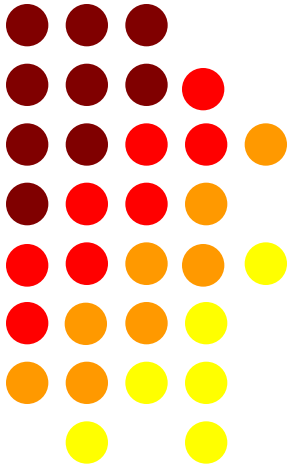
# INTRODUCTION TO MEASUREMENT & MECHATRONICS

GROUP OF INSTITUTIONS

# UNIT-5



# SYLLABUS

- **Introduction to Mechatronics:** 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.

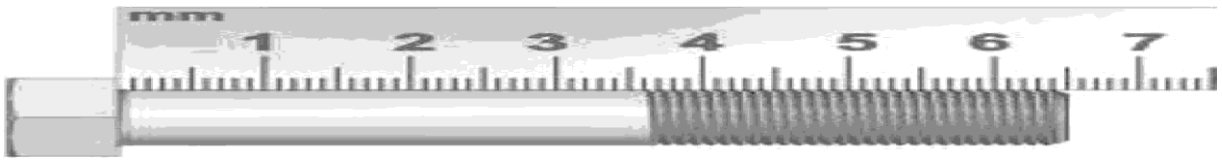
- **Overview of Mechanical Actuation System :** Kinematic Chains, Cam, Train Ratchet Mechanism, Gears and its type, Belt, Bearing,

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

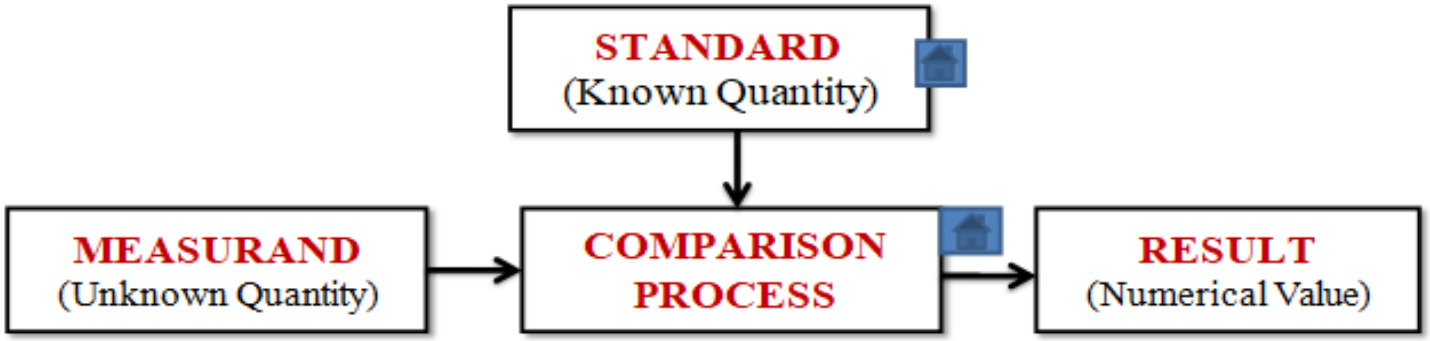
# Lecture No. 31

# INTRODUCTION OF MEASUREMENT

- Measurement is a process of comparing inputs with pre-defined standard and giving the output.
- Measurements are always made using an instrument of some kind.
- The basic objective of a measurement is to provide the required accuracy at a minimum cost.
- The result of a measurement is normally in two parts: a number and a unit of measurement,
- e.g. 'How long is it? ... 2 meters.'



# MEASUREMENT




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

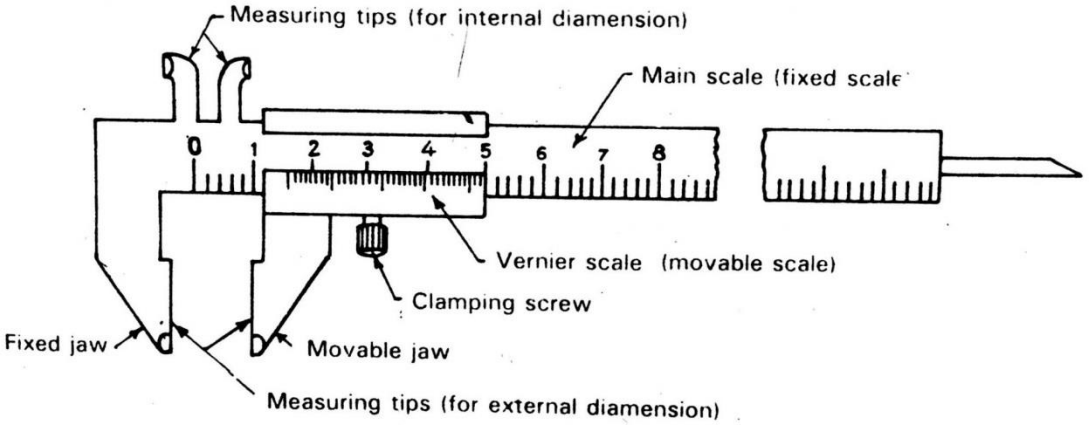
**Comparison:** To compare the measurand (physical quantity) with a known **Standard** for evaluation.

**Standard/Reference:** The physical quantity or property to which quantitative comparisons are to be made, which is **internationally accepted.**

# MODES OF MEASUREMENT

- **Based upon the number of conversions, three basic categories of measurements have been developed. They are;**

1. **Primary measurement**
2. **Secondary measurement**
3. **Tertiary measurement**



# Classification of Measuring Instruments

There are number of criteria based on which the measuring instruments can be classified.

## 1. On the basis of Mode of Measurement

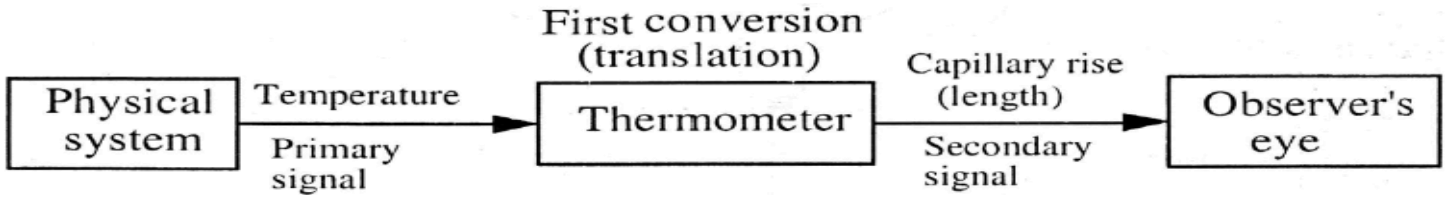
1. **Primary Measurement instruments**
2. **Secondary Measurement instruments**
3. **Tertiary Measurement instruments**

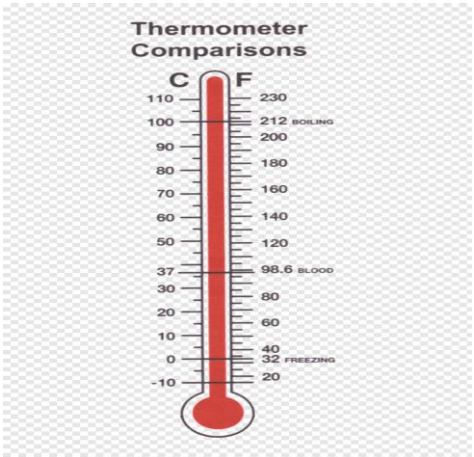
# PRIMARY MEASUREMENT

- Direct observation and comparison is done.
- Not involvement of any conversion.
- Ex. Length, Height, Depth or Width etc. measurement

# SECONDARY MEASUREMENT

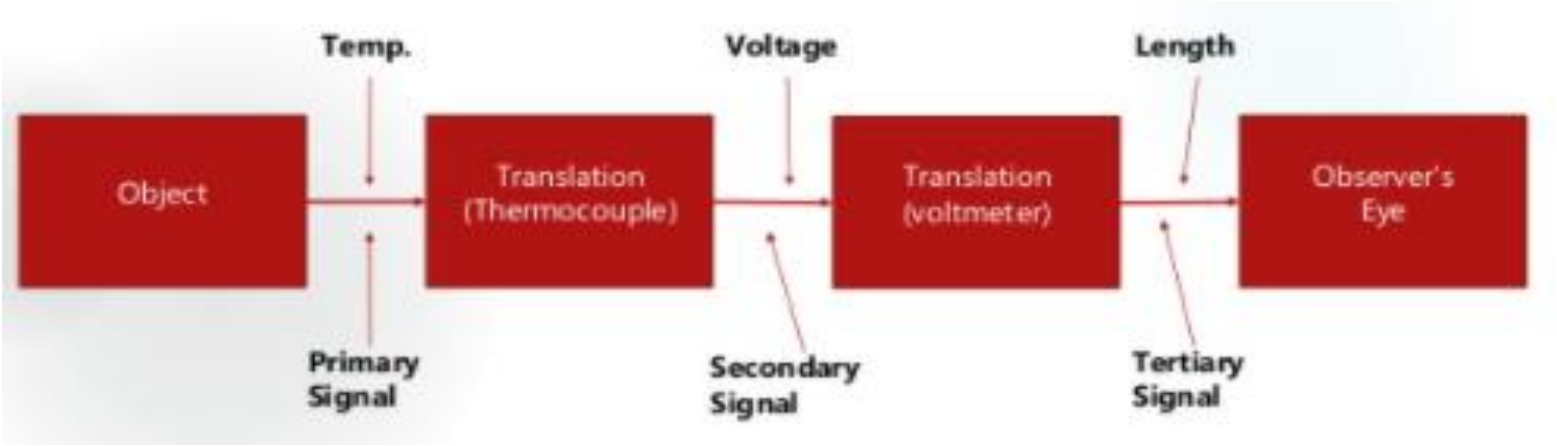
- Indirect method
- Involvement of one conversion
- Ex. Pressure or Temperature measurement



# TERTIARY MEASUREMENT

- Indirect method
- Involvement of two conversion
- A tertiary measurement involves two translations ( conversions).
- A typical examples of such a measurement is the measurement of temperature of an abject by thermocouple.



