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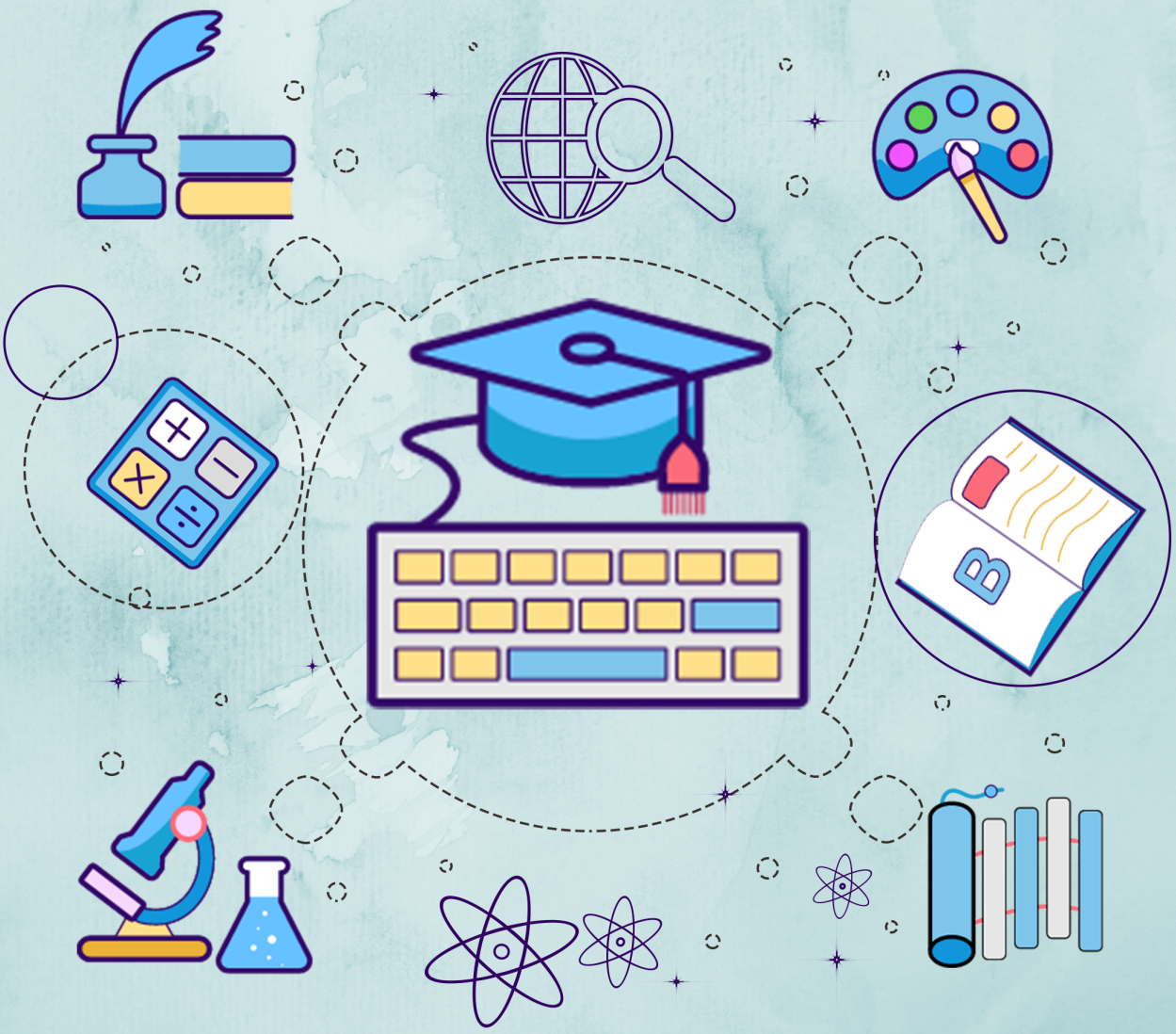

SYLLABUS | STUDY MATERIALS | TEXTBOOK

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KTU STUDY MATERIALS

BASICS OF MECHANICAL ENGINEERING

EST120

Module 2

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REFRIGERATION

Refrigeration

Transfer of heat from lower temperature region to a higher temperature region to maintain a space at a temperature lower than the surrounding atmospheric temperature.

