR Systems

It consists of four processes:

• 1-2 Isentropic compression in a compressor

• 2-3 Constant-pressure heat rejection in a condenser

• 3-4 Throttling in an expansion device(constant enthalpy)

• 4-1 Constant-pressure heat absorption in an evaporator

**Working Principle**

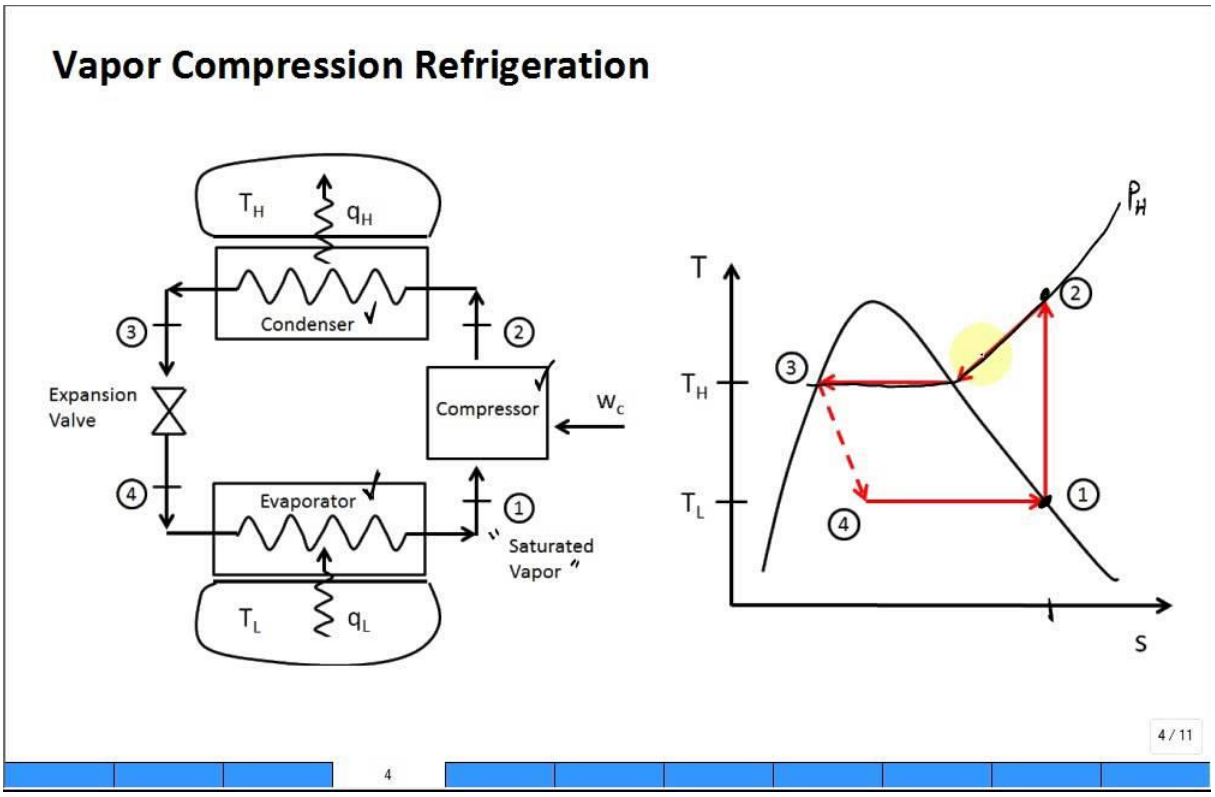
• In vapour-compression refrigeration cycle, the refrigerant enters the compressor at state 1 as saturated vapour and is compressed isentropically to the condenser pressure. The temperature of the refrigerant increases during this isentropic compression process to well above the temperature of the surrounding medium.

• The refrigerant then enters the condenser as superheated vapour at state 2 and leaves as saturated liquid at state 3 as a result of heat rejection to the surroundings. The temperature of the refrigerant at this state is still above the temperature of the surroundings

• The saturated liquid refrigerant at state 3 is throttled to the evaporator pressure by passing it through an expansion valve or capillary tube. The temperature of the refrigerant drops below the temperature of the refrigerated space during this process

• The refrigerant enters the evaporator at state 4 as a low-quality saturated mixture, and it completely evaporates by absorbing heat from the refrigerated space. The refrigerant leaves the evaporator as saturated vapour and re-enters the compressor, completing the cycle

• The area under the process curve 4-1 represents the heat absorbed by the refrigerant in the evaporator, and the area under the process curve 2-3 represents the heat rejected in the condenser




## Q. What is PMM1?Explain with suitable example. [BPUT 1st SEM 2016-17]

**PERPETUAL MOTION MACHINE OF THE FIRST KIND**

- The first law states the general principle of the conservation of energy. Energy is neither created nor destroyed , but only gets transformed from one form to another.
- There can be no machine which could continuously supply mechanical work without some other form of energy disappearing simultaneously.
- Such a fictitious machine is called a perpetual motion machine of the first kind, or in brief, PMM1. A PMM1 is thus impossible.
- The converse of the above statement is also true, i. e. there can be no machine which would continuously consume work without some other form of energy appearing simultaneously.

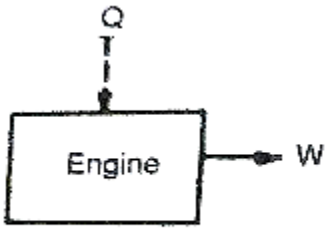



FIG. A PMM1

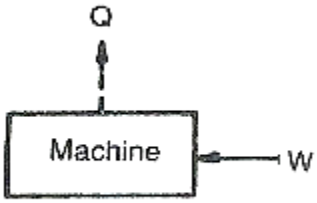



FIG. The converse of PMM1

**Q. Explain briefly about slip and creep of a belt in belt drive.**

**[BPUT 1st SEM 2016-17]**

# SLIP

The effect of slip is a decrease in the speed of belt on driving shaft and then driven shaft.