# Classification of Measuring Instruments

## 2. On the basis of state of contact of the instrument with the medium

1. **Contact type**
2. **Non- contact type**

## 3. On the basis of nature of signal being processed

1. **Analog measuring instruments**
2. **Digital measuring instruments**

# Classification of Measuring Instruments

## 4. On the basis of condition of pointer

1. Deflection type measuring instrument
2. Null type measuring instruments

## 5. On the basis of power source requirement

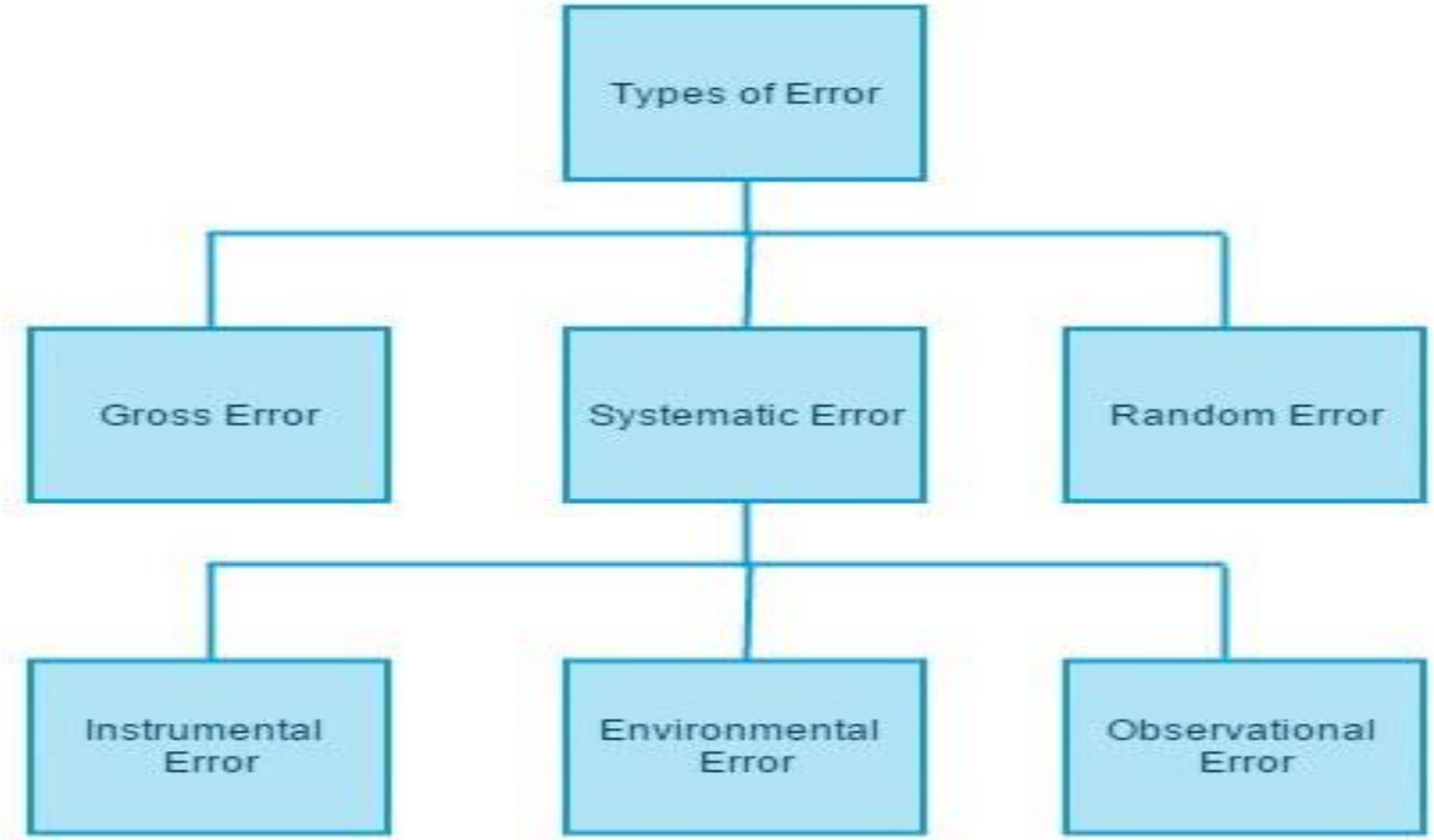
1. Self sufficient instruments (Active instruments)
2. Power operated instruments (Passive instruments)

# ERRORS IN MEASUREMENT

- It is defined as a difference between indicated or measured value and true value.
- It is impossible to made measurement with perfect accuracy.
- Errors are normally classified in three categories:

1. **Gross errors,**
2. **Systematic errors and**
3. **Random errors.**

# ERRORS IN MEASUREMENT



# 1. Gross Error

- Human mistakes
- Careless readings,
- Mistake in recordings
- Can not treated mathematically
- Can be avoided only by taking care in reading and recording

# Systematic Error

- Systematic errors occurs as a result of a flaw in the experimental design or apparatus
- Systematic errors cause the measured value to be consistently higher or lower than the actual value
- They can not be reduced by conducting repeated trials
- Systematic error may be instrumental, environmental, operational and observational.

# Systematic Error

## a. Instrumental error

- Limiting accuracy
- Due to poor design or construction /assembly of instruments
- Improper selection of instrument
- Example:- Errors due to friction, wear, slips, vibration

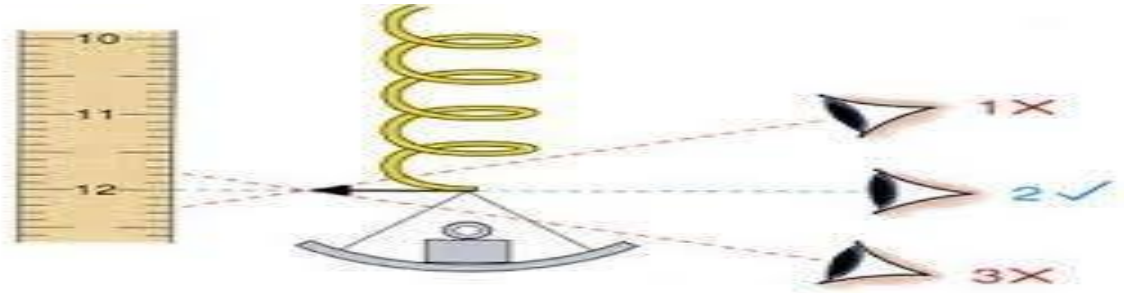
## b. Environmental errors

- Due to external conditions to the measuring instrument, including conditions in the area surrounding the instrument,
- Such as effects of change in temperature, humidity, barometric pressure, or magnetic or electrostatic fields.
- For ex. Buoyant effect of the wind causes errors on precise measurement of weights by pan balance.

# Systematic Error

## c. Observation errors

- Due to poor capabilities and carelessness of operators.
- **e.g.** Parallax : These errors may arise when the pointer and scale not in same plane or line of vision of observer is not normal to the scale




## d. Operational error

- Misuse of instrument.
- Poor operational techniques.
- e.g. Errors in flow measurement if flow- meter is placed immediately after a valve or a bend.

# 3. Random Error

- Random errors are caused by unpredictable changes in the experiment
- With random errors, there s an equal probability of the measured value being too high or too low
- Random errors can not be eliminated but can be reduced by conducting repeat trails.
- E.g. Change in the environment during the experiment such as room temperature.

# Systematic Error vs Random Error

| SYSTEMATIC ERROR | RANDOM ERROR |
|---|---|
| Repetitive in Nature | Random in Nature |
| These errors result from improper conditions and procedures | These errors are inherent in the measuring system |
| Controlled in magnitude and sense | Accidental in nature and difficult to control |
| After proper analysis these errors can be reduced or eliminated | Can not be eliminated |
| Statistical methods does not apply on error | Statistical methods only apply on error |
| Example: Parallax error, Calibration error, etc. | Slight displacement of measuring joint, friction of mating parts, combined effect etc. |

# CALIBRATION

- May be defined as process of determining output scale of a measuring instrument.

## Need of Calibration:

- To maintain quality control and quality assurance in production.
- To comply with requirements of global trade.
- To meet the requirement of ISO guides.
- To promote international recognition.

# CALIBRATION

## SPAN :

- It is defined as **range of value** of input signal that an instrument is designed to measure.
- Hence it is a difference between highest value and the lowest value of the input signal that can be measured by any instrument.

## RESOLUTION:

- It is defined as smallest increment in the input signal which can be satisfactory detected by the measuring instrument .
- In other words it is the **least count** of the measuring instrument.
- The resolution of an instrument is said to be high if it can measure even a smallest change in the input.
- **For example:** The resolution of a micrometre is 0.01 mm.
- **Readability of the scale is important.**
- **Resolution indicates the ease with which the value can be read from the scale.**

## CALIBRATION

### THRESHOLD:

it is defined as the minimum value of input signal which can be detected by the measuring instrument.

No output is generated below the threshold value.

### ACCURACY:

Accuracy of a measuring instrument may be defined as the degree of closeness of the output to the true value of measured quantity.

**Accuracy is the ability of the instrument to measure the accurate value (Conformity).Or Accuracy is a measure of rightness.**

### PRECISION:

Precision of measuring instrument is defined as its ability to reproduce the same output repeatedly for the same input.