Applications:

1. Long preservation of food items without spoiling.
2. Preserved transportation of food products.
3. Preserving life saving drugs, vaccines, etc.
4. Medical and surgical aid in operation theatres, intensive care units, etc.
5. Making ice, dry ice, cryogenic fluids etc.
6. Providing comfort air conditioning
7. Working environment for efficient operation of computers, precision machineries, etc.

Unit of Refrigeration

- Unit – tonne
- 1 tonne = amount of R.E produced by melting 1 tonne of ice at 0°C → water at 0°C in 24 hrs.

Coefficient Of Performance (COP)

$$COP = \frac{\text{Heat removed in kJ/s}}{\text{Work supplied in kW}}$$

Refrigeration System:

System used for accomplishing the process of refrigeration.

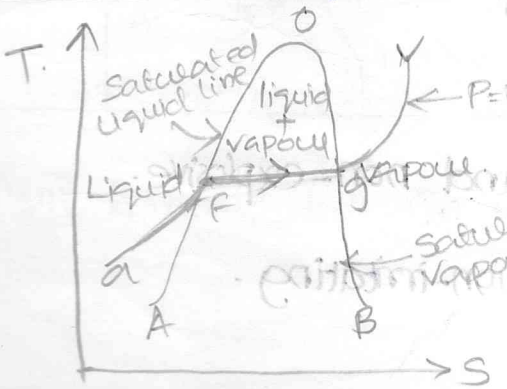
Refrigerated Space:

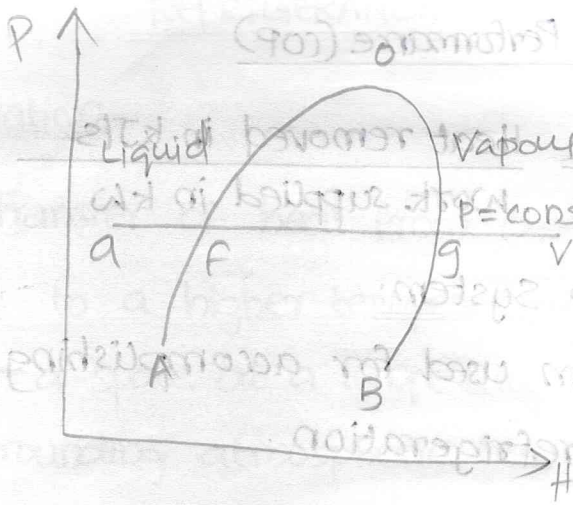
Region that is maintained at a temperature lower than its surroundings.

Refrigerant:

- Working fluid
- Heat carrying medium which absorbs heat from the low temperature region and discards it to the high temperature region.
  - e.g., Ammonia, Freon, etc.,

T-S and P-H Diagrams of Refrigerants.





OA - Saturated liquid line

OB - Saturated vapour line

afgv - constant pressure heat absorption process.

Left of AO - Liquid

Right of OB - Vapour

Between region - liquid + vapour.

Desirable Properties Of a Refrigerant.

