AKTU

FME

Unit III : Refrigeration and AC

Unit-3 : AKTU Syllabus

Introduction to Refrigeration and Air-Conditioning

Refrigeration: Refrigerating effect, Ton of Refrigeration; Coefficient of performance, methods of refrigeration, construction and working of domestic refrigerator, concept of heat pump.

Air-Conditioning: Its meaning and application, humidity, dry bulb, wet bulb, and dew point temperatures, comfort conditions, construction and working of window air conditioner.

Refrigeration and Refrigerant

- **Refrigeration** is a process of maintaining lower temperature compare to surrounding temperature.

- In order to maintain temperature continuously refrigeration system must run on a cycle.

- **Refrigerant** is a substance used for producing lower temperature.

- Example are NH_3, water, air, R-11, R-12, R-134 etc.

- Refrigerants absorb heat at a low temperature and reject heat at a higher temperature .

Applications of Refrigeration

- Refrigeration has numerous applications across various industries and everyday life.
- Its primary purpose is to lower the temperature of a given space or substance.

These are some common applications of refrigeration:

- Food preservation
- Food processing
- Beverage industry
- Pharmaceuticals
- Air conditioning
- Industrial processes
- Ice production
- Cold storage warehouses
- Transport refrigeration
- Laboratories

1 tonne of refrigeration [AKTU]

- It is the amount of heat that is to be removed from one tonne of **water** at zero **(0^oC)** in order to convert it into **ice** at 0 ^oC in one day (**24 hours**).

- Tonne of refrigeration represents heat transfer rate.

1 T.R. = 3.5 kJ/s = 3.5 kW = 210 kJ/min

Methods for Refrigeration

- **There are several methods used for refrigeration, each based on different principles and technologies.**

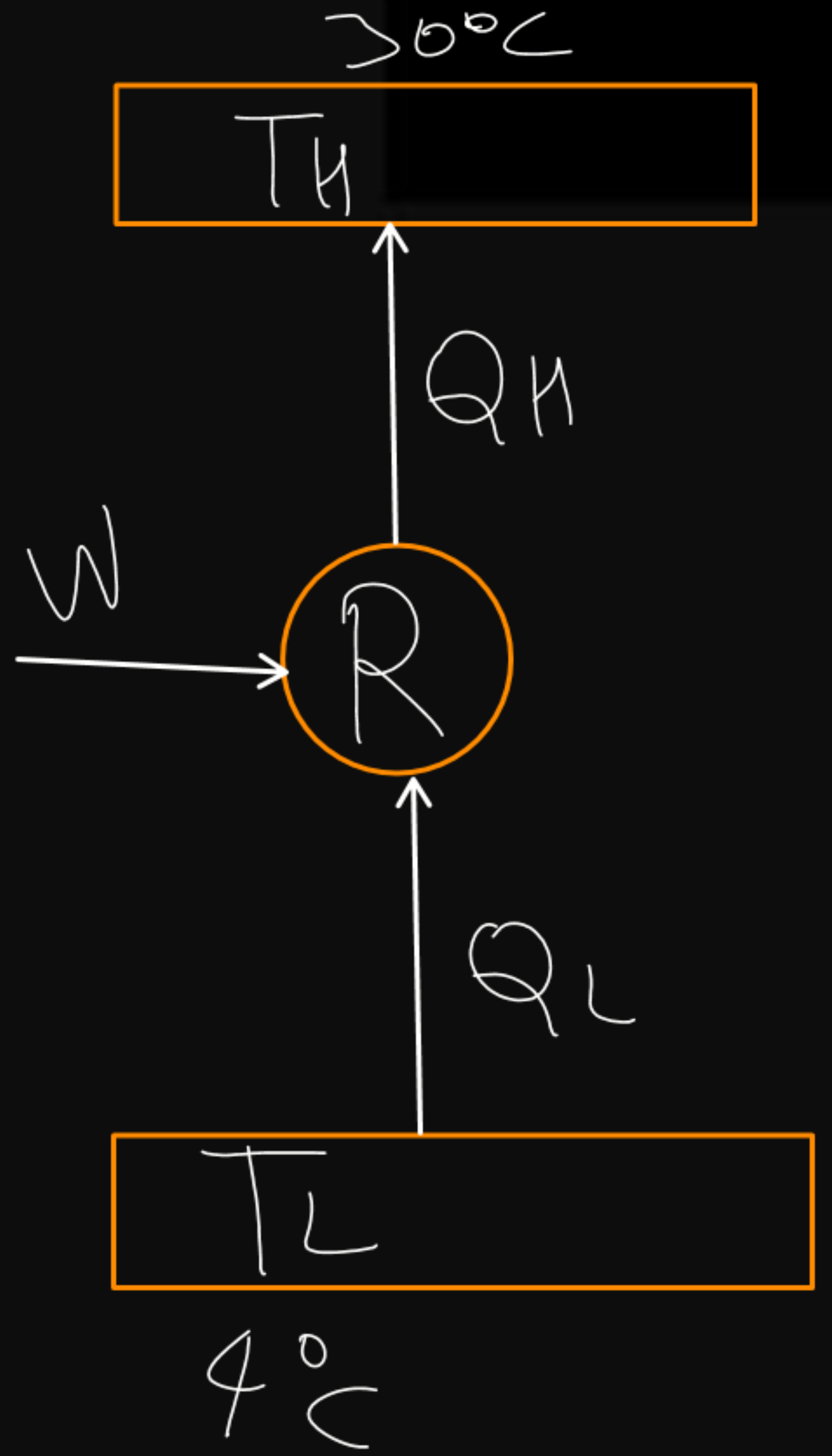
Here are some of the most common methods for refrigeration

- Vapour Compression Refrigeration
- Absorption Refrigeration
- Thermoelectric Refrigeration
- Evaporative Cooling
- Magnetic Refrigeration
- Air Cycle Refrigeration
- Steam Ejector Refrigeration

Each of these refrigeration methods has its advantages and specific applications. The choice of method depends on factors like cooling requirements, energy efficiency, space limitations, and the specific industry or application involved. Advances in technology continue to improve these methods and open up new possibilities for efficient and sustainable refrigeration solutions.

Refrigerator and Heat Pump. [AKTU : 2020-21]

- $\boxed{\textbf{Clausius Statement:}}$ "It is impossible to construct a device which operates on a cycle and transfer heat from low temperature body to high temperature body **without any external work**."

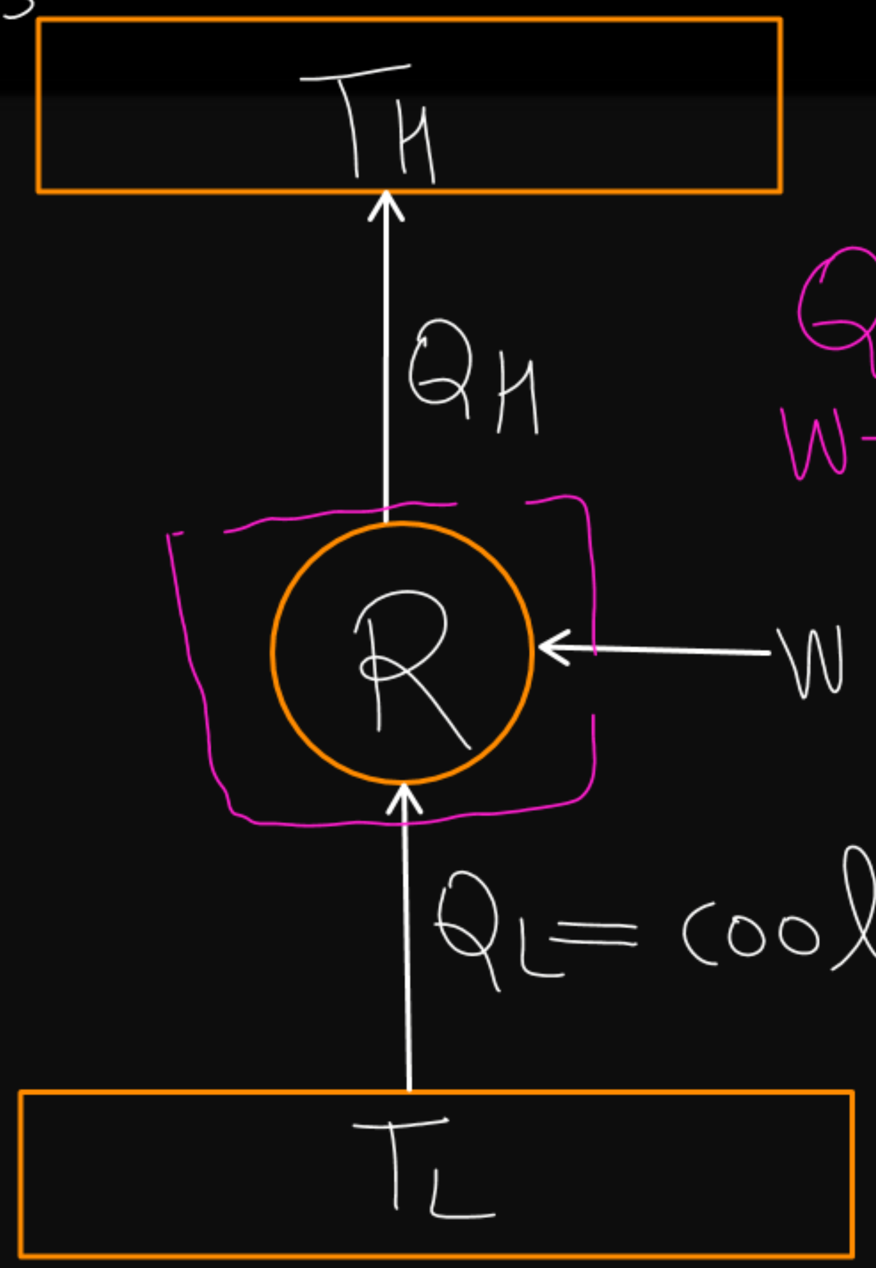


Refrigerator

- Refrigerator works on the **Clausius statement.**
- It absorbs the heat from the low temperature medium and rejects heat into high temperature medium by consuming external work.
- Refrigerator used to **maintain low temperature** as compared to surrounding.

Refrigerator

2.5 1.5



$Q_{in} = Q_{out}$

$W + Q_L = Q_H$

$\boxed{W = Q_H - Q_L}$ **

$$COP_R = \frac{\textit{Desired Effect}}{\textit{Work Required}}$$

$$COP_R = \frac{\textit{Cooling Effect}}{\textit{Work Required}}$$

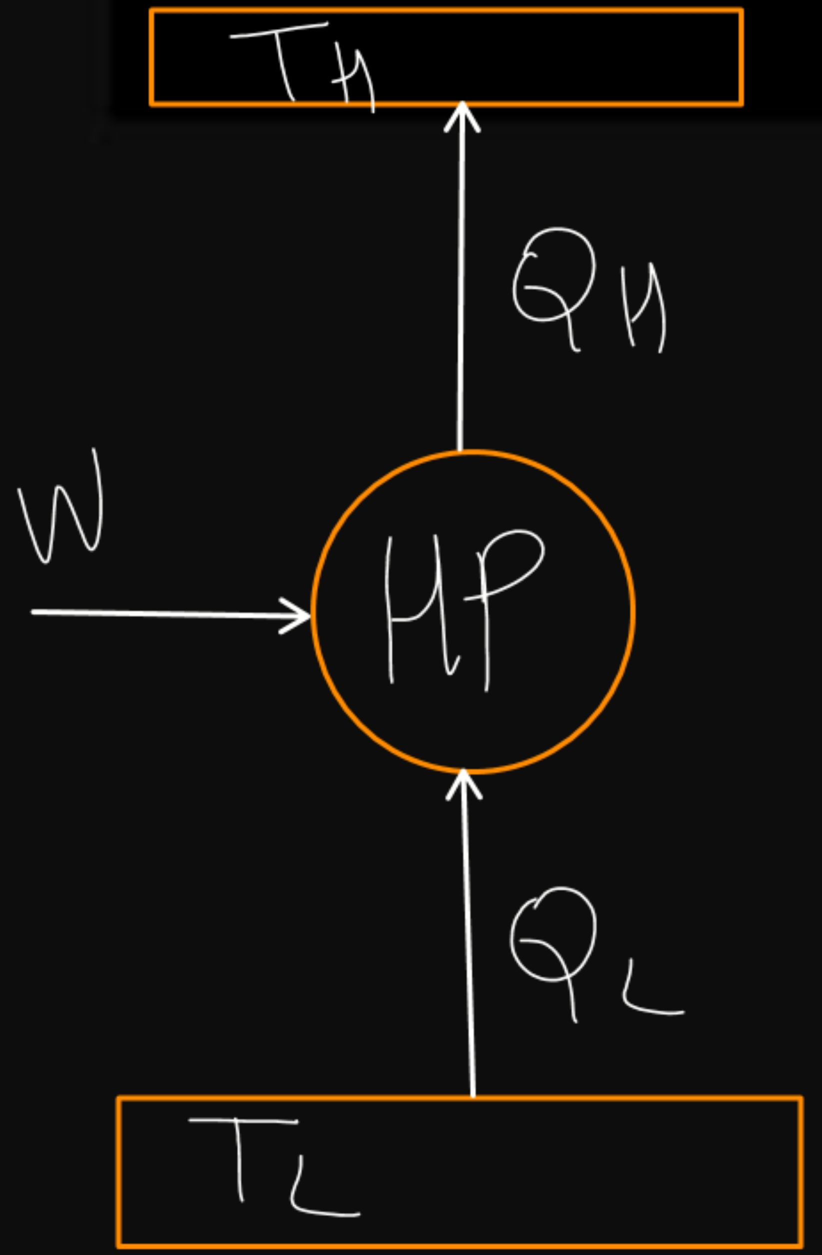
$$(COP)_R = \frac{Q_L}{W}$$

$$\boxed{(COP)_R = \frac{Q_L}{Q_H - Q_L}}$$

$$(COP)_R = \frac{T_L}{T_H - T_L}$$

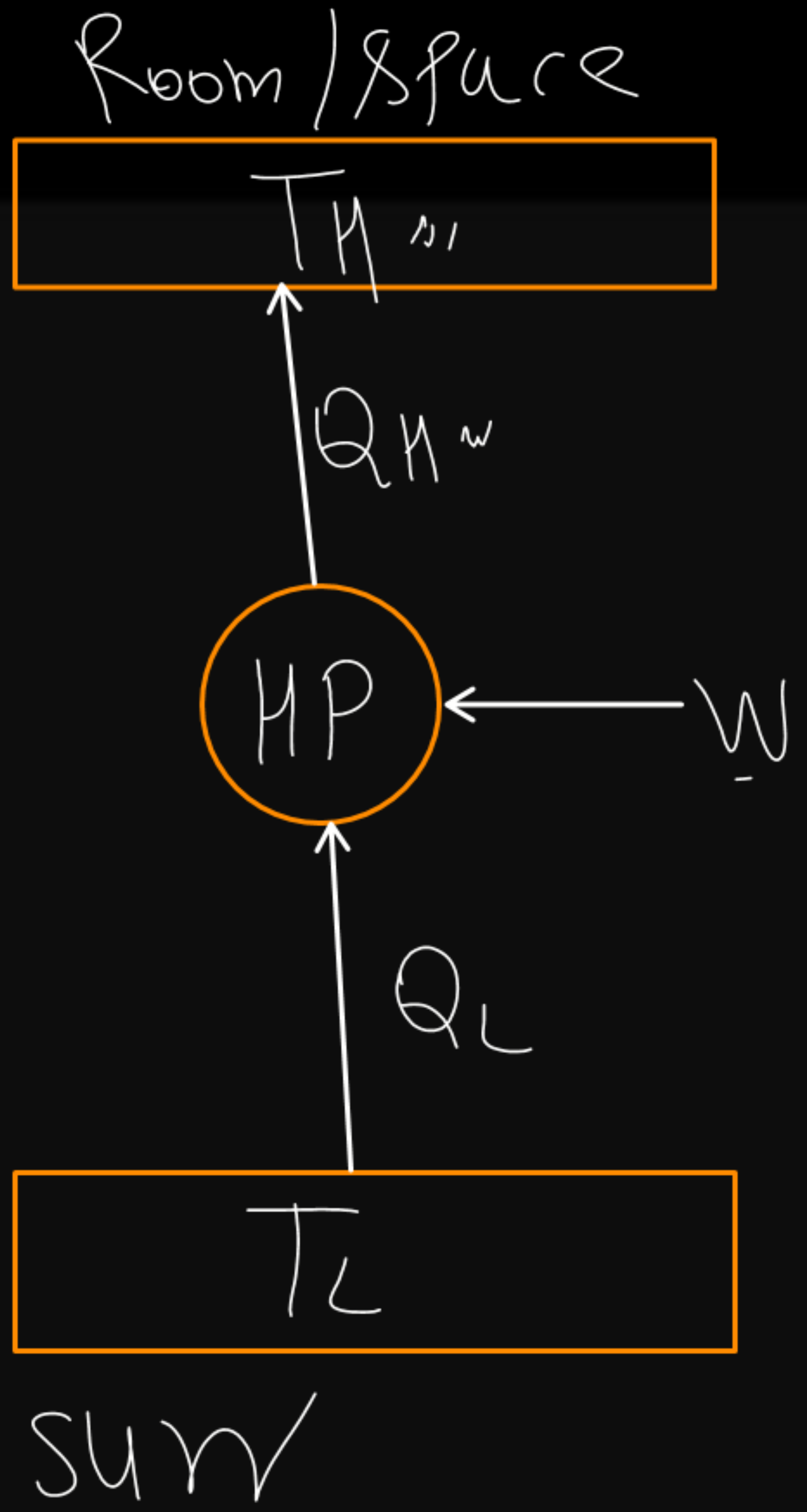
$T \rightarrow K$

Heat Pump



- Heat Pump works on the **Clausius statement.**
- It absorb the heat from the low temperature medium and rejects heat into high temperature medium by consuming external work.
- Heat pump used to **maintain High temperature** as compared to surrounding.

Heat Pump



$$COP_{H.P.} = \frac{\text{Desired Effect}}{\text{Work Required}}$$

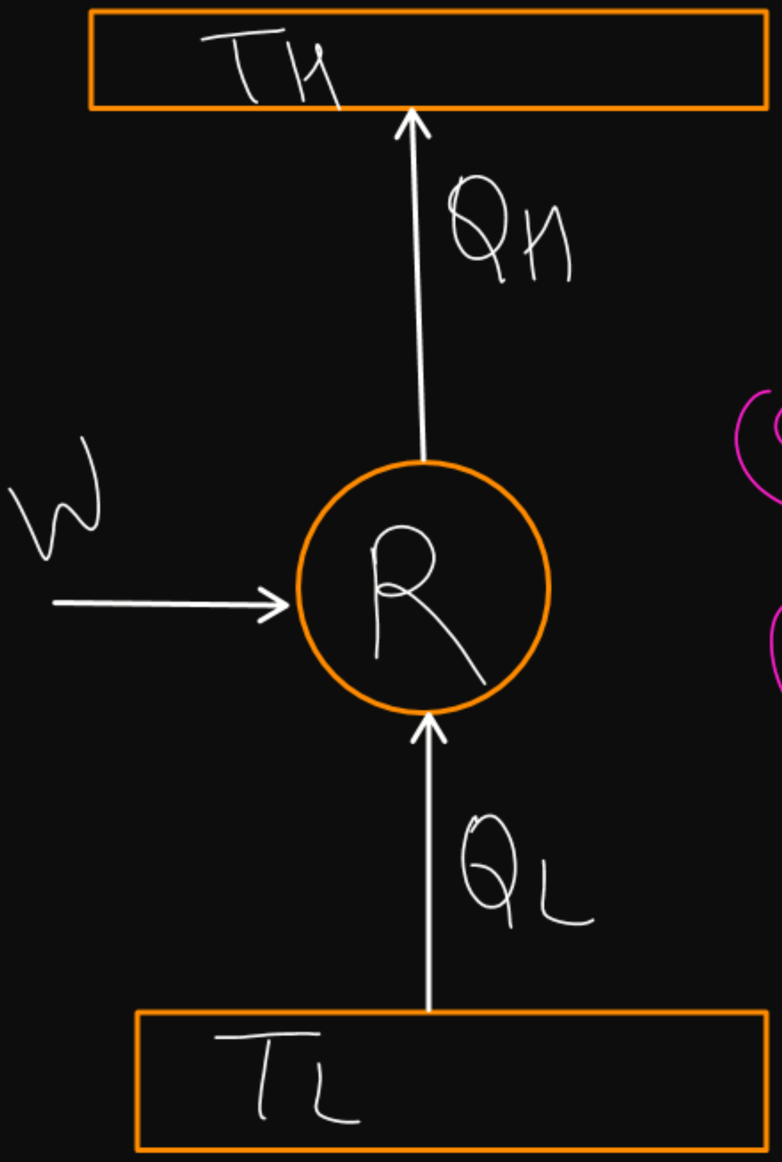
$$COP_{H.P.} = \frac{\text{Heating Effect}}{\text{Work Required}}$$

$$(COP)_{HP} = \frac{Q_H}{W}$$

$$(COP)_{HP} = \frac{Q_H}{Q_H - Q_L}$$

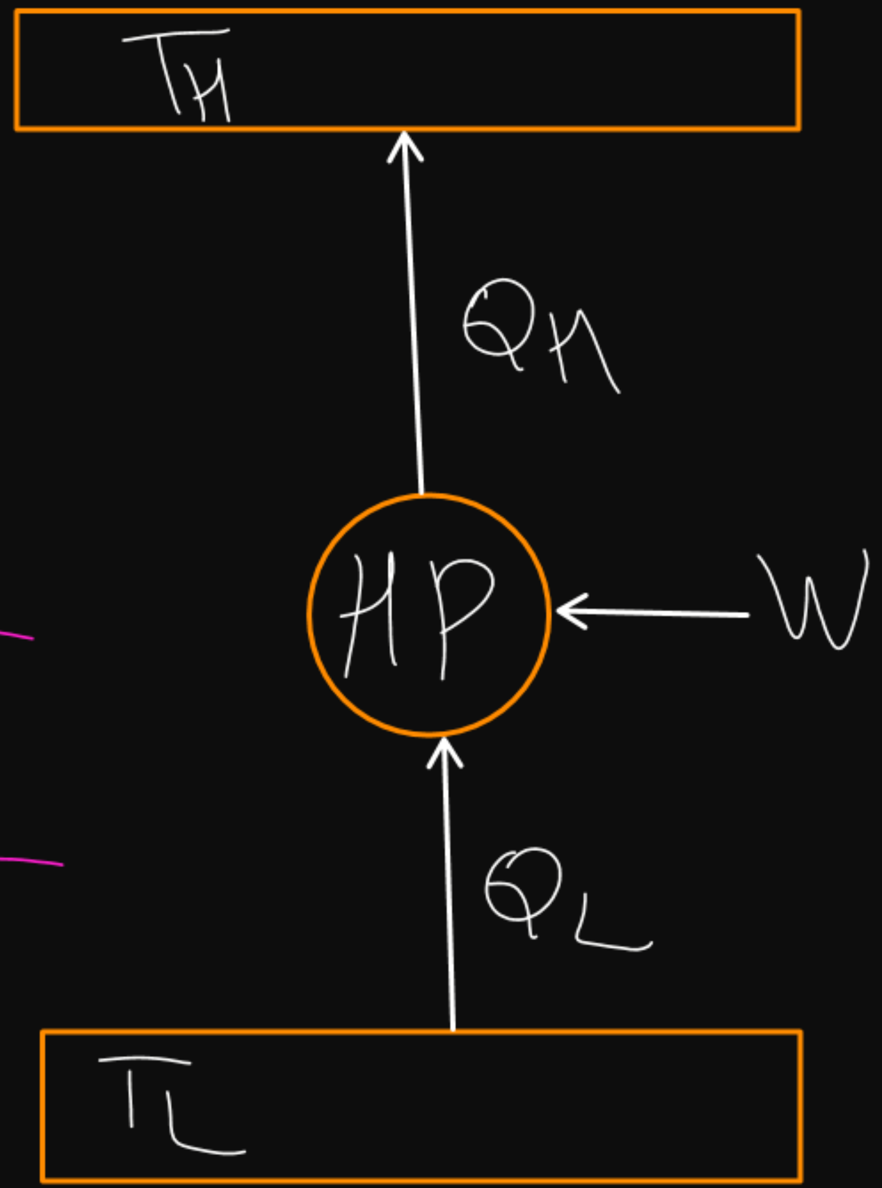
$$(COP)_{HP} = \frac{T_H}{T_H - T_L}$$

Relation between the COP of refrigerator and heat pump



$$(COP)_R = \frac{Q_L}{Q_H - Q_L} \quad \text{--- (I)}$$

$$(COP)_{HP} = \frac{Q_H}{Q_H - Q_L} \quad \text{--- (II)}$$



$$(COP)_{HP} - (COP)_R = \frac{Q_H}{Q_H - Q_L} - \frac{Q_L}{Q_H - Q_L}$$

$$(COP)_{HP} - (COP)_R = \frac{Q_H - Q_L}{Q_H - Q_L} = 1$$

$$\boxed{(COP)_{HP} = 1 + (COP)_R}$$

⭐⭐⭐

Coefficient of Performance [AKTU]

- The efficiency of a refrigerator and heat pump is expressed in terms of the coefficient of performance (**COP**).
- The value of COP can be greater than unity.
- Thermal efficiency can never be greater than 1.
- The COP represents the running cost of refrigerator and heat pump.
- Higher COP indicates a more efficient system, as it produces more cooling or heating for a given amount of energy input.
- Higher the value of COP lower the running cost.

Methods for Refrigeration

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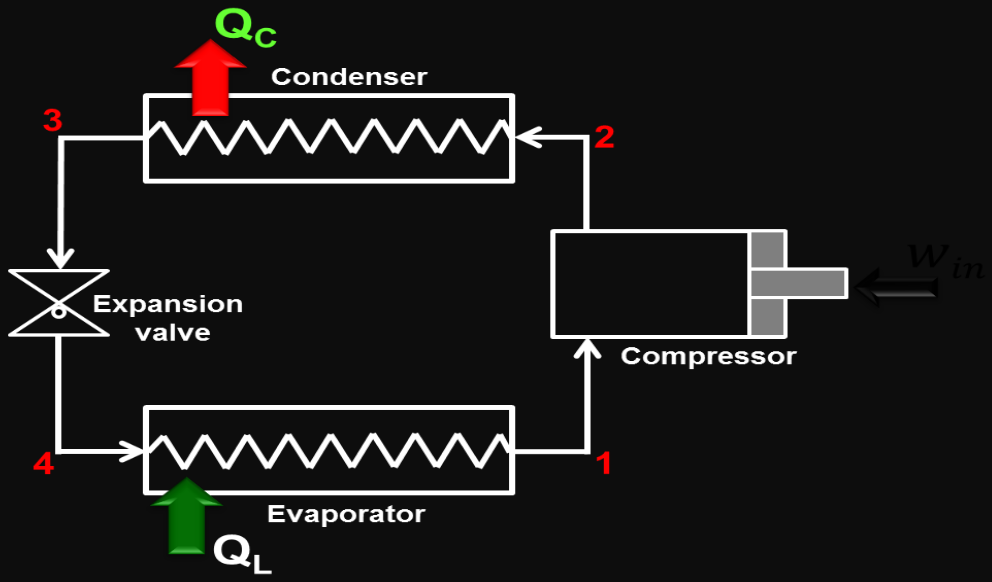
Vapour Compression Refrigeration System [AKTU]



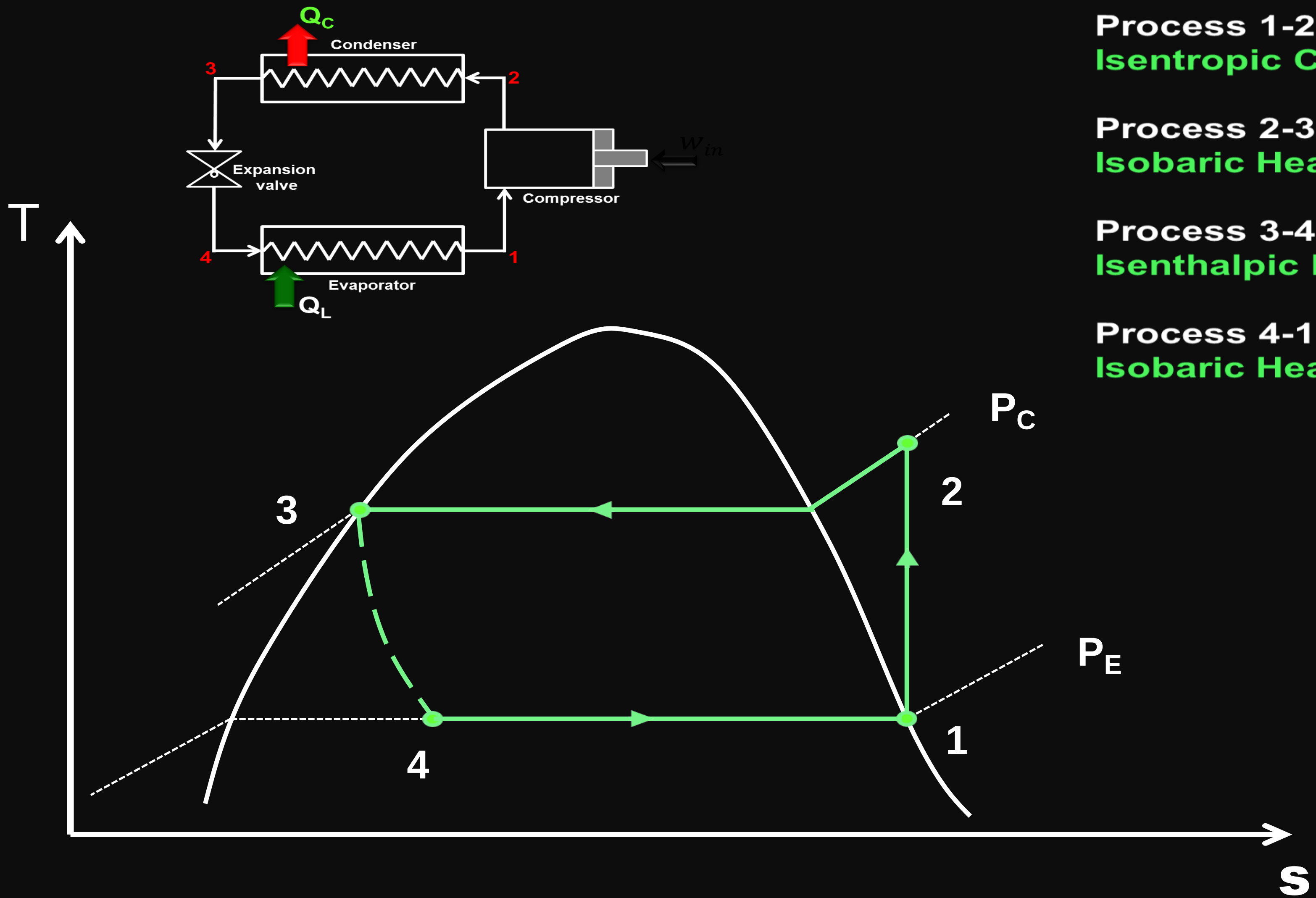
Schematic diagram of single stage vapour compression cycle

Process 1-2
Isentropic Compression

Process 2-3
Isobaric Heat Rejection

Process 3-4
Isenthalpic Expansion

Process 4-1
Isobaric Heat Addition



Process 1-2
Isentropic Compression

Process 2-3
Isobaric Heat Rejection

Process 3-4
Isenthalpic Expansion

Process 4-1
Isobaric Heat Addition

Construction and working of domestic refrigerator [AKTU]

- Refrigerator is a cyclic device which is used to maintain **lower temperature** as compared to surrounding temperature.
- The construction and working of a domestic refrigerator are based on the principles of vapor compression refrigeration.

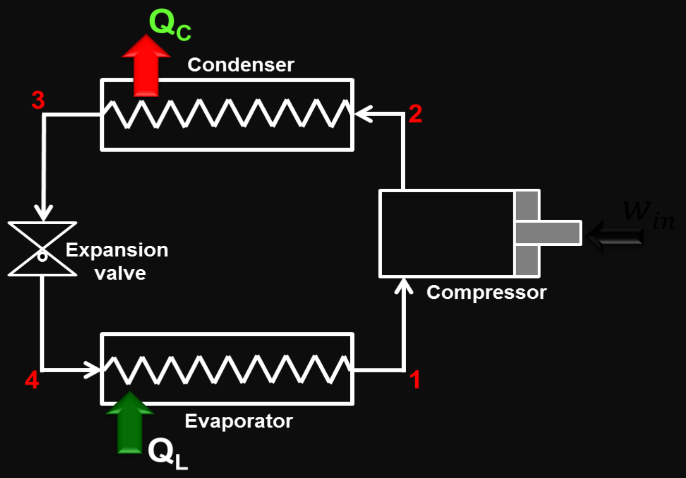
Main components of refrigerator are

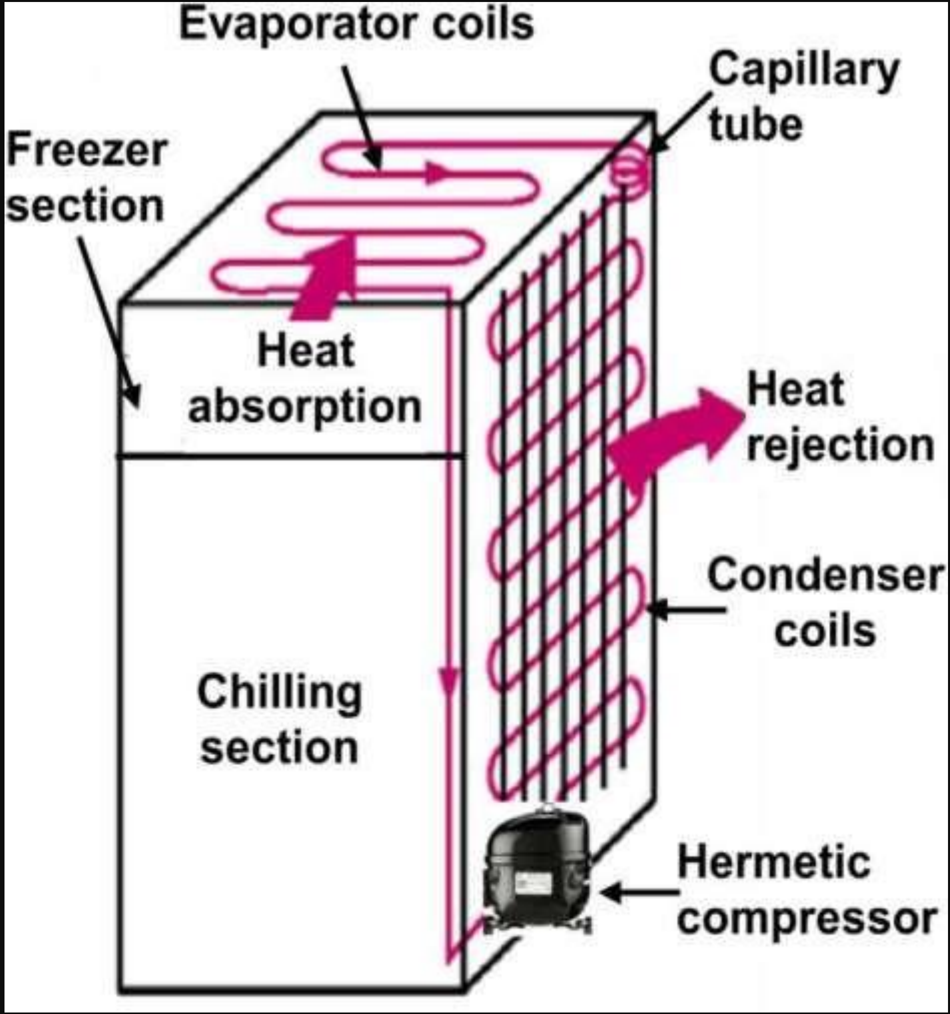
Compressor(1-2)

Condenser (2-3)

Thermal Expansion Valve or Capillary Tube(3-4)

Evaporator(4-1)




Evaporator coils
Capillary tube
Freezer section
Heat absorption
Heat rejection
Condenser coils
Chilling section
Hermetic compressor

COMPRESSOR :

- The compressor is the heart of the refrigeration system.
- It is an electric motor-driven pump that compresses the low-pressure, low-temperature refrigerant gas into a high-pressure, high-temperature gas.