**Precision** refers to how closely **individual measurements** agree with each other (Repeatability). **Precision** is a measure of **exactness**

# FACTORS AFFECTING ACCURACY AND PRECISION OF A MEASURING SYSTEM

- A measuring system is made of five basic elements. These are:

1. Standard
2. Work piece
3. Instrument
4. Person
5. Environment.

- These are the factors which affects the accuracy and precision

# Lecture No. 32

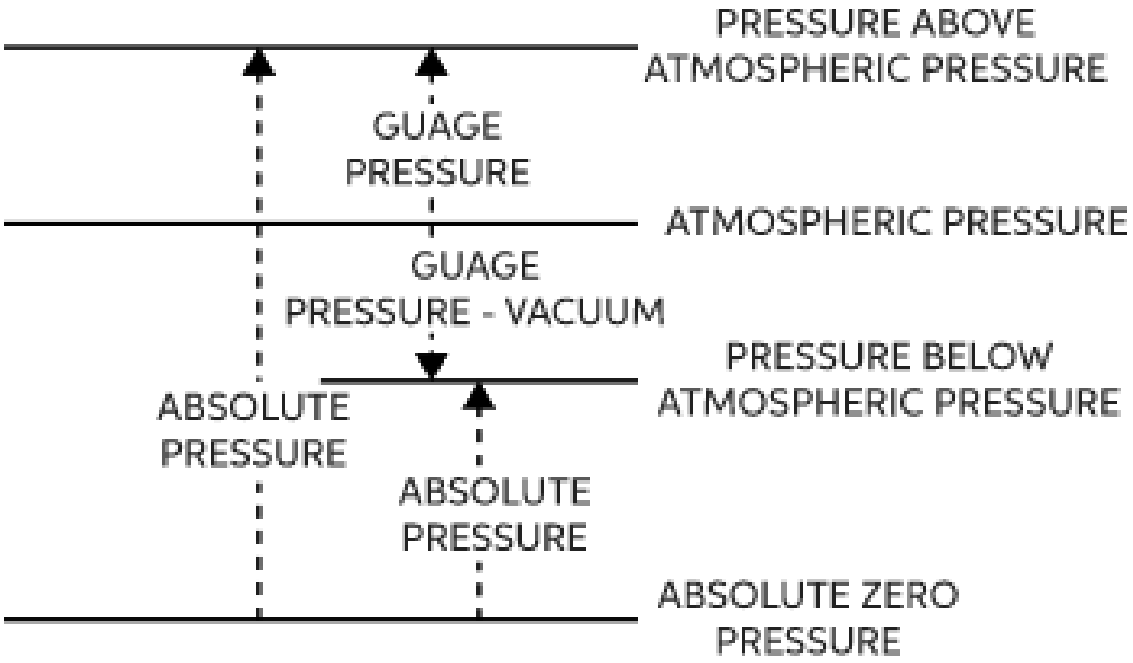
# Pressure Measurement

The pressure is defined as the force acting per unit area. If a uniform force F is acting normal to an area A then pressure is defined as

$$Pressure = \frac{Force}{Area}$$

Following are the different types of pressure based on the reference pressure:

- **Absolute pressure:** Pressure measured relative to a perfect vacuum.
- **Atmospheric pressure:** Pressure related to the atmosphere that surrounds the earth is atmospheric pressure.
- **Gauge pressure: P**ressure measured relative to the ambient atmospheric pressure. It can be positive or negative




The relationship between the above three pressures is given as follows:

Absolute pressure = Atmospheric pressure + Gauge pressure.

# Pressure Measurement

The pressure of a fluid is measured by the following devices:

- Manometers,
- Mechanical gauges.

## Manometer

Manometer is a device used to measure pressure at a single or multiple points in a single or multiple pipelines, by balancing the fluid column by the same or another column of fluid.

- Manometers can be categorized into two types-

1. Simple Manometer,
2. Differential Manometer.

# Pressure Measurement

## Mechanical Gauges

Mechanical gauges are defined as the devices used foe measuring the pressure by balancing the fluid column by spring or dead weight.

- The commonly used mechanical gauges are-

1. Diaphragms pressure gauge,
2. Bourdon Tube pressure gauge,
3. Dead weight pressure gauge,
4. Bellows pressure gauge.

# A. Simple Manometers

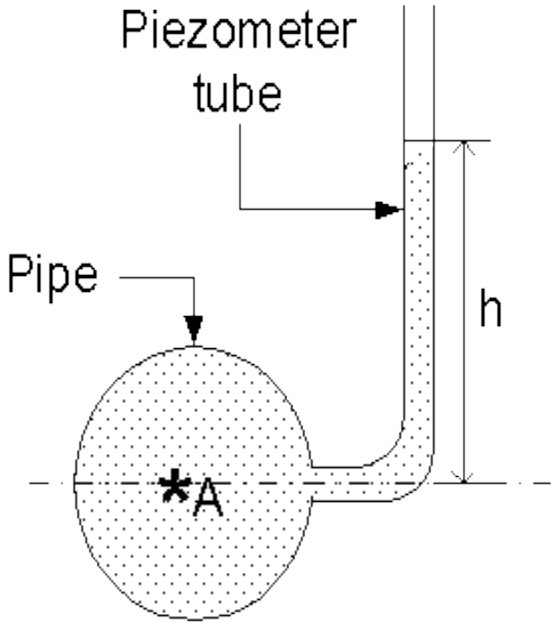
- A simple manometer consists of a glass tube having one of it end connects to a point where pressure is to be measured and another end remains open to atmosphere.

- Common types of simple manometer are:

1. Piezometer
2. U-Tube Manometer
3. Single Column Manometer

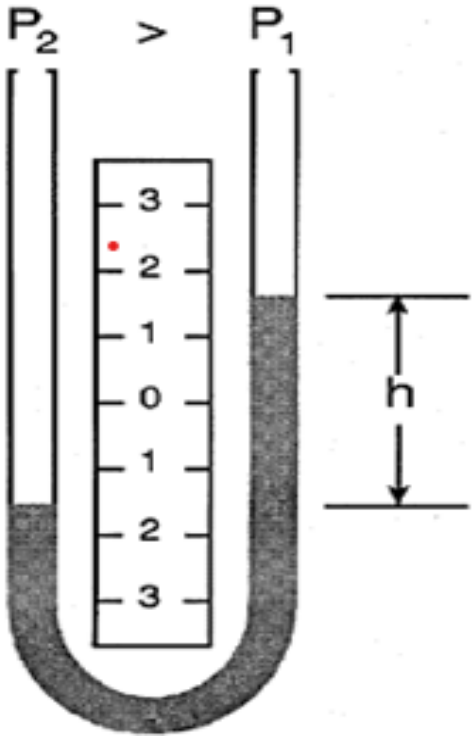
# 1. Piezometer

- Piezometer is one of the simplest forms of manometers. It can be used for measuring moderate pressures of liquids.
- The pressure at any point in the liquid is indicated by the height of the liquid in the tube above that point.
- The pressure at point A is given by $p = \rho g h$



# 2. U-Tube Manometer

- This manometer consist of U- shaped tube in this manometric fluid is filled.
- Water and mercury are used as a manometric fluid.
- Advantage of using these fluid is that mass density of these fluid can be obtained easily, and they do not stick to the tube.




since

$P = \rho g h$

$h = (P_1 - P_2)/\rho g$

$P_1 - P_2 = \rho g h$

Where

ρ - mass density of fluid,

g - gravity

$P_1$ - unknown pressure

$P_2$ - atmospheric pressure

# 3. Single Column Manometer

- Single column manometer directly gives the pressure by measuring the height in the other limb

- Due to large cross-sectional area of the reservoir, for any variation in pressure, the change can be appreciable.

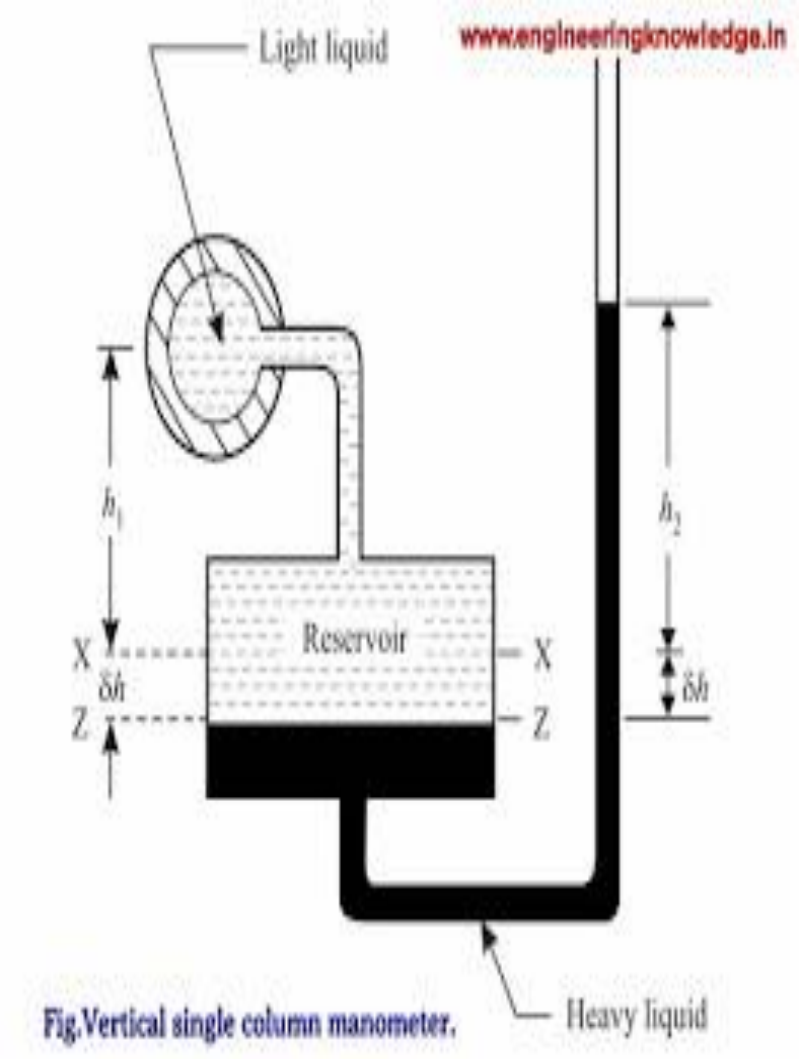


Fig.Vertical single column manometer.