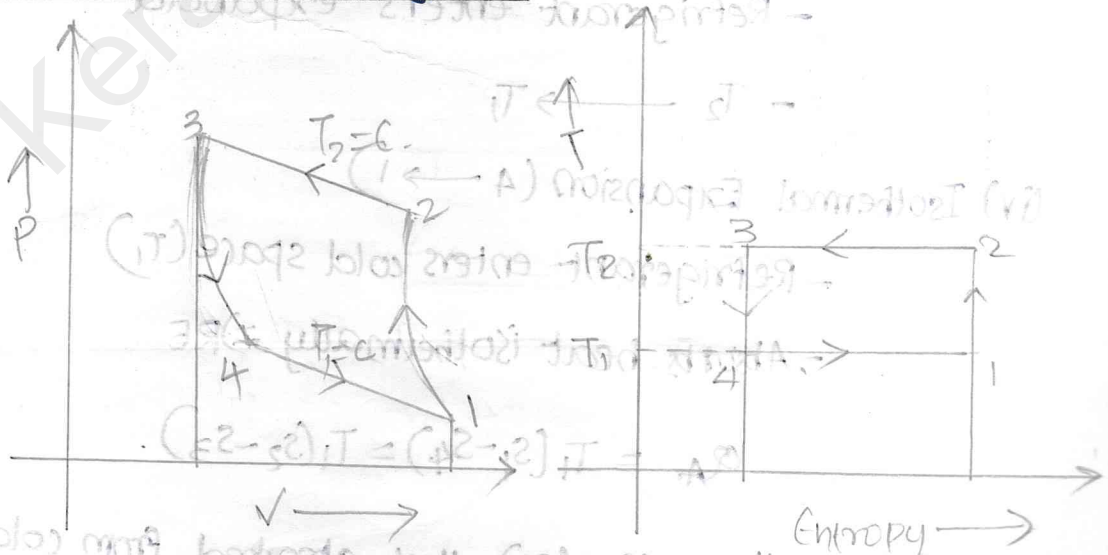
1. Saturation Pressure - slightly above / equal to atm. pressure
2. Latent heat - high
3. Specific vol. - low
4. Chemically stable.
5. Non-flammable and non-explosive.
6. Non-toxic and non-irritating.

7. Critical temperature - high (compared to condensing temp.)
8. Specific heat - low
9. Leakage detection easy
10. Cost - low and easy availability.
11. Non corrosive.

Reversed Carnot Cycle.

The Reversed Carnot cycle operating between two temperatures can give maximum COP for any mechanical refrigeration system. Hence, it is chosen as the criterion to find the perfection of practical refrigeration system.

p-V and T-s Diagram.



If the direction of Carnot heat engine cycle is reversed, then the cycle becomes reverted carnot refrigeration cycle. It consists of four reversible processes:

(i) Isentropic compression (1 → 2)

- Refrigent enters compressor
- Low Temp. (T_1) —compressed external work→ High Temp. (T_2)

(ii) Isothermal compression (2 → 3)

Heat rejected, $Q_R = T_2(S_2 - S_3)$

(iii) Isentropic Expansion (3 → 4)

- Refrigerant enters expander
- $T_2 \longrightarrow T_1$

(iv) Isothermal Expansion (4 → 1)

- Refrigerant enters cold space (T_1)
- Absorbs heat isothermally ⇒ RE

$$Q_A = T_1(S_1 - S_4) = T_1(S_2 - S_3).$$

- Refrigerating effect (RE) = Heat absorbed from cold space.

$$RE = Q_A = T_1 (S_2 - S_3)$$

$$Q_R = T_2 (S_2 - S_3)$$

$$COP = \frac{RE}{W} = \frac{Q_A}{Q_R - Q_A} = \frac{T_1}{T_2 - T_1}$$

Limitations:

- Isothermal heat absorption and rejection - practically not possible unless the process is very very simple.
- Isentropic compression and expansion - practically not possible due to the irreversibilities.

Vapour Compression Refrigeration.

(From text)

AIR CONDITIONING

Air conditioning is the process of controlling and maintaining the internal atmosphere in a confined space. It involves the simultaneous control of temperature, humidity, motion and purity of atmosphere in the space of interest.

Classification:

(i) Based on the major function of the air conditioning system:

- Comfort air conditioning
- Industrial air conditioning

(ii) Based on arrangement of equipments in the air conditioning system:

- Central system
- Unitary system
- Combined system

PSYCHOMETRIC PROPERTIES

Properties that define the characteristics of moist air are known as psychometric properties.

1. Specific humidity: (ω)
   (Absolute humidity / Humidity Ratio)

Ratio of mass of water vapour to the mass of dry air present in a given volume of atmospheric ~~air~~ air

2. Relative Humidity (ϕ)

$$\phi = \frac{\text{Actual mass of water vapour}}{\text{mass of water vapour contained in saturated air of same vol.}}$$

$\phi = 1$ (saturated air)

$\phi < 1$ (unsaturated air)

$\phi = 0$ (dry air)

3. Dry Bulb Temperature(T):

Temperature of atm. air measured by an ordinary thermometer.

4. Wet Bulb Temperature (T_W):

Temperature of atm. air measured by a thermometer whose bulb is covered by a wetted cotton wick.