Let $\omega_1$ is angular velocity of driving pulley

$\omega_2$ is angular velocity of driven pulley

$S_1$ is percentage slip between driving pulley and belt

$S_2$ is percentage slip between driven pulley and belt

S is total percentage slip

Peripheral speed of the driving pulley = $\frac{\omega_1 D_1}{2}$

Speed of belt on driving pulley= $\frac{\omega_1 D_1}{2}\left(\frac{100-S_1}{100}\right)$

This is also the speed of the belt on driven pulley

Now , peripheral speed of driven pulley = $\frac{\omega_1 D_1}{2}\left(\frac{100-S_1}{100}\right)\left(\frac{100-S_2}{100}\right)$

If S is total slip percentage, peripheral speed of driven pulley= $\frac{\omega_1 D_1}{2}\left(\frac{100-S}{100}\right)$

Or $\frac{\omega_1 D_1}{2}\left(\frac{100-S_1}{100}\right)\left(\frac{100-S_2}{100}\right)=\frac{\omega_1 D_1}{2}\left(\frac{100-S}{100}\right)$

Or $S= S_1 +S_2-0.01 S_1S_2$

Thus velocity ratio, VR= $\frac{D_1}{D_2}\left(\frac{100-S}{100}\right)=\frac{N_2}{N_1}$

# Creep

When belt passes from slack to tight side, a certain portion of belt extends and again contracts when belt passes through tight to slack side. Due to fluctuation in length of the belt , there is relative motion between belt and pulley surface. This relative motion is known as creep. Considering the creep , velocity ratio can be expressed by,

$$\frac{N_2}{N_1}=\frac{D_1}{D_2}x\frac{E+\sqrt{\sigma_2}}{E+\sqrt{\sigma_1}}$$

Where $N_1$ and $N_2$ are the speeds of driving and driven pulleys , respectively; $D_1$ and $D_2$ are the diameters of driver and driven pulleys, respectively; $\sigma_1$ and $\sigma_2$ are the stresses developed in tight and slack side of belt, respectively; and E is the modulus of elasticity of belt materials.

## Q. Prove that amount of heat transferred in a constant pressure process is change in enthalpy.

**[BPUT 1st SEM 2016-17]**

The first law for a closed stationary system of unit mass

$dQ=du+pdv$

Again $h=u+pv$

$dh=du+pdv+vdp$

$=dQ+vdp$

$$dQ=dh-vdp \qquad \text{(iii)}$$

For constant pressure process dp=0

$$(dQ)_p=dh$$

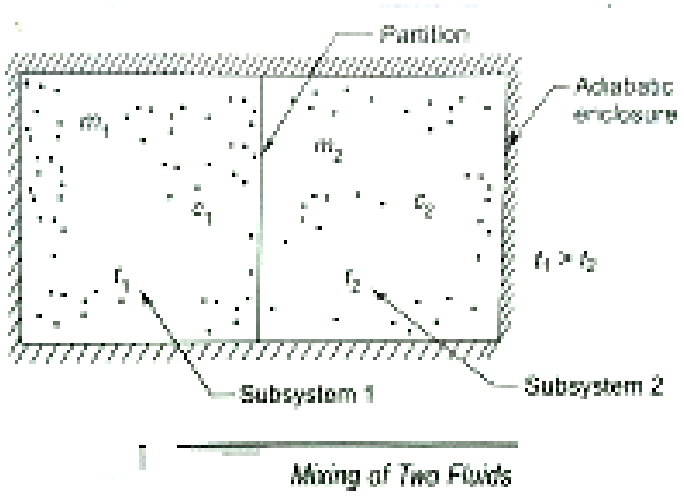
Or $(Q)_p=(\Delta h)_p$

Hence the heat transfer in constant pressure process is change in enthalpy.

## Q. Show that adiabatic mixing of two fluids is irreversible.

**[BPUT 1st SEM 2016-17]**

**MIXING OF TWO FLUIDS**




Mixing of Two Fluids

- Subsystem 1 having a fluid of mass $m_1$ , specific heat $c_1$ , and temperature $t_1$ , and subsystem 2 consisting of a fluid of mass $m_2$ , specific heat $c_2$ , and temperature $t_2$ , comprise a composite system in an adiabatic enclosure.
- When the partition is removed, the two fluid mix together , and at equilibrium, let $t_f$ be the final temperature, and $t_2 < t_f < t_1$. Since energy interaction is exclusively confined to the two fluids , the system being isolated

$m_1c_1(t_1-t_f)=m_2c_2(t_f-t_2)$

Or $$t_f = \frac{m_1c_1t_1 + m_2c_2t_2}{m_1c_1 + m_2c_2}$$

- Entropy change for the fluid in subsystem 1

$$\Delta S_1 = \int_{T_1}^{T_f} \frac{dQ_{rev}}{T} = \int_{T_1}^{T_f} \frac{m_1c_1dT}{T} = m_1c_1 \ln \frac{T_f}{T_1}$$

$$= m_1c_1 \ln \frac{t_f + 273}{t_1 + 273}$$

This will be negative , since $T_1>T_f$

- Entropy change for the fluid in subsystem 2

$$\Delta S_2 = \int_{T_2}^{T_f} \frac{m_2c_2dT}{T} = m_2c_2 \ln \frac{T_f}{T_2} = m_2c_2in \frac{t_f + 273}{t_2 + 273}$$

This will be positive , since $T_2<T_f$

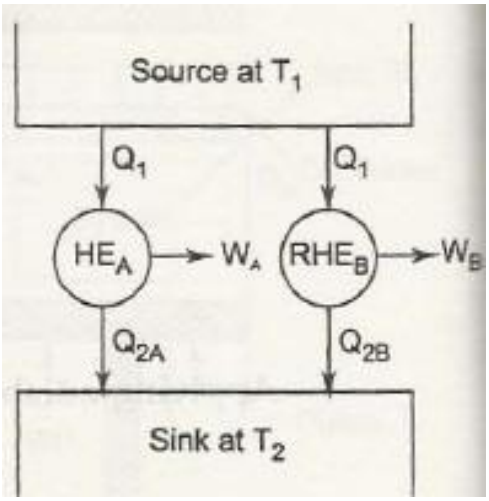
Hence, $\Delta S_{univ}=\Delta S_1+\Delta S_2= m_1c_1 \ln \frac{T_f}{T_1} + m_2c_2 \ln \frac{T_f}{T_2}$

$\Delta S_{univ}$ will be positive definite , and the mixing process is irreversible.