# Single Column Manometer

There are basically two types of single column manometers, on the basis of *right limb* of manometer:

1. Vertical single column manometer
2. Inclined single column manometer

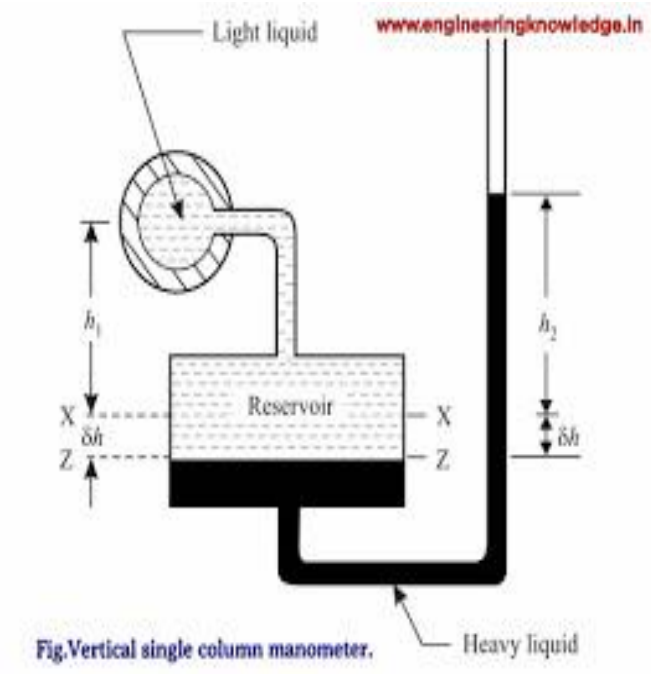
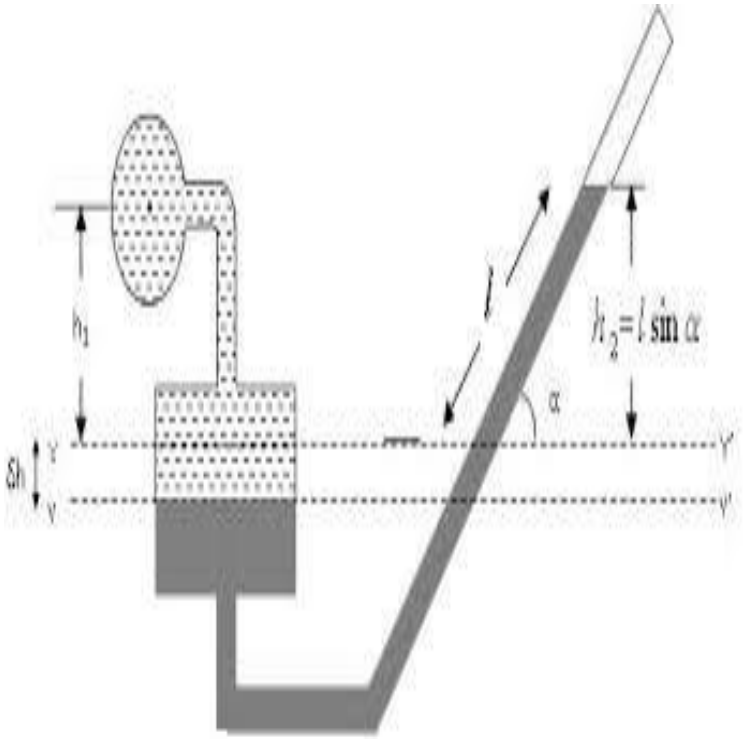


Fig.Vertical single column manometer.



# NUMERICALS

**Q.1** *The right limb of a simple U-tube manometer containing mercury is open to the atmosphere while the left limb is connected to a pipe in which a fluid of sp. gr. 0.9 is flowing. The centre of the pipe is 12 cm below the level of mercury in the right limb. Find the pressure of fluid in the pipe if the difference of mercury level in the two limbs is 20 cm.*

**Solution.** Given :

Sp. gr. of fluid, $S_1 = 0.9$

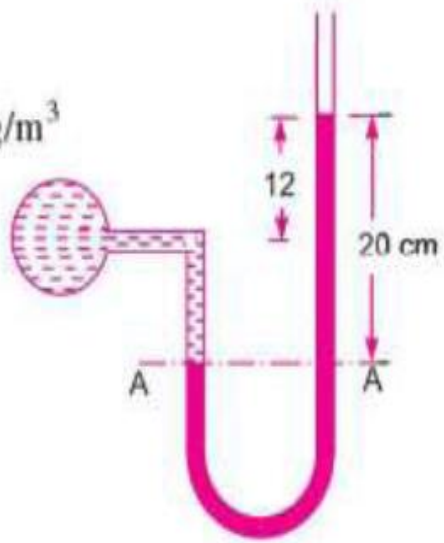
$\therefore$ Density of fluid, $\rho_1 = S_1 \times 1000 = 0.9 \times 1000 = 900 \text{ kg/m}^3$

Sp. gr. of mercury, $S_2 = 13.6$

$\therefore$ Density of mercury, $\rho_2 = 13.6 \times 1000 \text{ kg/m}^3$

Difference of mercury level, $h_2 = 20 \text{ cm} = 0.2 \text{ m}$

Height of fluid from A-A, $h_1 = 20 - 12 = 8 \text{ cm} = 0.08 \text{ m}$




Let $p$ = Pressure of fluid in pipe

Equating the pressure above A-A, we get

$$p + \rho_1 g h_1 = \rho_2 g h_2$$

or $$p + 900 \times 9.81 \times 0.08 = 13.6 \times 1000 \times 9.81 \times .2$$

$$p = 13.6 \times 1000 \times 9.81 \times .2 - 900 \times 9.81 \times 0.08$$

$$= 26683 - 706 = 25977 \text{ N/m}^2 = \mathbf{2.597 \text{ N/cm}^2}. \text{ Ans.}$$

# NUMERICALS

**Q.2** *A simple U-tube manometer containing mercury is connected to a pipe in which a fluid of sp. gr. 0.8 and having vacuum pressure is flowing. The other end of the manometer is open to atmosphere. Find the vacuum pressure in pipe, if the difference of mercury level in the two limbs is 40 cm and the height of fluid in the left from the centre of pipe is 15 cm below.*

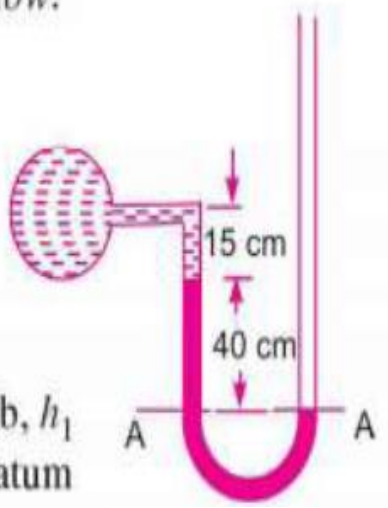
**Solution.** Given :

Sp. gr. of fluid, $S_1 = 0.8$

Sp. gr. of mercury, $S_2 = 13.6$

Density of fluid, $\rho_1 = 800$

Density of mercury, $\rho_2 = 13.6 \times 1000$




Difference of mercury level, $h_2 = 40$ cm $= 0.4$ m. Height of liquid in left limb, $h_1 = 15$ cm $= 0.15$ m. Let the pressure in pipe $= p$. Equating pressure above datum line $A$-$A$, we get

$$\rho_2 g h_2 + \rho_1 g h_1 + p = 0$$

$$\therefore \quad p = -[\rho_2 g h_2 + \rho_1 g h_1]$$

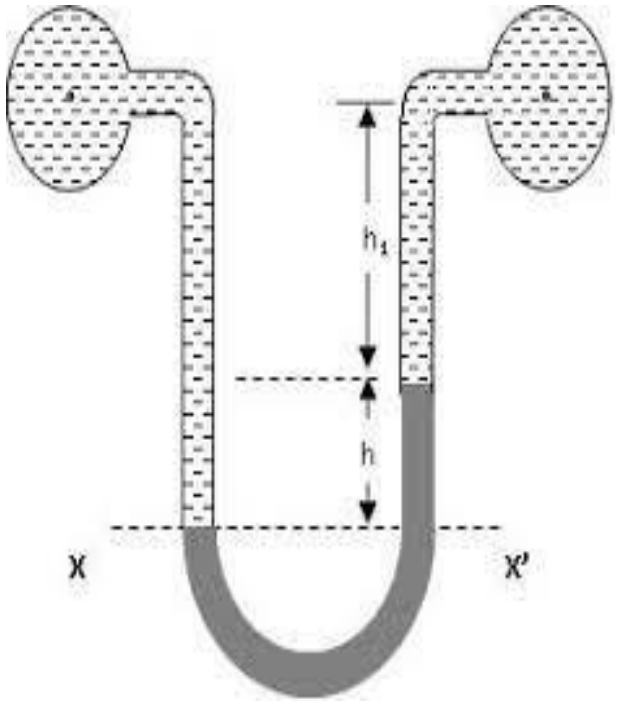
$$= -[13.6 \times 1000 \times 9.81 \times 0.4 + 800 \times 9.81 \times 0.15]$$

$$= -[53366.4 + 1177.2] = -54543.6 \text{ N/m}^2 = \mathbf{-5.454 \text{ N/cm}^2}. \text{ Ans.}$$

# B. Differential Manometers

- Differential manometers are used to measure the difference of pressures between two points in a pipe or in two different pipes.