5. Dew Point Temperature(T_{dp}):

Temperature of atm. air at which the water vapour present in the air starts condensing.

Condensation occurs when air is cooled at constant pressure to a temperature below the dew point temperature.

HUMIDIFICATION AND DEHUMIDIFICATION

- ↑sing humidity of air – humidification
- ↓sing humidity of air – dehumidification.

(i) Cooling and humidification:

Achieved by either spraying water into air or by forcing the air to pass through a pad soaked with water. When the air pass over the pad, a part of water evaporates and mixes with air, thus humidifying it. Heat required for evaporation is absorbed from the air, thus cooling the air.

(ii) Dehumidification with cooling

Air is passed over a cooling coil whose temperature is much below the dew point temperature of air. When air pass over the coil, the temperature of air reduces and becomes less than dew point temperature. Since temperature of air is lower than its dew point temperature, some of the water vapour in the air condenses and drips down in

a collecting tank below it. Thus the temperature and humidity of air reduces.

AIR CONDITIONING SYSTEMS

1. Central Air Conditioning System

Components are all grouped together in one central mechanical room. Extensive duct work is used to supply conditioned air to all spaces to be airconditioned. Used when the total cooling capacity required is more than 20 tonnes. Widely used in theatres, departmental stores, restaurants, and other public buildings.

Components:

(i) Compressor
(ii) condenser with cooling tower.
(iii) Cooling coil (evaporator) or heating coil (steam)
(iv) A blower with motor
(v) Sprays for cooling, heating, humidifying or dehumidifying.
(vi) Filters and odour removing equipment.
(vii) Control devices.

Methods Used:

(i) All air System:

- Part of air after cooling the room is returned to the air handling unit along with some fresh air, for the next cycle.
- cooling provided by conditioned air supplied by central air handling unit.

(ii) All water System

Chilled water from the central unit is conveyed to the room using insulated plumbing lines and is circulated through heat exchangers for cooling the room space. After cooling, water is then recirculated by bringing it back to the central unit.

(iii) Air water System:

- combination of air and water distribution system
- Major load - by water coils.
- Air distribution - take care of humidity control and ventilation.

Advantages:

1. Low initial cost
2. Space of equipment - not critical.

(3) Low running cost.

(4) No problem of noise in the room

Disadvantages:

(1) Requires large ducts occupying large space.

(2) Individual room control cannot be easily achieved.

2. Unitary Air Conditioning System.

- Make use of factory assembled air conditioning unit.
- All components are assembled together as a single unit.

Advantages:

(a) Ease of selection

(b) Easy repairing

(c) Easy installation and removal.

(d) Failure in any system affect only one room.

(e) Individual room temperature control can be achieved.

HYDRAULIC PUMP

A hydraulic pump is a machine which increases the energy of a liquid utilising the mechanical energy supplied to it.

1. Centrifugal Pump

- Has high output and high efficiency.
- Simple design, hence used in almost all fields.

Principle:

When the impeller of a pump is made to rotate by external means, the liquid mass entrapped by the impeller is thrown away from the centre of rotation, by which K.E is imparted to the liquid. The K.E is then converted to pressure head due to the shape of the casing of the pump and the liquid gets lifted up. Since the liquid is lifted by centrifugal action, the pump is called centrifugal pump.)

Main Parts:

* Impeller:- Rotating solid disc with curved blades.
  - Mounted on a shaft which is connected to an electric motor.
  - central portion known as eye of impeller.