## Q. State and prove CARNOT'S THEOREM.

**CARNOT'S THEROEM**

- It states that of all heat engines operating between a given constant temperature source and a given constant temperature sink , none has a higher efficiency than a reversible engine.



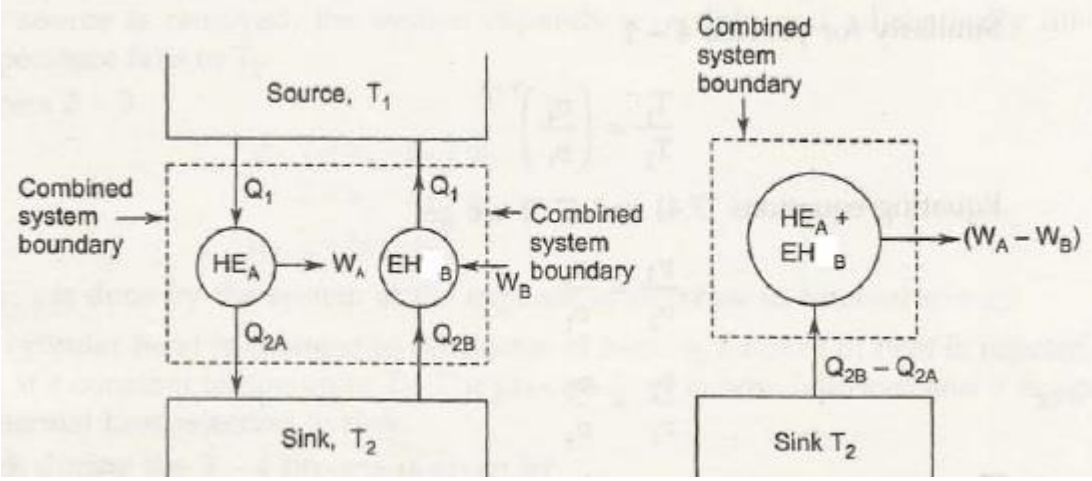

- Let two heat engines $E_A$ and $E_B$ operate between the given source at temperature $T_1$ and the given sink at temperature $T_2$ as shown in above figure.
- Let $E_A$ be any heat engine and $E_B$ be any reversible heat engine . We have to prove that the efficiency of $E_B$ is more than that of $E_A$ .
- Let us assume that this is not true and $\eta_A > \eta_B$ . Let the rates of working of the engines be such that

$Q_{1A}=Q_{1B}=Q_1$

Since $\eta_A > \eta_B$

$$\frac{W_A}{Q_{1A}} > \frac{W_B}{Q_{1B}}$$

Or $W_A > W_B$




- Now . let $E_B$ be reversed . Since $E_B$ is a reversible heat engine , the magnitudes of heat and work transfer quantities will remain the same, but the directions will be reversed, as shown in the above figure.
- Since $W_A > W_B$ , some part of $W_A$ (equal to $W_B$) may be fed to drive the reversed heat engine $E_B$.
- Since $Q_{1A}=Q_{1B}=Q_1$, the heat discharged by $E_B$ may be supplied to $E_A$ . The source may , therefore , be eliminated. The net result is that $E_A$ and reversed $E_B$ together constitute a heat engine which, operating in a cycle , produces net work $W_A-W_B$ while exchanging heat with a single reservoir at $T_2$ .
- This violates the Kelvin-Planck statement of the second law. Hence the assumption that $\eta_A > \eta_B$ is wrong.

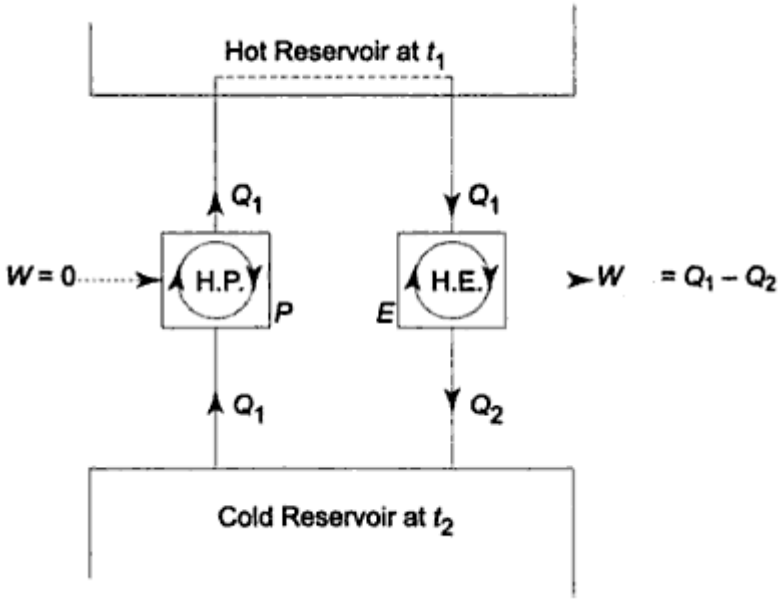
  Therefore $\eta_B \geq \eta_A$

## Q. What is EQUIVALENCE OF KELVIN-PLANCK AND CLAUSIUS STATEMENTS?

- The equivalence of the two statements will be proved if it can be shown that the violation of one statement implies the violation of the second and vice versa.
- Let us first consider a cyclic heat pump P which transfers heat from a low temperature reservoir($t_2$) to a high temperature reservoir($t_1$) with no other effect, i.e. with no expenditure of work, violating Clausius statement.
- Let us assume a cyclic heat engine E operating between the same thermal energy reservoirs, producing $W_{net}$ in one cycle. The rate of working of the heat engine is such that it draws an amount of heat $Q_1$ from the hot reservoir equal to that discharged by the heat pump. Then the