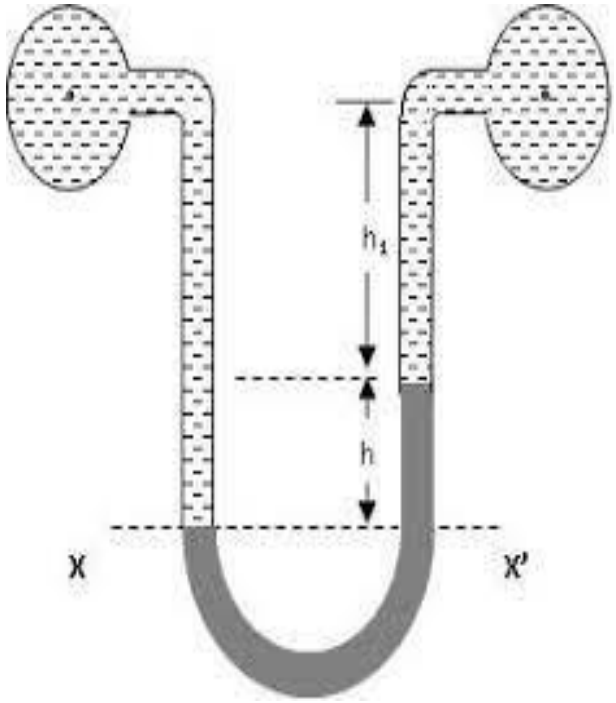
- The simplest differential manometer is a U-shaped tube with both ends at the same height. A liquid, usually water or mercury, rests at the bottom of the tube.

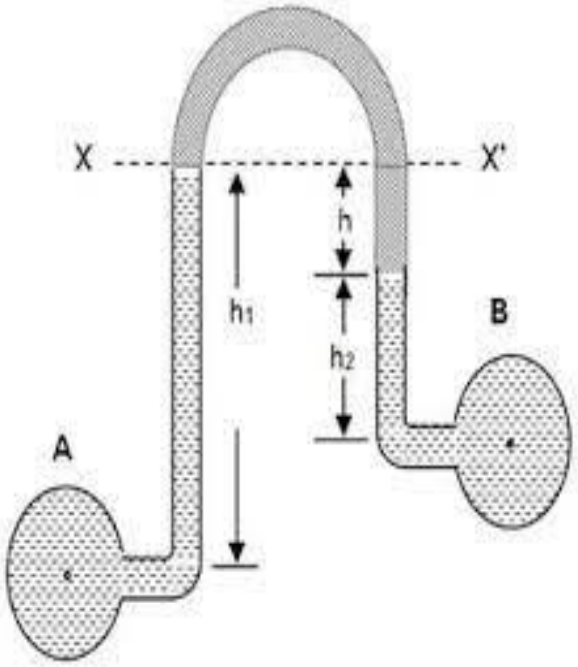


# Types

There are two types of differential manometers.

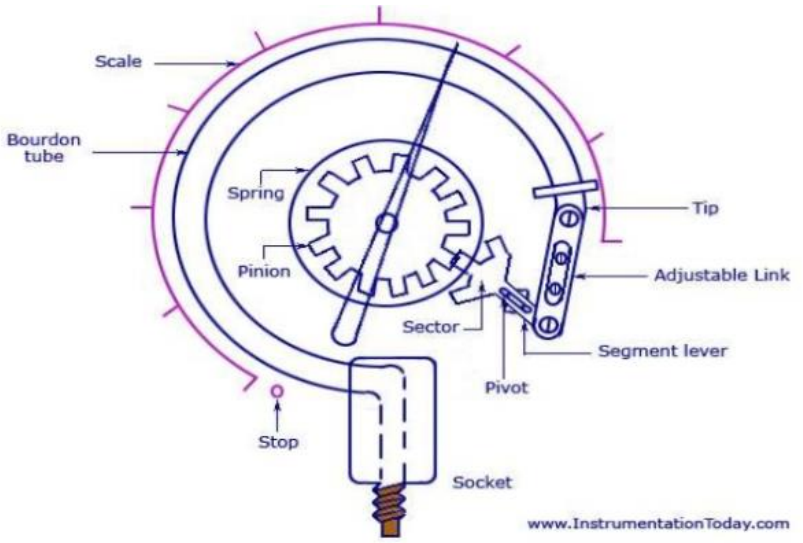
1. U-tube upright differential manometer
2. U-tube inverted differential manometer



# BOURDON TUBE PRESSURE GAUGE

- **Principle:** The Bourdon tube works on a simple principle that a bent tube will change its shape. A pressure is applied internally, the tube straightens and returns to its original form when pressure is released.
- The tip of the tube moves with the internal pressure change and is easily converted with a pointer on to a scale.



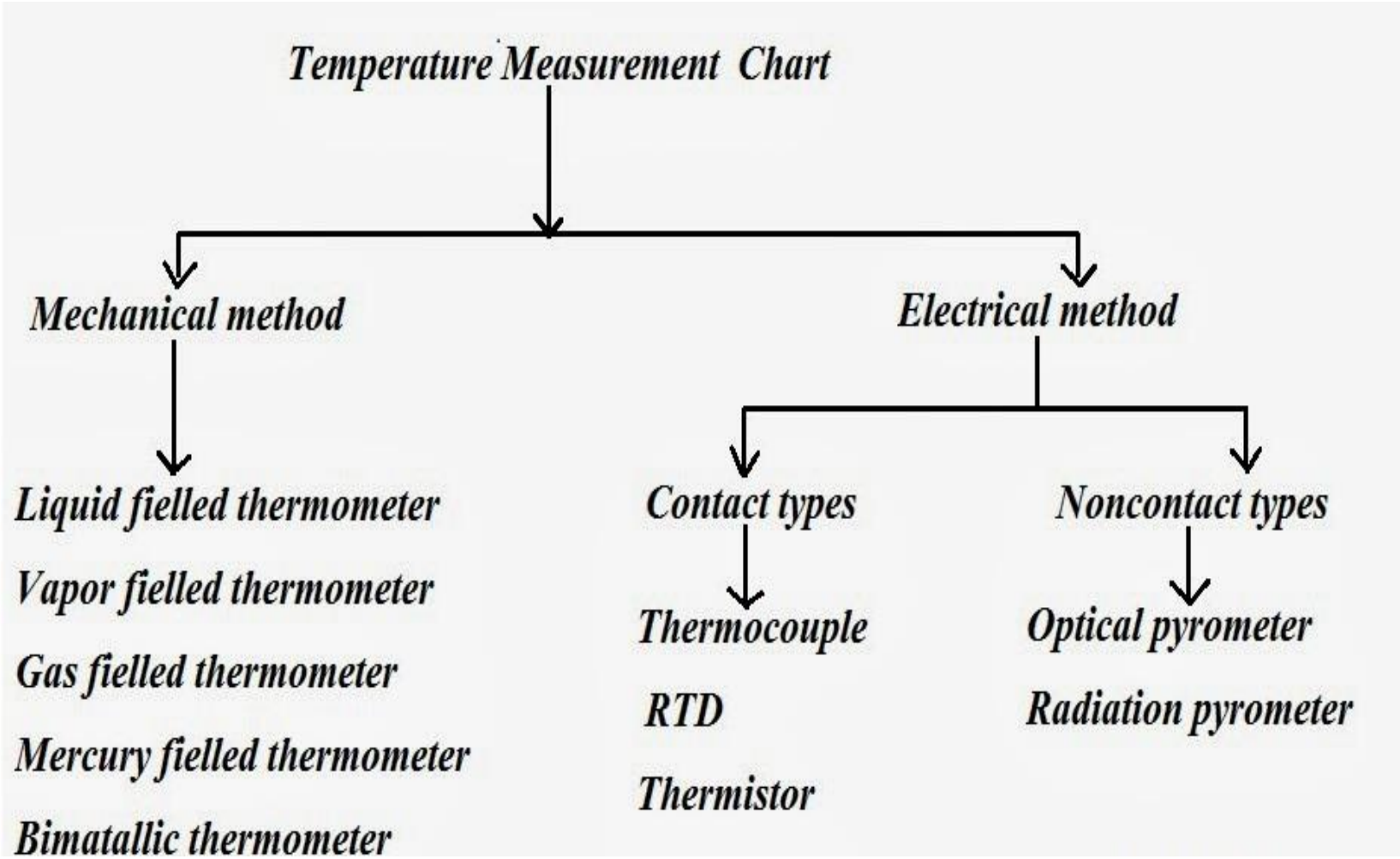
Bourdon Tube Pressure Gauge

# Lecture No. 33

# Temperature Measurement

- Temperature of a body is defined as degree of hotness or coldness measured on a definite scale.
- The principle of temperature measurement is based on ***Zeroth law of thermodynamics.***
- Heat is often confused with temperature, but these two are different concept.
- Heat- Form of energy
- Temperature- Measurable manifestation of thermal energy.

# Temperature Measuring Devices



# Thermocouple

- The **thermocouple** can be defined as a kind of temperature device/sensor that is used to measure the temperature at one specific point in the form of the EMF or an electric current.