CONDENSER :

- The condenser is a coil or set of coils located at the back or bottom of the refrigerator.
- The high-pressure refrigerant gas from the compressor flows through the condenser, and as it releases heat to the surroundings, it condenses into a high-pressure liquid.

Expansion Valve (Thermal Expansion Valve or Capillary Tube):

- **The expansion valve is a small device that creates a pressure drop, allowing the high-pressure liquid refrigerant to expand and turn into a low-pressure, low-temperature mixture of liquid and vapor.**
- **The capillary tube is a fixed-length narrow tube that serves as an expansion device in some refrigerators.**

Evaporator:

- **The evaporator is a coil or set of coils located inside the refrigerator's main compartment, usually in the freezer section.**
- **The low-pressure refrigerant from the expansion valve absorbs heat from the refrigerator's interior, causing it to evaporate into a low-pressure vapor.**

Good practices to minimize the amount of energy consumed by refrigerator

1. Open the refrigerator door the fewest times possible for the shortest duration possible.

2. Cool the hot foods to room temperature first before putting them into the refrigerator.

3. Check the door gasket for leaks

4. Avoid unnecessarily low temperature settings.

5.Avoid excessive ice build-up on the interior surfaces of the evaporator.

Working Process:

The refrigeration cycle starts when the compressor starts running. The entire process involves four stages:

Stage 1 - Compression: The compressor sucks in low-pressure refrigerant vapor from the evaporator and compresses it to a high-pressure, high-temperature gas.

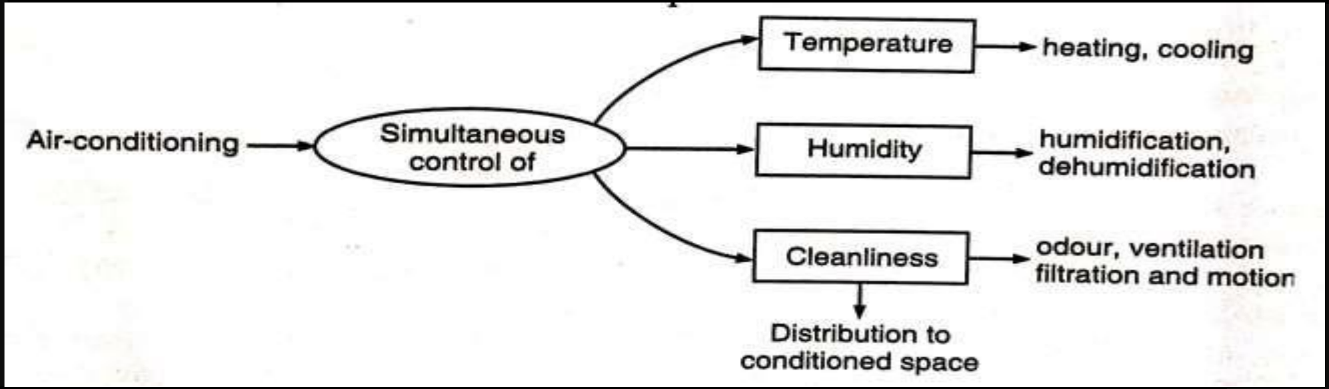
Stage 2 - Condensation: The high-pressure refrigerant gas flows through the condenser coils where it releases heat to the surrounding air or water, causing it to condense into a high-pressure liquid.

Stage 3 - Expansion: The high-pressure liquid refrigerant then passes through the expansion valve or capillary tube, where it undergoes a sudden pressure drop, resulting in its expansion into a low-pressure mixture of liquid and vapor.

Stage 4 - Evaporation: The low-pressure refrigerant mixture enters the evaporator coils inside the refrigerator's main compartment. As it absorbs heat from the interior of the refrigerator, it evaporates into a low-pressure vapor.

The cycle then repeats as the low-pressure vapor returns to the compressor, and the process continues to maintain a cool temperature inside the refrigerator.

‘Air-Conditioning’ and its applications [AKTU]



- Air conditioning is a process of controlling and modifying the temperature, humidity, and air quality of an indoor space.

- It is used to create a comfortable and controlled environment for occupants, regardless of the external weather conditions.

‘Air-Conditioning’ and its applications

Air conditioning has a wide range of applications across various sectors

- Residential
- Commercial Buildings
- Hospitals and Healthcare Facilities
- Educational Institutions
- Transportation
- Server Rooms and Data Centers
- Sports Facilities
- Theatres and Auditoriums
- Museums and Art Galleries

(i) Dry Air (ii) Atmospheric air (iii) Saturated air

(i) **Dry air** **:** It is a mixture of nitrogen, oxygen, and small amounts of some other gases.

(ii) **Atmospheric air** **:** Air in the atmosphere normally contains some **water vapor** (or *moisture*), **number of pollutants** and referred as **atmospheric air.**

(iii) **Saturated air** **:** Saturated air is air that holds water vapor at its **highest level** i.e. just about to condense.

Psychrometry?

- Moist air is the mixture of **water vapour and dry air**.

- The properties of moist air are called **Psychrometric properties.**

- The science in which we deal with the **Psychrometric properties** is known as **psychrometry**.

(i) specific humidity (ii) relative humidity

(i) specific humidity:

- Specific humidity can be defined as the mass of water vapor present in a unit mass of dry air.
- It is also known as absolute humidity or humidity ratio and denoted by ω.

$$\omega = \frac{\text{mass of w.v.}}{\text{mass of d.a.}}$$

Unit
kg of water vapour / kg of dry air

$$\Rightarrow \omega = \frac{m_v}{m_a}$$

$$\Rightarrow \omega = \frac{V/v_v}{V/v_a}$$

$$\Rightarrow \omega = \frac{v_a}{v_v}$$

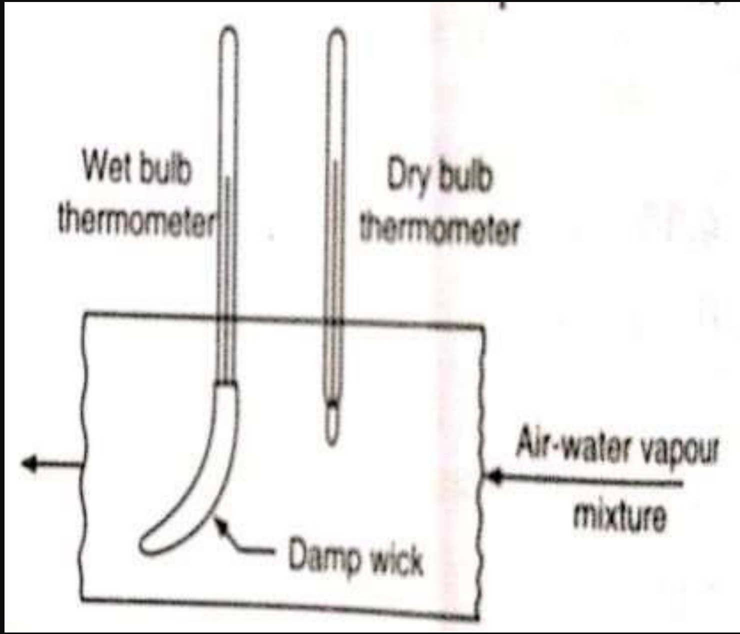
(ii) Relative Humidity(ϕ) [AKTU]

- Relative humidity (RH) is a measure of the amount of moisture in the air relative to the maximum amount of moisture that the air can hold at a given temperature and pressure.
- It is expressed as a percentage. Relative humidity indicates how close the air is to its saturation point.
- When the relative humidity is 100%, the air is saturated, and it cannot hold any more moisture at that temperature and pressure.
- If the relative humidity is less than 100%, the air is not saturated, and there is potential for more water vapor to be added before reaching saturation.

(i) Dry Bulb Temperature [AKTU] (ii)Wet Bulb Temperature [AKTU]

(i) Dry Bulb Temperature

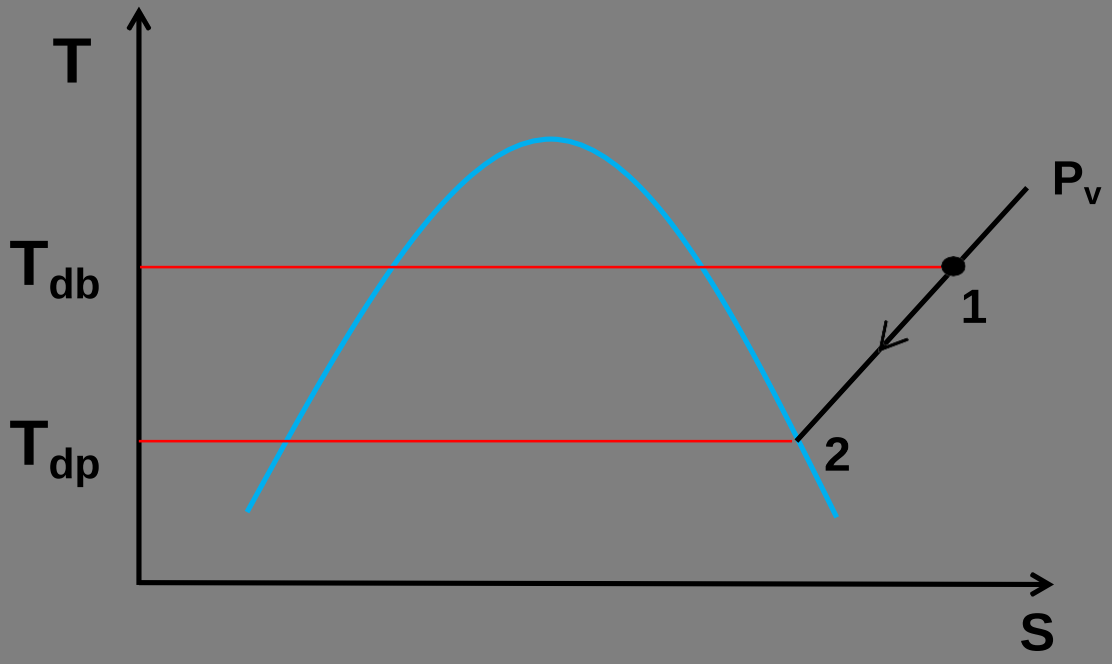
- It refers to the temperature of the air measured by a standard thermometer that is not affected by moisture.
- In other words, it is the ambient air temperature that we commonly refer to when discussing the weather or indoor climate.
- The dry bulb temperature is measured in degrees Celsius (°C) or Fahrenheit (°F).



(ii)Wet Bulb Temperature

- The wet bulb temperature is another important parameter used to measure air temperature, particularly in the context of humidity and cooling processes.
- It is the temperature recorded by a thermometer covered with a water-soaked cloth or wick, exposed to the airflow.
- As water evaporates from the cloth, it cools the thermometer, and the wet bulb temperature is lower than the dry bulb temperature.

(iii) Dew point Temperature [AKTU]



(iii) Dew point Temperature

- The air in atmosphere contain moisture (water vapour).
- If we reduce the temperature of the air at constant pressure, moisture get condense.
- The temperature at which **first drop of dew is formed or condensation begins** when the air is cooled at **constant pressure** is known as dew point temperature.
- Denoted by T_{dp}.

Human comfort and conditions for comfort air conditioning ?

- **Human Comfort refers to the control of temperature and humidity of air** and its circulation.
- So that the resulting environment becomes human friendly.
- **General human comfort conditions are to maintained in the range of**

- **Te**mperatures 22 °C to 27 °C
- Relative humidity 40% to 60%
- Air velocity 5 m/min to 8 m/min

Working of window type air-conditioner

- Air-Conditioning is a process of controlling air temperature, humidity, quality and ventilation in a space (Building or Vehicle).

- **Air conditioning can be used in both domestic and commercial environments.**

- This process is most commonly used to achieve a more comfortable interior environment, typically for humans and other animals.

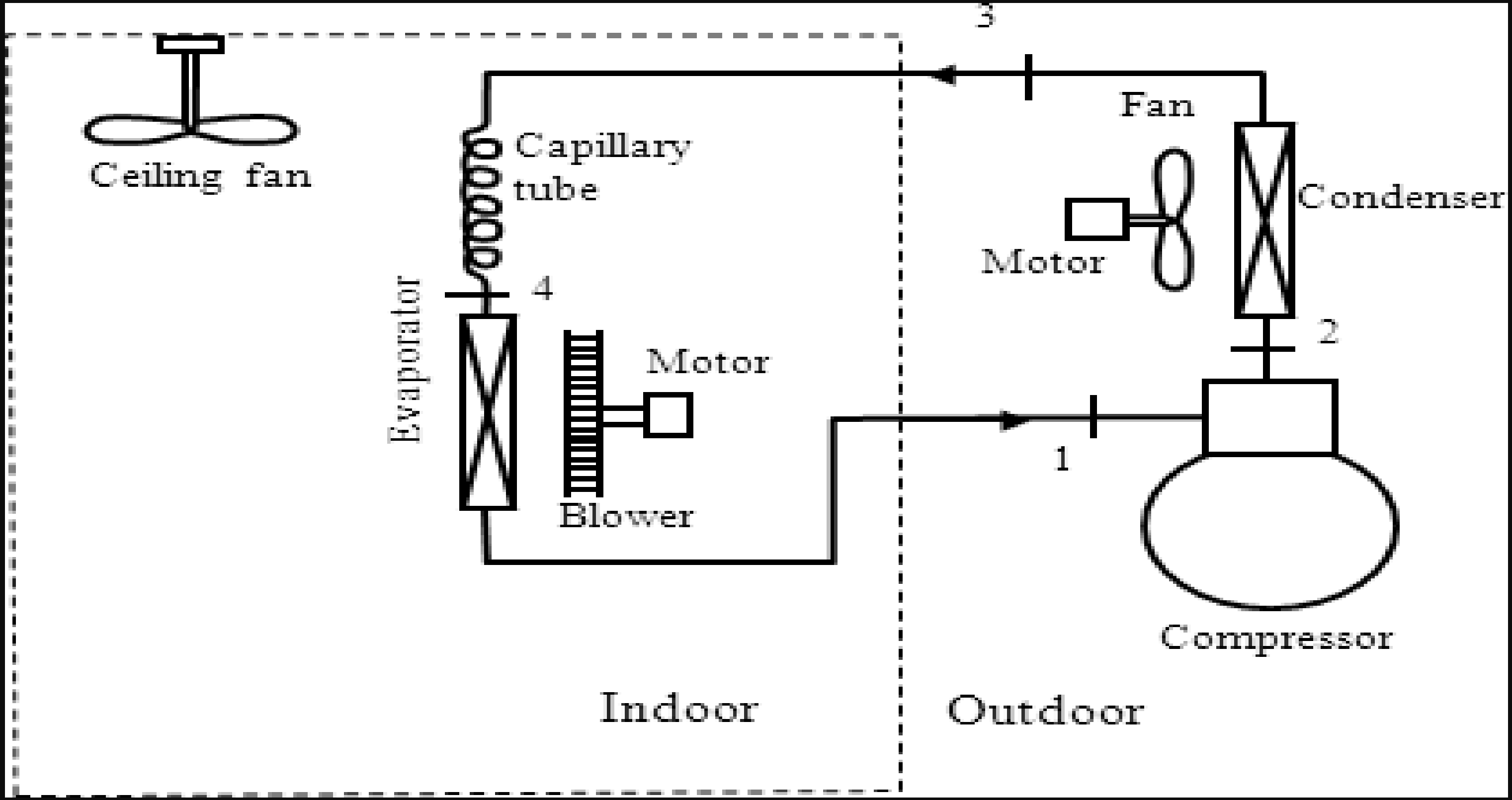
Window Air Conditioner [AKTU]

- Window air conditioner is sometimes referred to as room air conditioner.

- **It is the simplest form of an air conditioning system and is mounted on windows or walls.**

- It is a single unit that is assembled in a casing where all the components are located.

Window Air Conditioner



Construction of Window Air Conditioner

It consists of various components

1. Compressor:

- **The compressor is the main component of the window air conditioner.**
- **It compresses the low-pressure, low-temperature refrigerant gas and turns it into a high-pressure, high-temperature gas.**

2. Condenser:

- **The condenser is a coil located on the back or bottom of the air conditioner.**
- **The high-pressure refrigerant gas flows through the condenser, releases heat to the outside air, and condenses into a high-pressure liquid.**

3. Expansion Valve:

- The high-pressure liquid refrigerant then passes through an expansion valve, which is a small device that causes a pressure drop.
- This leads to the expansion of the refrigerant into a low-pressure, low-temperature mixture of liquid and vapor.

4. Evaporator:

- The low-pressure refrigerant mixture enters the evaporator coil located inside the front part of the air conditioner, behind the air intake grille.
- As the warm indoor air is drawn over the evaporator coil by the blower fan, the refrigerant absorbs heat from the air, causing it to evaporate into a low-pressure vapor.

5. Blower Fan:

The blower fan is located inside the air conditioner and is responsible for drawing indoor air over the evaporator coil and then blowing the cooled air back into the room.

Working of Window Air Conditioner

The working of a window air conditioner involves a process called vapor compression refrigeration, which consists of four stages:

1. **Compression:** The compressor sucks in the low-pressure, low-temperature refrigerant vapor from the evaporator and compresses it into a high-pressure, high-temperature gas.
2. **Condensation:** The high-pressure refrigerant gas flows through the condenser coils, where it releases heat to the outdoor air and condenses into a high-pressure liquid.
3. **Expansion:** The high-pressure liquid refrigerant then passes through the expansion valve, causing it to expand rapidly and turn into a low-pressure, low-temperature mixture of liquid and vapor.

4. Evaporation: The low-pressure refrigerant mixture enters the evaporator coil, where it absorbs heat from the indoor air. The warm air becomes cooler as it passes over the cold evaporator coil, and the refrigerant evaporates into a low-pressure vapor.

The process repeats continuously as long as the air conditioner is running, removing heat and humidity from the indoor air and providing a cooling effect.

The cooled air is then blown back into the room by the blower fan, while the heat extracted from the indoor air is expelled outside through the condenser.

Specification of Window Air Conditioner

A window air-conditioner is normally specified by the following parameters:

- Cooling Capacity : 1, 1.5 and 2 ton etc
- Overall dimensions : length x width x height
- Voltage and Power Consumption: AC, 220-240 volts
- Control : site or remote
- Fan Speeds
- Dehumidification
- Airflow Direction
- Noise Level

AKTU

FME

Unit II : IC Engine and EVs

Unit-2: Introduction to IC Engines and Electric Vehicles

Syllabus

IC Engine:

- Basic definition of engine and Components of engine
- Construction and Working of Two stroke and four stroke SI & CI engines
- Merits and demerits, scavenging process;
- Difference between two-stroke and four stroke IC engines
- Difference between SI and CI Engines

Electric vehicles and hybrid vehicles:

- Electric vehicles and its Components
- Advantages and disadvantages of EVs
- Hybrid electric vehicles and its Components
- Advantages and disadvantages of HEVs
- EV batteries, Chargers, drives, transmission and power devices., HEV drive train components

Engine : definition

- It is a device which converts one form of energy into another form of useful energy.

$$Chemical\ Energy \rightarrow Thermal\ energy \rightarrow$$ Mechanical Energy

Based on combustion engines are classified into

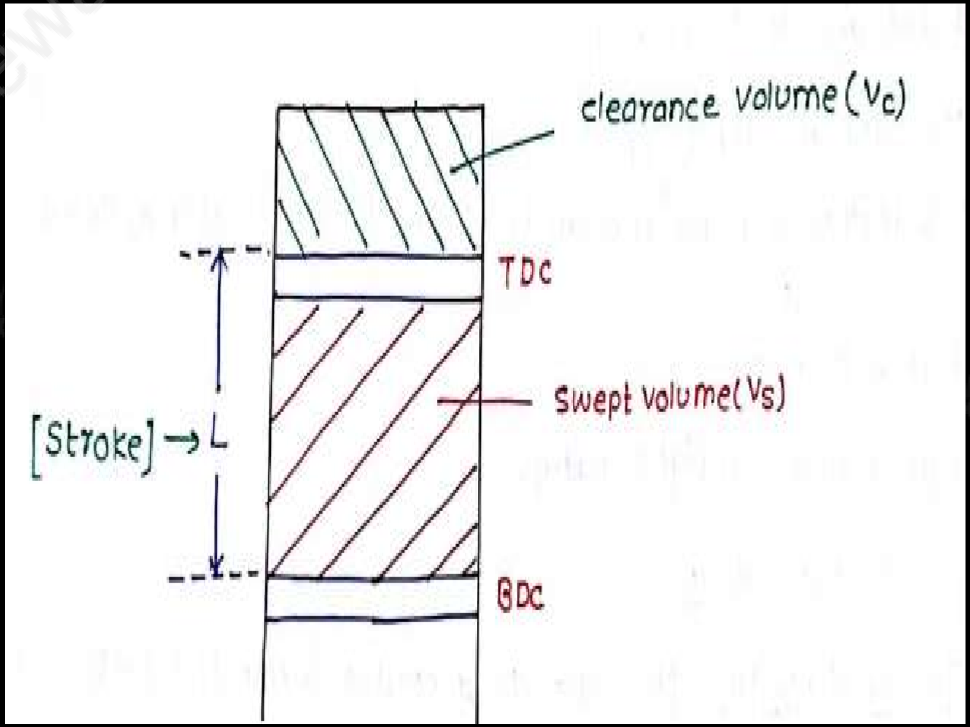
- Internal Combustion Engine (I.C. Engine)
- External Combustion Engine (E.C. Engine)

Internal Combustion Engine [AKTU : 2020-21]

❖ **In internal combustion engine the burning or combustion of the fuel takes place inside the cylinder.**

Example- Automobile Engines

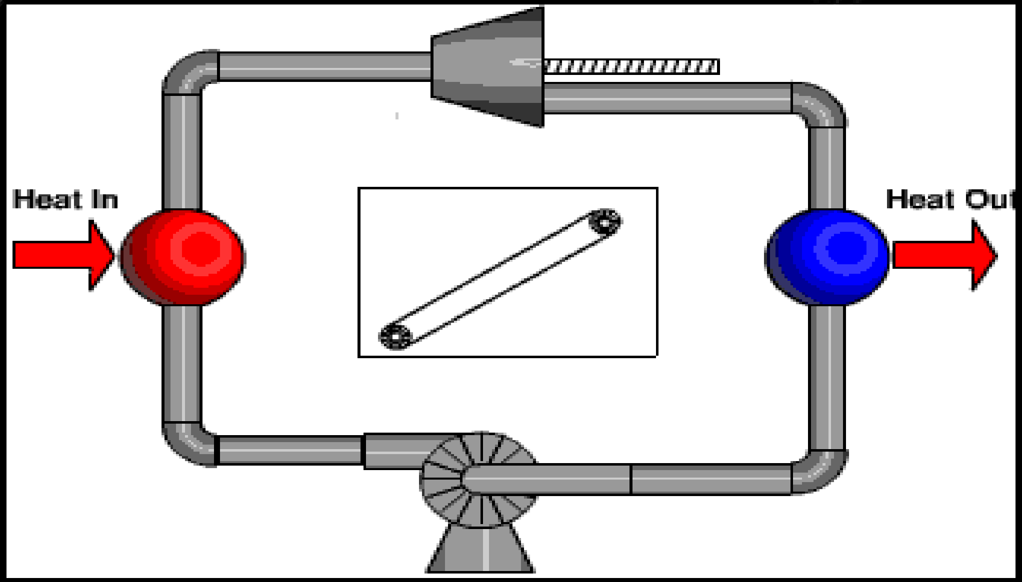
- **Petrol engine**
- **Diesel engine**



External Combustion Engine

❖ In external combustion engine the combustion of the fuel takes place **outside** the engine.

Example- Steam Engine, Closed gas turbine etc.



Differences between ICE and ECE

S. No.	EC Engine	IC Engine
1	Combustion of fuel is outside the engine	Combustion of fuel is inside the engine
2	Bulky due to presence of auxiliary apparatus like boiler and condenser.	It is light and compact
3	High ratio of weight to power output	Low ratio of weight to power output
4	It can use cheaper fuels including solid fuels	High grade fuels are used with proper filtration
5	Higher requirement of water for dissipation of heat	Lesser requirement of water
6	Lower efficiency about 15-20%	Higher efficiency about 35-40%
7	Silent operation due to outside combustion	Very noisy operated engine

GATEWAY CLASSES

Advantages of an I.C. Engine [AKTU]

These are the following advantages of an I.C. Engine

1. Mechanical Simplicity
2. Low initial cost due to absence of boiler, turbine condenser etc.
3. High efficiency than external combustion engine
4. Power to weight ratio is high
5. Very suitable for small power requirement applications
6. Starting time is very less
7. Requires less maintenance

Dis-advantages of an I.C. Engine

These are the following disadvantages of an I.C. Engine

1. Variety of fuels that can be used is limited to very fine quality gaseous and liquid fuel.
2. Fuel used is very costly like gasoline or diesel.
3. Engine emissions are generally high compared to external combustion engine.
4. Not suitable of large scale power generation.
5. In case of reciprocating internal combustion noise is generated due to detonation.

Classification of an I.C. Engine

1. On the basis of strokes used

- Two Stroke cycle Engines
- Four Stroke Cycle Engines

2. On the basis of cycle used

- Otto Cycle Engines
- Diesel Cycle Engines
- Dual Cycle Engines

3. On the basis of types of fuel used

- Petrol Engines
- Diesel Engines
- Gas Engines

4. On the basis of types of Ignition Method :

- Spark Ignition (SI)
- Compression Ignition (CI)

5. On the basis of types of cooling system used:

- Air cooled engines
- Water cooled engines

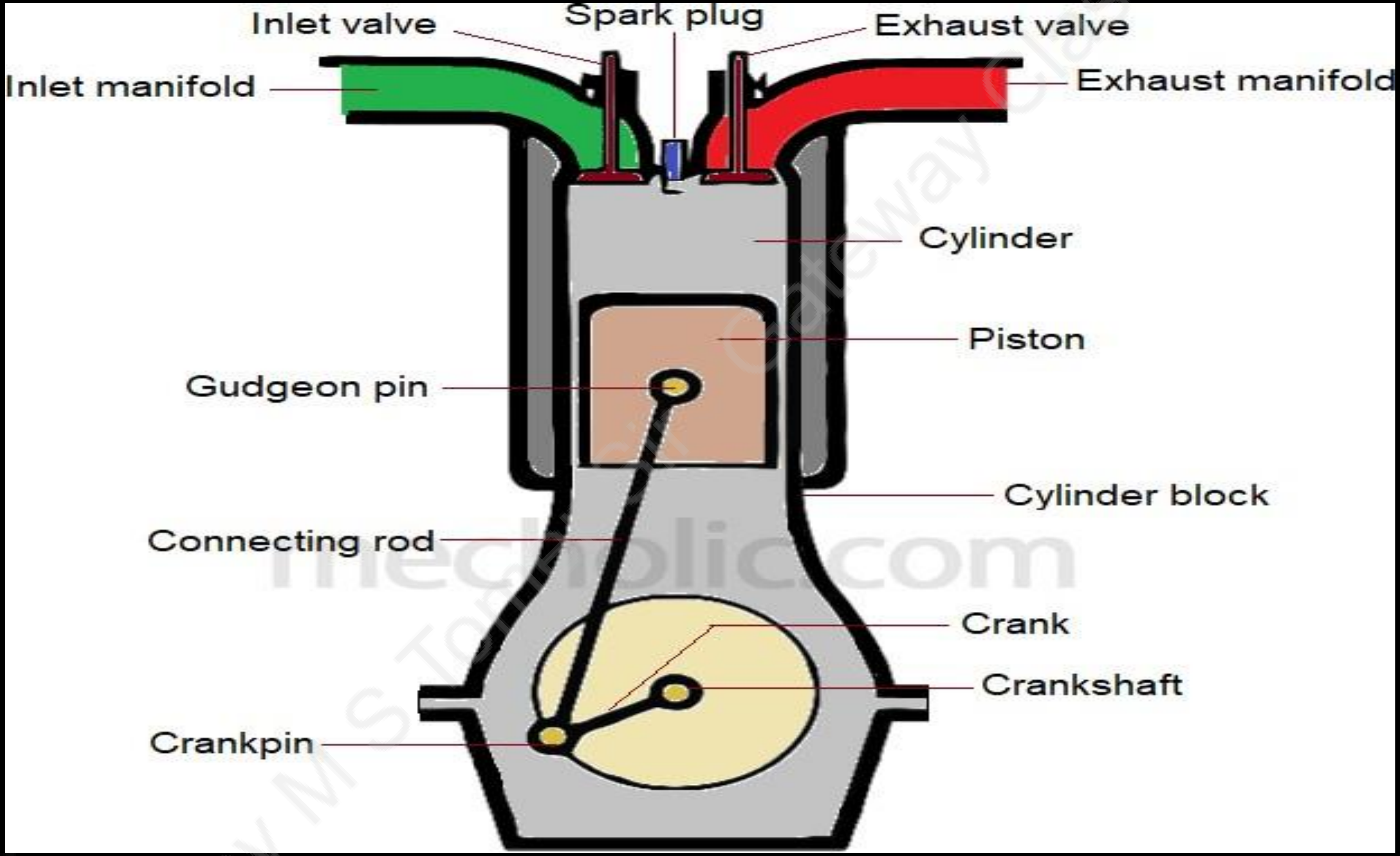
5. On the basis of number of cylinders used:

- Single cylinder engines
- Multi cylinders engines

6. On the basis of types of different position of cylinder :

- Horizontal cylinder engines
- Vertical cylinder engines
- Inclined cylinder engines

Main Components of an I.C.E. [AKTU : 2021-22,23]



Cylinder Block: The foundation of the engine, housing the cylinders where the combustion process occurs. It is made of cast iron or aluminum.

Cylinders: These are cylindrical chambers where the combustion of fuel and air takes place. It is made of cast iron or aluminum.

Pistons: Pistons are cylindrical components that move up and down inside each cylinder. The pressure created by the combustion process forces the pistons down, converting the pressure into mechanical motion. It is made of aluminum alloy, sometimes with steel reinforcement.

Crankshaft: The crankshaft is a rotating shaft connected to the pistons through connecting rods. It converts the linear motion of the pistons into rotational motion, which is then used to drive the wheels of the vehicle. It is made of forged steel or nodular cast iron.

Camshaft(s): The camshaft controls the opening and closing of intake and exhaust valves. It is made of steel or cast iron .It is synchronized with the crankshaft and is responsible for timing the engine's valve operation.

Valves: **Valves are responsible for allowing the intake of air and fuel into the combustion chamber (intake valve) and expelling the exhaust gases (exhaust valve) after combustion. These are made of stainless steel .**

Combustion Chamber: The area inside the cylinder where the air and fuel mixture is ignited by a spark plug (in petrol engines) or by compression (in diesel engines).

Spark Plugs: In gasoline engines, spark plugs are used to ignite the air-fuel mixture in the combustion chamber, creating the controlled explosion that drives the piston down. It is made of Ceramic insulator with metal electrodes

Intake and Exhaust Manifolds: These are pathways that direct the intake air and fuel mixture into the cylinders and expel the exhaust gases out of the engine, respectively.

Fuel Injection/Carburetor System: The system responsible for mixing air and fuel in the right proportion before it enters the combustion chamber. Older engines use carburetors, while modern ones use fuel injection systems.