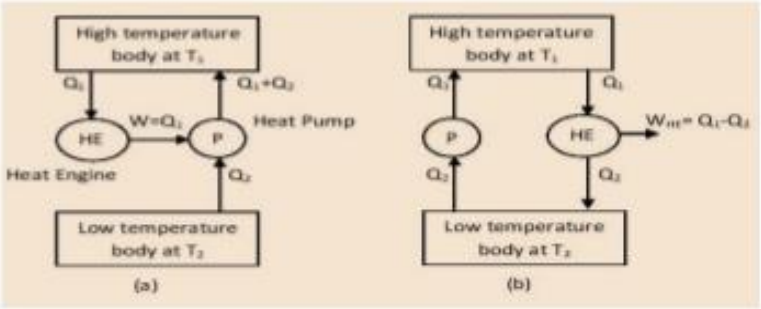
hot reservoir may be eliminated and the heat $Q_1$ discharged by the heat pump is fed to the heat engine.

- So we see that the heat pump P and the heat engine E acting together constitute a heat engine operating in cycles and producing net work while exchanging heat only with one body at a single fixed temperature. This violates the Kelvin-Planck statement.



## Equivalence of Kelvin- Planck statement and Clausius statement

Though Kelvin- Planck statement and Clausius statement of second law of thermodynamics appear two different interpretations of the same basic fact, but both these statements are equivalent in all aspects. For establishing equivalence of the two statements, it has to be proved that violation of Kelvin-Planck statement implies the violation of Clausius statement and vice-versa. This is explained as under:




- Let us now consider a perpetual motion machine of the second kind which produces net work in a cycle by exchanging heat with only one thermal energy reservoir(at $t_1$) and thus violates the Kevin-Planck statement.
- Let us assume a cyclic heat pump (P) extracting heat $Q_2$ from a low temperature reservoir at $t_2$ and discharging heat to the high temperature reservoir at $t_1$ with the expenditure of work W equal to what the PMM2 delivers in a complete cycle.
- So E and P together constitute a heat pump working in cycles and producing the sole effect of transferring heat from a lower to a higher temperature body, thus violating the Clausius statement.

## Q. What do you mean by thermodynamic equilibrium?

## Thermodynamic Equilibrium

Thermodynamics deals with equilibrium states. The word equilibrium implies a state of balance. In an equilibrium state there are no unbalanced driving forces within the system. A system in equilibrium experiences no changes when it is isolated from its surroundings.

A system is said to be in thermodynamic equilibrium, if it satisfies the following requirements of equilibrium

(i)Mechanical equilibrium (ii)Thermal equilibrium (iii) Chemical equilibrium

**THERMAL EQUILIBRIUM**

If the temperature of the system does not change with time and has same value at all points of the system , then the system is said to be in thermal equilibrium.

**MECHANICAL EQUILIBRIUM**

If there are no unbalanced forces within the system or between the surroundings, and the pressure in the system is same at all points and does not change with respect to time, then the system is said to be in mechanical equilibrium.

**CHEMICAL EQUILIBRIUM**

If there is no chemical reaction takes place in the system and the chemical composition which is same through the system does not vary with time, then the system is said to be in chemical equilibrium.

## Q. Define state, path, process and cycle.

**State:** It is the condition of a system as defined by the values of all its properties. It gives a complete description of the system. Any operation in which one or more properties of a system change is called a change of state.

**Path And Process**

The succession of states passed through during a change of state is called the path of the system. A system is said to go through a process if it goes through a series of changes in state. If a path is completely specified ,then it is called a process.

Example-isothermal process, a process in which temperature remains constant.

**CYCLE**

A thermodynamic cycle is defined as a series of state changes such that the final state is identical with the initial state.

## Q. What is path and point function? Differentiate.

**PATH FUNCTION AND POINT FUNCTION**

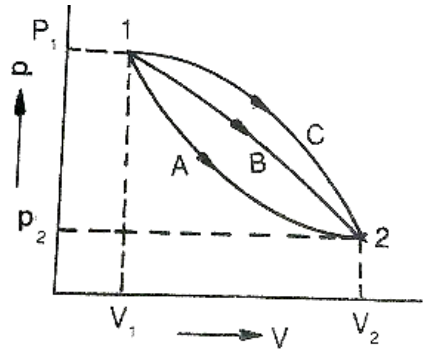



FIG. *Work—a path function*

- With reference to the above figure ,it is possible to take a system from state 1 to state2 along many quasi-static paths, such as A,B or C. Since the area under each curve represents the work for each process, the amount of work involved in each case is not a function of the end states of the process, and it depends on the path the system follows in going from state1 to state2. For this reason, work is called a path function and is an inexact or imperfect differential.
- Thermodynamic properties are point functions, since for a given state, there is a definite value for each property, The change in a thermodynamic property of a system in a change of state is independent of the path the system follows during the change of state, and depends only on the

initial and final states of the system. The differentials of point functions are exact or perfect differentials.

**DIFFERENTIATE BETWEEN POINT FUNCTION VS PATH FUNCTION**

| Point Function | Path Function |
|---|---|
| 1. Any quantity whose change is independent of the path is known as point function | 1. Any quantity, the value of which depends on the path followed during a change of state is known as path function |
| 2. The magnitude of such quantity in a process depends on the state | 2. The magnitude of such quantity in a process is equal to the area under the curve on a property diagram |
| 3. These are exact differential | 3. These are inexact differential. Inexact differential is denoted by δ |
| 4. Properties are the examples of point function like pressure(P), volume(V),Temp.(T),Energy etc. | 4. Ex: Heat and work |