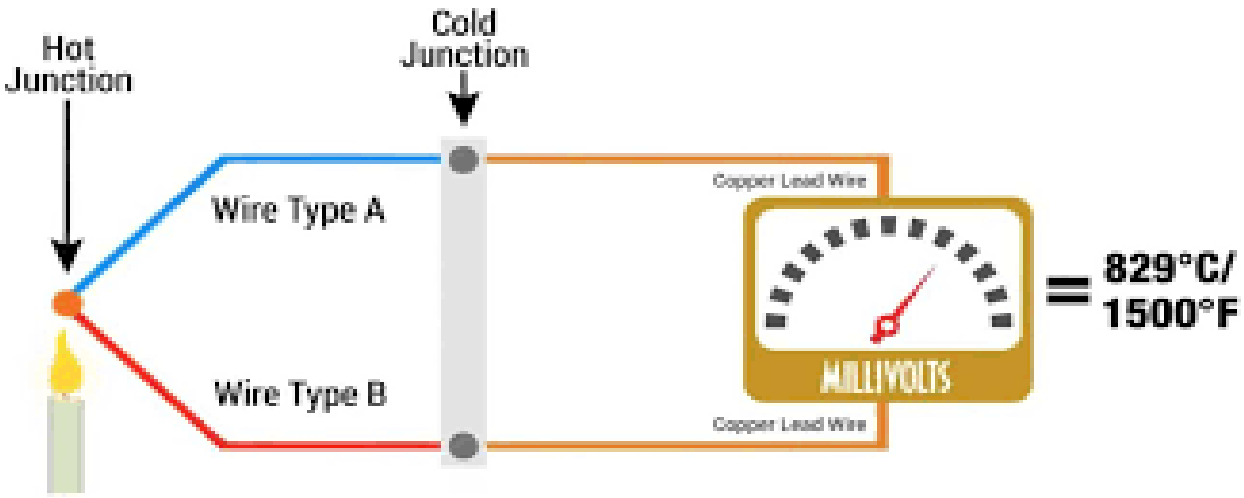
- This sensor comprises two dissimilar metal wires that are connected together at one junction.

- The temperature can be measured at this junction, and the change in temperature of the metal wire stimulates the voltages.

- The **thermocouple** working **principle** is based on the **Seebeck Effect.**

## Seebeck Effect:-

This effect states that when a closed circuit is formed by jointing two dissimilar metals at two junctions, and junctions are maintained at different temperatures then an electromotive force (e.m.f.) is induced in this closed circuit.



# Pyrometer

- A **pyrometer** is a type of remote-sensing thermometer used to measure the temperature of distant objects.
- Pyrometer is a non-contact type temperature measuring device.
- Pyrometer is of two types-

1. Optical Pyrometer
2. Radiation Pyrometer

# Lecture No. 34

# Force Measurement

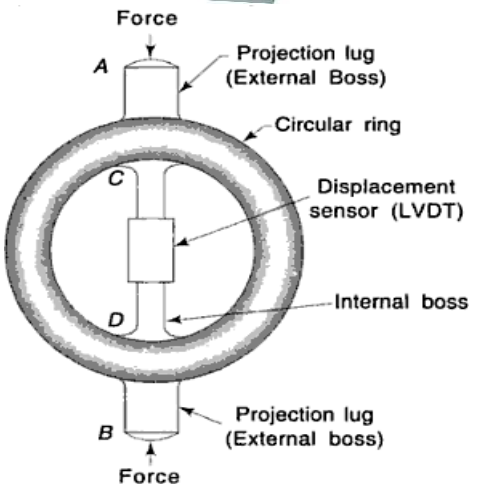
- A **load cell** is an electromechanical device OR a force transducer.

- It converts a force such as tension, compression, pressure, or torque into an **measurable electrical signal** that can be measured and standardized.

- As the force applied to the **load cell** increases, the electrical signal changes proportionally.

# 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.
- It works on the principle of LVDT which senses the displacement caused by the force resulting in a proportional voltage.
- It is provided with the projection lugs for loading. An LVDT is attached with the integral internal bosses C and D for sensing the displacement caused by application of force.
- When the forces are applied through the integral external bosses A and B, the diameter of ring changes depending upon the application which is known as ring deflection.



# Torque Measurement

- **Torque** or **power** transmitted by a shaft is measured by a device known as dynamometer.

- **Types Of Dynamometer:-**

Dynamometer is of two types-

Absorption Dynamometer:

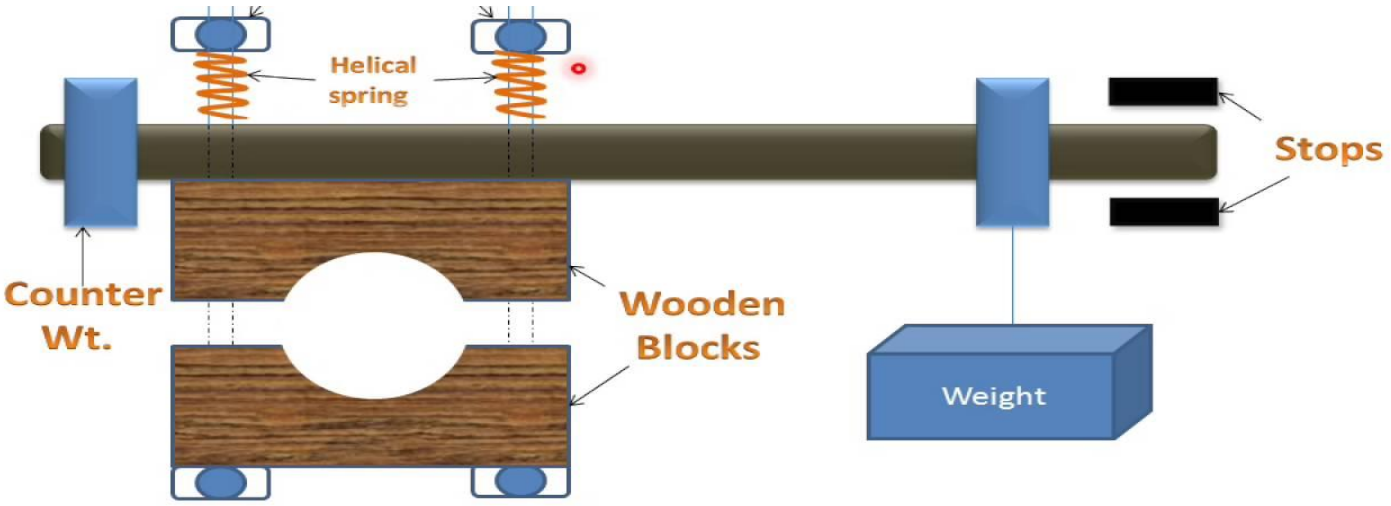
1. Prony Brake Dynamometer
2. Rope Brake Dynamometer

Transmission Dynamometer:

1. Belt Transmission Dynamometer
2. Torsion Dynamometer

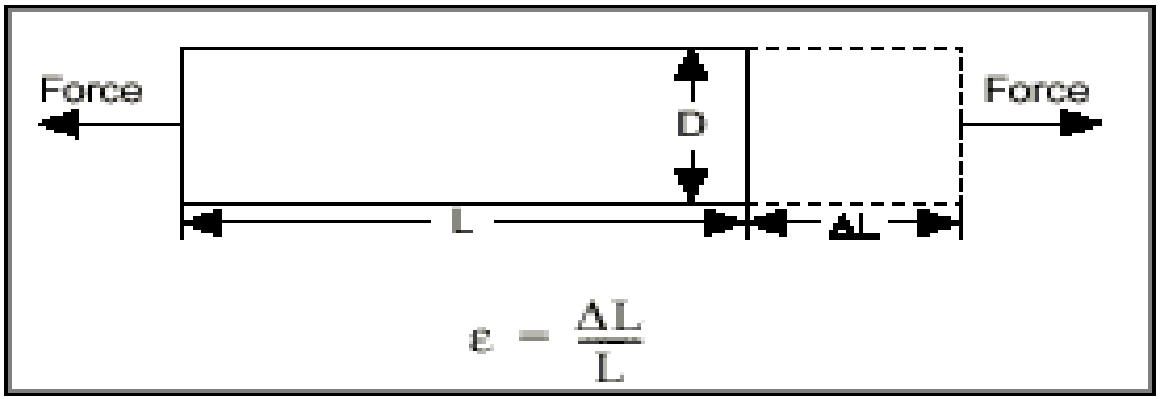
# Prony Brake Dynamometer

- It is the simplest form of absorption type dynamometer. It has two wooden blocks that are placed on a pulley which is fixed on the shaft of the engine whose power is to be measured.
- The wooden blocks are clamped together with two sets of bolts and nuts.
- To control the speed of pulley, the pressure is adjusted over a pulley with the help of a helical spring present between the nut and the upper block.