IC Engine Terminology [AKTU]

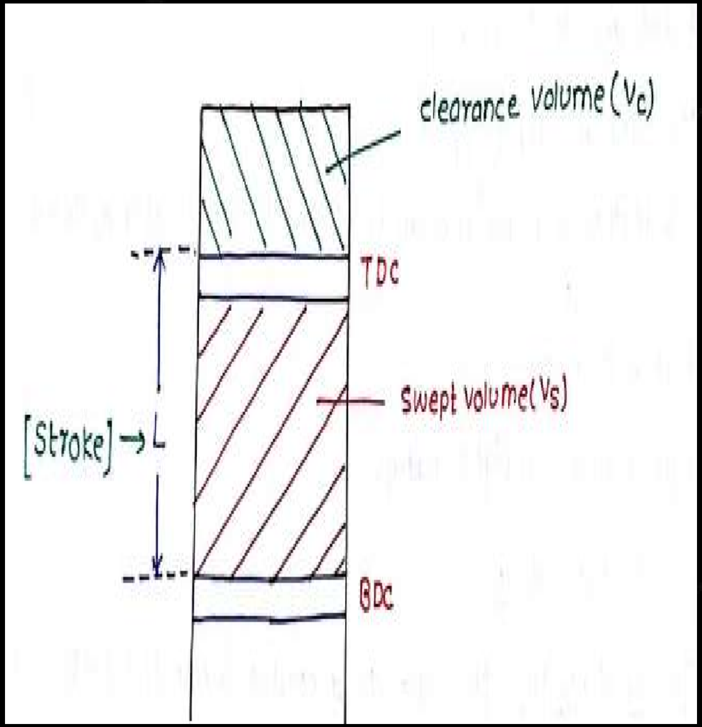
Top-Dead-Center (TDC): It is position of the piston when it is farthest from the crank shaft.

Bottom-Dead-Center (BDC): It is the position of the piston when it is nearest to the crankshaft.

Stroke: When piston moves from TDC to BDC or BDC to TDC is known as stoke.

Stroke Length (L): It is the distance between TDC and BDC.

Bore (D): Inner diameter of the cylinder or diameter of the piston face.



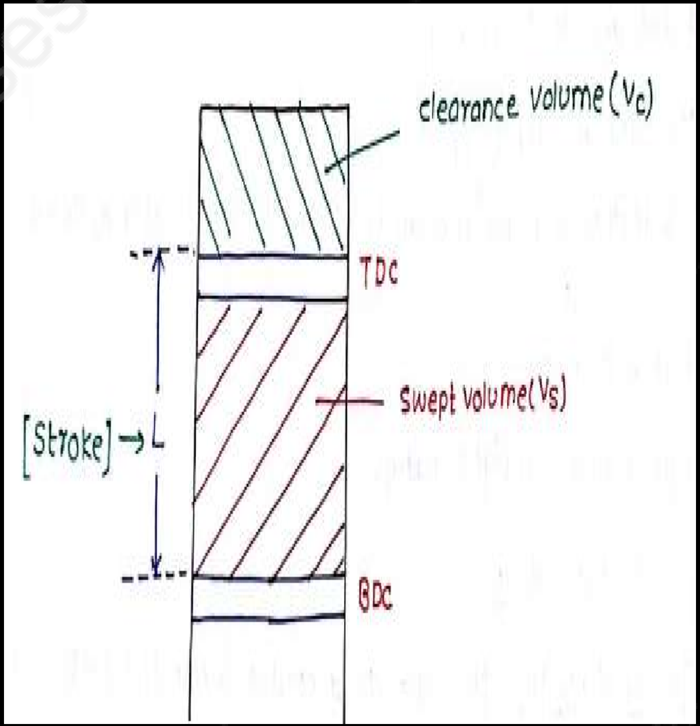
IC Engine Terminology [AKTU : 2021-22]

Swept Volume (V_S): Volume displaced by the piston as it travels through one stroke.

$$V_s = \frac{\pi}{4} D^2 L$$

Total swept volume $V_s = K \frac{\pi}{4} D^2 L$

Where K = no. of cylinders



Clearance Volume (V_C): It is the volume of the cylinder when piston is at TDC, therefore it is minimum volume.

Compression ration (r): It is defined as the ratio of volume before compression to the volume of after compression.

Volume before compression = $V_C + V_S$

Volume after compression = V_C

Four Stroke Engines

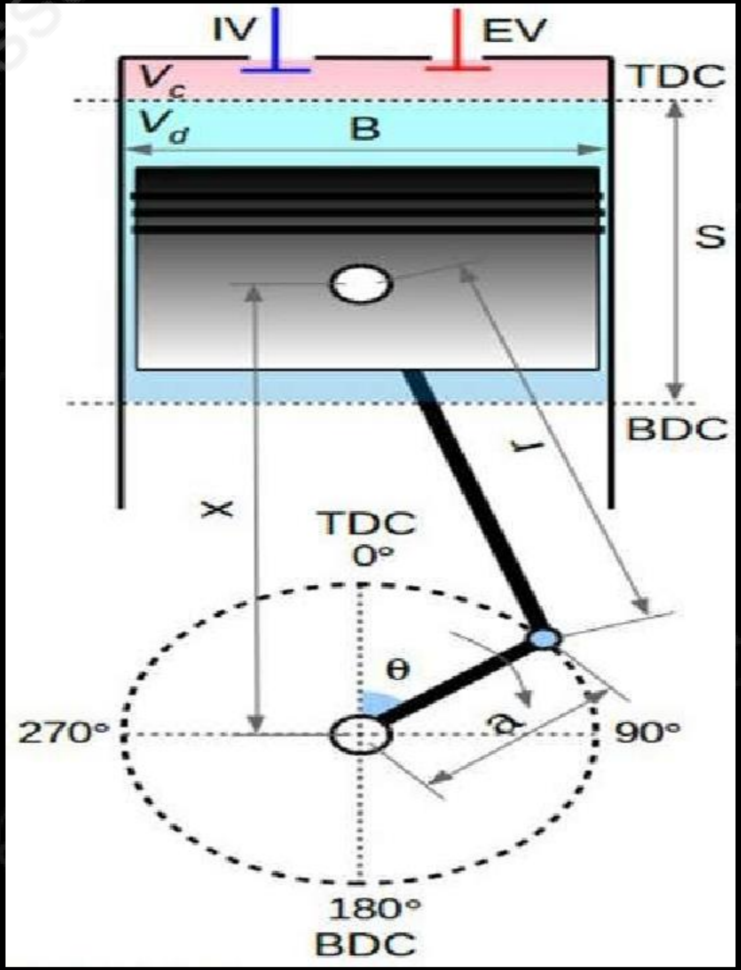
- If a Cycle of an engine is completed in **FOUR strokes of the piston** or **TWO revolution (720^o)** of the crank is known as four stroke engine.

- Cycle consists of processes i.e. Intake, Compression, Expansion and Exhaust.

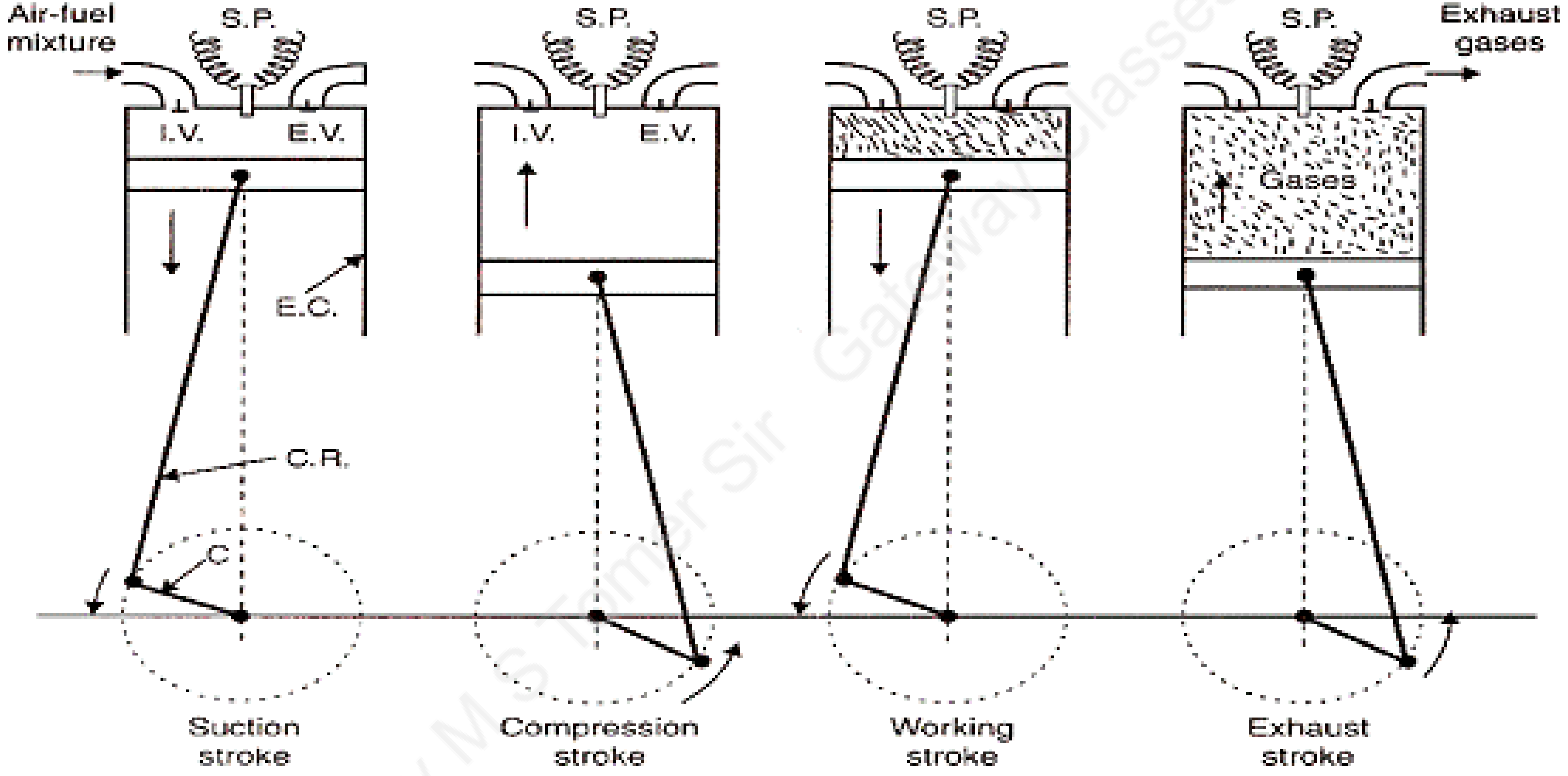
- **Four Stroke Engines may be SI or CI.**

- SI engines work on Otto cycle

- CI engines work on Diesel cycle



Working of Four Stroke SI Engines [AKTU : 2021-22]



I.V = Intel valve, E.V. = Exhaust valve, E.C. = Engine cylinder, C.R. = Connecting rod
C = Crank, S.P. = Spark plug.

Working of Four Stroke SI Engines [AKTU : 2021-22]

The working of a four-stroke spark-ignition (SI) engine involves four strokes:

1. Intake
2. Compression
3. Power
4. Exhaust.

These strokes are repeated in a continuous cycle to produce power

1.Intake Stroke (Suction)

- Piston moves downward from TDC to BDC.
- Inlet valve is opened and the exhaust valve is closed.
- Pressure inside the cylinder is reduced below the atmospheric pressure.
- The mixture of air fuel is sucked into the cylinder through the inlet valve.
- The timing of the intake valve is controlled by the camshaft, which is synchronized with the engine's rotation.

2. Compression Stroke:

- Compression Stroke:
- Piston moves up from BDC to TDC.
- Both inlet and exhaust valves are closed.
- Temperature and pressure increased due to compression of air
- fuel mixture in the cylinder.
- At the end of compression combustion starts with spark plug.

3. Power Stroke (Expansion):

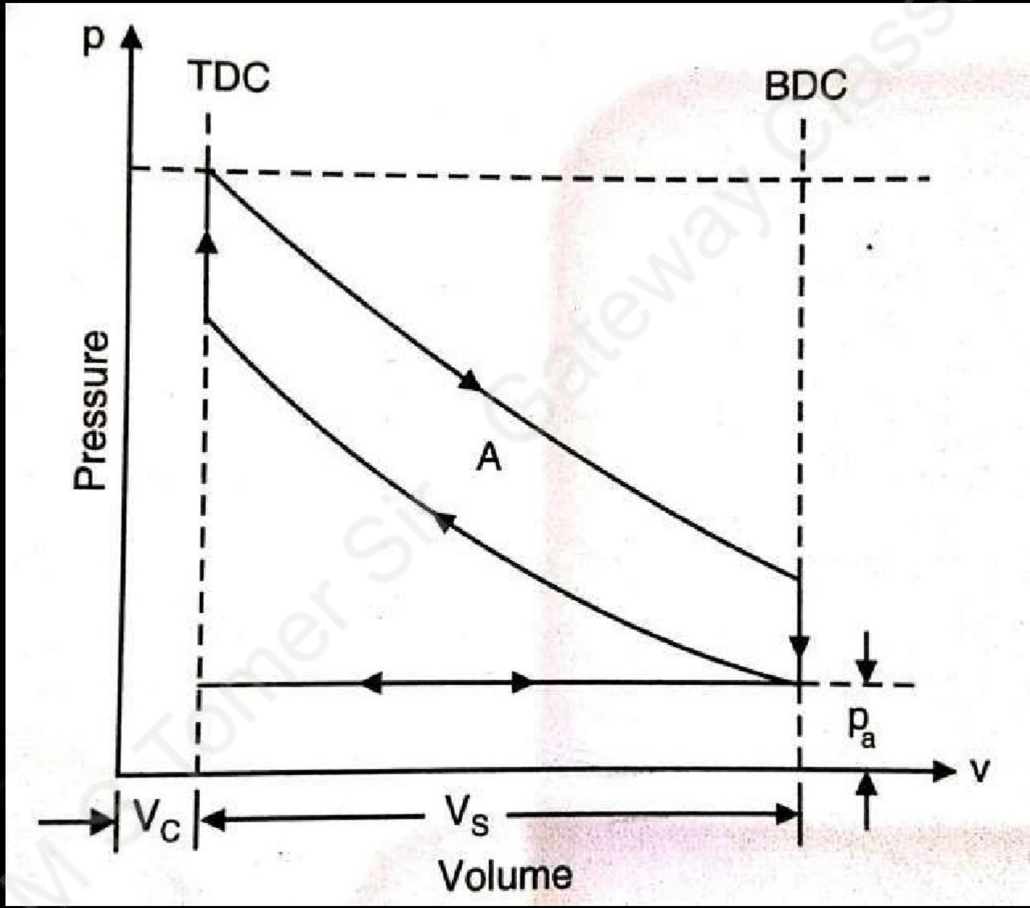
- The burning gases expand rapidly.
- Gases exert an impulse (thrust or force) on the piston.
- The piston is pushed from TDC to BDC.
- This linear motion of the piston is converted into rotary motion of the crankshaft through connecting rod.
- Both inlet and exhaust valves are closed.

4. Exhaust Stroke:

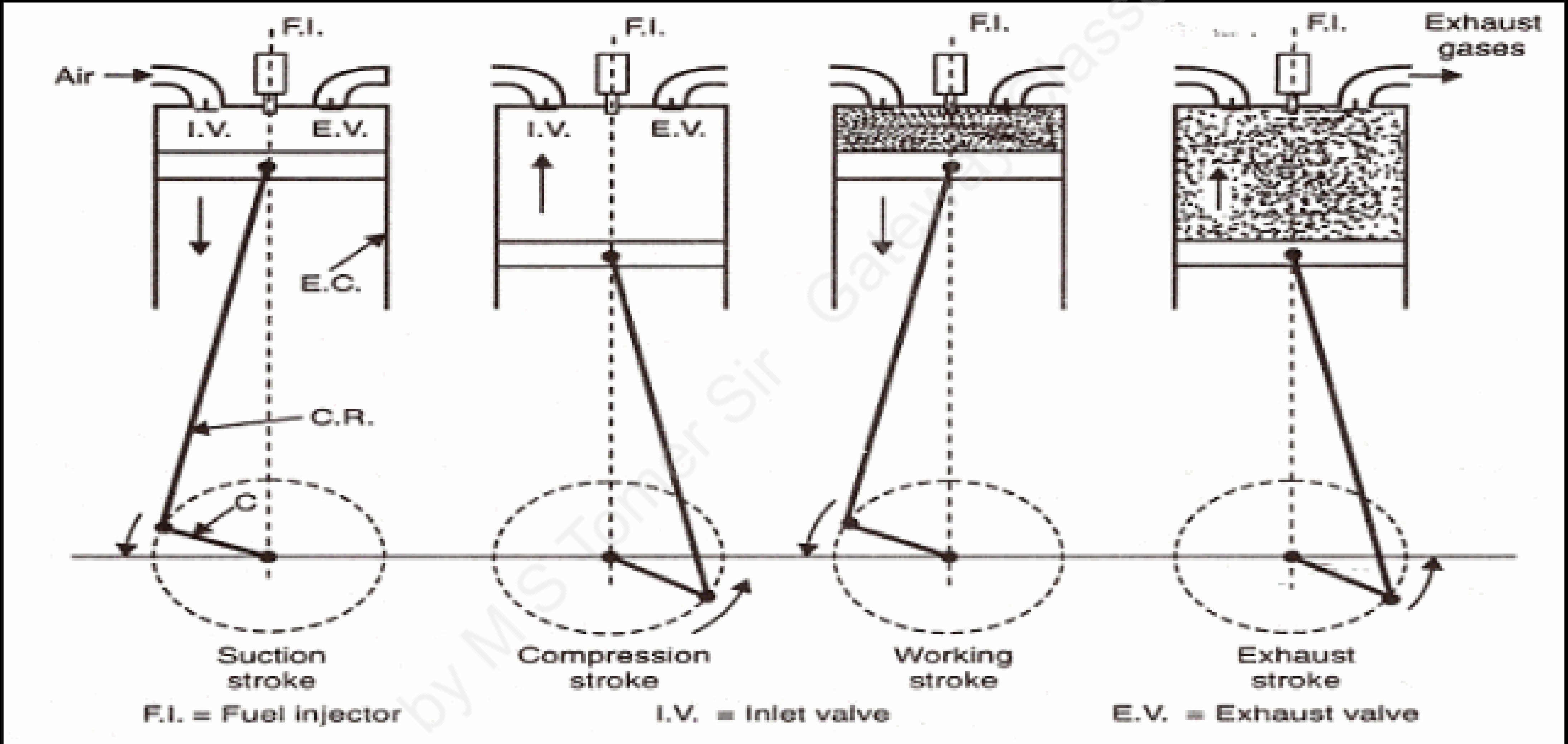
- Piston moves upward from BDC to TDC.
- Exhaust valve is opened and the inlet valve is closed.
- The burnt gases are forced out to the atmosphere through the exhaust valve.
- The inlet valve opens slightly before TDC and the cylinder is ready to receive fresh charge to start a new cycle.

After the exhaust stroke, the cycle repeats, and the engine continues to operate as long as there is a supply of air-fuel mixture and a spark to ignite it.

P-V diagram for Otto Cycle : SI Engine



Working of Four Stroke CI Engines [AKTU : 2020-21]



Working of Four Stroke CI Engines [AKTU : 2020-21]

The working of a four-stroke compression-ignition (CI) engine involves four strokes:

1. Intake
2. Compression
3. Power
4. Exhaust.

These strokes are repeated in a continuous cycle to produce power

1.Intake Stroke (Suction)

- Piston moves from TDC to BDC.
- Inlet valve is opened and the exhaust valve is closed.
- When piston moves from TDC to BDC ,the pressure inside the cylinder is reduced below the atmospheric pressure.
- Fresh air from the atmosphere is sucked into the engine cylinder through air cleaner and inlet valve.

2. Compression stroke:

- Piston moves from BDC to TDC.
- Both inlet and exhaust valves are closed.
- The only air is drawn during suction stroke is compressed to a high pressure and temperature.

- **3. Power Stroke (Expansion):**

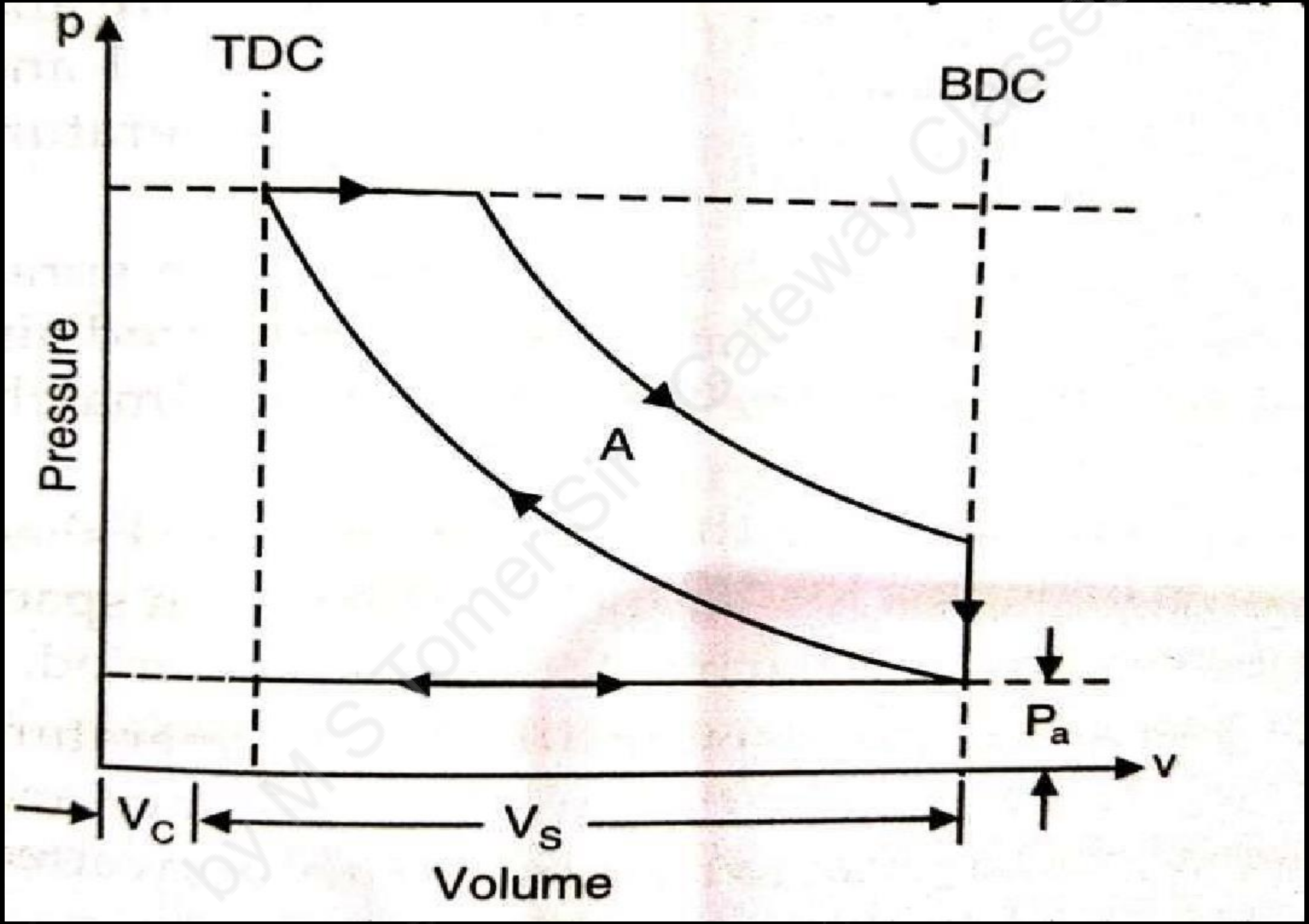
- Fuel (diesel) is injected inside the cylinder with the help of fuel injector.
- The burning gases expand rapidly and push the piston from TDC to BDC.
- This linear motion of piston is converted into rotary motion of the crank shaft through connecting rod.
- Both inlet and exhaust valves are closed.

Exhaust Stroke:

- Piston moves from BDC to TDC.
- Exhaust valve is opened the inlet valve is closed.
- The burnt gases are forced out to the atmosphere through the exhaust valve.
- The inlet valve opens slightly before TDC and the cylinder is ready to receive fresh air to start a new cycle.

After the exhaust stroke, the cycle repeats, and the engine continues to operate as long as there is a supply of air-fuel mixture and a spark to ignite it.

P-V diagram for Diesel Cycle : CI Engine



P-V diagram for Diesel Cycle : CI Engine

. A carburettor is used to supply......

A. Petrol,air and lubricating oil
B. Air and diesel
C. Petrol and lubricating oil
C. Petrol and air

How many degrees of rotation the crankshaft does in a complete engine cycle (4 strokes ICE) ?

A. 720^{o}

B. 540^{o}

C. 360^{o}

Which is the correct order of the engine strokes ?

A. 1. intake 2. exhaust 3. compression 4. power

B. 1. power 2. intake 3. compression 4. exhaust

C. 1. intake 2. compression 3. power 4. exhaust

Differences between SI and CI Engines [AKTU : 2021-22]

S. No.	SI Engine	CI Engine
1	It works on **OTTO Cycle** or constant volume heat addition.	It works on **DIESEL Cycle** or constant pressure heat addition.
2	During the intake or suction process, **air and fuel** are used.	During the intake or suction process, **only air** is used.
3	The fuel used **Petrol** which is highly volatile. Self Ignition temperature is high.	The fuel used **Diesel** which is low volatile. Self- ignition temperature is low.
4	The fuel is supplied by **Carburetor.**	The fuel is supplied by **Injector.**
5	The maintenance **cost is low.**	The maintenance **cost is high.**
6	It is used in Small Vehicles.	It is used in Heavy Vehicles.
7	The compression ratio is **6 to 10.**	The compression ratio is **16 to 22.**
8	The starting of this engine is **easy.**	Starting is a little difficult comparatively SI engine.
9	It produces **less noise.**	It produces **high noise.**
10	**Lower thermal efficiency** because of the low compression ratio.	**High** thermal efficiency because of the high compression ratio.

TWO Stroke Engines

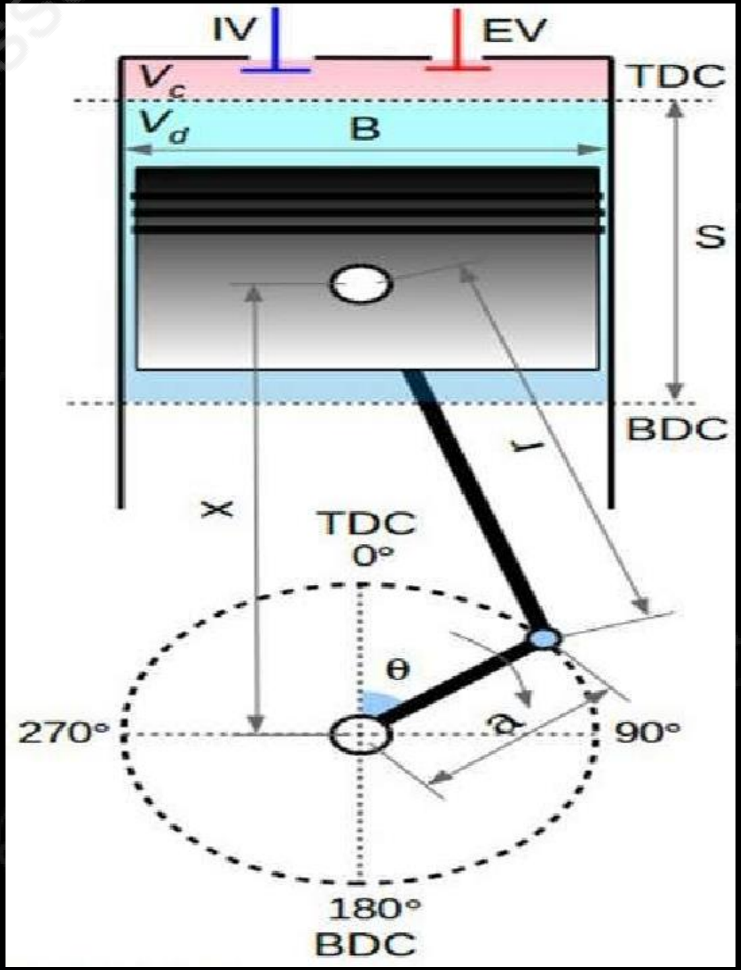
- If a Cycle of an engine is completed in **TWO strokes of the piston** or **ONE revolution (360^o)** of the crank is known as four stroke engine.

- Cycle consists of processes i.e. Intake, Compression, Expansion and Exhaust.

- **Four Stroke Engines may be SI or CI.**

- SI engines work on Otto cycle

- CI engines work on Diesel cycle

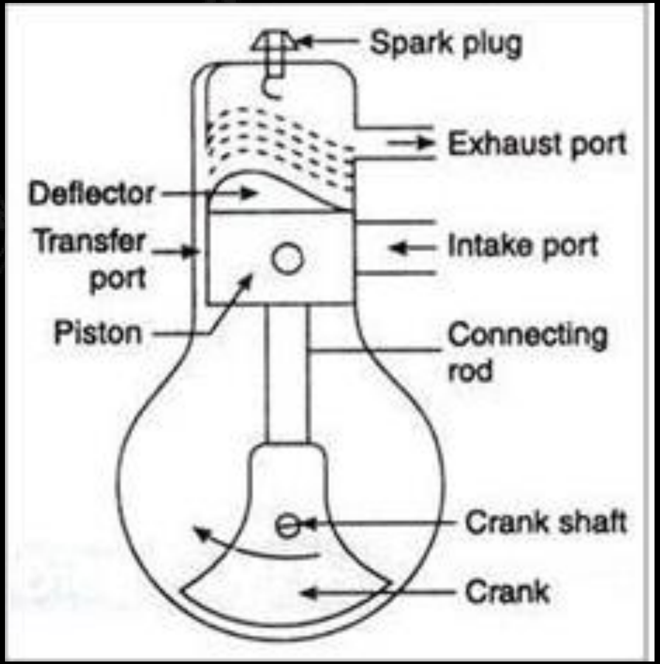


TWO Stroke Vs FOUR Engines

Working of Two Stroke SI Engines [AKTU : 2020-21]

Working

- The working of a two-stroke spark-ignition (SI) engine involves a simpler cycle compared to a four-stroke engine.
- It completes one power cycle in just two strokes of the piston.
- These engines are commonly used in small applications like motorcycles, scooters etc.



1.Intake and Compression:

- The piston moves from (BDC) to (TDC).
- Both transfer and exhaust ports are covered by the piston.
- Air fuel mixture which is already transferred into the cylinder is compressed by moving piston.
- The pressure and temperature increases at the end of compression.
- As piston almost reaches the top dead center. The air fuel mixture inside the cylinder is ignited by means of an electric spark produced by a spark plug.
- At the same time, the inlet port is uncovered by the piston. Fresh air fuel mixture enters the crankcase through the inlet port.

2. Power and Exhaust:

- The burning gases expand in the cylinder. The burning gases force the piston to move down. Thus useful work is obtained.
- When the piston moves down, the air fuel mixture in the crankcase is partially compressed.
- This compression is known as crank case compression.
- At the end of expansion, exhaust port is uncovered. Burnt gases escape to the atmosphere. Transfer port is also opened.

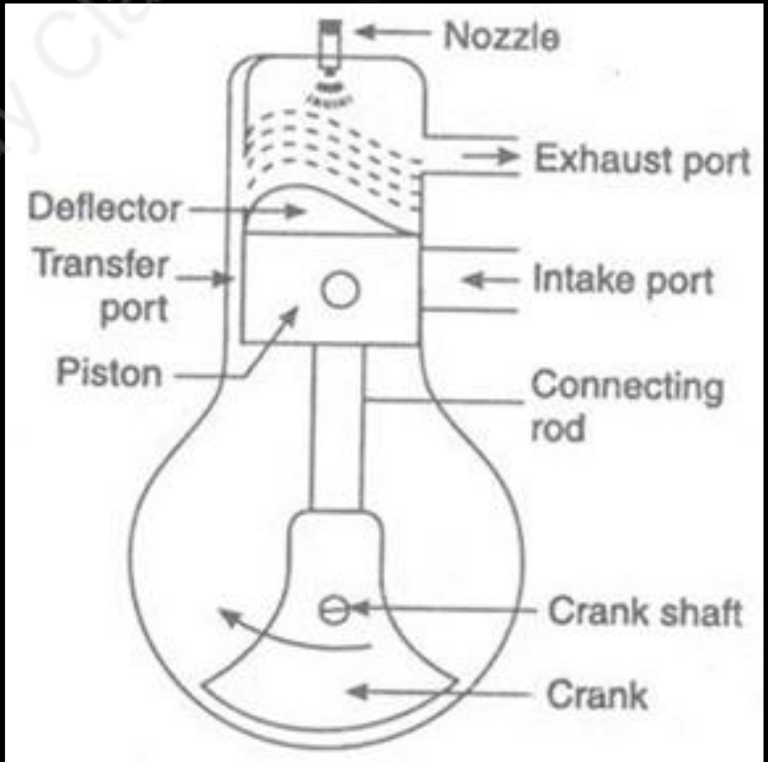
Working of Two Stroke CI Engines [AKTU : 2020-21]

Working

- The working of a two-stroke compression-ignition (CI) engine involves a simpler cycle compared to a four-stroke engine.

- It completes one power cycle in just two strokes of the piston.

- These engines are commonly used in small applications like motorcycles, scooters etc.



Working of Two Stroke CI Engines [AKTU : 2020-21]

1.Intake and Compression:

- The piston moves from (BDC) to (TDC).
- Both transfer and exhaust ports are covered by the piston.
- Air which is already transferred into the cylinder is compressed by moving piston.
- The pressure and temperature increases at the end of compression.
- Piston almost reaches the top dead center. The fuel is injected into the hot compressed air inside the cylinder.
- The fuel mixed with hot air and burns.
- The admission of fresh air into the crankcase continues till the
- piston reaches the top dead center.