## Q. Derive PdV work for various processes.

**pdV-WORK IN VARIOUS QUASI-STATIC PROCESSES**

(a) Constant pressre process(isobaric or isopiestic process)

$$W_{1-2} = \int_{V_1}^{V_2} pdV = p(V_2 - V_1)$$

(b) Constant volume(isochoric process)

$$W_{1-2} = \int pdV = 0$$

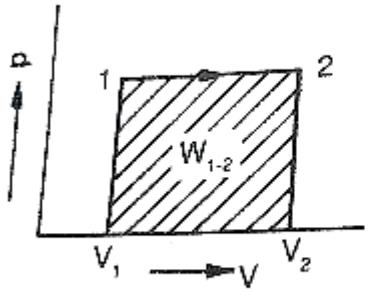



FIG. Constant pressure process

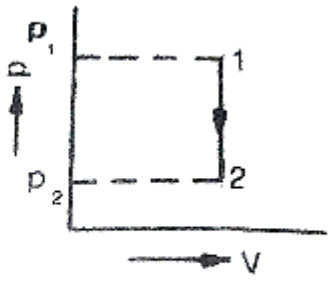



FIG. Constant volume process

(c) Isothermal process or process in which Pv=C

$$W_{1-2} = \int_{V_1}^{V_2} p dV$$

$pV=p_1V_1=C$

$$p=\frac{(p_1V_1)}{V}$$

$$W_{1-2} = p_1V_1\int_{V_1}^{V_2}\frac{dV}{V} = p_1V_1 \ln\frac{V_2}{V_1}$$

$=p_1V_1\ln(P_1/P_2)$

(d) Polytropic Process in which $PV^n=C$, where n is a constant

$$pV^n = p_1V_1^n = p_2V_2^n = C$$

Or $$p = \frac{p_1V_1^n}{V^n}$$

Hence $$W_{1-2} = \int_{V_1}^{V_2} pdV = \int_{V_1}^{V_2} \frac{p_1 V_1^n}{V^n}.dV = \left(p_1 V_1^n\right)\left[\frac{V^{-n+1}}{-n+1}\right]_{V_1}^{V_2}$$

$$= \frac{p_1 V_1^n}{1-n}\left(V_2^{1-n} - V_1^{1-n}\right) = \frac{p_2 V_2^n x V_2^{1-n} - p_1 V_1^n x V_1^{1-n}}{1-n}$$

$$= \frac{p_1 V_1 - p_2 V_2}{n-1} = \frac{p_1 V_1}{n-1}\left[1 - \left(\frac{p_2}{p_1}\right)^{n-1/n}\right]$$

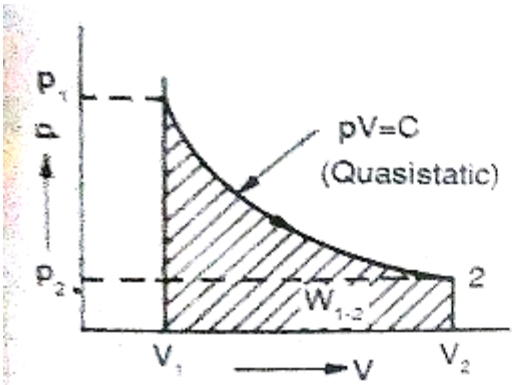



FIG. Process in which pV = constant

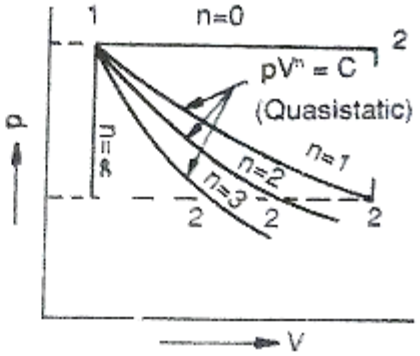
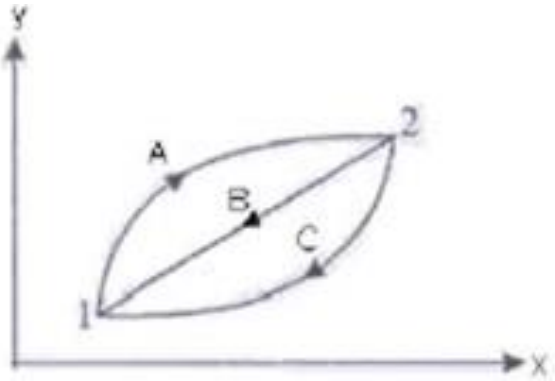



FIG. Process in which $pV^n$ = constant

## Q. Prove ENERGY –A PROPERTY OF THE SYSTEM.




- Consider a system which changes its state from state 1 to state 2 by following the path A and returns from state 2 to state 1 by following the path B as shown in the figure. So the system undergoes a cycle.

- Writing the first law for path A

$Q_A = \Delta E_A + W_A$ (I)

And for parh B

$Q_B = \Delta E_B + W_B$ (ii)

The processes A and B together constitute a cycle, for which

$(\sum W)_{cycle} = (\sum Q)_{cycle}$

Or $W_A + W_B = Q_A + Q_B$

Or $Q_A - W_A = W_B - Q_B$ (iii)

From equations –(i),(ii)&(iii), it gives

$\Delta E_A = -\Delta E_B$ (iv)

Similarly , had the system returned from state 2 to state 1 by following the path C instead of path B

$\Delta E_A = -\Delta E_C$ (v)

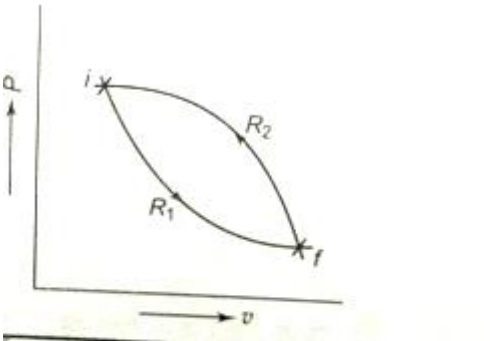
From equation –(iv) & (v)

$\Delta E_B = \Delta E_C$ (vi)

Therefore, it is seen that the change in energy between two states of a system is the same, whatever path the system may follow in undergoing that change of state.If some arbitrary value of energy is assigned to state 2, the value of energy at state 1 is fixed independent of the path of the system follows.