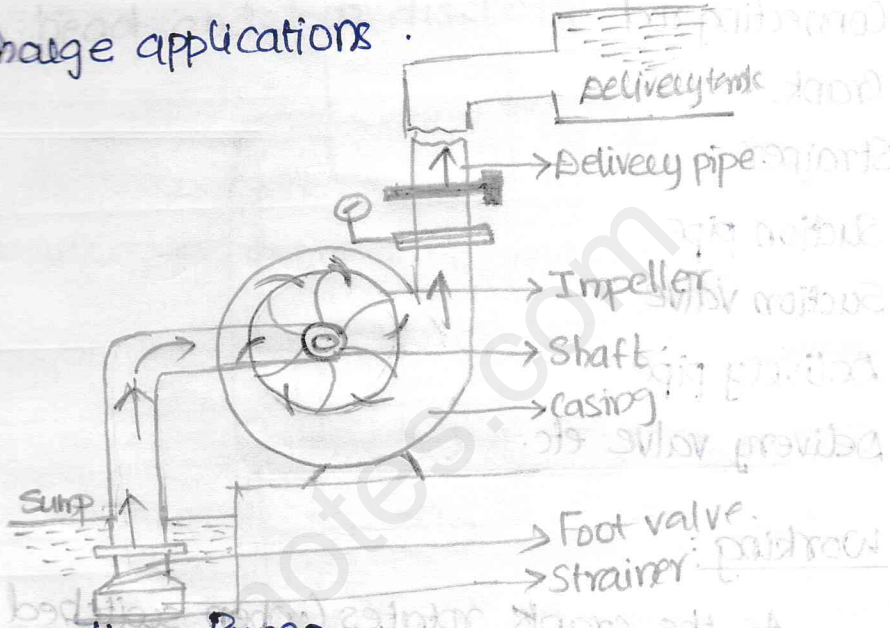
* Casing :- Air ~~tight~~ tight chamber surrounding impeller.
* Suction Pipe
* Delivery Pipe
* Foot valve :- Unidirectional valve which permit water from sump to the pump.
* Strainer : Used to protect the pump from leaves and wooden pieces.

Working :

- Priming :
  - Operation of filling the suction pipe and casing with the liquid to be pumped.
  - Used to remove air particles and help to create strong vacuum to achieve pumping action.
- After priming switch on the motor and impeller rotates. It creates vacuum at inlet hence water is reached into eye of impeller. Impeller creates impelling action. So velocity of liquid ↑ses. Now this high velocity liquid reached at the top of the casing. The construction of casing is on the basis of gradual increase of area. So velocity of liquid ↓ses and K.E is converted into pressure energy, i.e., we get high pressure

liquid at delivery pipe so we can lift the liquid to the required height (tank).

- It is commonly used for low head and high discharge applications.



2. Reciprocating Pump

- It is a +ve displacement pump and it operates on the principal of pushing of liquid by a piston (reciprocating motion) in a closed cylinder.
- Required low pressure at inlet and high pressure at outlet is obtained by reciprocating motion of piston.

Main parts:

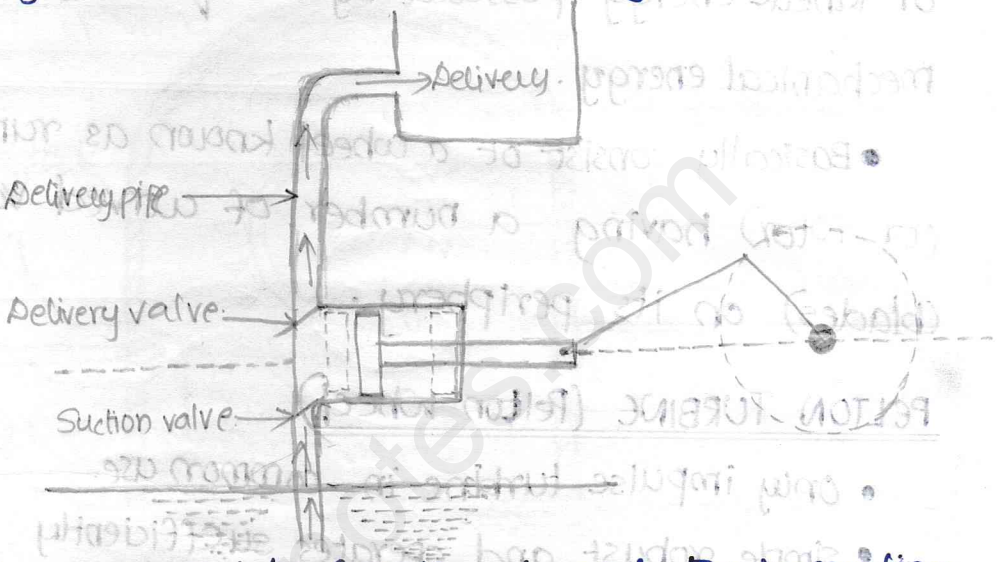
* Cylinder
* Piston
* Connecting rod
* Crank
* Strainer
* Suction pipe
* Suction valve
* Delivery pipe
* Delivery valve etc.