2. Power and Exhaust:

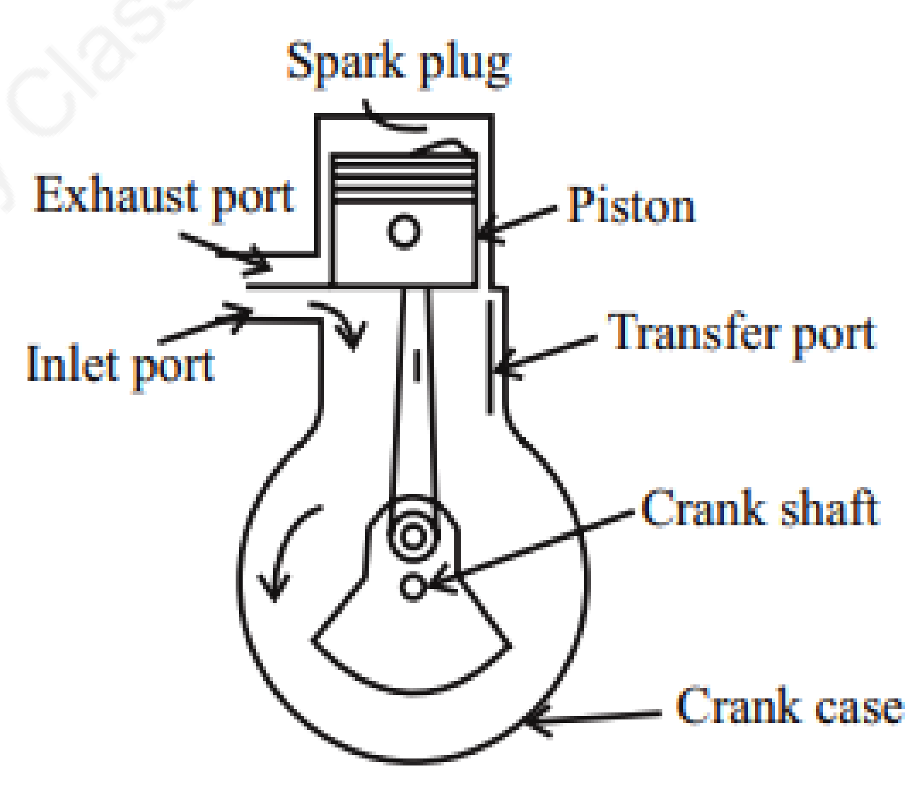
- The burning gases expand in the cylinder.
- Burning gases force the piston to move down. Thus useful work is obtained.
- At the same time, the air in the crank case is compressed partially by the movement of the piston from TDC to BDC.
- At the end of expansion, the exhaust port is uncovered.
- The burnt gases escape to the atmosphere through the exhaust port.

Scavenging process [AKTU : 2020-21]

Scavenging:

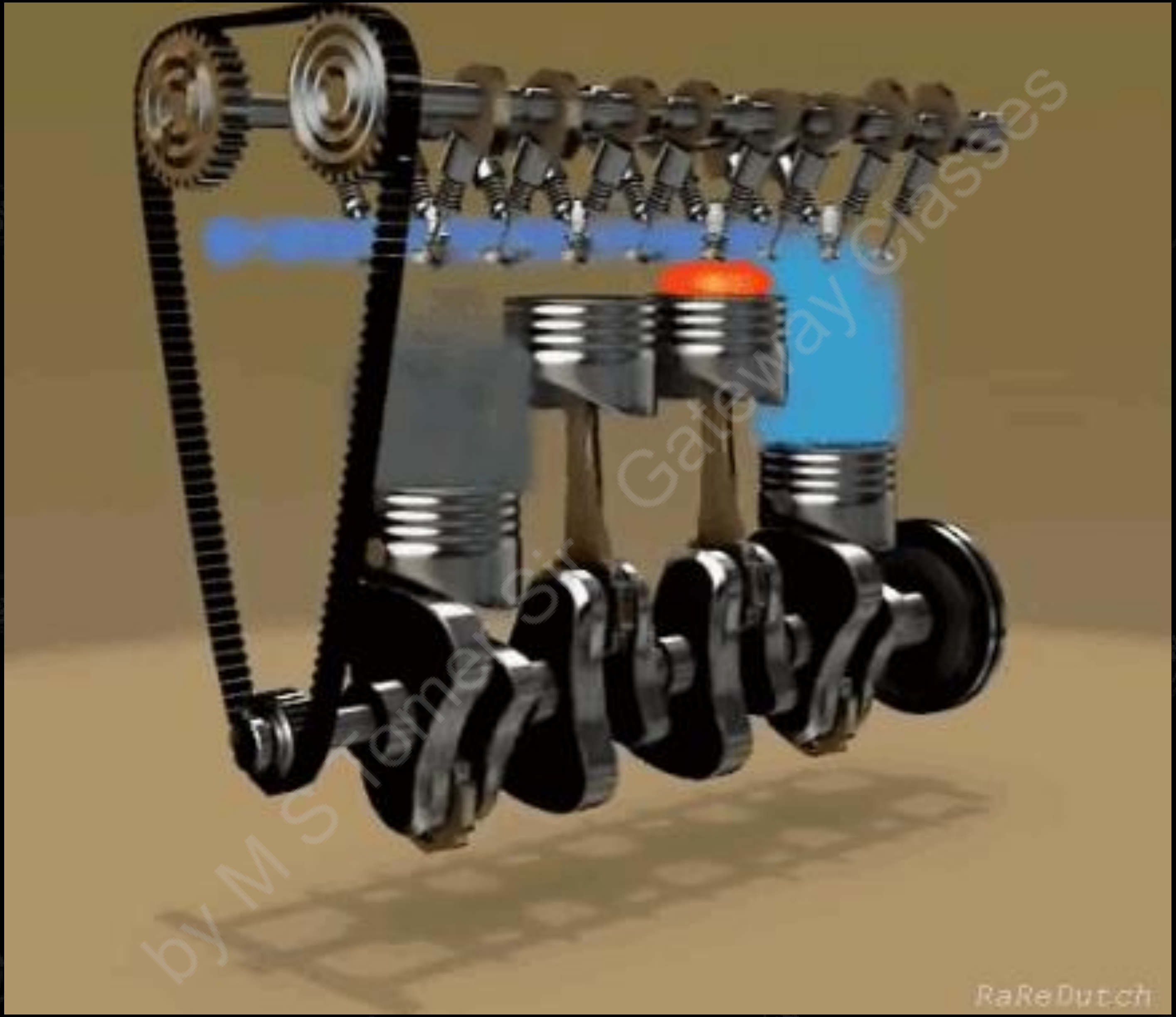
- Scavenging is a process of pushing exhaust gases out of the cylinder.
- One of the critical aspects of two-stroke engine design is scavenging, which involves replacing the exhaust gases with fresh air-fuel mixture to optimize combustion efficiency.

- The charge (air fuel mixture or air) enters the engine cylinder from the crank case at a pressure higher than the exhaust gases.



Differences between 4 strokes and 2 strokes engines [AKTU : 2021-22]

S. No.	4-Stroke Engine	2-Stroke Engine
1	Four stroke of the piston and **two revolution** of crankshaft	Two stroke of the piston and **one revolution** of crankshaft
2	One power stroke in every two revolution of crankshaft	One power stroke in each revolution of crankshaft
3	Power produce is less	Theoretically twice power
4	**Heavier flywheel** due to non-uniform turning movement	**Lighter flywheel** due to more uniform turning movement
5	Lesser cooling and lubrication requirements	Greater cooling and lubrication requirements
6	**Contains valve** and valve mechanism	**Contains ports** arrangement
7	Volumetric efficiency and Thermal efficiency are **high** but mechanical efficiency is **low**.	Volumetric efficiency and Thermal efficiency are **low** but mechanical efficiency is **high**.
8	Heavy and bulky	Light and compact



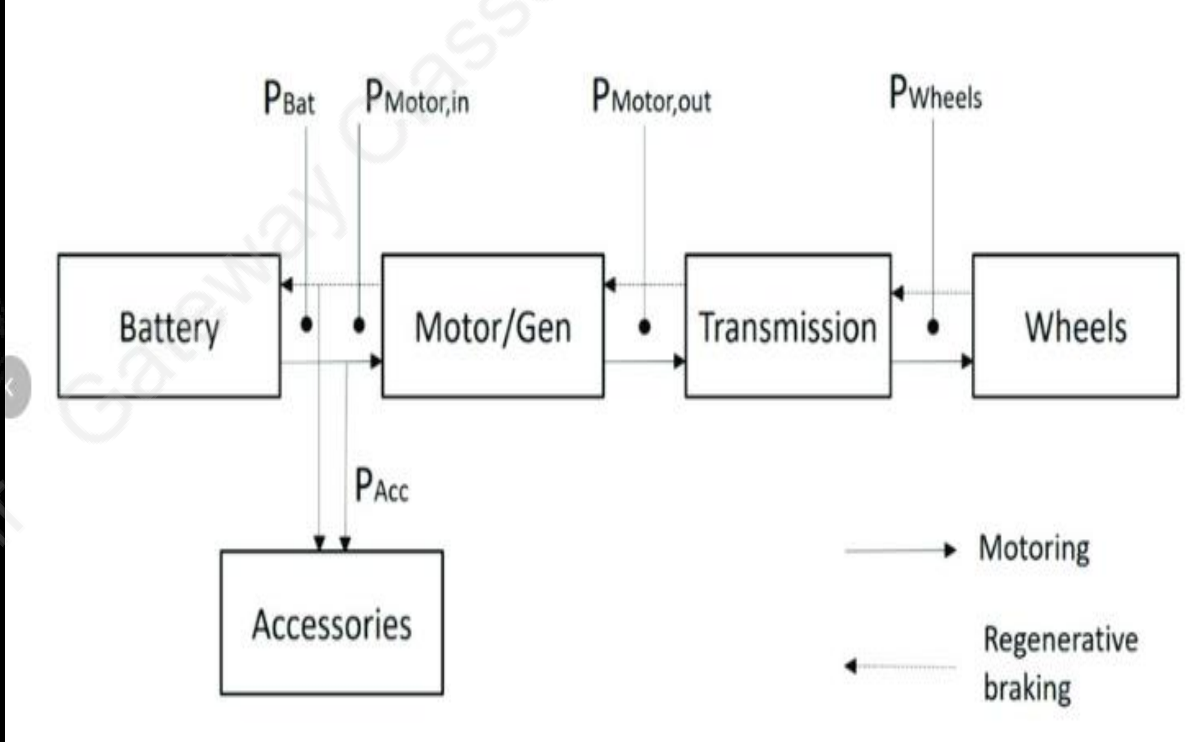
GATEWAY CLASSES

Electric vehicle [AKTU-2021-22]

- An electric vehicle (EV) is a vehicle that uses one or more electric motor for propulsion.
- The electric motors are the replacement of ICE.

Main components of electric vehicle are

- Battery
- Electric motor
- Battery charger
- Power electric converter



Electric vehicles (EVs) have gained popularity in recent years due to their potential to reduce greenhouse gas emissions and dependence on fossil fuels.

Advantages and Dis-advantages of an Electric vehicle

Advantages:

- **Environmental Benefits:** EVs produce zero emissions, which helps reduce air pollution and greenhouse gas emissions, leading to improved air quality and a healthy environment.
- **Energy Efficiency:** Electric vehicles are more energy-efficient than internal combustion engine vehicles. They convert a higher percentage of energy from the electricity grid into usable power for driving, reducing energy waste.
- **Lower Operating Costs:** EVs have lower operating costs compared to traditional gas-powered vehicles. Electricity is generally cheaper than gasoline, and EVs require less maintenance due to less moving parts.
- **Reduced Noise Pollution:** Electric vehicles are quieter than internal combustion engine vehicles, reducing noise pollution in urban areas and creating a quieter driving experience.
- **Government Incentives:** Many governments offer incentives and subsidies to encourage the adoption of electric vehicles, such as tax credits, reduced registration fees etc.
- **Regenerative Braking:** EVs often have regenerative braking systems, which recapture energy during braking and store it in the battery, further improving energy efficiency.

Advantages and Dis-advantages of an Electric vehicle

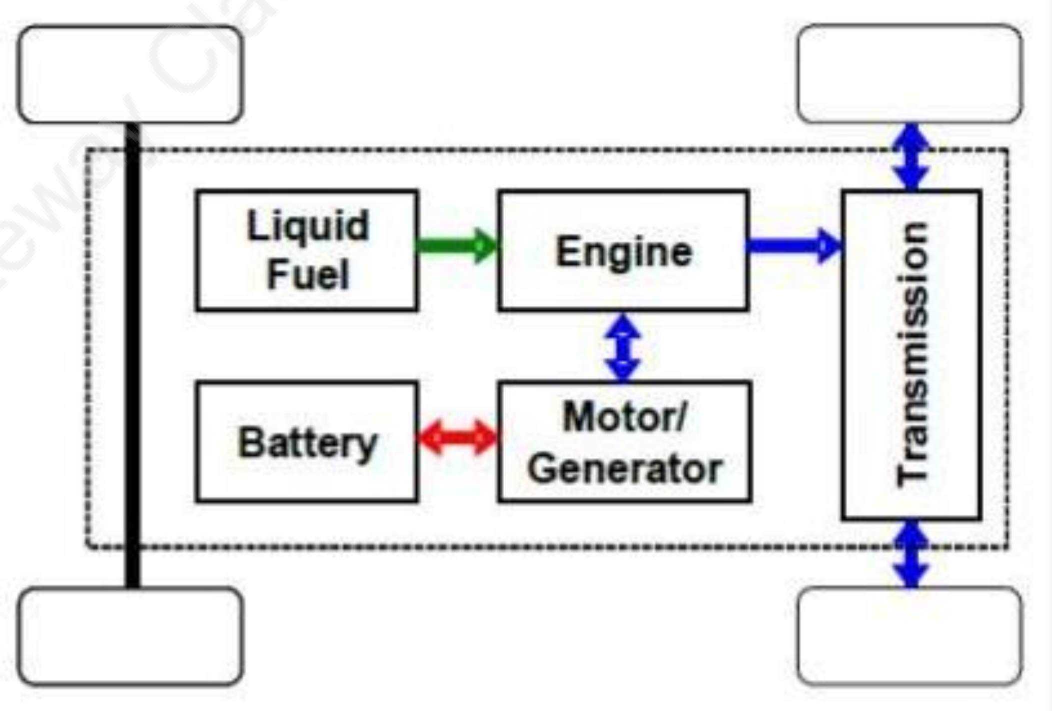
Disadvantages

- **Limited Driving Range:** One of the primary challenges with EVs is their limited driving range compared to conventional vehicles. Although ranges are improving, some EVs may still not be suitable for long-distance travel without frequent charging.
- **Charging Infrastructure:** The availability of charging stations can be limited in some areas, making it difficult for EV drivers to charge their vehicles conveniently, especially in remote regions.
- **Longer Refueling Time:** Charging an EV takes longer than refueling a conventional vehicle with gasoline. Even with fast-charging technology, it may still take several minutes to an hour to charge fully, depending on the battery capacity and charging speed.
- **Initial Cost:** Electric vehicles generally have a higher cost compared to traditional gasoline-powered cars, mainly due to the cost of batteries. However, prices have been decreasing as technology advances and production scales up.
- **Battery Life and Recycling:** Battery life and recycling are ongoing concerns for EVs. While battery technology is improving, eventually, all batteries will degrade and need replacement. Proper battery recycling and disposal are essential to minimize environmental impacts.

Hybrid Electric Vehicles (HEV)

- A hybrid vehicle is a type of automobile that combines two or more power sources to provide propulsion.

- The most common type of hybrid vehicle is the hybrid electric vehicle (HEV), which typically combines an internal combustion engine (ICE) and an electric motor.



Types of hybrid vehicles

Parallel Hybrid Electric Vehicle (PHEV):

- In a parallel hybrid, both the internal combustion engine and the electric motor are connected to the vehicle's transmission, allowing either or both power sources to drive the wheels simultaneously.
- The electric motor assists the engine during acceleration and provides regenerative braking to recharge the battery when the vehicle slows down.

Series Hybrid Electric Vehicle (SHEV):

- In a series hybrid, the internal combustion engine does not directly drive the wheels.
- Instead, it serves as a generator to charge the battery, which then powers the electric motor that drives the wheels.
- The engine may come into direct operation in certain situations, such as when the battery charge is low or during high-power demands.

EV Batteries

GATEWAY CLASSES

- Electric vehicle (EV) batteries are a critical component of electric vehicles, providing the energy storage needed to power the electric motor and propel the vehicle.
- These batteries are typically rechargeable and store electrical energy in the form of chemical energy allowing the vehicle to travel without the need for an internal combustion engine.

Types of EV Batteries

1. Lithium-ion (Li-ion) Batteries
2. Solid-State Batteries:

1. Lithium-ion (Li-ion) Batteries:

- Lithium-ion batteries are the most common type used in electric vehicles due to their high energy density, which allows for longer driving ranges and better performance.
- They offer a good balance between energy capacity, weight, and cost. Many EV manufacturers use variations of lithium-ion chemistry, such as lithium iron phosphate (LiFePO4) and lithium nickel manganese cobalt oxide (NMC).

EV Batteries

GATEWAY CLASSES

2. Solid-State Batteries:

- Solid-state batteries are an emerging technology that aims to replace the liquid electrolyte in traditional lithium-ion batteries with a solid-state electrolyte.
- These batteries have the potential to offer higher energy densities, faster charging times, and improved safety compared to conventional lithium-ion batteries. However, they are still in the early stages of commercialization and not yet widely used in EVs.

Electric vehicle (EV) Chargers

- Electric vehicle (EV) chargers are devices used to recharge the batteries of electric vehicles.
- There are different types of EV chargers, each with varying charging speeds and applications.

Types of EV chargers:

1.Level 1 Charger (120V):

- Level 1 chargers are the most basic and usually come with the electric vehicle when purchased. They operate on a standard 120-volt household outlet.
- These chargers are relatively slow and are suitable for overnight charging at home. Level 1 chargers typically provide a charging rate of about 3 to 5 miles of range per hour of charging.

2. Level 2 Charger (240V):

- Level 2 chargers are more powerful than Level 1 chargers and require a 240-volt outlet. They are commonly installed at homes, workplaces, and public charging stations.
- Level 2 chargers provide faster charging rates, typically adding around 10 to 30 miles of range per hour of charging, depending on the vehicle and charger specifications.

3. DC Fast Charger (Level 3 Charger):

- DC fast chargers, also known as Level 3 chargers, are high-powered chargers commonly found at public charging stations, rest areas, and along highways.
- They provide rapid charging by delivering direct current (DC) power to the vehicle's battery.
- DC fast chargers can recharge an EV to 80% capacity in around 30 minutes, making them ideal for long-distance travel and quick top-ups.

4.Tesla Supercharger

- Tesla Superchargers are exclusive to Tesla electric vehicles.
- They are high-speed DC fast chargers designed specifically for Tesla cars.
- Superchargers can provide fast charging rates and are strategically placed along highways and popular travel routes to support long-distance travel for Tesla owners.

For more Subject/pdf Notes
Download Gateway Classes Application
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Link in Description

Thank You

FUNDAMENTALS OF MECHANICAL ENGINEERING (BME-101/201)

UNIT-4
Lec-1

As per
New Syllabus 2022-23

Today's Target

- ✓ Properties of Fluid
- ✓ AKTU Numerical
- ✓ Practice Numerical

Unit –IV SYLLABUS

- Introduction: Fluids properties, pressure, density, dynamic and kinematic viscosity, specific gravity, Newtonian and Non-Newtonian fluid, Pascal's Law and Continuity Equation.

- Working principles of hydraulic turbines (Pelton Wheel and Francis)& pumps (Centrifugal and Reciprocating) and their classifications and hydraulic lift.

Introduction

- . A matter exists in either the solid state or the fluid state.

S | L | G

- The fluid state is further divided into
  - Liquid state
  - Gaseous state
- In fact the same matter may exist in any one of the three states i.e. solid, liquid and gaseous.
- For example water occurs in a liquid state, may also occur in solid state as ice and in a gaseous state as vapour.

S/L/G

....Introduction

- In solids the molecules are very closely spaced.
- In liquids the spacing between the molecules is relatively large.
- In gases the space between the molecules is still larger.

Fluid Mechanics

- "Fluid mechanics is that branch of science which deals with the behavior of the fluids at rest as well as in motion."

- In general the scope of fluid mechanics is very wide which includes the study of all liquids and gases.

- It has applications in mechanical, civil, chemical and biomedical engineering etc.

fluid

Fluid

- Fluid may be defined as a substance which is capable of flowing.
- It has no definite shape of its own, but conforms to the shape of the containing vessel.

OR

- "A fluid is a substance which deforms continuously under the action of tangential or shear force."
- A liquid is a fluid, which possesses a definite volume, which may vary slightly with temperature and pressure.
- A gas is a fluid, which is compressible and possesses no definite volume but it always expands until its volume is equal to that of the container.
- Examples of fluids are : Water, Milk, Kerosene, Petrol, Gases etc

Basic Properties of Fluid

1. Pressure
2. Specific volume
3. Density
4. Specific Weight
5. Specific Gravity
6. Dynamic Viscosity
7. Kinematic Viscosity

1.Pressure (P)

❖ "It is defined as normal force per unit area."

$$\boxed{P = \frac{F}{A}}$$

❖ It is a scalar quantity.

❖ Units of Pressure :

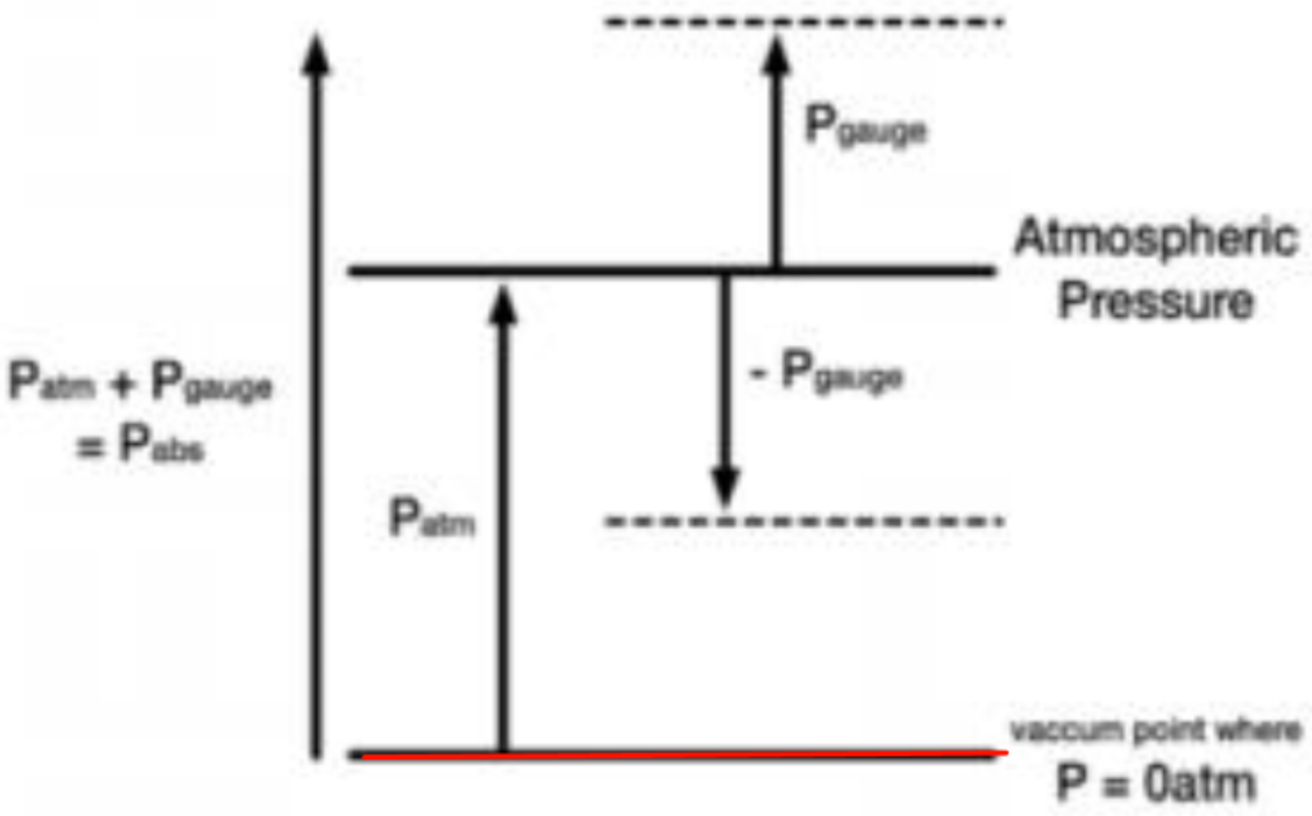
➢ N/m^2

➢ Pascal (Pa) (1 Pa = 1 N/m^2)

➢ atm (1 atm = 101325 Pa = 101.325 kPa)

➢ Bar (1 bar $=10^5$ Pa $= 10^5$ N/m^2

P=



is

Numerical 4.1 [AKTU-2021-22]

What is the $\boxed{\text{absolute}}$ pressure experienced by a pressure sensor, if the atmospheric pressure of a fluid is $\boxed{2\ \text{atm}}$, gauge pressure is $\boxed{5\ \text{atm}}$ and differential pressure is 3 atm.

$$P_{abs} = P_{atm} + P_g$$

$$= 2 + 5$$

$$= 7\ \text{atm} \quad \underline{\text{Ans}}$$

Specific volume/Density

$\underbrace{\text{Specific volume}}_{v}$ / $\underbrace{\text{Density}}_{\rho}$

$\boxed{\rho = \frac{m}{V}} = \frac{100\ kg}{90\ m^3}$

$\rho = 1.1\ kg/m^3$

$\boxed{\rho = \frac{1}{v} \text{ or } v = \frac{1}{\rho}}$

air

$m = 100\ kg$

$V = 90\ m^3$

$v = \frac{V}{m} = \frac{90\ m^3}{100\ kg}$

$= 0.9\ m^3/kg$

2. Density($\boxed{\rho}$) or mass density

- "It is defined as mass per unit volume of the substance."

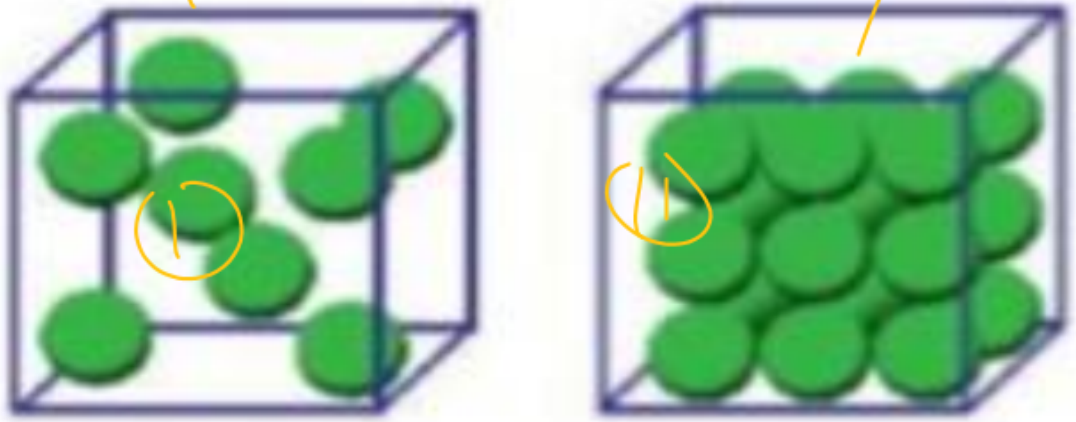
$$\boxed{\rho = \frac{m}{V}}$$

$$\boxed{\rho_s > \rho_l > \rho_g}$$

- Units of density
  - Kg/m³
  - g/cm³ or g/cc (1 g/cc = 10³ kg/m³)

$\rho_1 = \frac{m}{V}$ V

$\rho_2 = \frac{m}{V}$ V



$\rho = \frac{m}{V}$

- For example
  - ρ_{water} = 1000 kg/m³
  - ρ_{air} = 1.2 kg/m³
  - ρ_{steel} = 7850 kg/m³

3.Specific Weight (ω) or weight density

- "It is defined as weight per unit volume ."

$$\boxed{\omega = \frac{weight}{Volume} = \frac{mg}{V} = \rho g} \qquad [\rho = \frac{m}{V}]$$

- Unit of specific weight is N/m^3

4.Specific Gravity

- “ It is defined as the density of the fluid w.r.t. the density of standard fluid.”

$$\boxed{\textbf{Specific Gravity(s)} = \frac{\textit{density of a fluid}}{\textit{density of standartd fluid}}}$$

- For liquid, standard fluid is water (at 4 °C(**39.2 °F**), 1 atm, $\boxed{\text{1000 kg/m}^3}$).
- For gases, standard fluid is Air/H_2.

Numerical-4.2

Calculate the specific weight, density and specific gravity of one litre of a liquid which weighs 7 N.

(i) Sp. wt = ?

(ii) $\rho = ?$

(iii) Sp. gravity = ?

$V = 1$ lit [given

$= 1 \times 10^{-3}\ m^3$

$Wt = 7N$

(i) $Sp\ wt = \frac{Wt}{V} \Rightarrow Sp.wt = \frac{7\ N}{10^{-3}\ m^3} = 7000\ \frac{N}{m^3}$ Ans

(ii) $Sp\ wt = \frac{Wt}{V} = \frac{mg}{V} = \rho g$

$7000 = \rho \times 9.81 \Rightarrow \boxed{\rho = 713\ kg/m^3}$ Ans

(iii) $Sp.\ gravity = \frac{\rho_{fluid}}{\rho_{std\ fluid}} = \frac{\rho_{liq}}{\rho_w}$

$= \frac{713}{1000}$

$= 0.713$ Ans

Numerical-4.3

Calculate the density, specific weight of one litre of petrol of specific gravity = 0.7.

Try your self

FUNDAMENTALS OF MECHANICAL ENGINEERING (BME-101/201)

UNIT-4
Lec-2

As per
New Syllabus 2022-23

MST Sir

Today's Target

- ✓ Newton's law of Viscosity.
- ✓ Dynamic Viscosity
- ✓ Kinematic Viscosity
- ✓ TYPES OF FLUID

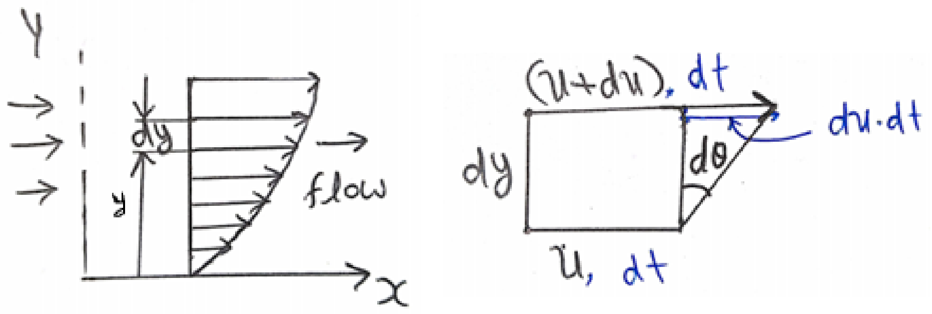
Dynamic Viscosity

- "Two adjacent layers of the fluid **resist** the motion of each other such a fundamental property of the fluid is known as **viscosity or dynamic viscosity**" denoted by **μ**.
- Therefore the frictional force between the adjacent layers is known as viscous shear force.

$$\tan d\theta = \frac{du.dt}{dy}$$

if dΘ is very small $d\theta = \frac{du.dt}{dy}$

$$\frac{d\theta}{dt} = \frac{du}{dy}$$



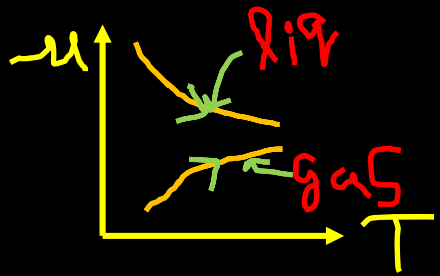
Where $\frac{d\theta}{dt}$ = Rate of angular(shear) deformation and $\frac{du}{dy}$ = Velocity gradient.

Cause of Viscosity

- Basic cause of viscosity is **cohesive forces** between the molecules.
- Because in case of liquid cohesive force is high and in case of gases cohesive force is very less.
- Therefore viscosity of liquid is very high as compared to viscosity of gases.

Dependency of Viscosity on Temperature

- Viscosity of liquid decreases with increase in temperature.[if T↑ then cohesion ↓]



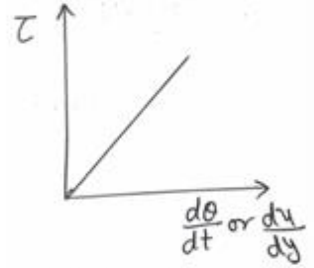
- Viscosity of gases increases with increase in temperature.[if T↑ then randomness↑]

Newton's law of Viscosity.

❖ According to Newton's law of viscosity "Shear stress between the layers of fluid is directly proportional to rate of shear deformation."

$$\tau \propto \frac{d\Theta}{dt} \quad \text{or} \quad \tau \propto \frac{du}{dy} \qquad \left[\text{Because } \frac{d\Theta}{dt} = \frac{du}{dy}\right]$$

$$\tau = \mu \frac{du}{dy}$$



❖ Where μ is proportionality constant(**property of fluid**) which is known as viscosity or dynamic viscosity.

❖ Unit of viscosity

➢ MKS : $\frac{N-s}{m^2} = \frac{kg-m}{s^2} \times \frac{s}{m^2} = \frac{kg}{m-s}$ [F = ma]

➢ **CGS :** $\frac{gm}{cm-s} = \frac{10^{-3} kg}{10^{-2}\, m-s} = 0.1\, \frac{kg}{m-s} = 0.1\, \frac{N-s}{m^2}$

❖ $\frac{gm}{cm-s}$ = 1 Poise = 0.1 $\frac{N-s}{m^2}$

Kinematic Viscosity

- "Ratio of dynamic Viscosity and density is called Kinematic Viscosity, denoted by **ν.**

$$\nu = \frac{\mu}{\rho}$$

- Unit of Kinematic Viscosity

- MKS : m^2/s
- CGS : cm^2/s

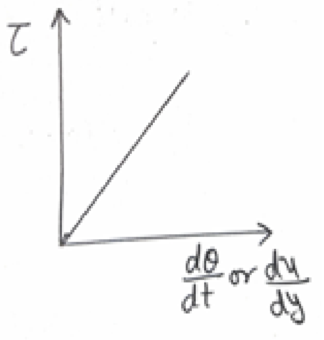
$$1\,\frac{cm^2}{s} = 10^{-4}\,\frac{m^2}{s} = 1 \text{ stoke}$$

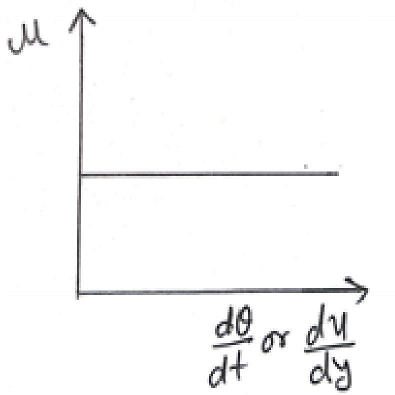
❖ **NEWTONIAN FLUID :** "All the fluids which obey Newton's law of viscosity are known as Newtonian fluids."