Therefore , energy has a definite value for every state of the system. Hence , it is a point function and a property of the system

## Q. Explain ENTROPY.




Two Reversible Paths $R_1$ and $R_2$ Between Two Equilibrium States i and f

- Let a system be taken from an initial equilibrium state I to a final equilibrium state f by following the reversible path $R_1$ as shown in the figure above. The system is brought back from f to i by following another reversible path $R_2$ . Then the two paths $R_1$ and $R_2$ together constitute a reversible cycle.
- From Clausius' theorem

$$\oint_{R_1R_2} \frac{dQ}{T} = 0$$

- The above integral may be replaced as the sum of two integrals, one for path $R_1$ and the other for path $R_2$.

$$\int_{i_{R_1}}^{f} \frac{dQ}{T} + \int_{f_{R_2}}^{i} \frac{dQ}{T} = 0$$

Or

$$\int_{i_{R_1}}^{f} \frac{dQ}{T} = -\int_{f_{R_2}}^{i} \frac{dQ}{T}$$

Since $R_2$ is a reversible path

$$\int_{i_{R_1}}^{f} \frac{dQ}{T} = \int_{i_{R_2}}^{f} \frac{dQ}{T}$$

- Since $R_1$ and $R_2$ represent any two reversible paths, $\int_{i_R}^{f} \frac{dQ}{T}$ is independent of the reversible path connecting I and f. Therefore , there exists a property of a system whose value at the final state f minus its value at the initial state i is equal to $\int_{i_R}^{f} \frac{dQ}{T}$.
- This property is called entropy, and is denoted by S.
- If $S_i$ is the entropy at the initial state I, and $S_f$ is the entropy at the final state f, then

$$\int_{i_R}^{f} \frac{dQ}{T} = S_f - S_i$$

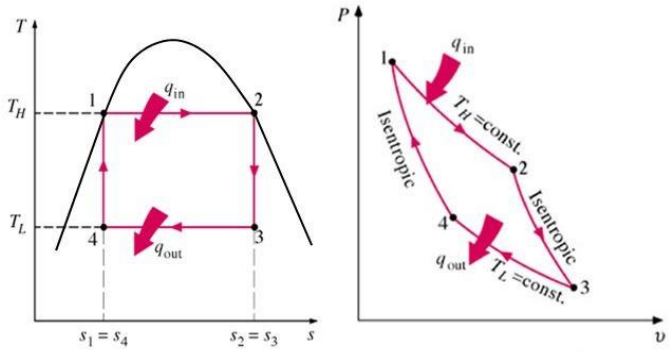
- When the two equilibrium states are infinitesimally near

$$\frac{dQ_R}{T} = dS$$

- Where dS is an exact differential because S is a point function and a property. The subscript R in dQ indicates that heat dQ is transferred reversibly.
- The word 'entropy' was first used by Clausius, taken from the Greek word 'tropee' meaning 'transformation'. It is an extensive property , and has the unit J/K. The specific entropy

S=S/m in J/KgK

## Q. Draw T-S diagram of CARNOT Cycle and find its efficiency.



- The Carnot cycle comprising two reversible isotherms and two reversible adiabatics forms a rectangle in the T-S plane as shown in the above figure.
- Process 1-2 represents reversible isothermal heat addition $q_{in}$ to the system at $T_H$ from an external source, process 2-3 is the reversible adiabatic expansion of the system producing $W_E$ amount of work , process 3-4 is the reversible isothermal heat rejection $q_{out}$ from the system to an external sink at $T_L$ , and the process 4-1 represents reversible adiabatic compression of the system consuming $W_c$ amount of work.
- Area 1234 repreents the net work output per cycle and the area under 1-2 indicates the quantity of heat added to the system $q_{in}$
- Hence $$\eta_{Carnot} = \frac{q_{in} - q_{out}}{q_{in}} = \frac{T_H(S_2 - S_1) - T_L(S_3 - S_4)}{T_H(S_2 - S_1)}$$

$$= \frac{T_H - T_L}{T_H} = 1 - \frac{T_L}{T_H}$$

## Q. What is IC Engine, classify . Name the major components with their functions.

**Internal combustion engine:**

In this engine, the combustion of air and fuels take place inside the cylinder and are used as the direct motive force. It can be classified into the following types:

1. According to the basic engine design- (a) Reciprocating engine (Use of cylinder piston arrangement), (b) Rotary engine (Use of turbine)

2. According to the type of fuel used- (a) Petrol engine, (b) diesel engine, (c) gas engine (CNG, LPG), (d) Alcohol engine (ethanol, methanol etc)

3. According to the number of strokes per cycle- (a) Four stroke and (b) Two stroke engine

4. According to the method of igniting the fuel- (a) Spark ignition engine, (b) compression ignition engine and (c) hot spot ignition engine

5. According to the working cycle- (a) Otto cycle (constant volume cycle) engine, (b) diesel cycle (const6. According to the fuel supply and mixture preparation- (a) Carburetted type (fuel supplied through the

carburettor), (b) Injection type (fuel injected into inlet ports or inlet manifold, fuel injected into the cylinder just before ignition).

7. According to the number of cylinder- (a) Single cylinder and (b) multi-cylinder engine

8. Method of cooling- water cooled or air cooled

9. Speed of the engine- Slow speed, medium speed and high speed engine

10. Cylinder arrangement-Vertical, horizontal, inline, V-type, radial, opposed cylinder or piston engines.

11. Valve or port design and location- Overhead (I head), side valve (L head); in two stroke engines: cross scavenging, loop scavenging, uniflow scavenging.

12. Method governing- Hit and miss governed engines, quantitatively governed engines and qualitatively governed engine

14. Application- Automotive engines for land transport, marine engines for propulsion of ships, aircraft engines for aircraft propulsion, industrial engines, prime movers for electrical generators.ant pressure cycle) engine, (c) dual combustion cycle (semi diesel cycle) engine.