# Strain Measurement

- Strain is the amount of deformation due to an applied force.
- More specifically strain is defined as the **fractional change in length**
- Strain can be negative(compressive) or positive(tensile) .
- Strain is dimensionless quantity. But expressed as in ***micro strain***

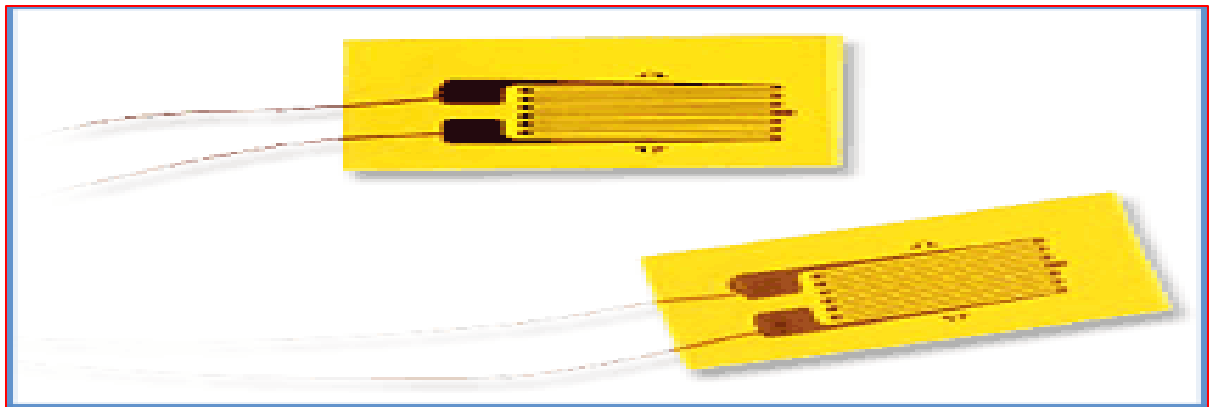


# Strain Measurement

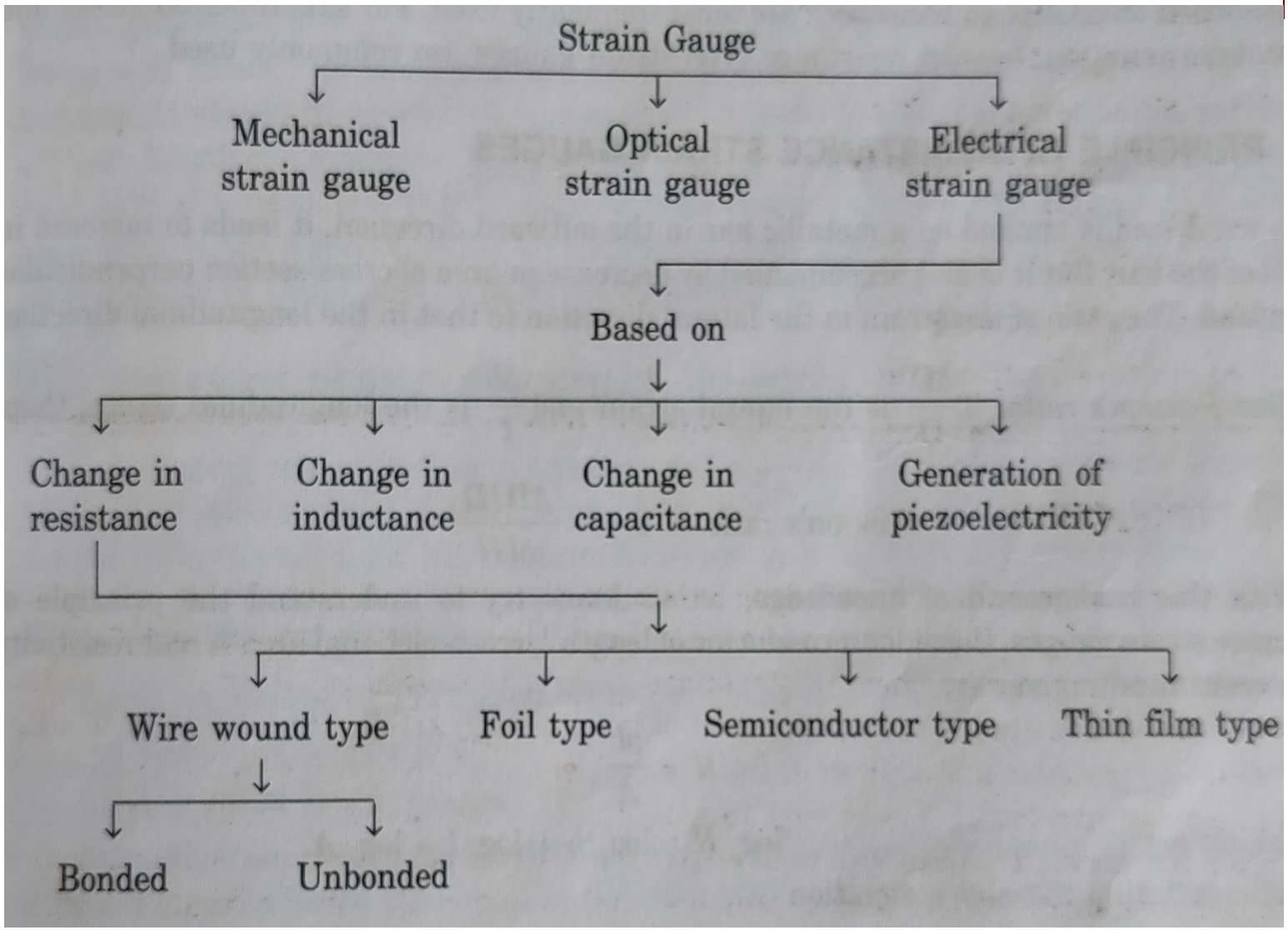
- **Strain Gauge** is a device used to measure deformation (strain) of an object.
- Strain gauges have been developed for the accurate measurement of strain.
- Fundamentally, all strain gauges are designed to convert mechanical motion into an electronic signal.

# Strain Gauge

- Strain gauge (sometimes referred to as a Strain gage) is a sensor whose resistance varies with applied force; it converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured.
- When external forces are applied to a stationary object, stress and strain are the result. Stress is defined as the object's internal resisting forces, and strain is defined as the displacement and deformation that occur.



# Strain Gauge Classification



# Mechanical strain gauge

- Mechanical strain gauges are also called **extensometer.**
- In these gauges, changes in length is magnified mechanically using gear or levers.
- Mechanical strain gauges are comparatively large in size.
- They are suitable for use only where sufficient area is available on the test specimen for mounting the gauge.

# Optical strain Gauge

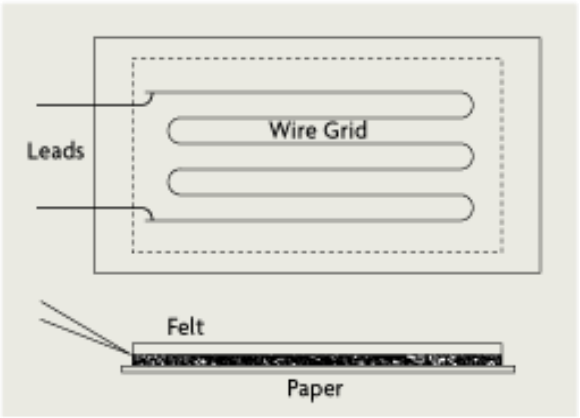
- Optical strain gauges are similar to mechanical gauges.
- The difference being that magnification of change in dimension is achieved with multiple reflector using Mirrors or prisms.
- Because of this arrangement, inertia effect are drastically reduced.
- In this type of measurement accuracy is high.

# Electrical strain gauge

- Electrical strain gauges are based on measurement of change in resistance or inductance or capacitance.
- Inductance and capacitance type strain gauges are used for special purpose application.
- Gauges based on change in resistance are most commonly and frequently used.
- For experimental stress and strain determination bonded resistance type strain gauges are commonly used.

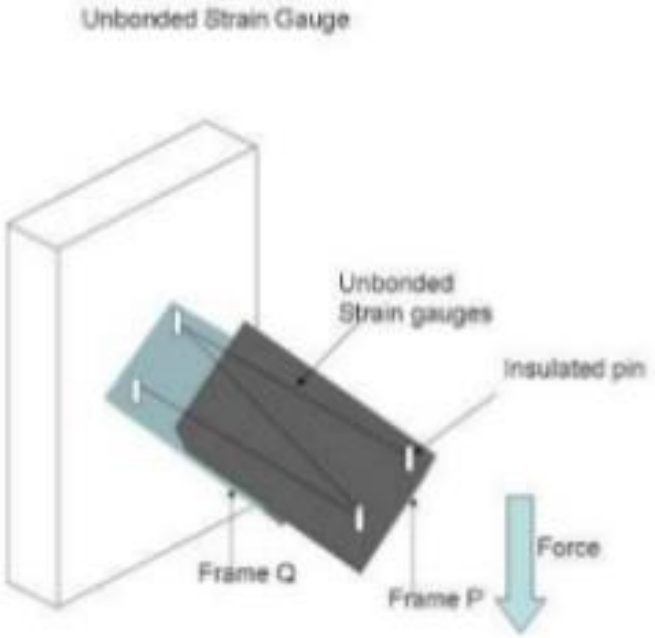
# Bonded Strain Gauge

- In this type strain gauge is bonded directly to the surface of the specimen being tested with a thin layer of adhesive cement .
- The bonded strain gauge will be either a wire type or a foil type as shown in the figure below.
- It is connected to a paper or a thick plastic film support.
- The measuring leads are soldered or welded to the gauge wire.



# Unbonded strain gauge

- The unbonded strain gage consists of a wire stretched between two points in an insulating medium such as air. One end of the wire is fixed and the other end is attached to a movable element.



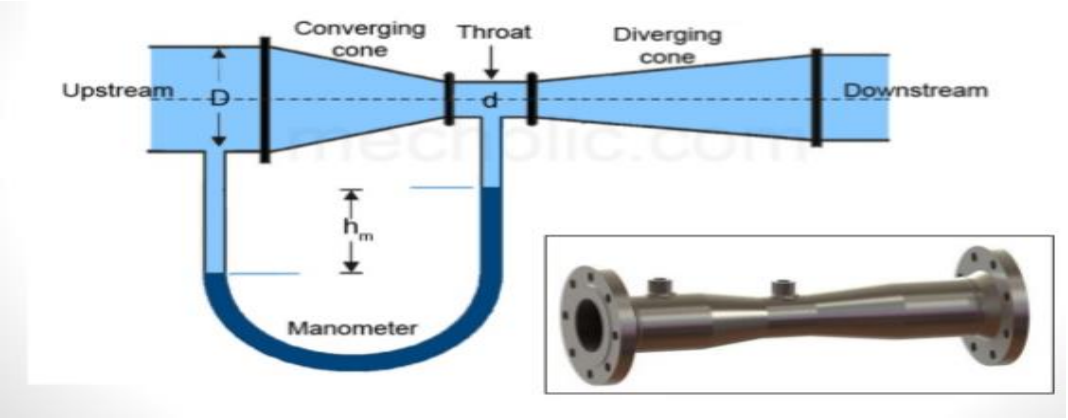
# Measurement of Mass flow Rate

## Venturi meter

**PRINCIPLE –**

It consist of two tapered sections in the pipelines with the gradual constriction at the centre. When fluid stream is suddenly allowed to pass through the narrow constriction, the velocity of the fluid at venturi meter increases as compared to the velocity of the fluid in the upstream. Thus decreasing the pressure head (Bernoulli's theorem). The difference in pressure head may be determined using manometer.