❖ There is a linear relation between magnitude of τ and $\frac{d\theta}{dt}$.

❖ Example : Air, water, kerosene, petrol etc.

$$\tau = \mu \frac{du}{dy} \quad \text{Or} \quad \tau = \mu \frac{d\theta}{dt}$$





$$\mu = \tau / \left(\frac{d\theta}{dt}\right)$$

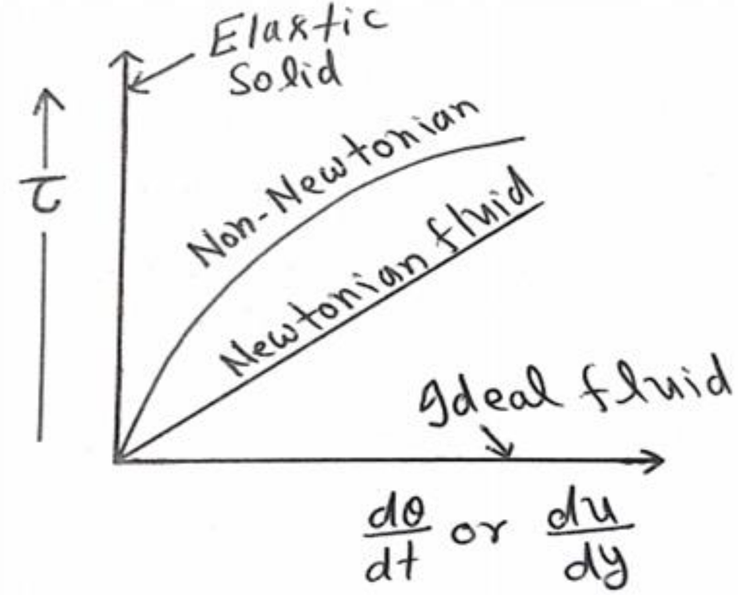
μ is the slope of (τ- $\frac{d\theta}{dt}$) diagram.

❖ Note: In Newtonian fluid the viscosity does not change for same fluid.

Non Newtonian fluids

- **Non Newtonian fluids:-**The fluids which do not follow Newton's law viscosity are known as Non-Newtonian Fluid.

- There is a non-linear relation between magnitude of τ and $\frac{d\theta}{dt}$.



Ideal and Real fluids

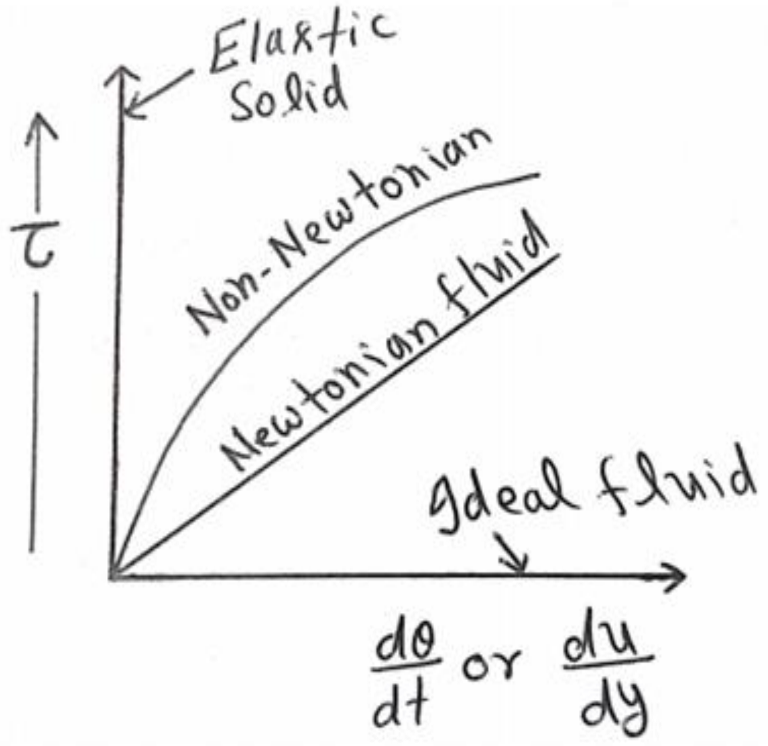
❖**IDEAL FLUID:-**Incompressible fluid having zero viscosity is called ideal fluid($\tau = 0$).

❖**Ideal fluid** do not actually exist in nature.

❖It is represented by horizontal line on (τ-$\frac{d\theta}{dt}$) diagram .

❖**Real fluid:** **Fluid** that have viscosity($\mu > 0$) and their motion known as viscous flow.

❖All the fluids in actual are real fluids.



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FUNDAMENTALS OF MECHANICAL ENGINEERING (BME-101/201)

70 M

100

UNIT-4
Lec-3

As per New Syllabus 2022-23

Today's Target

- ✓ Pascal's Law Statement
- ✓ Pascal's Law Derivation
- ✓ Applications of Pascal's Law
- ✓ Numerical Problem

Unit –III SYLLABUS

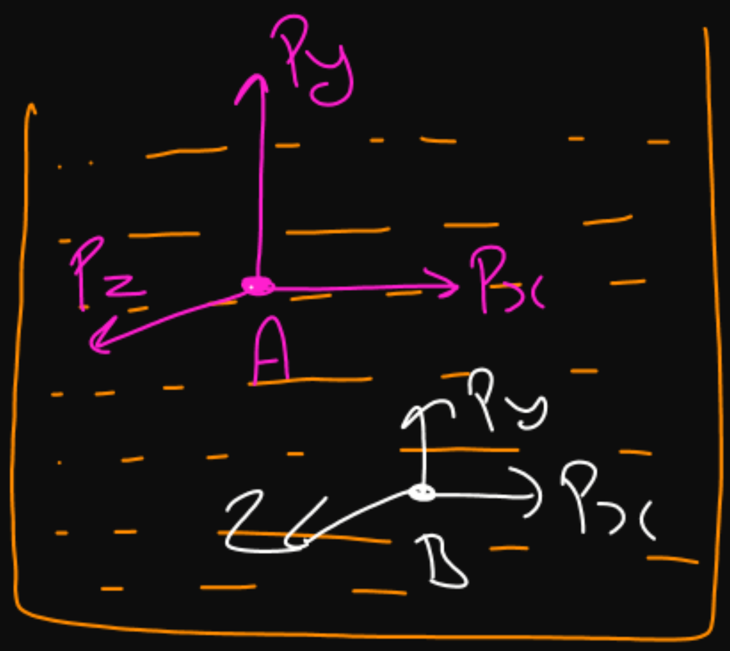
- Introduction: Fluids properties, pressure, density, dynamic and kinematic viscosity, specific gravity, Newtonian and Non-Newtonian fluid, Pascal's Law and Continuity Equation.

- Working principles of hydraulic turbines (Pelton Wheel and Francis)& pumps (Centrifugal and Reciprocating) and their classifications and hydraulic lift.

Pascal's Law Statement

Statement: Pressure at a point in fluid at rest is same in all the directions.

$P_x = P_y = P_z$



$P_x = P_y = P_z$

Applications of Pascal's law

- Hydraulic lift
- Hydraulic Jacks
- Hydraulic brakes
- Hydraulic pumps

Derivation : Pascal's Law

Let us consider a wedge shape fluid element whose thickness is $\boxed{\text{unity(1)}}$.

$\Sigma F_x = 0$ $\quad \rightarrow +ve \quad \leftarrow -ve$

$P_x \cdot dy - P \cdot ds \cdot \cos\theta = 0$

$P_x \cdot dy = P \cdot ds\cos\theta$

$P_x \cdot \cancel{dy} = P \cdot \cancel{dy}$

$\boxed{P_x = P}$ ---- (i)

$\Sigma F_y = 0$ $\quad \uparrow(+ve) \quad \downarrow(-ve)$

$P_y \cdot dx - P \cdot ds\sin\theta - W$

$P_y \cdot dx = P \cdot ds \cdot \sin\theta + \rho g \frac{dx\,dy}{2}$ $\quad \nearrow 0$

$P_y \cdot dx = P \cdot ds\sin\theta$

$P_y \cdot \cancel{dx} = P \cdot \cancel{dx}$

$\boxed{P_y = P}$ — (ii)

$W = mg$ $\quad [m = \rho \cdot V]$

$= \rho \cdot V \cdot g$

$W = \rho g \cdot \frac{dx\,dy}{2}$

from eqn (i) & (ii)

$\boxed{P_x = P_y}$

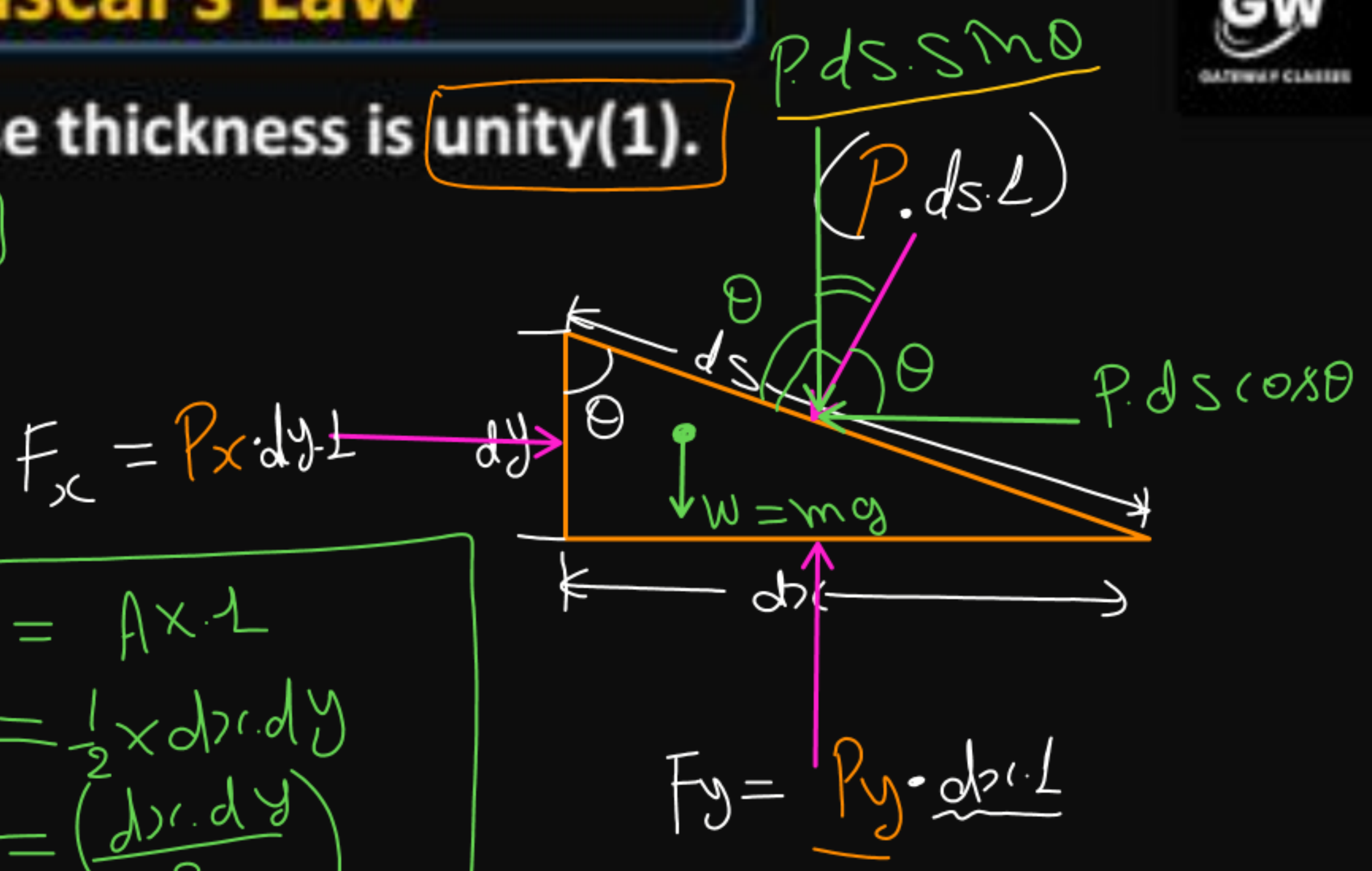
$\boxed{P_x = P_y = P_z}$ ⭐⭐⭐

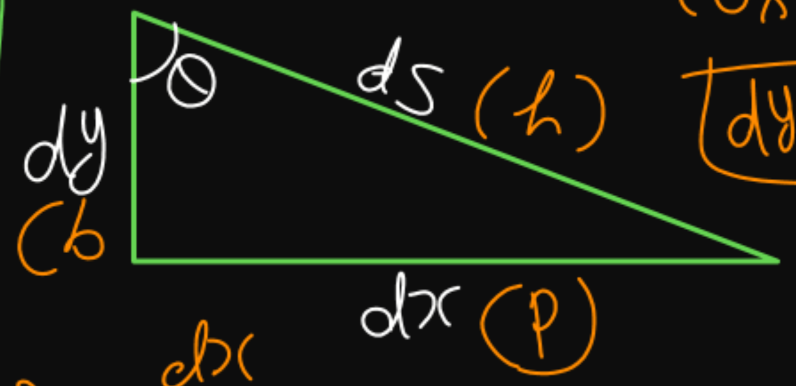
10 marks

$V = A \times 1$

$= \frac{1}{2} \times dx \cdot dy$

$= \left(\frac{dx \cdot dy}{2}\right)$





$\cos\theta = \frac{dy}{ds}$

$\boxed{dy = ds\cos\theta}$

$\sin\theta = \frac{dx}{ds}$

$\boxed{dx = ds\sin\theta}$

Example: Car's weight = 16,000 N, Plunger area = 50 cm^2 , Ram area = 4000 cm^2 . What is input force F_1 ?

$$P_1 = P_2$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

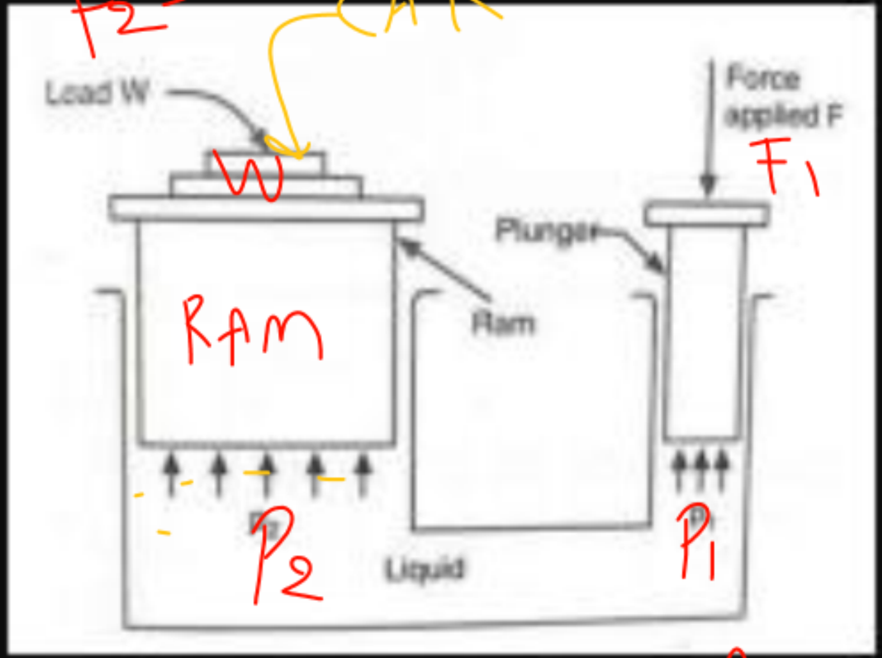
$$F_1 = \frac{A_1}{A_2} \times F_2$$

$$F_1 = \frac{50}{4000} \times 16000$$

$$\boxed{F_1 = 200\,N}$$ Ans

$F_2 = 16000N$

CAR



$A_2 = \frac{\pi}{4} d_2^2 = 4000\,cm^2$

$A_1 = \frac{\pi}{4} d_1^2 = 50\,cm^2$

Thank You

FUNDAMENTALS OF MECHANICAL ENGINEERING (BME-101/201)

UNIT-4

Lec-4

As per

New Syllabus 2022-23

Today's Target

- ✓ CONTINUITY EQUATION
- ✓ Numerical Problems

CONTINUITY EQUATION

- This equation is based on the principle of conservation of mass.
- The quantity of fluid per second is constant at all the cross sections through the pipe.

$\rho = \frac{m}{V}$

mass (kg)

$\frac{kg}{m^3} \times m^3$

$(kg/s)\ m = \rho . V$ → volume

$\left(\frac{m}{t}\right) = \rho . A . \frac{L}{t}$ $[V = AL]$ → sec

$\{V = \frac{m}{s}\}$

(kg/s)

$\dot{m} = \rho . A . V$ → Velocity

$\frac{kg}{m^3} \times m^2 \times \frac{m}{s} = \left(\frac{kg}{s}\right)$

$\rho_1 A_1 V_1$ ① $\rho_2 A_2 V_2$ ② $(\rho = C)$

fluid → liq [incomp], gas [comp]

$\dot{m} = \rho . A . V$

$\boxed{\rho_1 A_1 V_1 = \rho_2 A_2 V_2} \Rightarrow \boxed{\rho . A . V = C}$ → comp fluid (i.e. gases)

if $\rho_1 = \rho_2$ [incomp fluid]

$\boxed{A_1 V_1 = A_2 V_2} \rightarrow AV = C$

$\frac{kg}{m^3} \times \left(m^2 \times \frac{m}{s}\right) = \left(kg/s\right)$

$\rho \cdot A \cdot V = C$

$\cancel{\rho_1} A_1 V_1 = \cancel{\rho_2} A_2 V_2$

if fluid $\rightarrow$ Incomp

$\rho_1 = \rho_2$

$A_1 V_1 = A_2 V_2$

$\boxed{A \cdot V = C}$ $\Rightarrow$ Discharge $(Q) = A \cdot V \Rightarrow \left(\frac{m^3}{s}\right)$

$\downarrow$ Volume flow rate

$m^2 \times \frac{m}{s} = \left(\frac{m^3}{s}\right)$

$\longrightarrow$ fluid $\longrightarrow$

CONTINUITY EQUATION

- This equation is based on the principle of conservation of mass.
- The quantity of fluid per second is constant at all the cross sections through the pipe.

- Flow Rate → Volume flow rate ($\frac{m^3}{s}$) = $\frac{AL}{s}$ = A V [V = velocity]
- Flow Rate → mass flow rate ($\frac{kg}{s}$) = $\frac{\rho AL}{s}$ = ρ A V

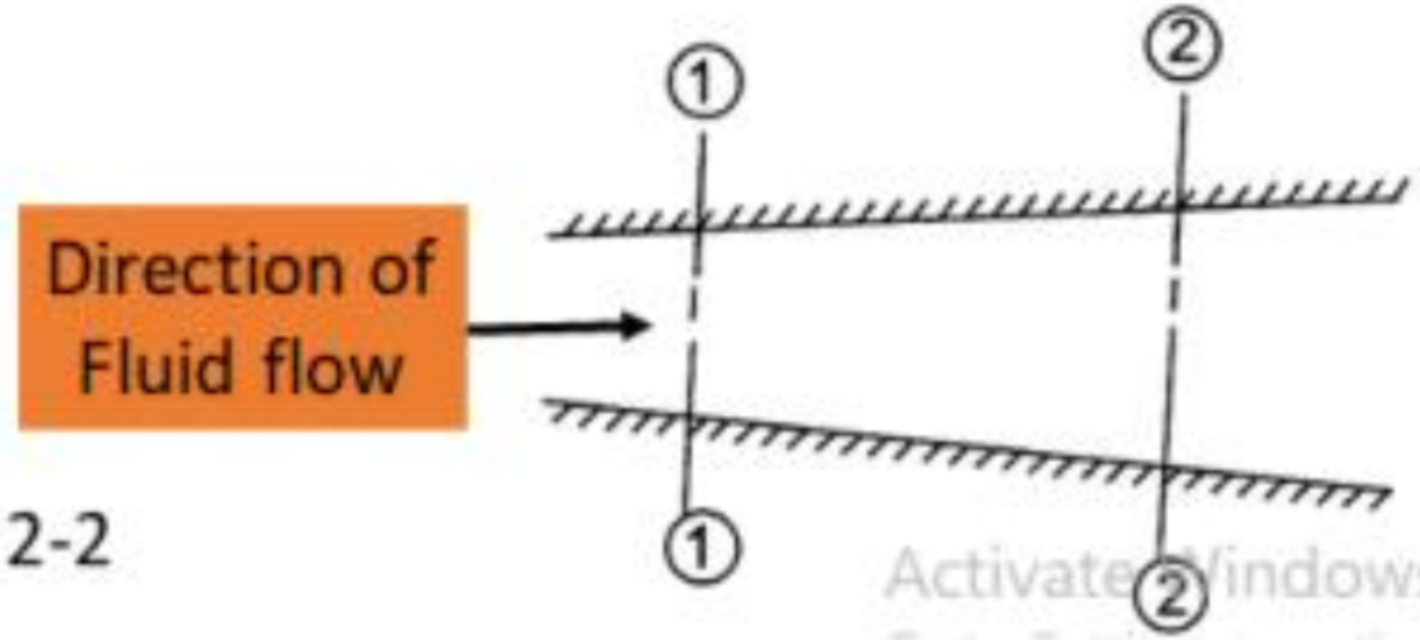
- Consider two cross sections as shown in figure:

Let V_1 = Average velocity at cross-section 1-1

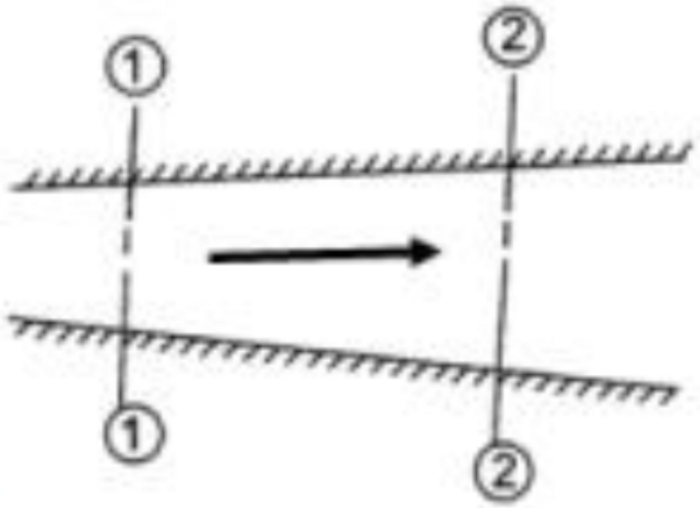
ρ_1 = density at section 1-1

A_1 = Area of pipe at section 1-1

and V_2, ρ_2, A_2 are corresponding values at section 2-2



- Rate of flow at section at 1-1 = $\rho_1 A_1 V_1$
- Rate of flow at section at 2-2 = $\rho_2 A_2 V_2$
- According to law of conservation of mass:
  Rate of flow at section at **1-1** = Rate of flow at section at **2-2**



$$\boxed{\rho_1 A_1 V_1 = \rho_2 A_2 V_2 = \text{Constant}}$$

- This **Continuity Equation is** applicable for the compressible fluids .
- If the fluid is In-compressible, i.e. water then $\rho_1 = \rho_2$ and continuity equation becomes:

$$\boxed{Q = A_1 V_1 = A_2 V_2 = \text{Constant}}$$

Problem *The diameters of a pipe at the sections 1 and 2 are 10 cm and 15 cm respectively. Find the discharge through the pipe if the velocity of water flowing through the pipe at section 1 is 5 m/s. Determine also the velocity at section 2.*

↳ liq → incomp ⇒ $A_1V_1 = A_2V_2$

(i) Discharge (Q) = ?

(ii) V_2 = ?

$m^2 \times \frac{m}{s} = \frac{m^3}{s}$

(i) $Q = \underline{A_1V_1} = A_2V_2$

$Q = \frac{\pi}{4}(d_1^2) \times V_1$

$= \frac{\pi}{4}(0.1)^2 \times 5$

$\boxed{Q = 0.039\ m^3/s}$ Ans

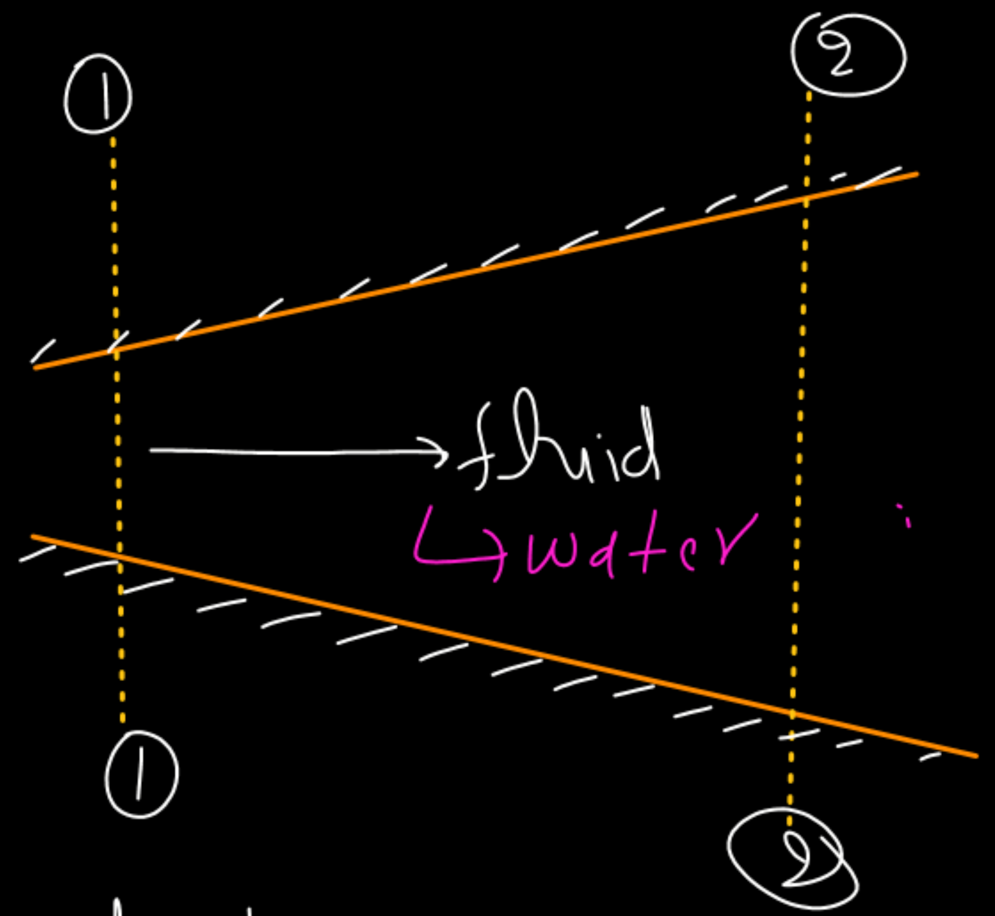
$A_1V_1 = A_2V_2$

$\frac{\pi}{4}d_1^2 \times V_1 = \frac{\pi}{4}d_2^2 \times V_2$

$d_1^2 V_1 = d_2^2 V_2$

$(10)^2 \times 5 = (15)^2 \times V_2$

$\boxed{V_2 = 2.22\ m/s}$ Ans



$d_1 = 10\ cm$ | $d_2 = 15\ cm$

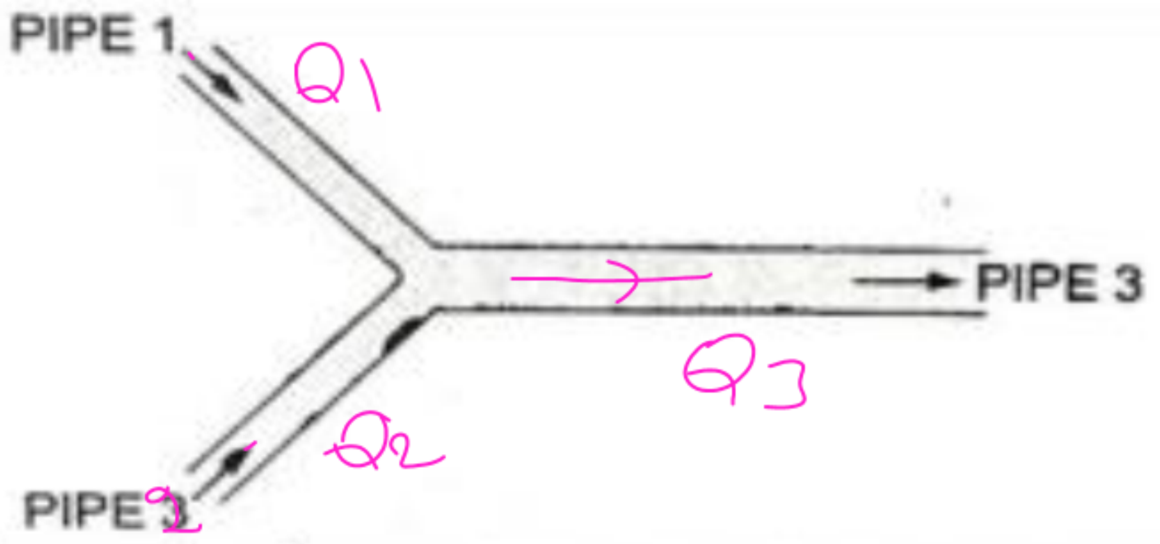
$V_1 = 5\ m/s$ | $V_2 = ?$

$A_1 = \frac{\pi}{4}d_1^2$ | $A_2 = \frac{\pi}{4}d_2^2$

Problem

Consider steady flow of water in a situation where two pipe lines (pipe 1 and pipe 2) combine into a single pipe line (pipe 3) as shown in figure. The cross-sectional area of all three pipelines are constant. The following data is given

Pipe number	Area (m^2)	Velocity (m/s)
1	1 A_1	1 V_1
2	2 A_2	2 V_2
3	2.5 A_3	? $V_3 = ?$



Assuming the water properties and the velocities to be uniform across the cross-section of the inlets and the outlet, the exit velocity (in m/s) in pipe 3 is

(a) 1
(b) 1.5
(c) 2
(d) 2.5

$$Q_1 + Q_2 = Q_3$$

$$Q = A \cdot V$$

$$A_1V_1 + A_2V_2 = A_3V_3$$

$$1 \times 1 + 2 \times 2 = 2.5 \times V_3$$

$$\Rightarrow \boxed{V_3 = 2\ m/s}$$

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FUNDAMENTALS OF MECHANICAL ENGINEERING (BME-101/201)

UNIT-4

Lec-5

As per

New Syllabus 2022-23

M S Tomer Sir

Today's Target

- ✓ Hydraulic Turbines

Hydraulic Machines

GW
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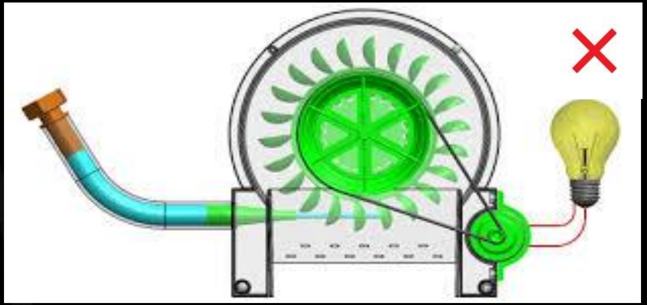
- Hydraulic machines are defined as those machines which convert either *hydraulic energy* into *mechanical energy* or *mechanical* energy into *hydraulic energy.*
- Hydraulic Energy- Energy possessed by water.
- Mechanical Energy- power produced at shaft of turbine.

Hydraulic Machines

GATEWAY CLASSES

Turbines

➢ The **hydraulic machines** which converts the hydraulic energy into mechanical energy, are called as **turbines**.



Pumps

➢ The **hydraulic machines** which converts mechanical energy into hydraulic energy , are called as **pump**.

Turbine

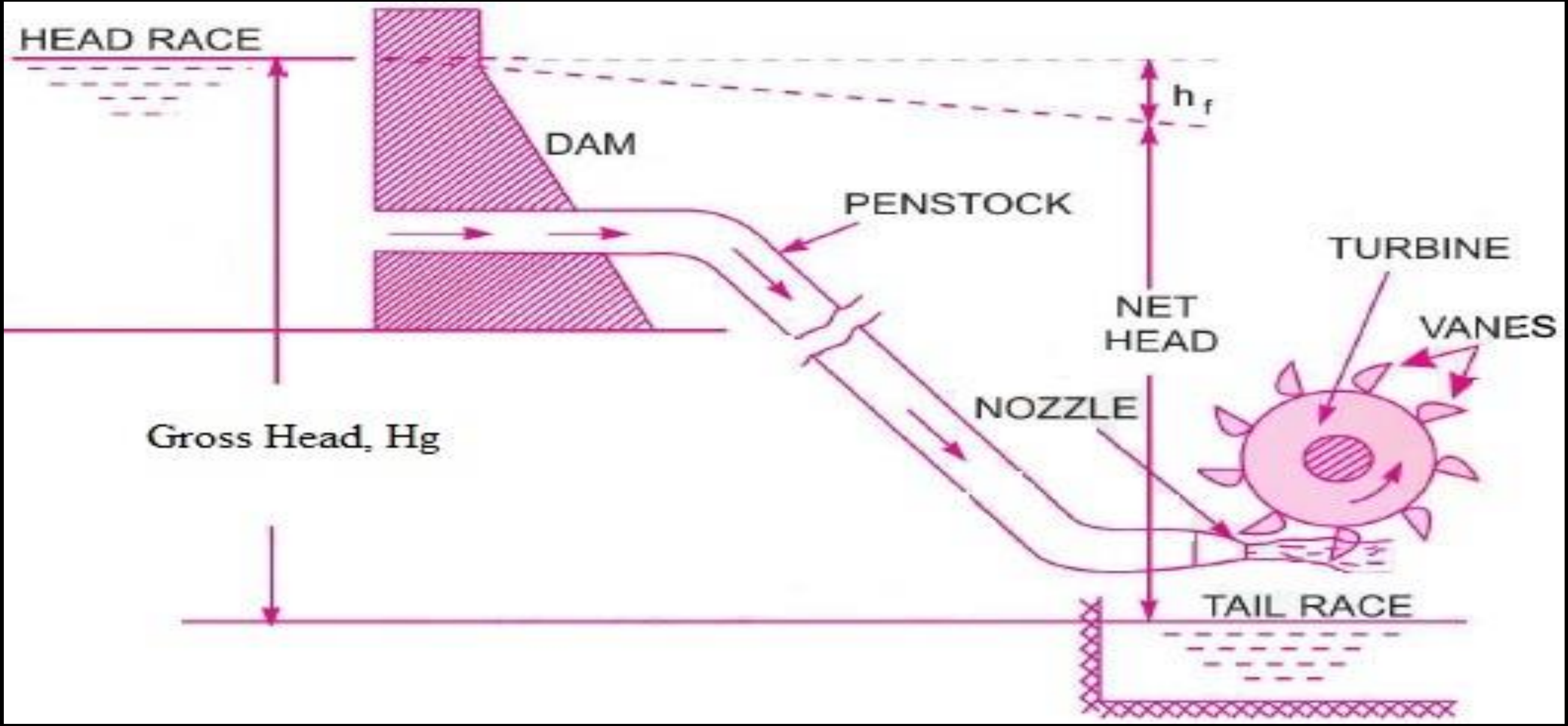
- Turbines are defined as the machines which convert the hydraulic energy into mechanical energy.