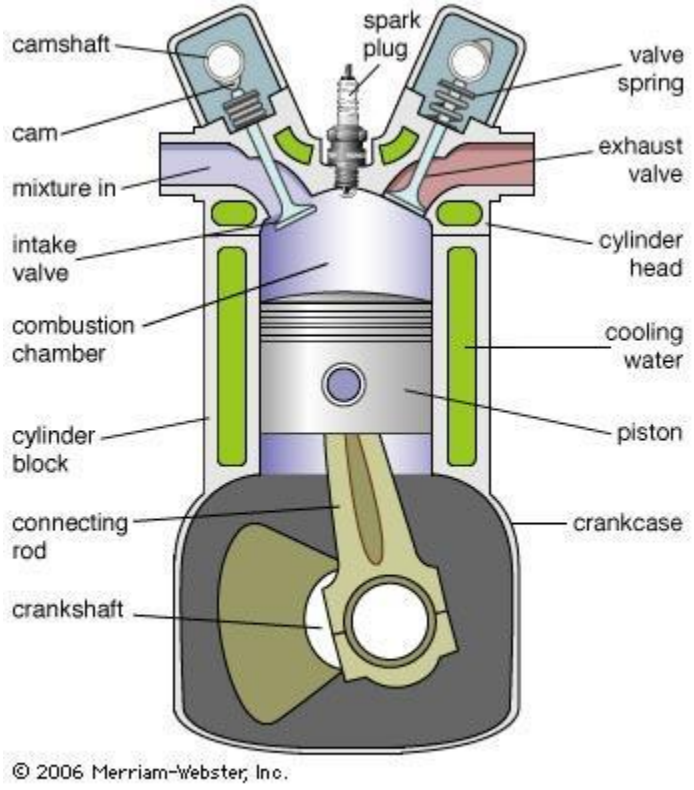
**Main components of reciprocating IC engines:**

Cylinder: It is the main part of the engine inside which piston reciprocates to and fro. It should have high strength to withstand high pressure above 50 bar and temperature above 2000 $^0$C. The ordinary engine is made of cast iron and heavy duty engines are made of steel alloys or aluminum alloys. In the multi-cylinder engine, the cylinders are cast in one block known as cylinder block.

Cylinder head: The top end of the cylinder is covered by cylinder head over which inlet and exhaust valve, spark plug or injectors are mounted. A copper or asbestos gasket is provided between the engine cylinder and cylinder head to make an air tight joint.

Piston: Transmit the force exerted by the burning of charge to the connecting rod. Usually made of aluminium alloy which has good heat conducting property and greater strength at higher temperature.

Figure  shows the different components of IC engine.




*Internal Combustion Engine*

Piston rings: These are housed in the circumferential grooves provided on the outer surface of the piston and made of steel alloys which retain elastic properties even at high temperature. 2 types of rings- compression and oil rings. Compression ring is upper ring of the piston which provides air tight seal to prevent leakage of the burnt gases into the lower portion. Oil ring is lower ring which provides effective seal to prevent leakage of the oil into the engine cylinder.

Connecting rod: It converts reciprocating motion of the piston into circular motion of the crank shaft, in the working stroke. The smaller end of the connecting rod is connected with the piston by gudgeon pin and bigger end of the connecting rod is connected with the crank with crank pin. The special steel alloys or aluminium alloys are used for the manufacture of connecting rod.

Crankshaft: It converts the reciprocating motion of the piston into the rotary motion with the help of connecting rod. The special steel alloys are used for the manufacturing of the crankshaft. It consists of eccentric portion called crank.

Crank case: It houses cylinder and crankshaft of the IC engine and also serves as sump for the lubricating oil.

Flywheel: It is big wheel mounted on the crankshaft, whose function is to maintain its speed constant. It is done by storing excess energy during the power stroke, which is returned during other stroke.

Terminology used in IC engine:

1. Cylinder bore (D): The nominal inner diameter of the working cylinder.

2. Piston area (A): The area of circle of diameter equal to the cylinder bore.

3. Stroke (L): The nominal distance through which a working piston moves between two successive reversals of its direction of motion.

4. Dead centre: The position of the working piston and the moving parts which are mechanically connected to it at the moment when the direction of the piston motion is reversed (at either end point of the stroke).

(a) Bottom dead centre (BDC): Dead centre when the piston is nearest to the crankshaft.

(b) Top dead centre (TDC): Dead centre when the position is farthest from the crankshaft.

5. Displacement volume or swept volume (Vs): The nominal volume generated by the working piston when travelling from the one dead centre to next one and given as,

$Vs=A \times L$

6. Clearance volume (Vc): the nominal volume of the space on the combustion side of the piston at the top dead centre.

7. Cylinder volume (V): Total volume of the cylinder.

$V= Vs + Vc$

8. Compression ratio (r): $r = V/V_C$

## Q. Define robot with functions, advantages and disadvantages.

**Definition of a Robot**

- A robot is an automatic device that performs functions normally ascribed to humans or a machine in the form of a human.

OR

- A robot is a software-controllable mechanical device that uses sensors to guide one or more end-effectors through programmed motion in a workpiece in order to manipulate physical objects.

**Functions of a Robot**

The functions of a robot can be classified into three areas:

1. "sensing" the environment by external sensors. Example :Vision, voice, touch, proximity and so on.
2. " Decision making" based on the information received from the sensors
3. "Performing" the task decided.

**ADVANTAGES AND DISADVANTAGES OF ROBOTS**

Following are the advantages and disadvantages of employing robots.

**Advantages:**

1. Lifting and moving heavy objects.
2. Working in hostile environments.
3. Providing repeatability and consistency.
4. Working during unfavourable hours.
5. Performing dull or monotonous jobs.
6. Increasing productivity, safety, efficiency and quality of products.
7. Achieving more accuracy than human beings.

**Disadvantages:**

1. The robots lack capability to respond in emergencies.
2. The initial and installation costs of equipments of robots are quit high.
3. They replace human workers, thus causing resentment among workers.

## Q. What are LAWS OF ROBOTICS?

Robots were required to perform according to three principles known as “three laws of robotics”, which are as valid for real robots as they are proposed by Sir Issac Asimov, and they are:

1st law- A robot should not injure a human being or , through inaction , allow a human to be harmed.