Working:

As the crank rotates (when switched on the motor) the piston moves out (left to right) which creates vacuum or low pressure in suction pipe. So liquid enter into cylinder through the suction valve. The delivery valve is closed in this stroke.

In return stroke the pressure developed in liquid opens the delivery valve and closes the suction valve. So liquid flows out to the tank through delivery pipe.

- Strainer is used to protect the pump from leaves and wooden pipes present in the sump.
- Reciprocating pump is generally used for high head and low discharge.



Comparison b/n Centrifugal and Reciprocating

Centrifugal Pump	Reciprocating Pump
• Low head and high discharge.	• High head and low discharge.
• Priming is required.	• No need of priming.
• Smooth flow.	• Pulsating flow.
• Compact size.	• Heavy size.
• Less initial cost	• High initial cost.
• Low maintenance cost	• High maintenance cost.
• Low wear and tear.	• High wear and tear.

HYDRAULIC TURBINES

Hydraulic turbine is a prime mover in which the shaft work is developed by converting the potential or kinetic energy possessed by a liquid into mechanical energy.

- Basically consist of a wheel known as runner (or rotor) having a number of curved vanes (blades) on its periphery.

PELTON TURBINE (Pelton wheel)

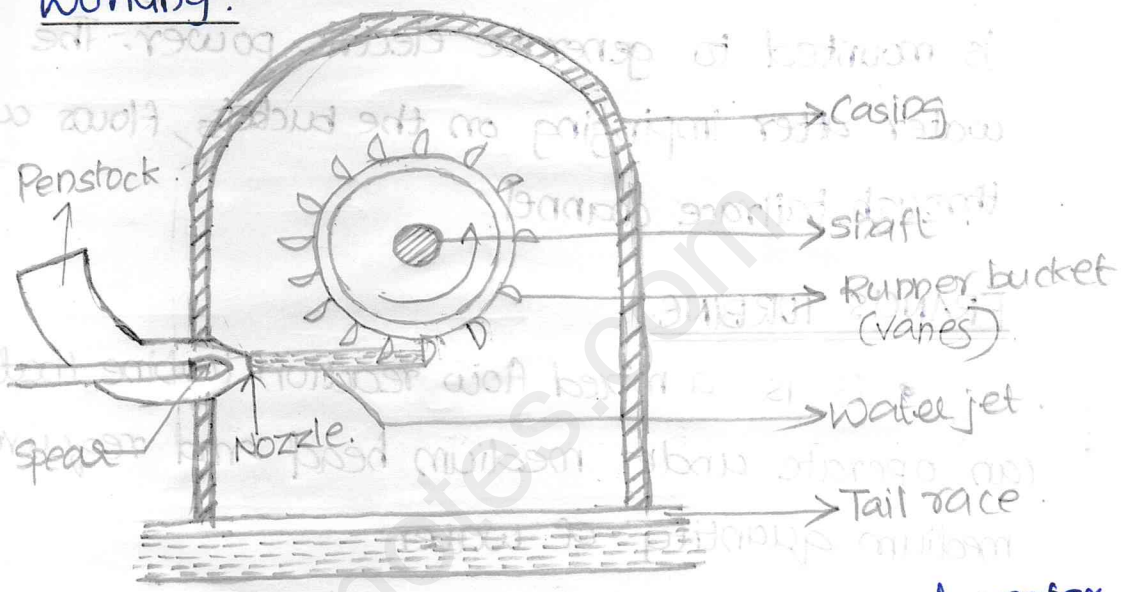
- Only impulse turbine in common use.
- simple, robust and operates efficiently
- Smooth running and good performance.

Major Components:

1. Runner :
   - Circular disc mounted on a shaft supported in bearings.
   - Cups / Buckets (double curved vanes) are equidistantly mounted on circumference of circular disc.
   - made of cast iron, bronze or stainless steel.
2. Splitter
3. Penstock – for conveying water from reservoir to turbine
   – concrete or steel pipes.