- This mechanical energy is used in running an electric generator which is directly coupled to the shaft of the turbine.

- Thus the mechanical energy is converted into electrical energy.

- The electric power which is obtained from hydraulic energy is known as *Hydro-electric power*.

General Layout of Hydro-electric power plant



Classification of turbine

The turbines are classified in the following ways:-

1. According to the type of energy available at inlet

(a) Impulse turbine (b) Reaction turbine

❖ If at the inlet of the turbine , only kinetic energy, the turbine is known as *impulse turbine*.

e.g. Pelton Turbine.

❖ If at the inlet of the turbine, water possesses kinetic energy as well as pressure energy, the turbine is known as *reaction turbine*.

e.g. Francis turbine, Kaplan turbine.

2. According to the *direction of flow* of water through runner:

a)Tangential flow turbine (e.g. Pelton Turbine)

b)Radial flow turbine (e.g. Francis Turbine)

c)Axial flow turbine (e.g. Kaplan Turbine)

d)Mixed flow turbine (e.g. Modern FrancisTurbine)

3. According to head available at the inlet of turbine

a) High head turbine e.g. P.T.

b) Medium head turbine e.g. F.T.

c)Low head turbine e.g. K.T

4. According to the specific speed of turbine

a)Low specific speed turbine e.g. P.T.

b) Medium specific speed turbine e.g. F.T.

c)High specific speed turbine e.g. K.T

5. According to the position of shaft of turbine

a) Horizontal shaft turbine

b) Vertical shaft turbine

(Pelton turbine has horizontal shaft whereas the rest have vertical shaft)

6. According to name of originator

a) Pelton Turbine(Pelton Wheel)

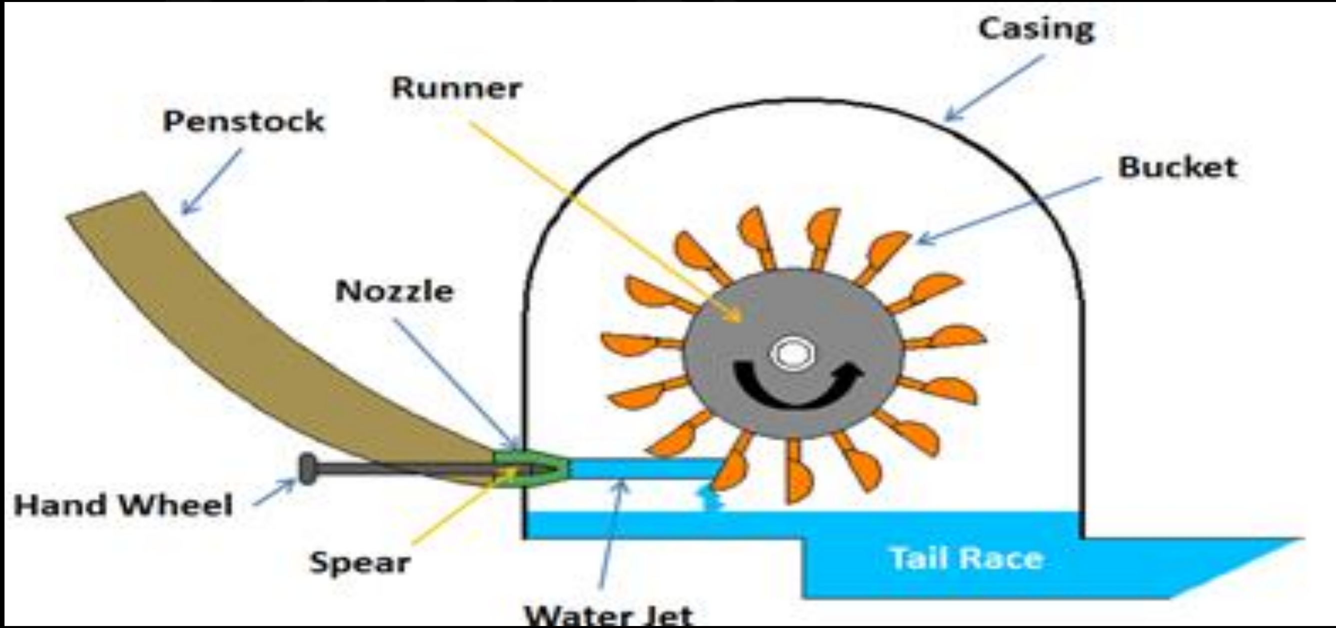
b) Francis Turbine

c) Kaplan Turbine

Impulse Turbine (Pelton)

Main parts of Impulse turbine(Pelton) are :-

1. Nozzle and flow regulating Arrangement (Spear)
2. Runner and buckets
3. Casing
4. Breaking jet



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GATEWAY CLASSES

1. Nozzle and Flow Regulating Arrangement (Spear)

- Nozzle is used to increase the kinetic energy of the water that is going to strike the buckets or vanes attached to the runner.
- The quantity of water that strikes the buckets is controlled by spear. The spear is installed inside the nozzle and regulates the flow of water that is going to strike on the vanes of the runner. A nozzle containing spear is shown in the figure .
- When the spear is move backward the rate of flow of water increases and when it is pushed forward the rate of flow of water decreases.

2. Runner and Buckets

- A wheel of the turbine consist of series of buckets/blades/vanes mounted on its periphery.

- The buckets are designed in such a way that the jet of water strikes the buckets, deflected through 160 degree to 170 degree.

- The buckets of the Pelton turbine are made up of cast iron, cast steel bronze or stainless steel.

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3. Casing:

The outer covering of this turbine is called casing. The Pelton turbine with the casing is shown in the figure.

- It is used to avoid accident and prevents the splashing of water.
- It does not perform any hydraulic function.
- The pressure throughout the turbine from inlet to outlet is atmospheric in case Impulse turbine.
- **Cast iron or fabricated steel plates** are used to make the casing of the Pelton Turbine.

4. Breaking jet

- When the jet of water is completely closed by pushing the spear in the forward direction than the amount of water striking the runner becomes zero.
- But still, the runner keeps moving due to the inertia of the runner.

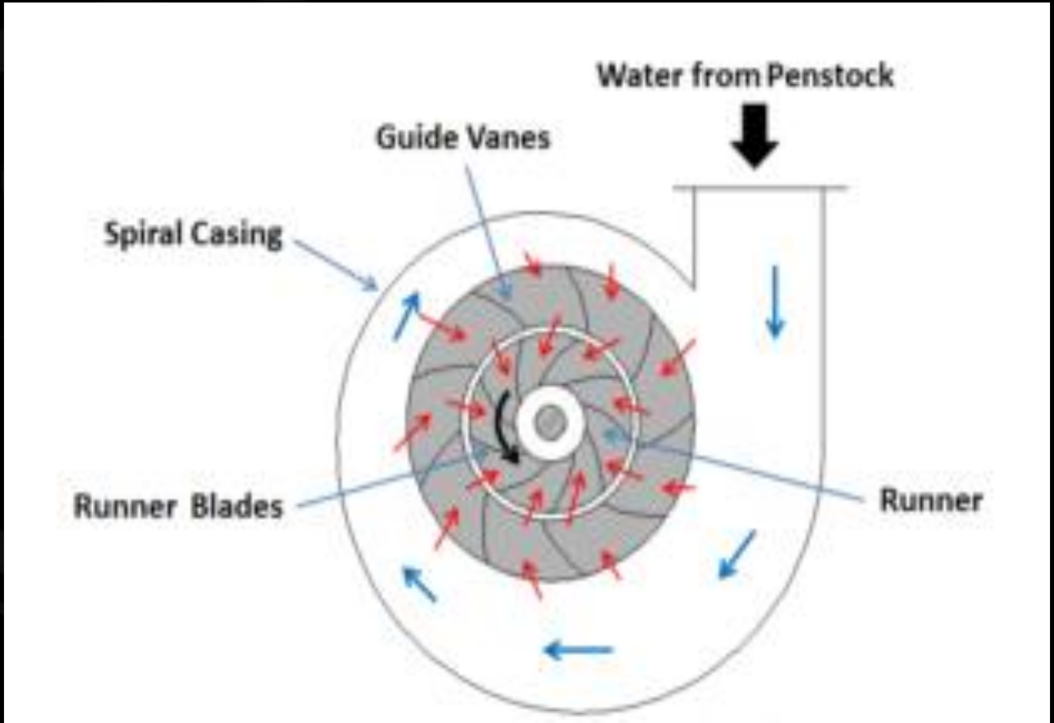
- In order to stop the runner in the shortest possible time, a small nozzle is provided which directs the jet of water at the back of the vanes.
- This jet of water used to stop the runner of the turbine is called breaking jet.

Reaction Turbine(Francis)

GATEWAY CLASSES

Main parts of reaction Turbine(Francis) are :-

1. Spiral Casing
2. Guide Vanes
3. Runner Blades
4. Draft tube



1. Spiral Casing

- Spiral casing is the inlet medium of water to the turbine.

- The water flowing from the reservoir or dam is made to pass through this pipe with high pressure.

- The blades of the turbines are circularly placed, which mean the water striking the turbines blades should flow in the circular axis for efficient striking.

- So the spiral casing is used, but due to circular movement of the water, it looses its pressure.

- To maintain the same pressure the diameter of the casing is gradually reduced, so as to maintain the pressure uniform, thus uniform momentum or velocity striking the runner blades.

2. Guide Vanes

- The guide vanes allow the water to strike the fixed blades on the runner without shock at inlet.

- Guide vanes are not stationary, they change their angle as per the requirement to control the angle of striking of water to turbine blades to increase the efficiency.

- They also regulate the flow rate of water into the runner blades thus controlling the power output of a turbine according to the load on the turbine.

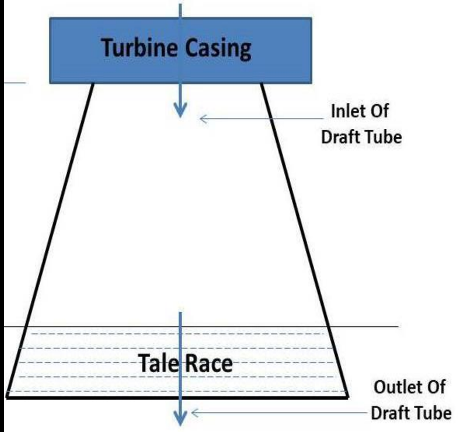
3. Runner Blades

- These are the fixed blades mounted on its periphery of runner.

- The performance and efficiency of the turbine dependent on the design of the runner blades. I

4. Draft tube

- The pressure at the exit of the runner of Reaction Turbine is generally less than atmospheric pressure.
- The water at exit cannot be directly discharged to the tail race.
- A tube or pipe of gradually increasing area is used for discharging water from the exit of turbine to the tail race.
- This tube of increasing area is called Draft Tube.
- One end of the tube is connected to the outlet of runner while the other end is sub-merged below the level of water in the tail-race.
- Pressure head is increased by decreasing the exit velocity.
- Overall efficiency and the output of the turbine can be improved.



Applications of Francis Turbine

- Francis turbine is the most widely used turbine in hydro-power plants to generate electricity.
- Mixed flow turbine is also used in irrigation water pumping sets to pump water from ground for irrigation.
- It is efficient over a wide range of water head and flow rate.
- It is most efficient hydro-turbine we have till date.

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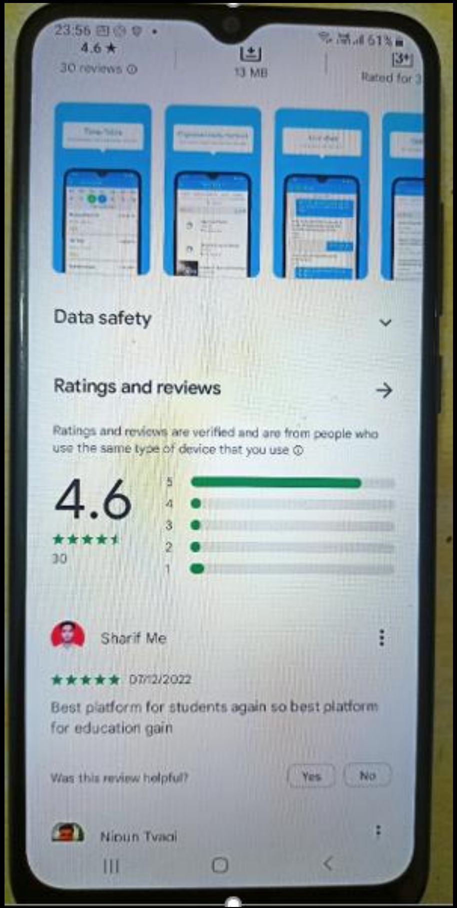

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FUNDAMENTALS OF MECHANICAL ENGINEERING (BME-101/201)

UNIT-4
Lec-6

As per
New Syllabus 2022-23

M S Tomer Sir

Today's Target

- ✓ Hydraulic Pump
- ✓ Hydraulic Lift

Pump

- The hydraulic machine which converts *Mechanical energy into Hydraulic energy* is known as pump.

- The hydraulic energy is in the form of *Pressure Energy*.

- If the mechanical energy is converted into pressure energy by means of centrifugal force acting on the fluid, the hydraulic machine is called *Centrifugal Pump*.

- The centrifugal pump works on the principle of *forced vortex flow.*

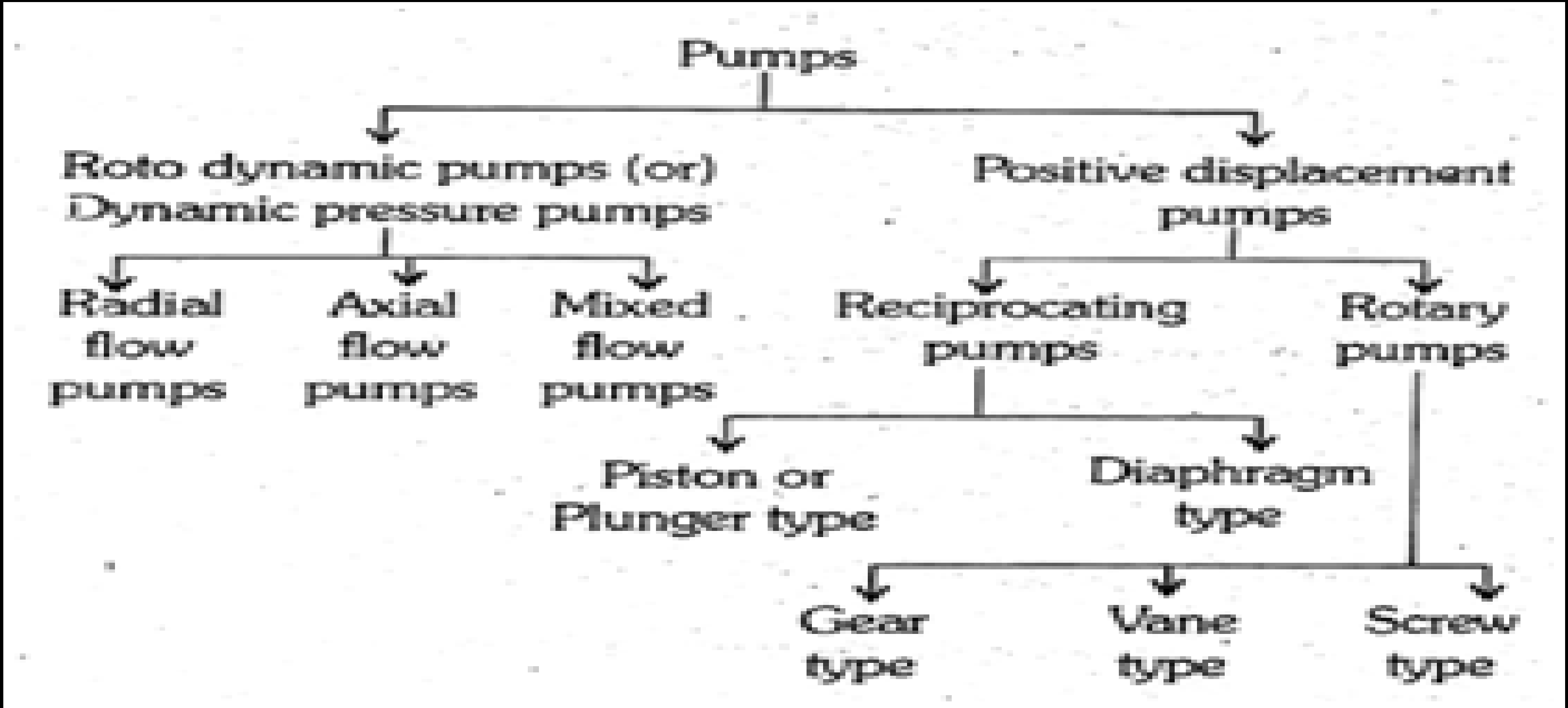
Classification of Pump

There exist a wide variety of pumps that are designed for various specific applications. However, most of them can be broadly classified into two categories as mentioned below-

1. Dynamic Pressure Pumps

2. Positive Displacement Pump

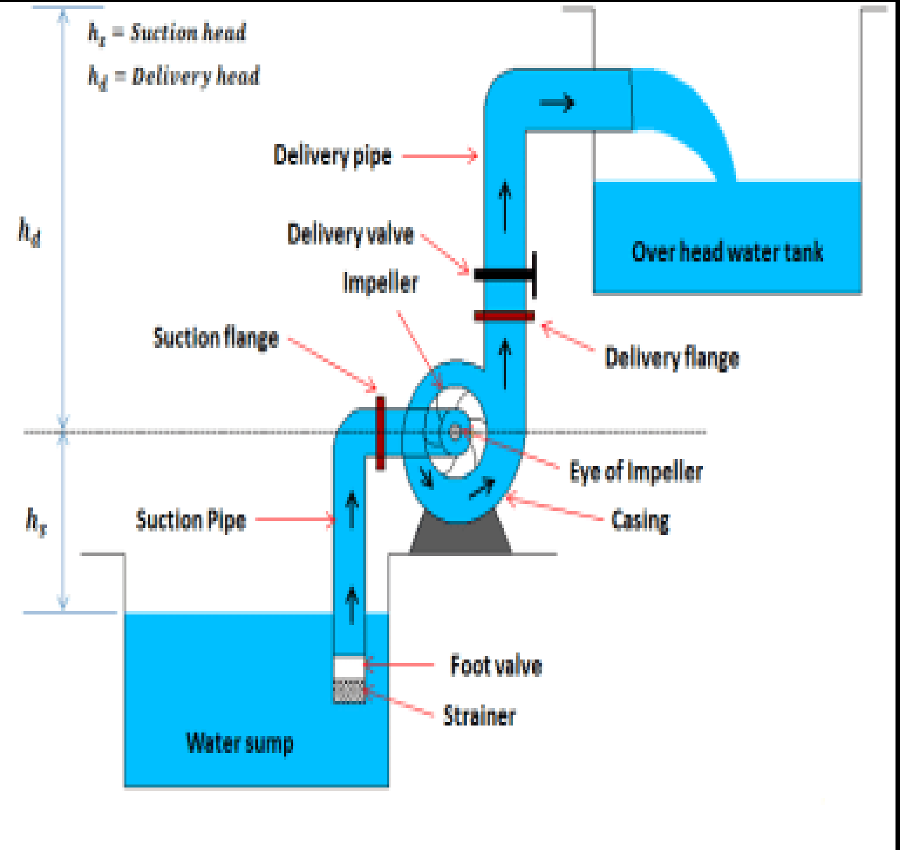
Classification of Pump



Centrifugal Pump

Main parts of a C.P. are :-

1. Impeller
2. Casing
3. Suction pipe with foot valve and a strainer.
4. Delivery pipe



Centrifugal Pump Working

- Centrifugal pump is a mechanical device designed to move a fluid by means of the transfer of rotational energy from one or more driven rotors, called impellers. Fluid enters the rapidly rotating impeller along its axis and is cast out by centrifugal force along its circumference through the impeller's vane tips

- Centrifugal pumps are used to induce flow or raise a liquid from a low level to a high level. These pumps work on a very simple mechanism. A centrifugal pump converts rotational energy, often from a motor, to energy in a moving fluid.

- The two main parts that are responsible for the conversion of energy are the impeller and the casing.
- The impeller is the rotating part of the pump and the casing is the airtight passage which surrounds the impeller.
- In a centrifugal pump, fluid enters into the casing, falls on the impeller blades at the eye of the impeller, and is whirled tangentially and radially outward until it leaves the impeller into the diffuser part of the casing.
- While passing through the impeller, the fluid is gaining both velocity and pressure

Applications of Centrifugal Pumps:

Centrifugal pumps are the most popular choice for fluid movement some of the major sectors that make use of these pumps are :

1. **Oil & Energy -** pumping crude oil, slurry, mud; used by refineries, power generation plants

2. **Industrial & Fire Protection Industry -** Heating and ventilation, boiler feed applications, air conditioning, pressure boosting, fire protection sprinkler systems.

3. **Waste Management, Agriculture & Manufacturing -** Wastewater processing plants, municipal industry, drainage, gas processing, irrigation, and flood protection

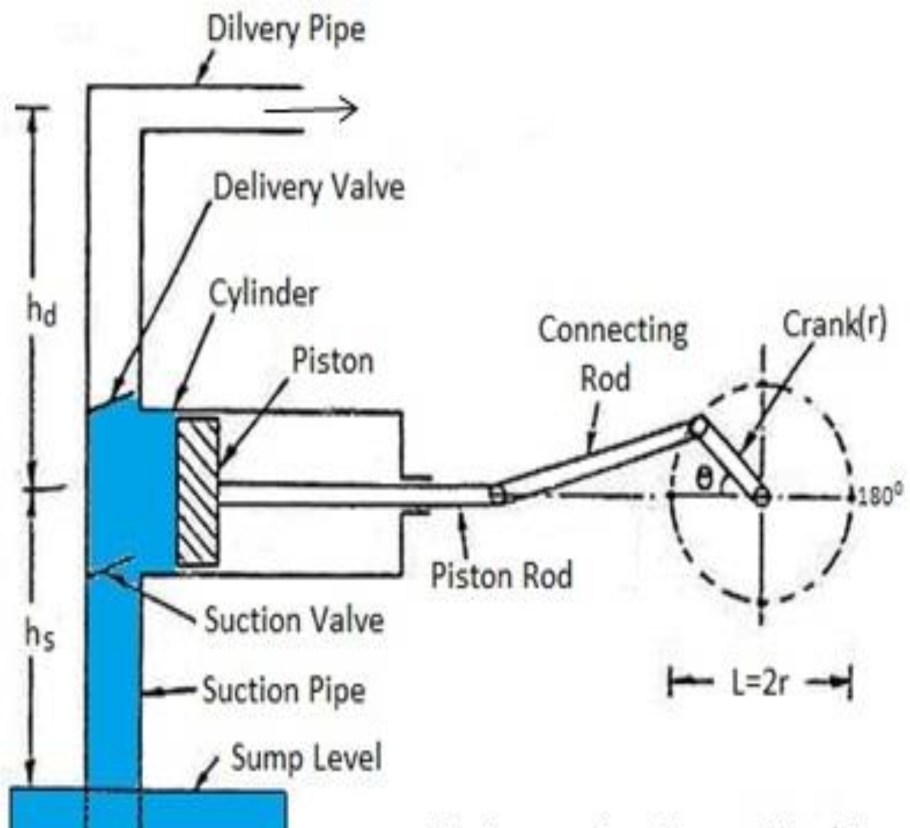
4. **Pharmaceutical, Chemical & Food Industries -** paints, hydrocarbons, petrochemical, cellulose, sugar refining, food and beverage production

5. **Various industries (Manufacturing, Industrial, Chemicals, Pharmaceutical, Food Production, Aerospace etc.) -** for the purposes of cryogenics and refrigerants.

Reciprocating Pump

The main components of R.P. are:

- Water Sump
- Strainer
- Suction Pipe
- Suction Valve
- Cylinder
- Piston and Piston rod
- Crank and Connecting rod
- Delivery valve
- Delivery pipe



Reciprocating Pump Working

- It is a machine that converts mechanical energy into hydraulic energy. Reciprocating pumps are in use where a certain quantity of fluid (mostly sump) has to be transported from the lowest region to the highest region by the application of pressure.

Water Sump: It is the source of water. From the sump, water is to be transported to the delivery pipes by the usage of the piston.

Strainer: It acts as a mesh that can screen all the dirt, dust particles, etc. from the sump. If there is no strainer, then the dirt or dust also enters into the cylinder which can jam the region and affects the working of the pump.

Suction Pipe: The main function of the suction pipe is to collect the water from the sump and send it to the cylinder via a suction valve. The suction pipe connects the water sump and the cylinder.

Suction Valve: It is a non-return valve which means it can take the fluid from the suction pipe and send it to the cylinder but cannot reverse the water back to it. In the sense, the flow is unidirectional. This valve opens only during the suction of fluid and closes when there is a discharge of fluid to outside.

Cylinder: It is a hollow cylinder made of cast iron or steel alloy and it consists of the arrangement of piston and piston rod.

Piston and Piston rod: For suction, the piston moves back inside the cylinder and for discharging of fluid, the piston moves in the forward direction.
The Piston rod helps the piston to move in a linear direction i.e. either the forward or the backward directions.

Crank and Connecting rod: For rotation, the crank is connected to the power source like engine, motor, etc. whereas the connecting rod acts as an intermediate between the crank and piston for the conversion of rotary motion into linear motion.

Delivery Pipe: The function of the delivery pipe is to deliver the water to the desired location from the cylinder.

Delivery valve: Similar to the suction valve, a delivery valve is also a Non-return valve. During suction, the delivery valve closes because the suction valve is in opening condition and during Discharge, the suction valve is closed and the delivery valve Is opened to transfer the fluid.
These are the various components of Reciprocating pump. Let’s understand the working principle of it.

Working Principle of Reciprocating Pump:

When the power supply is given to the reciprocating pump, the crank rotates through an electric motor.

- The angle made by the crank is responsible for the movement of the piston inside the cylinder. By referring to the above diagram, the piston moves towards the extreme left of the cylinder when the crank meets position A i.e. $\theta=0$.

- Similarly, the piston moves towards the extreme right of the cylinder when the crank meets the position C i.e. $\theta=180$.

- A partial vacuum in the cylinder takes place when the piston movement is towards the right extreme position i.e. ($\theta=0$ to $\theta=180$.) and that makes the liquid enter into the suction pipe.

- This is due to the presence of atmospheric pressure on the sump liquid which is quite less than the pressure inside the cylinder. Therefore, due to the difference in pressure, the water enters into the cylinder through a non-return valve.

- The water which stays in the volume of the cylinder has to be sent to the discharge pipe via discharge valve and this can be done when the crank is rotating from C to A i.e. (θ=180 to θ=360) which moves the piston in the forward direction.

- Due to the movement of the piston in a forward direction, the pressure increases inside the cylinder which is greater than the atmospheric pressure.

- This results in the opening of the delivery valve and closing of the suction valve.

- Once the water comes into the delivery valve, it cannot move back to the cylinder because it is a unidirectional valve or non-return valve.

- From there, it enters into the delivery pipe so that it can be sent to the required position.

- Therefore, in this way, the water is sucked and discharged from the sump to the desired location through the piston inside the cylinder.

Types of Reciprocating Pump

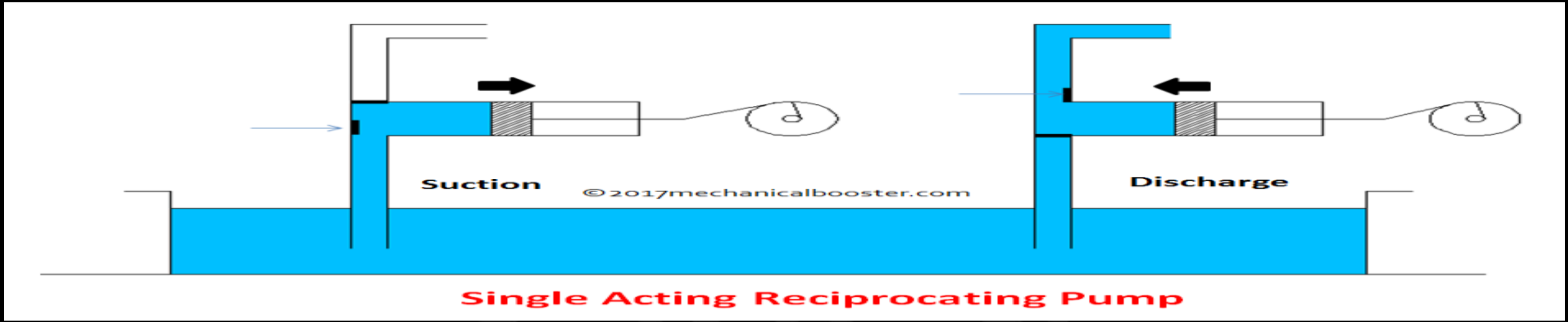
1. According to the water being in contact with one side or both sides of the piston-

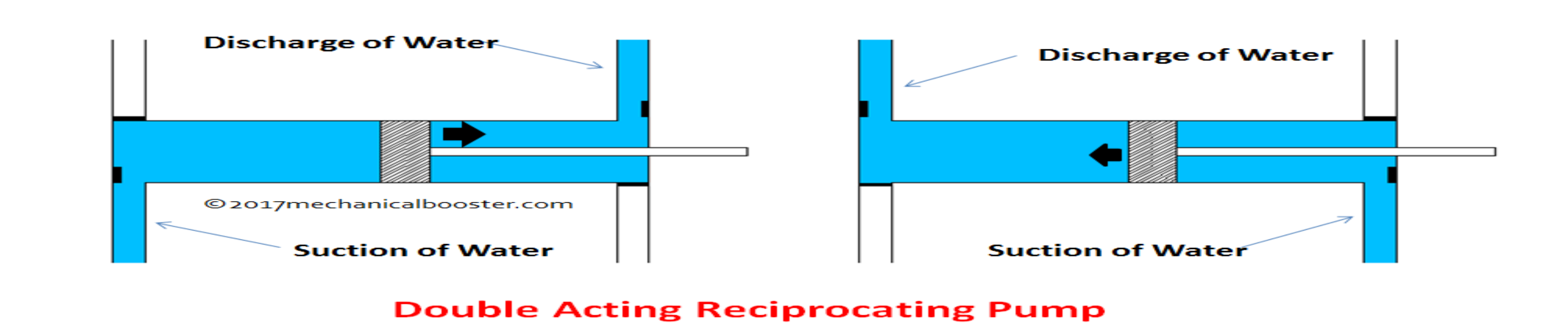
A. Single acting pump
B. Double acting pump

2. According to the number of cylinder provided

A. Single cylinder pump,
B. Double cylinder pump,
C. Triple cylinder pump.

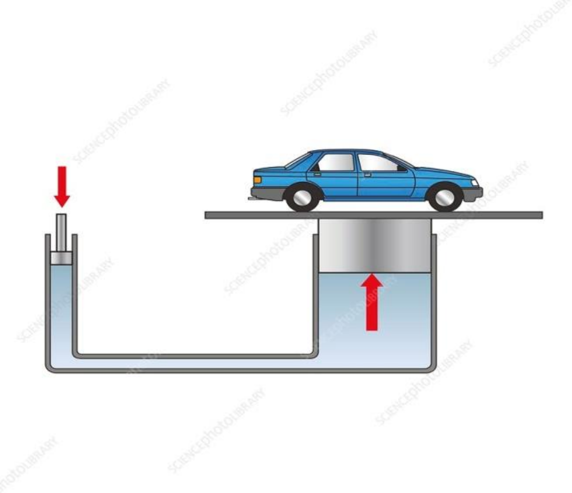
Double acting R.P.





Hydraulic Lift

- Hydraulic lift is a device used for carrying passenger or goods from one floor to another in multistoried building to raise heavy objects.
- It works on the principle of Pascal's Law.