2nd law- A robot must obey orders given by humans except when that conflicts with the First law.

3rd law- A robot must protect its own existence unless that conflicts with the first or second law.

These are very general laws and apply even to other machines and appliances. They are always taken care of in any robot design.

## Q. What are different ROBOT CONFIGURATION?

The majority of commercially available robots can be grouped into four basic configurations:

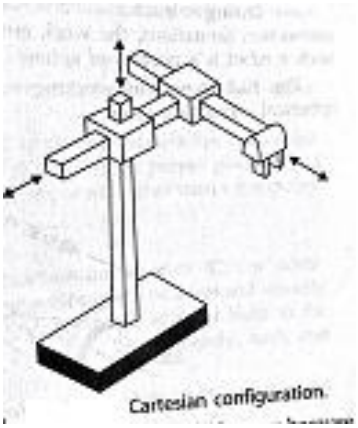
(i) Cartesian coordinate configuration

(ii) Cylindrical configuration

(iii) Spherical configuration

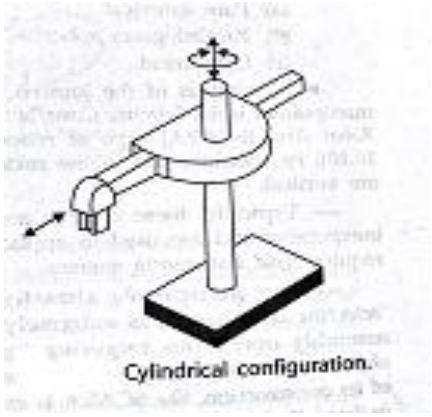
(iv) Jointed-arm configuration (Revolute)

**(i) Cartesian coordinate configuration:**



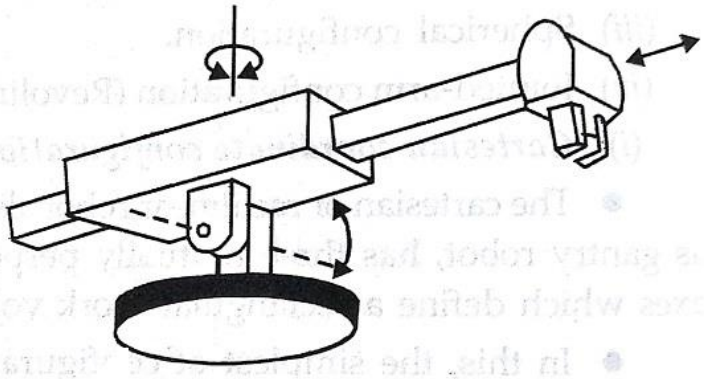

- The Cartesian or rectilinear robot also termed as gantry robot, has three mutually perpendicular axes which define a rectangular work volume.
- In this , the simplest of configurations, the link of the manipulator are constrained to move in a linear manner. Axes of a robotic device that behave in this way are referred to as “prismatic”.

**(ii) Cylindrical configuration:**




- Cylindrical configured robots use a vertical column with the robot arm attached to a side which can move up and down the column. Simultaneously, the arm can move radially with respect to the column.
- Usually , a full $360^0$ rotation in θ is not permitted, due to restrictions imposed by hydraulic , electrical, or pneumatic connections or lines. Also, there is minimum, as well as maximum extension(i.e .R), due to mechanical requirements. Consequently, the overall volume or work envelope is a portion of a cylinder.

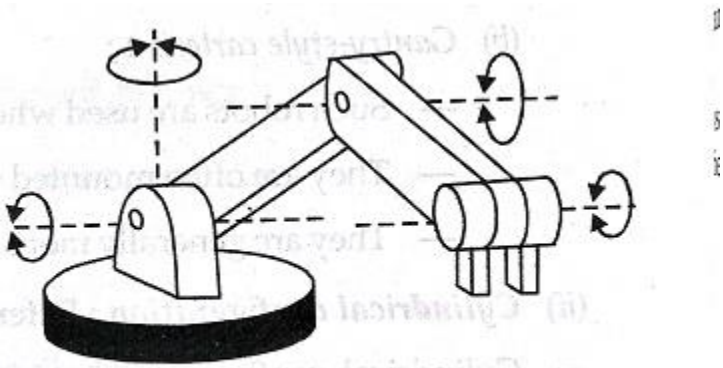
**(iii) Spherical (or polar) configuration:**



Spherical configuration.

- This configuration has a telescopic arm which pivots about a horizontal axis and also rotates about a vertical axis.
- Due to mechanical and/ or actuator connection limitations, the work envelope of such a robot is a portion of sphere.

**(iv) Jointed-arm configuration (Revolute):**



Jointed-arm configuration.

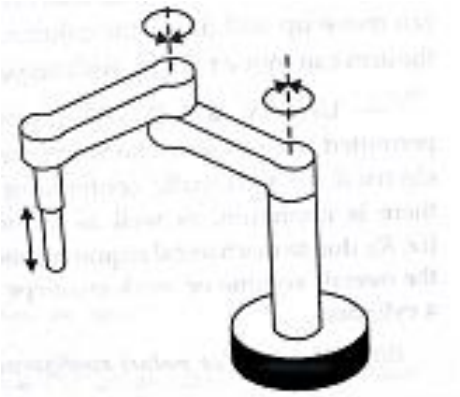
- The jointed-arm robot most resembles an human arm and consists of a series of links connected by rotary joints which when referenced from base are referred to as the shoulder, arm and wrist joints.
- There are actually three different types of jointed arm robots:

(a) Pure spherical.

(b) Parallelogram spherical.

(c) Cylindrical.

- A subclass of the jointed cylindrical manipulator is the Selective Compliance Assembly Robot Arm( SCARA) type of robot; its shoulder and elbow rotational axes are vertical.
- Typically , these devices are relatively inexpensive and are used in applications that require rapid and smooth motions.



SCARA body-and-arm assembly configuration.