4. Nozzle - increases kinetic energy of water
5. Spear - regulate water flow through turbine.
6. Casing - to prevent splashing of water to surroundings.

Working:



When inlet valve to turbine is opened, water from reservoir flows through inlet pipe (penstock) to the nozzle. In the nozzle, energy available in water is converted to kinetic energy. The jet of water leaving the nozzle impinges on the splitter of the bucket, gets divided into two and flows through both sides of the bucket and leave out through the other edge. Due to an impulsive force, bucket rotates and hence, the runner also rotates. As the runner moves, the bucket moves away and next bucket comes in position in front of the jet.

The jet now strikes on the next bucket, thus establishing a continuous rotation of the runner. When runner rotates, shaft also rotates. At the other end of the shaft, an electric generator is mounted to generate electric power. The water after impinging on the buckets, flows out through tailrace channel.

FRANCIS TURBINE

- It is a mixed flow reaction turbine that can operate under medium head and requires medium quantity of water.

Major components

1. Scroll casing (spiral casing)
2. Guide vanes (wicket gates)
3. Guide wheels
4. Runner
5. Draft tube – passage between runner and tailrace.

Working:

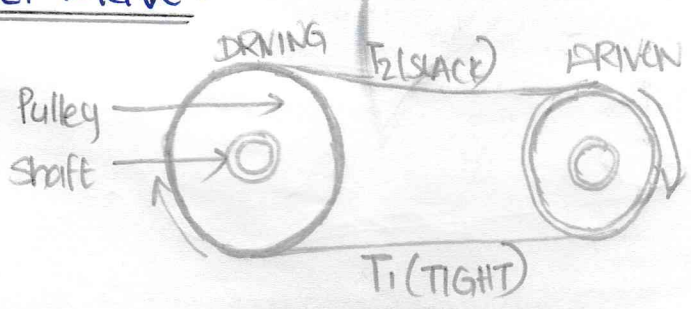
POWER TRANSMISSION DEVICES

The mechanical power can be transmitted from one shaft to another by four methods of mechanical drive. They are:

1. Gear drive: Very short distance power transmission.
2. Chain drive: Upto one metre power transmission.
3. Belt drive: Upto 15m
4. Rope drive: Upto 100 m

- The shaft from which the power is transmitted is known as driver shaft and shaft to which the power is transmitted is known as driven shaft.
- The choice of selection of power transmission devices depends on following factors:
  - Distance between the shaft
  - Amount of power to be transmitted.
  - Speed ratio
  - Accuracy

BELT DRIVE:



• Belt drive is used to transmit the power from one shaft to another at a considerable distance (upto 15m).

• Pulleys are mounted on driver and driven shaft. An endless belt is fitted tightly over these pulleys.

• Different types of belts used in belt drives are:

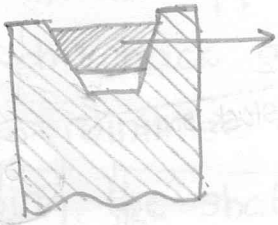
1) V-belt
2) Flat belt
3) Circular Belt

1) V-Belt

• Used for transmitting moderate power in workshop and factory when the two shaft are near to each other.

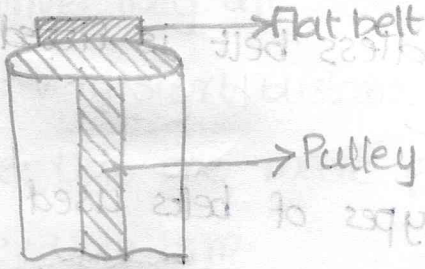
• Angle of V-belt is 30° - 40°.

• Slipping is almost negligible.



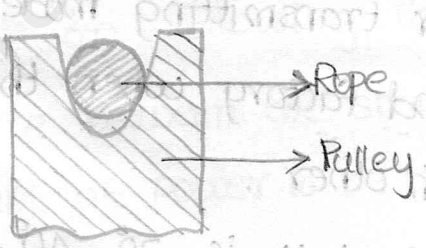
2) Flat Belt

- Used to transmit moderate power in factory and workshop when the distance b/n two shaft is upto 8m.