Types of Hydraulic Lift

The Hydraulic Lifts are of two types-

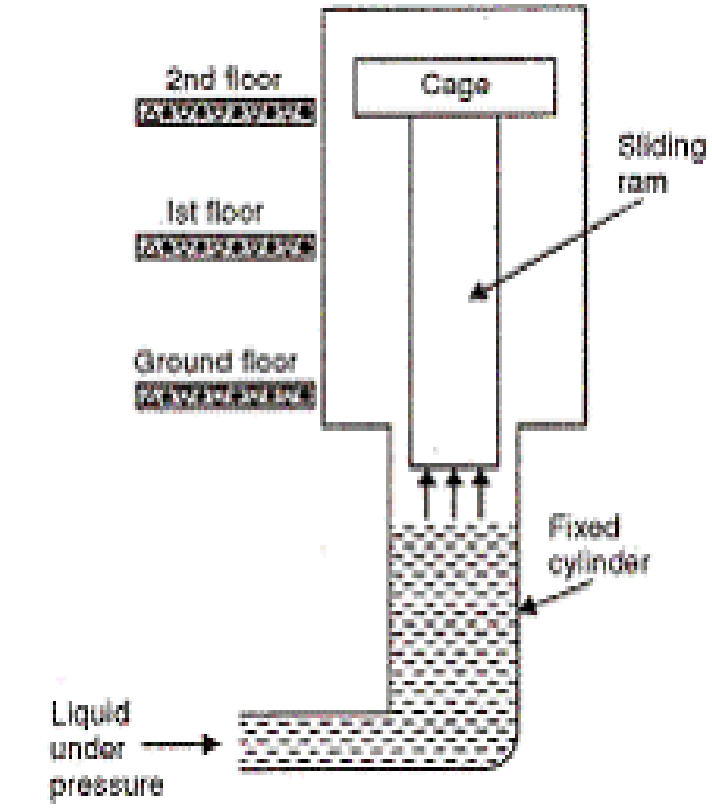
1. **Direct acting hydraulic lift**
2. **Suspended hydraulic lift**

1.Direct Acting Hydraulic Lift

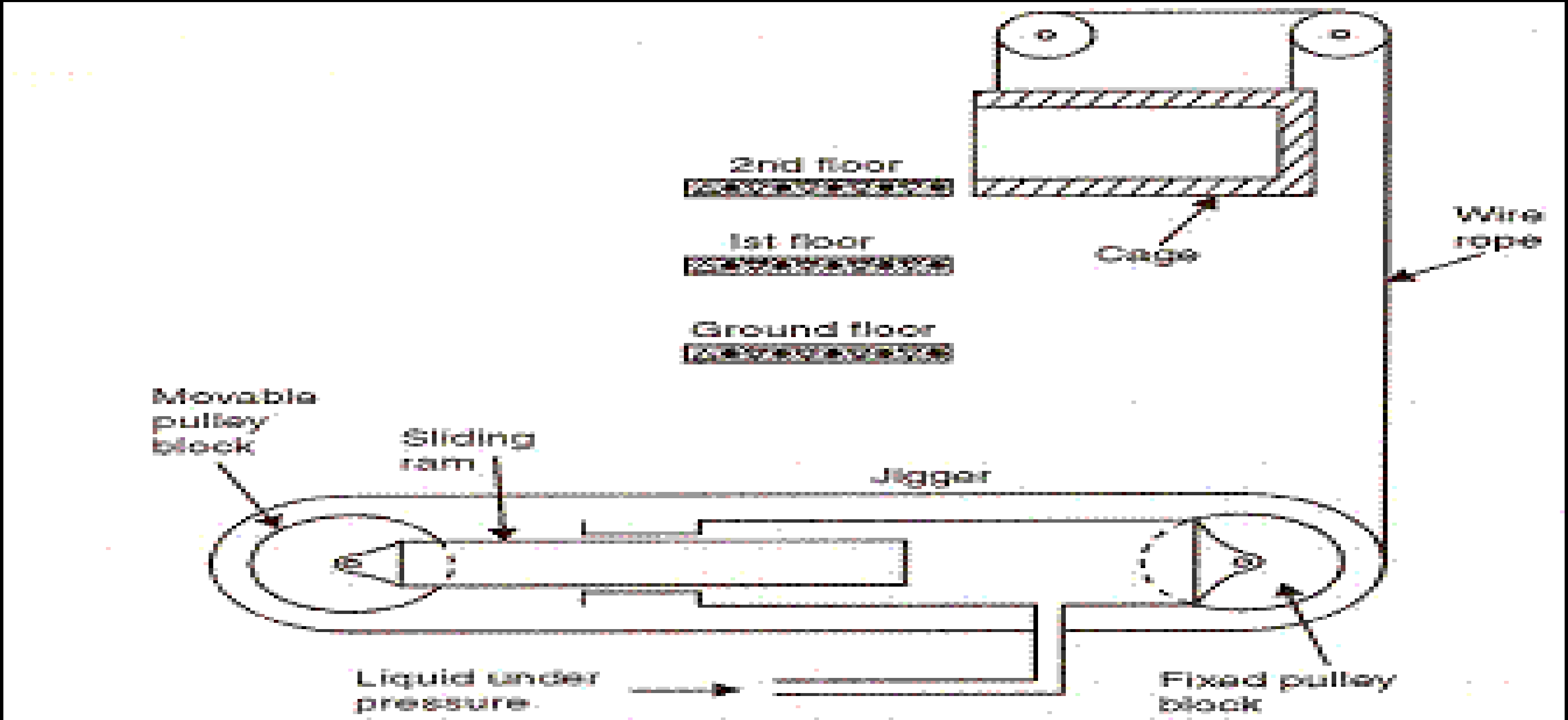
- It consists of a ram, sliding in the fixed cylinder.
- At the top of the sliding ram a cage is fitted.

- **Cage-** on which the person may be stand or goods may be placed.

- The liquid under pressure flows into fixed cylinder.
- This liquid exerts force on the sliding ram, which moves vertically up and thus raises the cage to the required height.



2. Suspended Hydraulic Lift



2. Suspended Hydraulic Lift

- When water under high pressure is admitted into the fixed cylinder of the jigger, the sliding ram is forced to move towards left.
- As one of the end of the sliding ram is connected to the movable pulley block.
- Hence the movable pulley block moves towards the left , thus increasing the distance between two pulley blocks.
- The wire rope connected to cage is pulled and the cage is lifted.
- For lowering the cage, water from fixed cylinder is taken out.
- The sliding ram moves towards right and hence movable pulley block also moves towards right.
- This decrease the distance between two pulley blocks and cage is lowered due to increased length of the rope

Thank You

GATEWAY CLASSES

UNIT-5
Lec-1

As per
New Syllabus 2022-23

Today's Target

- ✓ Measurement
- ✓ Error in measurements
- ✓ Accuracy and Precision

Unit-5: Introduction to Measurement and Mechatronics

Introduction to Measurement: Concept of Measurement, Error in measurements, Calibration, measurements of pressure(Bourdon Tube Pressure and U-Tube Manometer), temperature(Thermocouple and Optical Pyrometer), mass flow rate(Venturi Meter and Orifice Meter), strain(Bonded and Unbonded Strain Gauge), force (Proving Ring) and torques(Prony Brake Dynamometer); Concepts of accuracy, precision and resolution.

Introduction to Mechatronic Systems: Evolution, Scope, Advantages and disadvantages of Mechatronics, Industrial applications of Mechatronics, Introduction to autotronics, bionics, and avionics and their applications. Sensors and Transducers: Types of sensors, types of transducers and their characteristics.

Overview of Mechanical Actuation System – Kinematic Chains, Cam, Ratchet Mechanism, Gears and its type, Belt, Bearing.

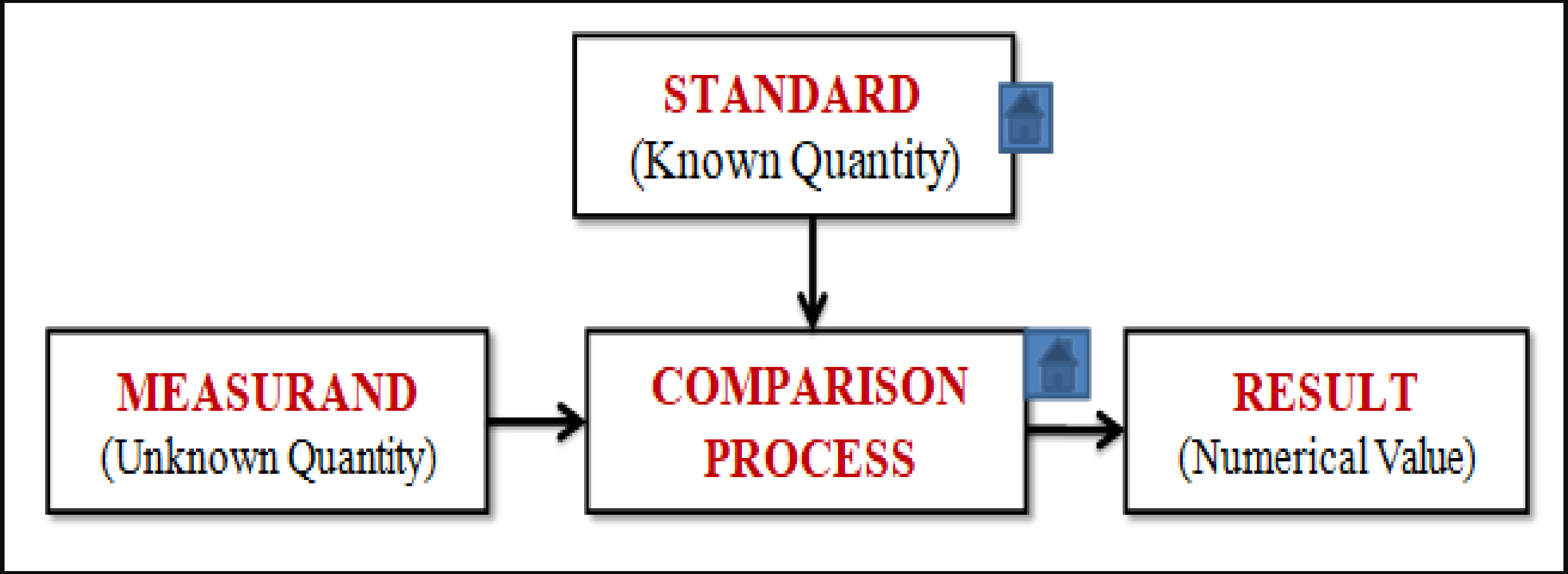
Hydraulic and Pneumatic Actuation Systems: Overview: Pressure Control Valves, Direction Control Valves, Rotary Actuators, Accumulators and Pneumatic Sequencing Problems.

MEASUREMENT

The measurement is the result of comparison between a quantity whose magnitude is unknown(known as measurand), with a similar quantity whose magnitude is known (known as standard) .

OR

It is the process of obtaining a quantitative comparison between a predefined standard and measurand (i.e the quantity being measured)



Measurand : A physical quantity such as length, weight, and angle to be measured.

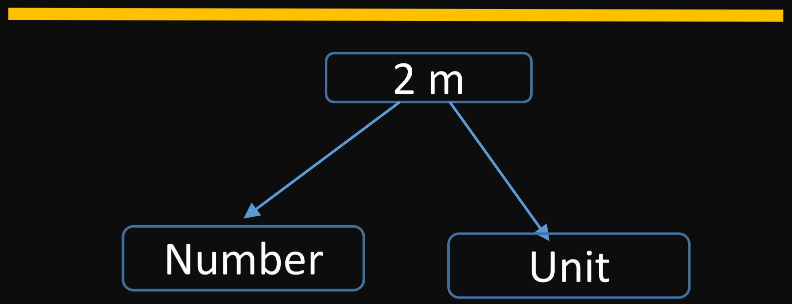
Standard/Reference: A physical quantity to which quantitative comparisons are to be made, which is internationally accepted.

- Measurements are always made using an instrument of some kind.

- Although the basic objective of a measurement is to provide the required accuracy at a minimum cost.

Result of measurement consist of two parts:

1. Number of measurement
2. Unit of measurement



In order that the results of measurements are meaningful, there are some requirements

- The standard used for comparison purpose must be accurately defined and should be commonly acceptable.
- The standard must be of the same character as the measurand.
- The apparatus used and the method adopted for the purpose of comparison must be provable.

Example of measuring instrument or tool:

- Ruler
- Thermometer
- Stop watch or watch
- Weighing Machine etc

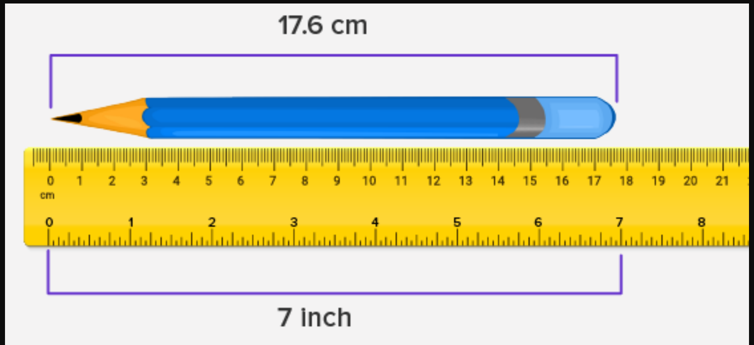
Methods of Measurement:

In precision measurement various methods of measurement are adopted depending upon the accuracy required and the amount of permissible error.

1. Direct Measurement Method

In this method the value of the physical parameter(measurand) is determined by comparing it directly with reference standards.

Example: Measurement of length with the help of scale



2. In-Direct Measurement Method

In this method the value of the physical parameter(measurand) is determined by indirect comparison with secondary standards through calibration.

The measurand is converted into an analogous signal which is subsequently processed and fed to end device that presents the result of measurement.

Based upon the complexity of measurement system, the measurement are generally grouped into three basic categories.

1. Primary Measurement (direct comparison)

2. Secondary Measurement (Involved one conversion)

3. Tertiary Measurement (Involved two conversion)

1. Primary Measurement:

The primary measurements provide subjective information only.

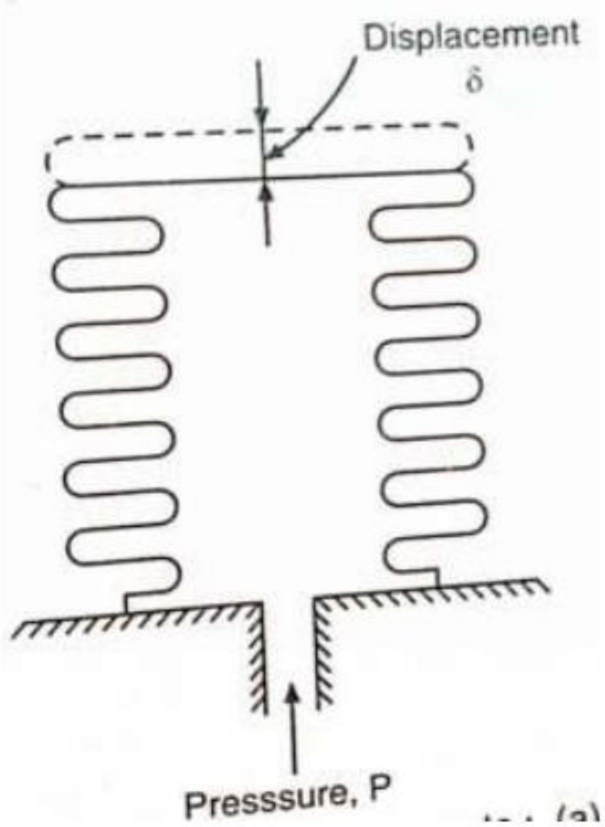
- Observer can indicates only that the content of one container is hotter than the content of other container.

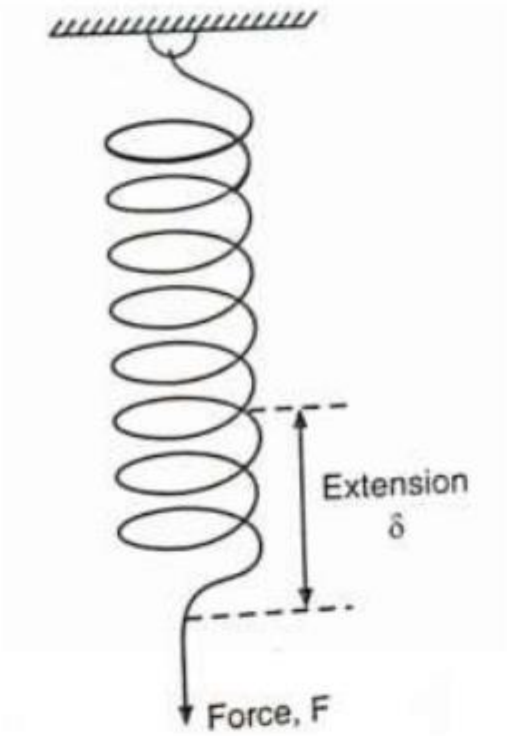
- One rod is longer than other rod.

- One object contains more or less mass than other.

2. Secondary Measurement:

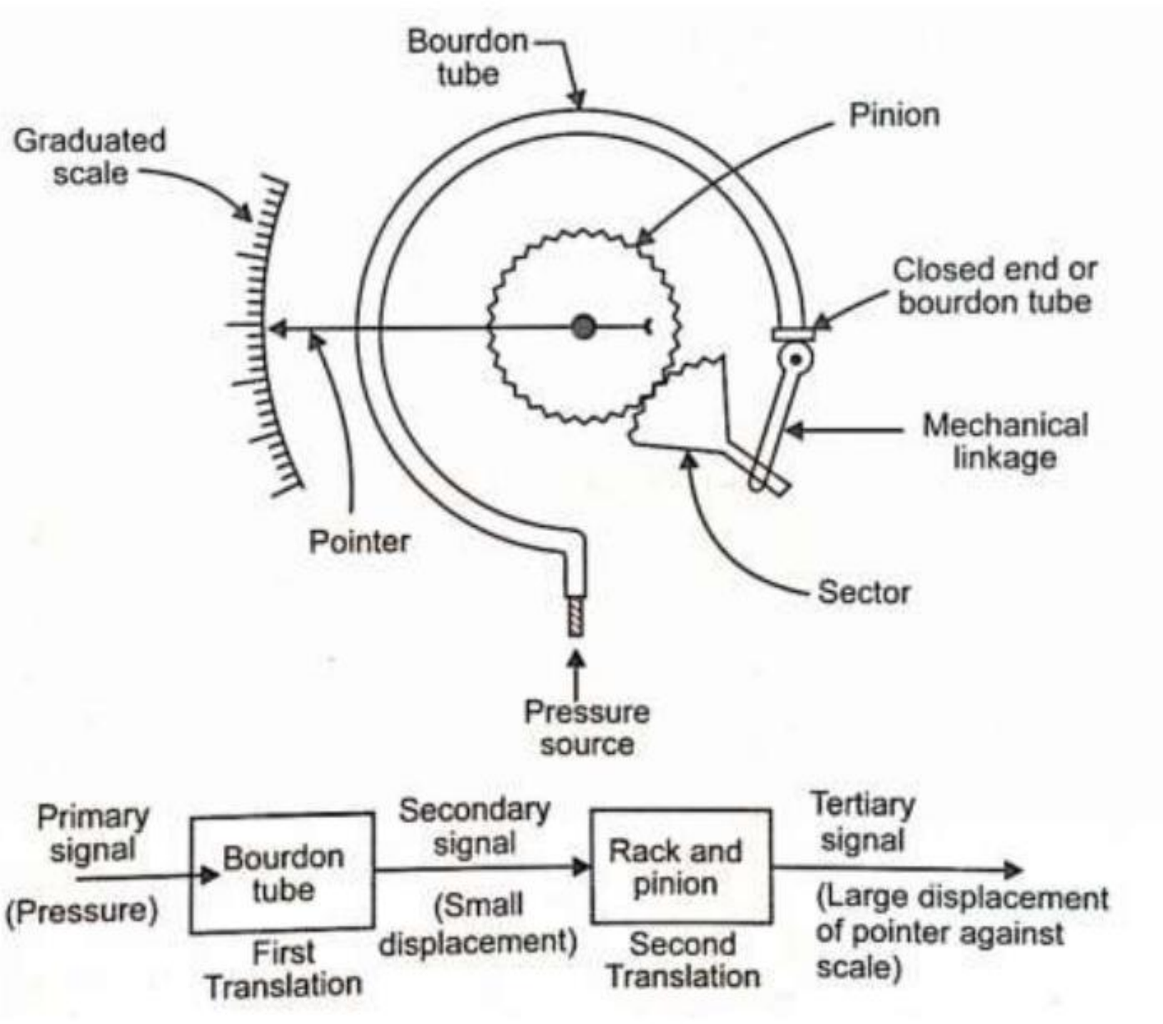
Conversion of pressure into displacement by means of bellows and the conversion of force into displacement by means of spring are simple examples of secondary measurement.





3. Tertiary Measurement

The measurement of pressure by a bourdon tube pressure gauge is an example of tertiary measurement.



UNIT-5
Lec-2

As per
New Syllabus 2022-23

M S Tomer Sir

Today's Target

- ✓ Error in measurements and its types
- ✓ Accuracy and Precision
- ✓ Calibration

Measurement of Pressure

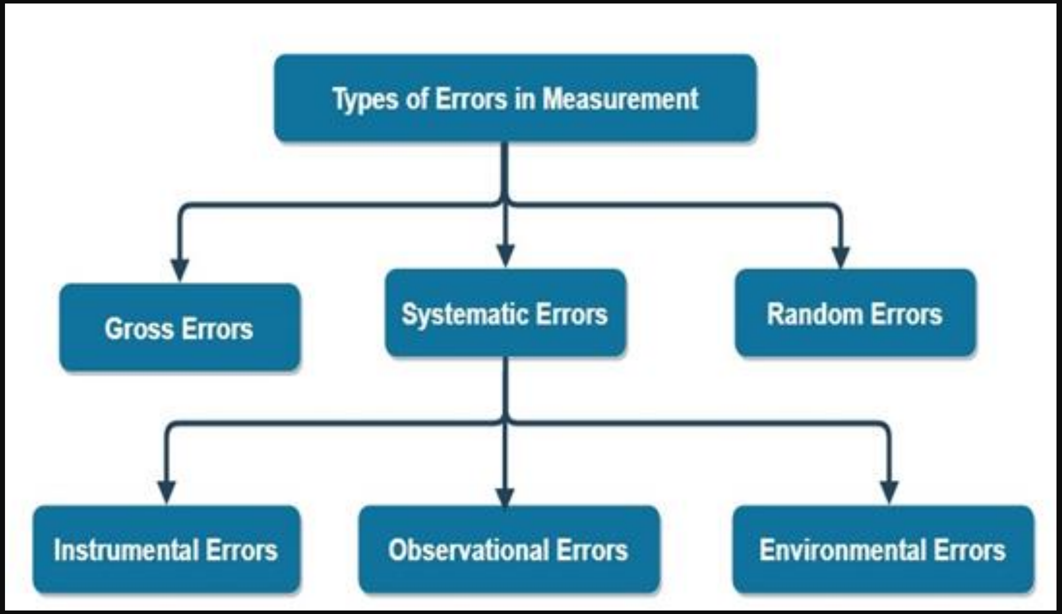
- ✓ U-tube Manometer
- ✓ Bourdon Tube Pressure Gauge

ERROR IN MEASUREMENT

It is defined as a difference between indicated or measured value and true value.

ERROR = TRUE VALUE – MEASURED VALUE

- No measurement can be made with perfect accuracy but it is important to find out what accuracy actually is and how different errors have entered in to measurement.
- A study of errors is a first step in finding ways to reduce them.
- Errors may arise from different sources and are usually classified as under.



Gross Error:

➢It mainly covers human mistakes in reading instruments and recording and calculating measurement results.

Gross errors can be avoided by using two suitable measures, and they are written below:

➢Proper care should be taken in reading, recording the data. Also, the calculation of error should be done accurately.

➢ By increasing the number of experiments, we can reduce the gross error. If each experimenter takes different points, then by taking the average of more readings we can reduce the gross

Systematic Error:

Systematic errors can be better understood if we divide it into subgroups.

(i) **Instrumental Error :** These errors arise due to three main reasons:

(a) **Due to inherent short coming in the instruments:** These errors arise due to faulty construction and calibration of the measuring instruments. These errors may cause the instrument to read too low or too high.

(b)Due to misuse of the instruments

(c)Due to loading effects of instruments

(ii) **Environmental Errors:** This type of error arises in the measurement due to the effect of the external conditions includes temperature, pressure, and humidity and can also include an external magnetic field.

(iii) **Observational Errors:** These are the errors that arise due to:

(a) An individual's bias, lack of proper setting of the apparatus, or an individual's carelessness in taking observations.

(b)The measurement errors also include wrong readings due to Parallax errors.

Random Error:

(a) The random errors are those errors, which occur irregularly and hence are random.

(b) The random errors are accidental, small and independent.

(c) They vary in an unpredictable manner.

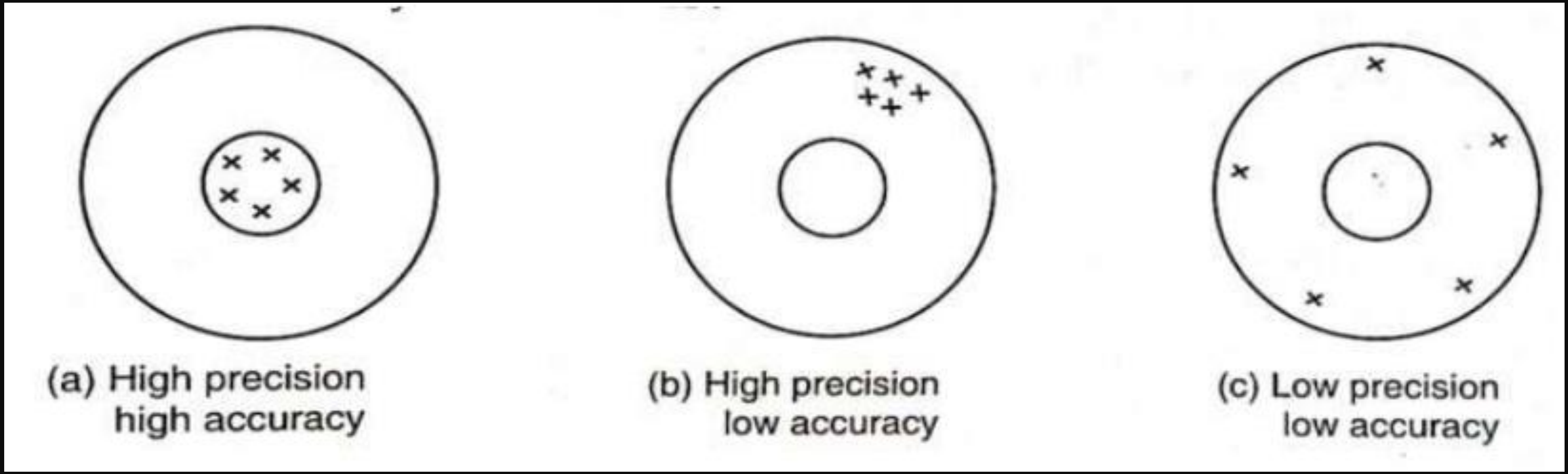
Differences between Systematic and Random Error

Basis for Comparison	Random Error	Systematic Error
Definition	Random error occurs in the experiment because of the uncertain changes in the environment	It is a constant error which remains same for all measurements
Causes	Environment, limitation of the instrument, etc.	Incorrect calibration and incorrectly using the apparatus
Minimize	By repeatedly taking the reading.	By improving the design of the apparatus
Magnitude of Error	vary	Constant
Direction of Error	occur in both the direction	occur only in one direction
Types	Do not have any type	Three

Accuracy and Precision

- In a set of measurements, accuracy is closeness of the measurements to a true value.

- In a set of measurements precision is the closeness of the measurements to each other.



Calibration in Measurement

- Instrument calibration is one of the primary processes used to maintain instrument accuracy.

Or

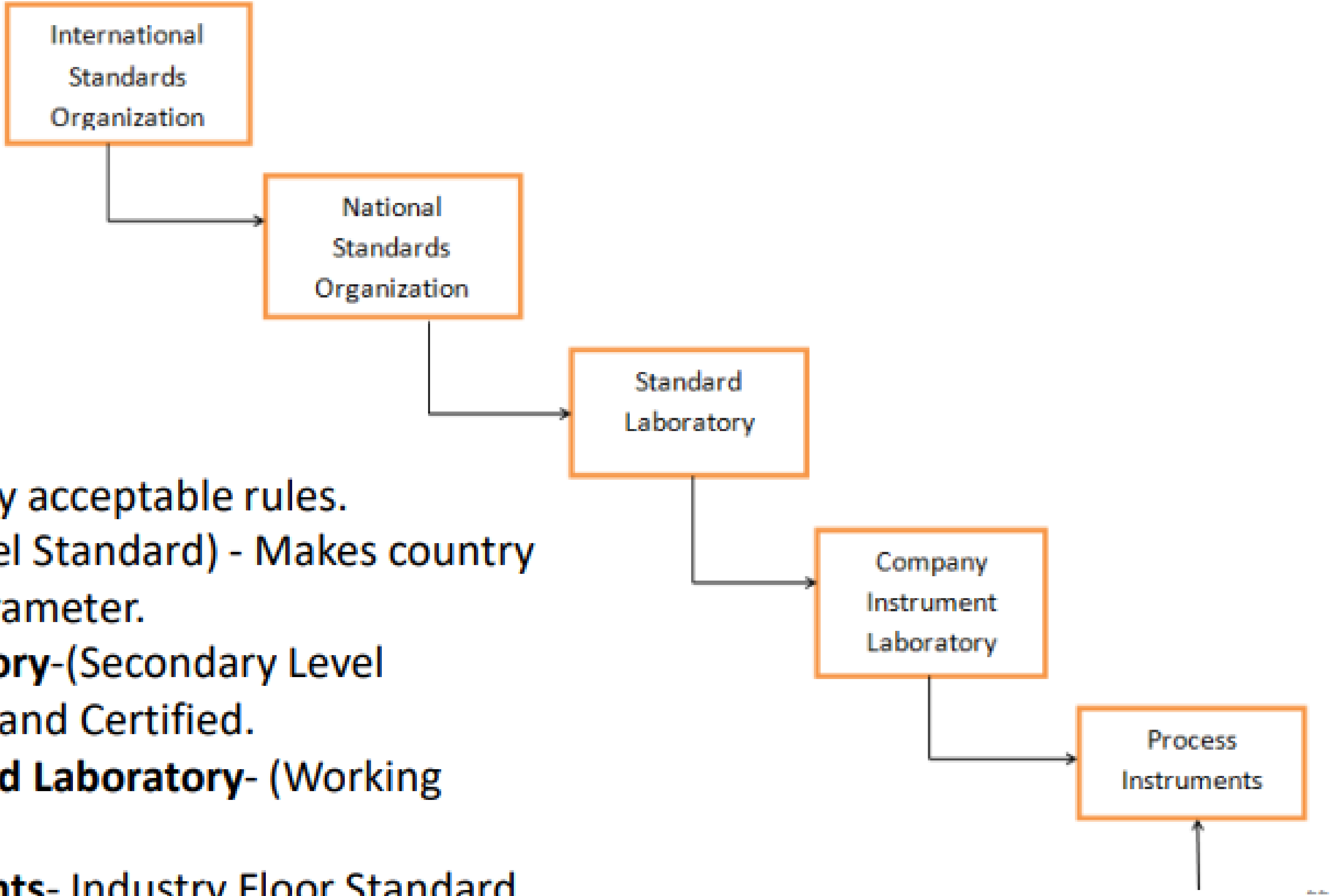
- Calibration is an activity of checking the accuracy and precision of measuring instrument by comparing it with the standard.

- Calibration provides consistency in readings and reduces errors, thus validating the measurement universally.

The procedure of calibration involves a comparison of the particular instrument with either:

(a) A primary standard
(b) (b) A secondary standard with a higher accuracy than the instrument to be calibrated
(c) (c) An instrument of known accuracy.

Calibration Standards:



ISO- Makes globally acceptable rules.
NSO-(Primary Level Standard) - Makes country level rules and parameter.
Standard Laboratory-(Secondary Level Standard) - Check and Certified.
Company Standard Laboratory- (Working Standard)
Process Instruments- Industry Floor Standard

Measurement of Pressure

❖"It is defined as normal force per unit area."

$$P = \frac{F}{A}$$

❖It is a scalar quantity.

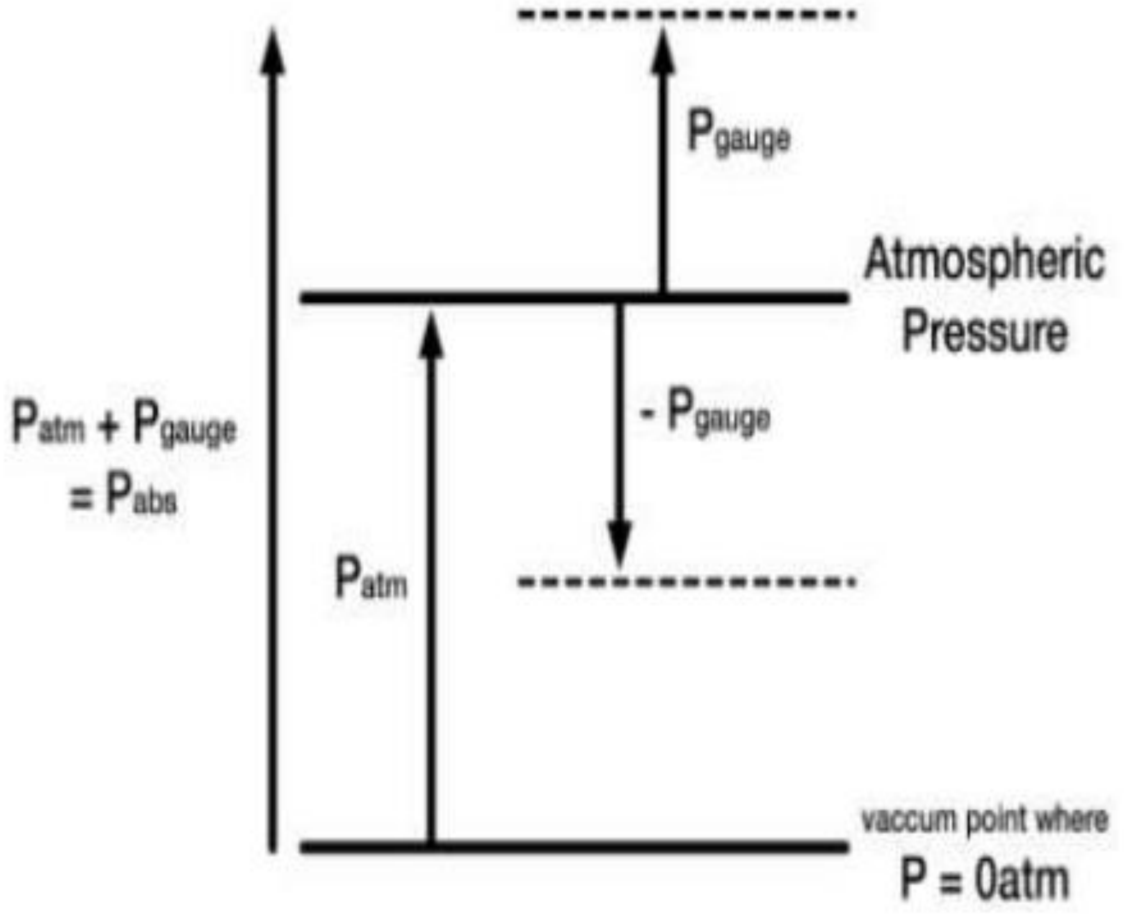
❖Units of Pressure :

➢ N/m^2

➢ Pascal (Pa) (1 Pa = 1 N/m^2)

➢ atm (1 atm = 101325 Pa = 101.325 kPa)

➢Bar (1 bar =10^5 Pa = 10^5 N/m^2



Manometer

- It is an instrument used for measuring the pressure at a point in a fluid by balancing the column of fluid by same or another fluid column.

- They are classified as

1. Simple Manometers

(a) Piezometers
(b) U-tube monomer
(c) Single column manometer

2. Differential manometers

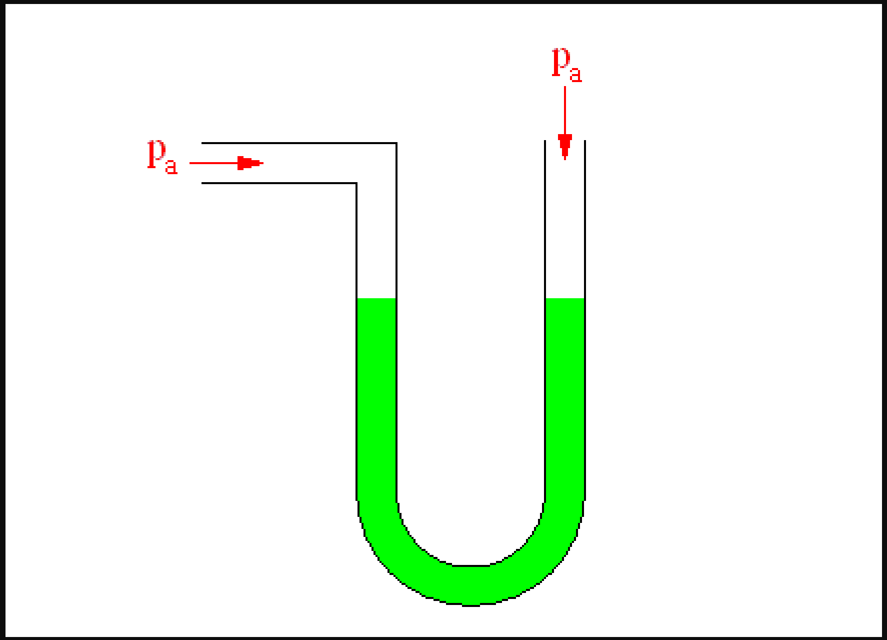
(a) U-Tube differential manometer
(b) Inverted U-Tube differential manometer

U-Tube Manometer

➢This manometer consists of U- shaped glass-tube as shown in figure.

➢One end of the U-tube is connected to the point where pressure has to be measured while other end remains open to the atmospheric pressure.

➢Water and mercury are used as a manometric fluid.



Advantages of Manometer

➢Simple & time-proven
➢High accuracy & sensitivity
➢Wide range of filling

Disadvantages of Manometer

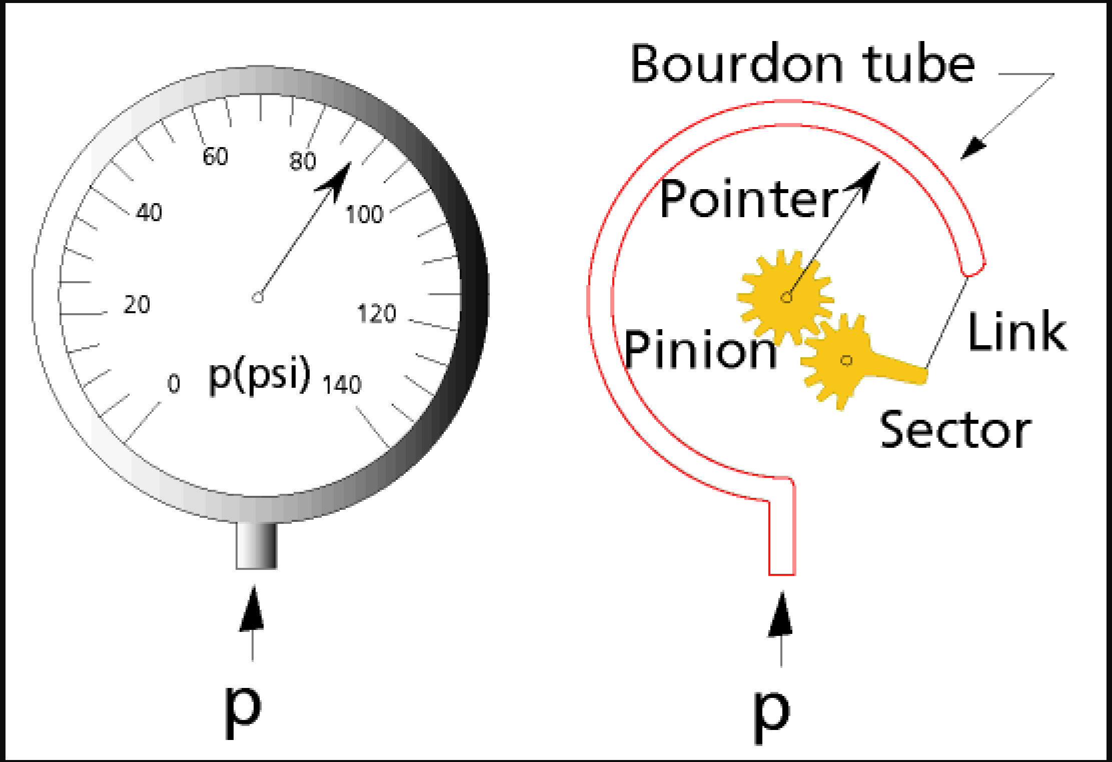
➢No over-range protection
➢Large & bulky
➢Measured fluids must be compatible with the manometer fluids
➢Need for levelling

Bourdon Tube Pressure Gauge

- Bourdon tube pressure gauge is used to measure the pressure from 0.6 bar to 7000 bar.
- It is a mechanical pressure measuring instrument.
- It operates without any electric power.

- When bourdon tube is subjected to applied pressure then it deflects.
- This deflection is proportional applied pressure.
- C-type bourdon tube consists of a long thin wall cylinder which is sealed at one end.
- Other end of tube is fixed and open at the application where pressure is be measured.

- Tip of tube is connected to a segmental liver through an adjustable link.
- Segmental liver is provided with a rack which meshes with a suitable pinion.
- This pinion is mounted on spindle.
- This spindle holds a pointer.
- Resulting movement of free end of tube causes the pointer to move over a scale



……..Bourdon Tube Pressure Gauge

Advantages of Bourdon Tube

- Low cost & simple construction
- Wide range ability
- Good accuracy
- Adaptable to transducer designs

Disadvantages of Bourdon Tube

- Low spring gradient below 50 psig
- Subject to Hysteresis
- Susceptible to shock & vibration

UNIT-5
Lec-3

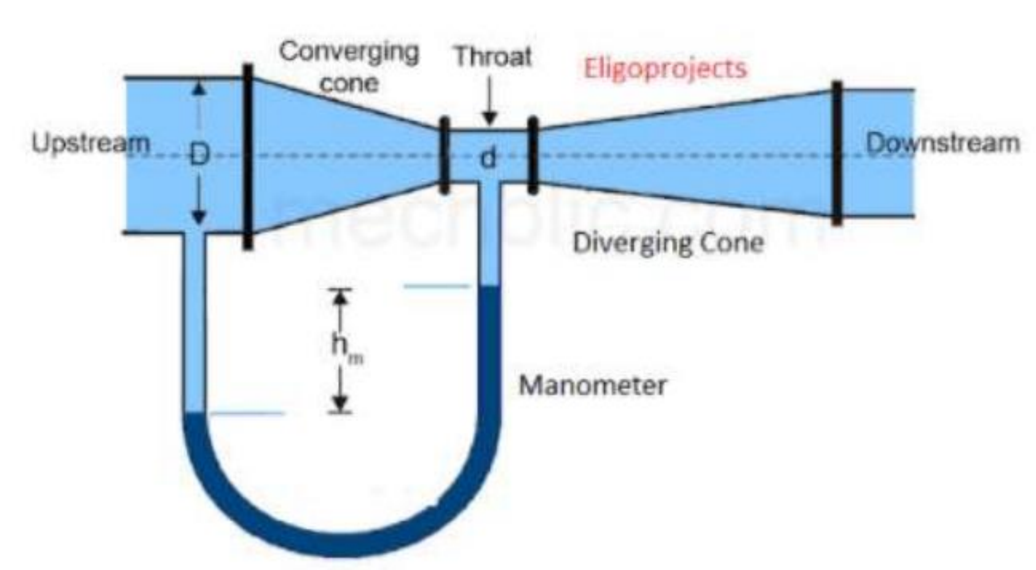
As per
New Syllabus 2022-23

Today's Target

Measurement of mass flow rate
- ✓ Venturi Meter
- ✓ Orifice meter

Venturi Meter

- It is a gradually converging-diverging device that is used to measure the discharge of fluid flow.
- Venturi meter is work on Bernoulli's equation.
- It is one of the costlier device to measure discharge.
- Accuracy is high.
- Losses are less.
- Value of C_d is high (0.94 to 0.98) [Coefficient of discharge ,$C_d = Q_{act} / Q_{th}$



Main parts of Venturimeter:-

1. Converging part
2. Throat
3. Diverging Part

$$Q = \frac{A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

- Cross sectional area of throat section is smaller than inlet section due to this the velocity of flow at throat section is higher than velocity at inlet section, this happen according to continuity equation.

- The increases in velocity at the throat result in decreases in pressure at this section , due to this pressure difference is developed between inlet valve and throat of the venturi-meter.

- This difference in pressure is measured by manometer by placing this between the inlet section and throat.

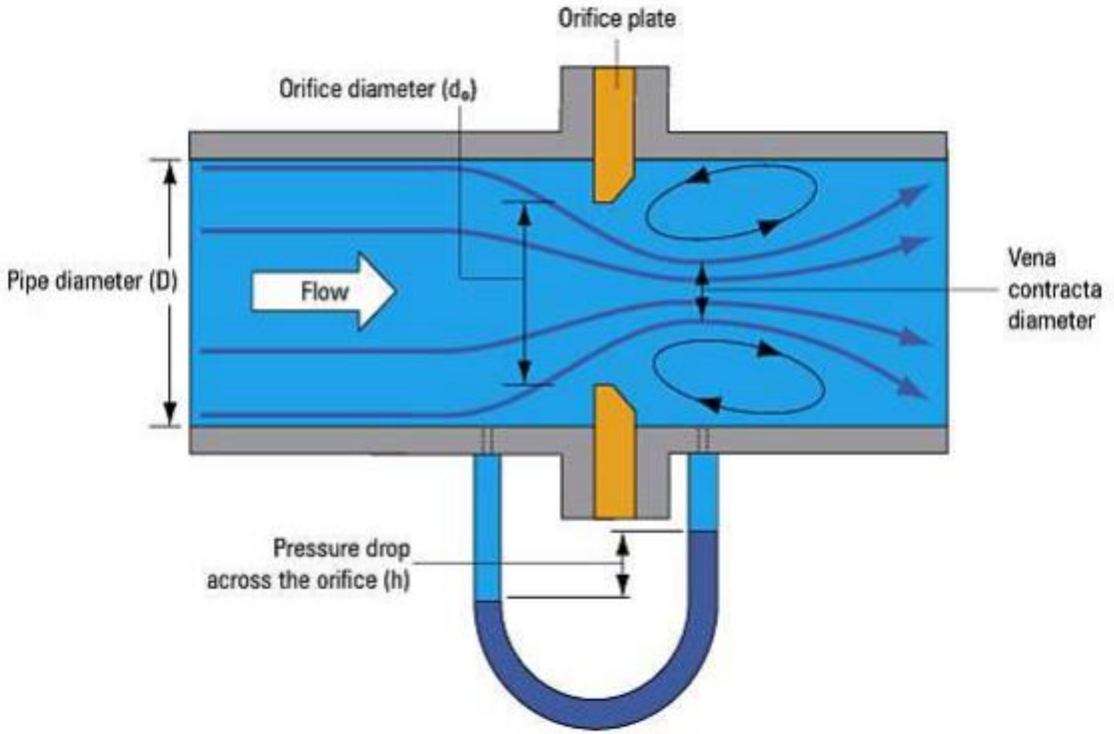
- Using pressure difference value we can easily calculate flow rate through the pipe.

Orifice Meter

$$Q = C_c A_0 \frac{\sqrt{2gh}}{\sqrt{1 - C^2_c\left(\frac{A_0}{A_1}\right)^2}}$$

- ❖ Orifice Meter is a cheapest device to measure **discharge**.
- ❖ Losses are high.
- ❖ Value of C_d is low (0.60 to 0.65) [Coefficient of discharge ,Cd = $\frac{Q_{act}}{Q_{th}}$]

- ➢ Orifice meter is device used to determine the rate of flow through pipe.
- ➢ It consist of flat circular plate which has a sharp edged circular hole called orifice.
- ➢ It is fixed concentric to pipe.
- ➢ The orifice diameter is generally kept half of the diameter of the pipe.
- ➢ It is based on the same principle as explained in venturimeter.
- ➢ The value of Cd varies between 0.60 to 0.65.
- ➢ It is a economical and less space is requred for fitting.



UNIT-5
Lec-4

As per
New Syllabus 2022-23

Today's Target

Measurement of Temperature

- Thermocouple Thermometer
- Optical Pyrometers

Measurement of Temperature

Temperature of a body is defined as degree of hotness or coldness of the body measured on a definite scale.

The commonly used scales for measuring temperature are:

- Kelvin scale (K)
- Centigrade scale (^{O}C)
- Fahrenheit scale (^{O}F)
- Rankine scale (R)

- The principle of temperature measurement is based on Zeroth law of thermodynamics.

- To measure the temperature quantitatively, we use some property of matter that change with temperature

- The instrument which is used for measuring temperature is a thermometer.

Temperature Measuring Instruments

Temperature Measurement

Mechanical Thermometer

1. Metallic expansion thermometers
   - (a). Expansion rod thermometers
   - (b). **Bimetallic Thermometer**
2. Filled system Thermometer
   - (a). **Liquid in glass thermometer (Thermometer)**
   - (b). Constant volume gas thermometers
   - (c). Vapour pressure thermometer

Electrical Thermometer

1. Metallic Resistance thermometer
2. Thermistor
3. **Thermocouple**

Radiation Thermometer

1. Total radiation pyrometer
2. Optical pyrometer

Note : For higher range of temperatures, i.e. above 650 ^{O}C, filled thermometer are unsuitable.
For higher range of temperatures, thermocouples and pyrometers are used.

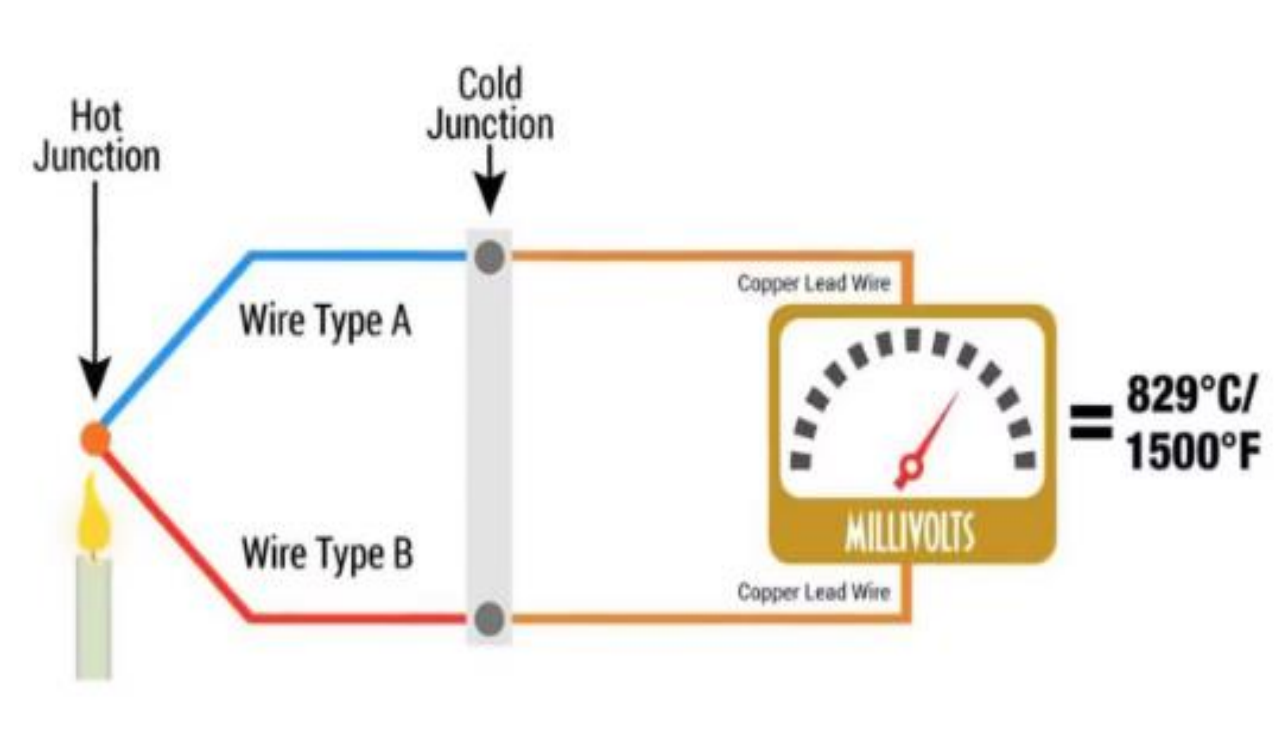
Thermocouple Thermometer

- It is the most popular electrical method for temperature measurement in industrial applications .

- The temperature range of this instrument depends upon the type of thermocouple materials used .

The major reasons behind their popularity are :

(i) Readings are consistent
(ii) They can measure over a wide range of temperature .
(iii) Their characteristics are almost linear with an accuracy of about 0 .05 % .



Thermocouple Thermometer

- The working of thermocouple is based on principle of Seeback Effect .

- When two junctions of a pair of dissimilar metals are maintained at different temperatures, e.m.f. is generated. This phenomenon of generation of em.f. is called Seebeck effect.

- A sensitive voltmeter connected to the circuit will indicate a voltage (emf) which is directly proportional to difference in temperature between hot junction and cold junction.

- The reference junction or cold junction is usually maintained at some constant temperature, such as 0^o C.

Optical Pyrometers

Principle of Optical Pyrometers :

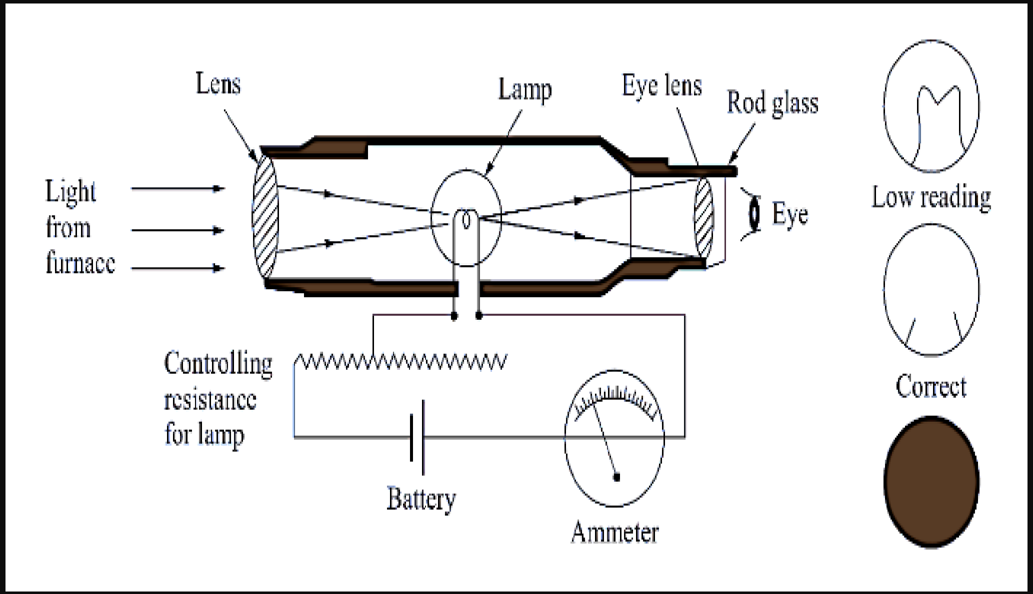
- It is a device which measures the temperature as a change in brightness of a colour.
- Acording to Planck's law, energy levels in the radiation emitted by a hot body are are distributed in different wavelengths.
- As the temperature of hot body rises,the emissive power shifts towards shorter wavelengths.
- The radiations from a hot body at high temperature fall within the visible region of electromagnetic spectrum.
- If we can measure brightness of the light of a given emitted by a hot source , we can estimate its temperature.
- This is the principle of optical pyrometers.
- It can be used to measure temperature in the range of 800 ^{o}C to 1200 ^{o}C.

Optical Pyrometers

Construction of Optical Pyrometers :

As shown in the fig.

- An eye piece at the right side and an optical lens on the left.
- A reference lamp, which is powered with the help of a battery.
- A rheostat to change the current and hence the brightness intensity.
- So as to increase the temperature range which is to be measured, an absorption screen is fitted between the optical lens and the reference bulb.
- A red filter placed between the eye piece and the reference bulb helps in narrowing the band of wavelength.



Optical Pyrometers

Working of Optical Pyrometers :

- As shown in the fig. using the rheostat, current can be varied in the tungsten lamp, so as to vary the brightness of light.

- The image of the radiating source (hot body) , produced by the objective lens system, is made to superimpose on the filament of electric lamp.

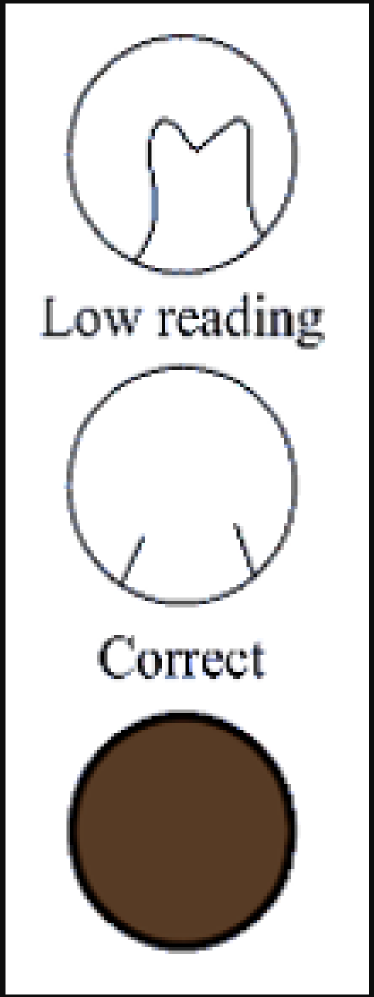
- The electric current through the filament is varied while being viewed through a filter and eye piece.

- The view shall appear one of the types as shown in fig.

- If the filament temperature is lower as compared to hot body temperature, it is less bright and appears darker.

- But when the brightness of filament is same as that of hot body, the filament disappears. At this state the temperature of the filament is equal to that of the hot body.

- The tungsten filament lamp is so calibrated that for known current, the temperature of the filament is also known.



Optical Pyrometers

Uses :

It is widely used accurate measurement of temperature.

- Furnace
- Molten metal
- Other heated material etc.

Advantages :

- Excellent accuracy within $\pm$ 5 °C
- No direct contact with the object whose temperature is to be measure.
- Measurement is independent of the distance between the body and instrument.
- Semiskilled operator is required

Dis-Advantages :

- Can not measure lower temperature
- Radiation is harmful

UNIT-5
Lec-5

As per
New Syllabus 2022-23

Today's Target

- Measurement of strain(Bonded and Unbonded Strain Gauge)
- Measurement of Force (Proving Ring)
- Measurement Torques (Prony Brake Dynamometer)

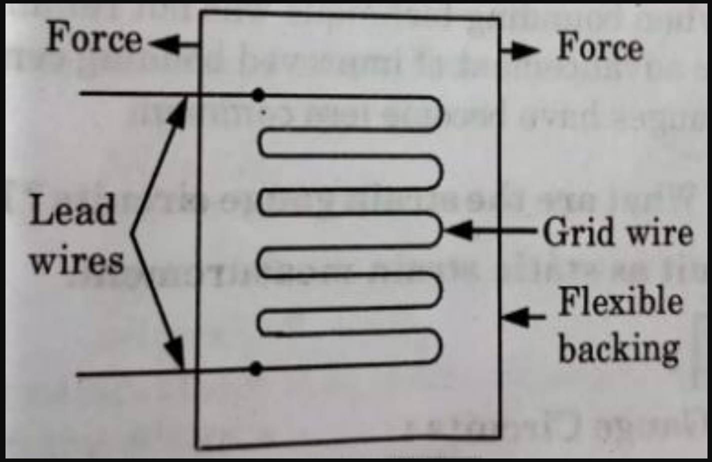
Measurement of strain(Bonded and Unbonded Strain Gauge)

Strain Gauge

- The transducers which measure the strain in the body or object are known as strain gauge.
- Strain is defined as the ratio of change in length to its original length. It is dimensionless quantity.

Bonded Strain Gauge.

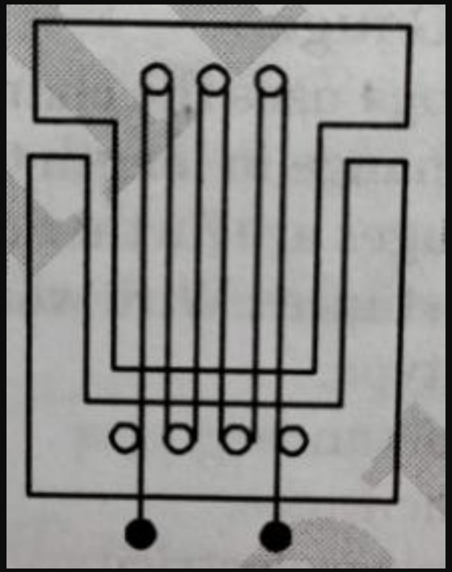
- These gauges are directly bonded (pasted) on the surface of the structure under study.
- Hence they are termed as bonded strain gauges.
- A bonded metal wire strain gauge is used for stress analysis.
- A resistance wire strain gauge has a wire of diameter 0.25mm or less.
- The grid of fine resistance wire is cemented to carrier. It can be a thin sheet of paper, Bakelite or a sheet of Teflon.
- To prevent the wire from any mechanical damage, it is covered on top with a thin sheet of material.
- The spreading of wire allows a uniform distribution of stress over the grid.
- The carrier is bonded with an adhesive material. Due to this, a good transfer of strain from carrier to a grid of wires is achieved.



Measurement of strain(Bonded and Unbonded Strain Gauge)

Unbonded Strain Gauge

- The unbonded resistance strain gauge uses a strain sensitive wire with one end fixed and the other end attached to a movable element.
- The basic design of this type of transducer is shown in Fig.
- Strain, induced on the wire by the displacement of the movable element, produces a change in resistance proportional to the displacement of the movable element.
- Unbonded strain gauge can measure very small motion of the order of 50 pm and very small forces. 4.
- The device is less robust than the bonded gauge and was developed at a time when bounding technique was not reliable.
- With the advancement of improved bonding cements, unbonded wire strain gauges have become less common.

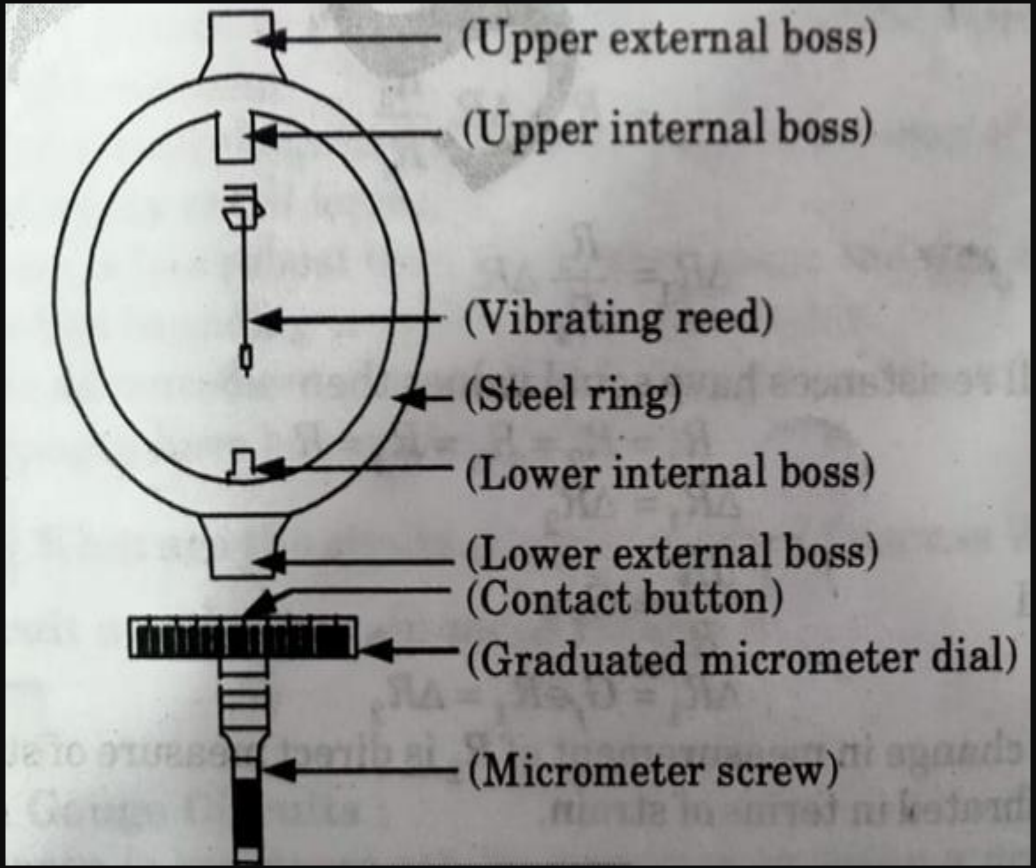


Measurement of Force (Proving Ring)

- The proving ring is a device used to measure force.
- It consists of an elastic ring of known diameter with a measuring device located in the center of the ring.
- Proving rings come in a variety of sizes. They are made of a steel alloy.
- Proving rings can be designed to measure either compression or tension forces. Some are designed to measure both.

Construction of Proving Ring:

- The proving ring consists of two main elements, the ring itself and the diameter-measuring system.
- Forces are applied to the ring through the external bosses.
- The resulting change in diameter, referred to as the deflection of the ring, is measured with a micrometer screw and the vibrating reed mounted diametrically within the ring.
- The micrometer screw and the vibrating reed are attached to the internal bosses of the ring.



……Measurement of Force (Proving Ring)

Working of Proving Ring:

- To read the diameter of the ring, the vibrating reed is set in motion by gently tapping it with a pencil.

- As the reed is vibrating, the micrometer screw on the spindle is adjusted until the contact-button on the spindle just touches the vibrating reed, dampening out its vibrations.

- When this occurs a characteristic buzzing sound is produced.

- At this point a reading of the micrometer dial indicates the diameter of the ring.

Measurement Torques (Prony Brake Dynamometer)

Working and construction of Prony Brake Dynamometer:

- It consists of two wooden blocks, placed around a pulley of radius r as shown in fig.
- The pulley is keyed to the shaft of the engine whose power to be measured.
- The wooden blocks are clamped by two nuts and bolts.
- A helical spring is placed between the nut and the upper wooden block in order to adjust the pressure on the pulley and hence control its speed.
- The upper block also has a long lever attached to it which carries a load L at its outer end.
- A counter weight is placed on the other end of lever to balance the brake when unloaded.
- The stops limit the motion of the lever.
- To measure shaft power using prony brake dynamometer, the lever is loaded with suitable load L and nuts tightened such that the engine shaft runs at a constant speed and the lever is in horizontal position.

Measurement Torques (Prony Brake Dynamometer)

- Under such working condition, moment due to load L balances moment due to frictional resistances force between wooden blocks and the pulley.

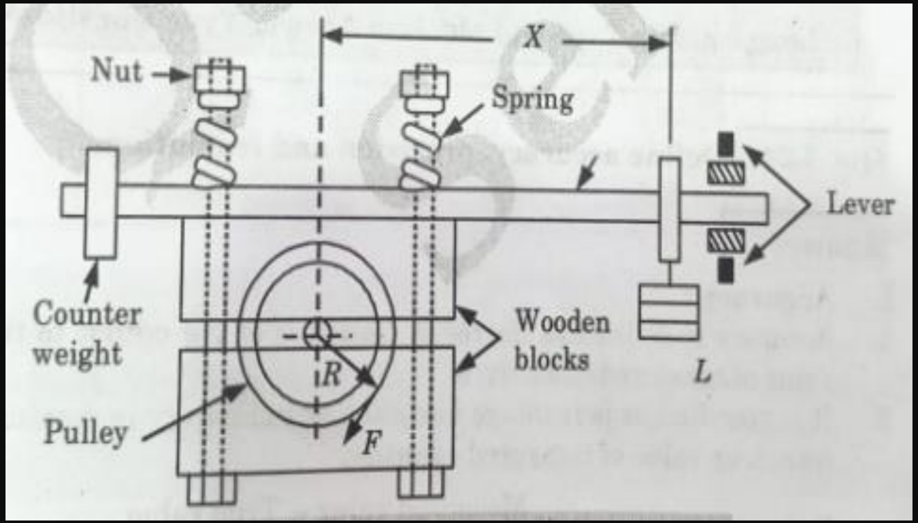
- Hence, torque(T) on the shaft is given by relation
  $T = L \times x = F \times r$

- Work done in one revolution = Torque x Angle turned = T x 2π

- Work done per minute = T x 2 π N
  where, N is the shaft speed in rpm.

- Power transmitted by the engine shaft,

$$P = \frac{Work\ done}{Time} = \frac{T \times 2\pi N}{60} \text{ watt.}$$



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Thank You