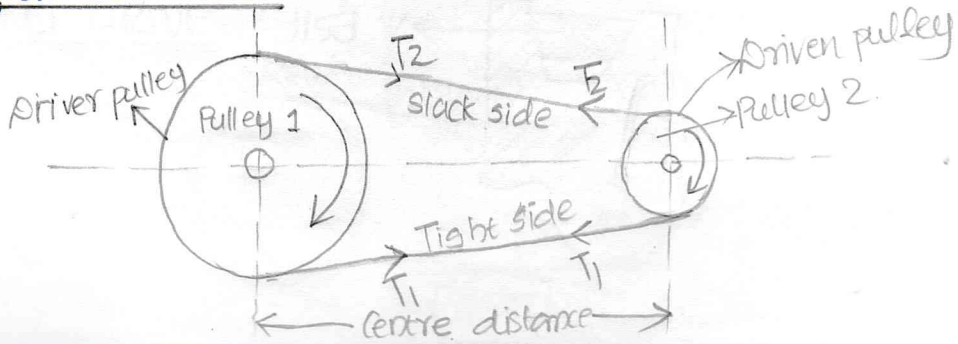
3) Circular Belt

- Used for transmitting large amount of power when the two shafts are more than 8m apart.
- Angle of circular belt is 40°-60°.



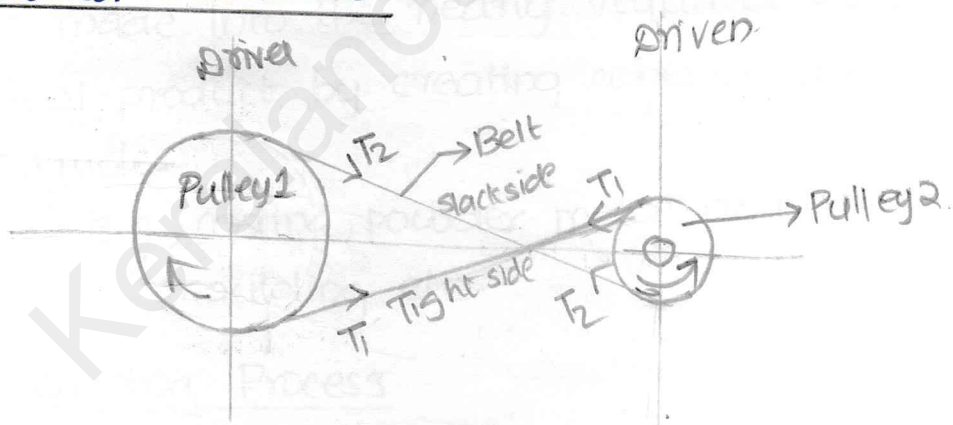
TYPES OF FLAT BELT DRIVES:

1. Open Belt Drive :



- Used to transmit power when the distance between the shaft is upto 15m.
- Shaft arranged in parallel to each other and rotating in same direction.
- Drived pulley pull the belt from one side and deliver the same to other side.
- Hence tension on the former side will be greater than later side.
- The side where tension is more is known as tight side and other side is known slack side.

2. Crossed Belt Drive:-

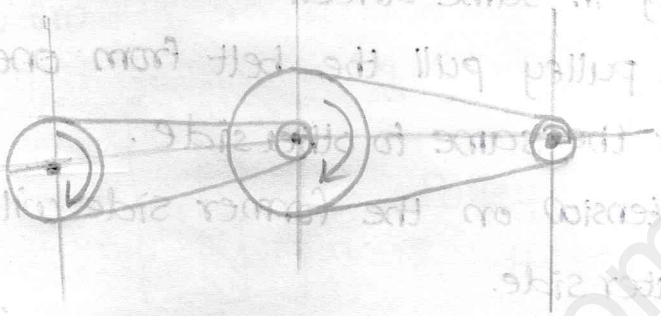


- It is used to connect shaft which are parallel and rotating in the opposite direction.
- The main drawback of crossed belt is rubbing.
- Inorder to minimise the wear and tear due to rubbing the shaft should be placed at

a minimum distance of ~~20b~~ 20b, where,

b - breadth of belt.

3. Compound Belt Drive



- It is used when