Manometer gives velocity of fluid.



**CONSTRUCTION –**

- A venturi meter consist of two tapered section inserted in a pipeline.
- It is placed between long straight pipes (Do not alter fitting).
- The upstream cone is shorter than in the downstream.
- No energy loss and eddies due to the smooth and gradual tappers.

**WORKING-**

- It is referred as variable head meter.
- In venturi meter, the velocity of fluid is increased at the throat due to constriction.
- With increase in velocity, pressure drops in the up-stream cone.
- The pressure difference is measured using manometer connected as shown in diag.

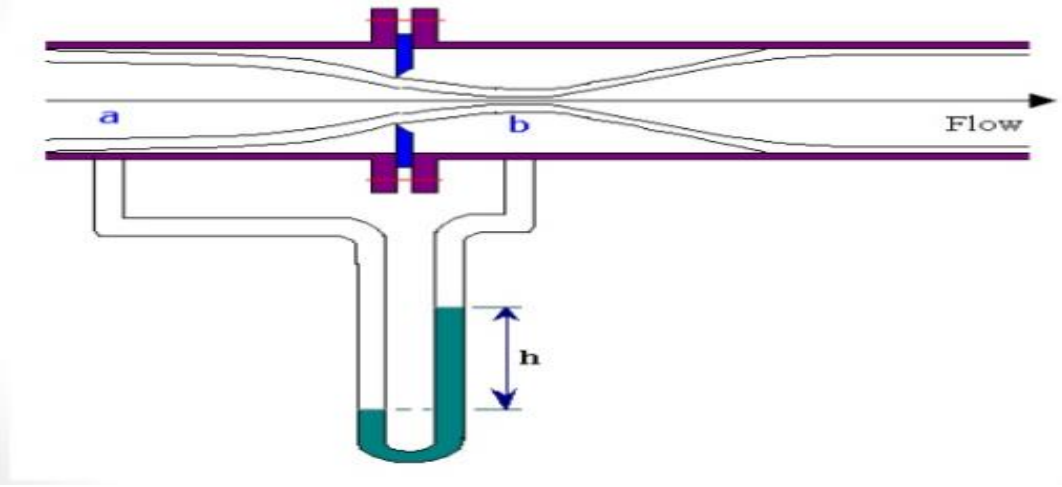
# Orifice Meter

## Orifice meter

**PRINCIPLE-**

When fluid stream is suddenly allowed to pass through the narrow constriction, the velocity of the fluid at orifice meter increases as compared to the velocity of the fluid in the upstream. Thus decreasing the pressure head (Bernoulli's theorem). The difference in pressure head may be determined using manometer.

Manometer gives velocity of fluid.



**CONSTRUCTION –**

- It is considered to be a thin plate containing a sharp aperture through which fluid flow.
- It is placed between long straight pipes ( to avoid altering)
- It can also be placed in the side and bottom.

**WORKING –**

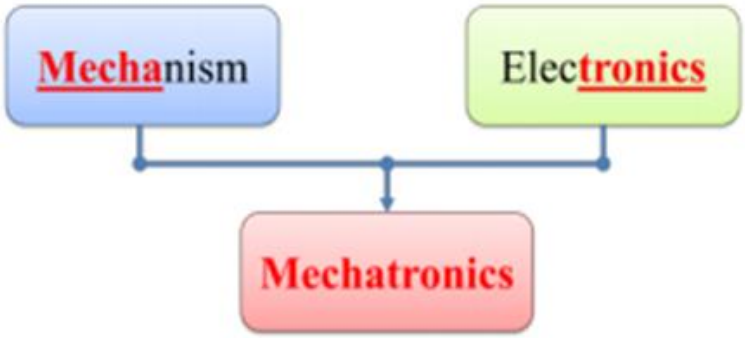
- Orifice meter is referred to as variable head meter (measures the variation in the pressure across fixed constriction)
- When fluid stream is allowed to pass through the cross-section of the orifice, the velocity of the fluid at point B increases at the expense of pressure head.
- Pressure at point A> Pressure at point B.
- Pressure difference is measured using manometer.
- If cross-section of pipe is known, the volume of liquid flowing per hour can be directly determined.

# Lecture No. 35

# Mechatronics

- Mechatronics is a concept of Japanese origin (1970's) and can be defined as the application of electronics and computer technology to control the motions of mechanical systems.

- It is a multidisciplinary approach to product and manufacturing system design. It involves application of electrical, mechanical, control and computer engineering to develop products, processes and systems with greater flexibility, ease in redesign and ability of reprogramming. It concurrently includes all these.



# Scope

- Mechatronics has large scope for engineers of all fields. Robotics Engineer, Electro-mechanical Engineer, Simulation Engineer, Mechanical Design Engineer, Electronics Technician, Project Engineer, and Systems Engineer are some positions students can take up later in their careers.
- Scope of Mechatronics also extends to areas of Artificial Intelligence, Industrial Automation and VLSI design. Design Engineer, Product Development Engineer, etc. are the common job profiles. Mechatronic engineering is an emerging field, but it has been around in one form or another for some time.

# Evolution Level of Mechatronics

1. **Primary Level Mechatronics:** This level incorporates I/O devices such as sensors and actuators that integrates electrical signals with mechanical action at the basic control levels. Examples: Electrically controlled fluid valves and relays

2. **Secondary Level Mechatronics:** This level integrates microelectronics into electrically controlled devices. Examples: Cassette players

3. **Third Level Mechatronics:** This level incorporates advanced feedback functions into control strategy thereby enhancing the quality in terms of sophistication called smart system. The control strategy includes microelectronics, microprocessor and other 'Application Specific Integrated Circuits' (ASIC). Example: Control of Electrical motor used to activate industrial robots, and automatic washing machines

4. **Fourth Level Mechatronics:** This level incorporates intelligent control in mechatronics system. It introduces intelligence and fault detection andisolation (FDI) capability systems.

# Advantages of Mechatronics

- Mechatronics is important because it enhances functionality and features. It brings more efficiency.
- Mechatronics adds intelligence to design of the system, by which efficiency of the system improves.
- It reduces cost. Mechanical solutions are expensive when compared to mechatronics solutions, which lowers cost.
- A mechatronic solution improves design time, product size and reliability. It is also more user-friendly and safer to use.
- Mechatronic uses microcontroller, by which precision, position, speed, flow rate, and variables can be controlled.
- Using mechatronic solution increases reliability. Mechanical designs get damaged over time whereas mechatronic design is more reliable. An example is the odometer present in the cars

# Disadvantages of Mechatronics

- High initial cost of the system
- Imperative to have knowledge of different engineering field for design and implementation.
- Specific problem for various system would have to be addressed separately and properly.
- It is expensive to incorporate mechatronic approach to an existing/old system.
- Maintenance and servicing are a costly affaire.

# Industrial application

- Mechatronics based automated systems such as automatic inspection and quality assurance, automatic packaging, record making, and automatic dispatch help to expedite the entire manufacturing operation. These systems certainly ensure a supply better quality, well packed and reliable products in the market.
- Automation in the machine tools has reduced the human intervention in the machining operation and improved the process efficiency and product quality.
- It is widely used in aeronautics engineering for unmanned aerial vehicles and automatic pilots. In the defense industry it is used for automatically guided vehicles and mine detection robots.

# Lecture No. 36

# Autotronics

## Definition:

- Autotronics can be defined as the combination of automobile and electronics or we can say that the use of electronics science in automobile vehicles is called autotronics.

## Major Areas:

- The use of electronics in the automobile field makes the system safe, improved and efficient.
- At present, in the new generation automobiles almost 75%-85% of automobile parts are embedded with electronics system.
- The main areas of automobiles using autotronics are engine controlling system, airbags, antilock braking system, lightening interiors, GPS, music systems etc.
- In the autotronics systems the use of control units like sensors, motors and digital equipment establishes a communication between the various essential system and components of the vehicle.

# Bionics

- Bionics is a field of technology that combines the study of biology in nature and its patterns, with mechatronics, which combines mechanical, electronics and software.
- Bionics consists of many different subject areas, but one of the most eye-catching and popular is bionic implants.
- These implants aim to improve the standard of living for people who have damaged body parts such as arms, legs, eyes, or even ears.

# Working of bionic implants

- It’s extremely hard to mimic the actions created by regular limbs. It’s something that software and hardware engineers have a lot of trouble working with.
- To solve this, all the successful bionics systems use machine learning to mimic physical movements.
- **Myoelectric** *(Myo = muscles)* sensors are used in bionic limbs to generate an electrical signal from muscle contractions.
- This is useful because it can get signals from the still functional nerve endings of the amputated limb. This means that the sensors can pick up when the user wants to move that area.
- In some cases, to improve the accuracy of myoelectric sensors, small incisions are made to place them closer to the muscle/nerve endings.

# Avionics

- **Avionics** are the electronics systems used on aircraft, artificial satellite, and spacecraft. Avionic systems include communications, navigation, the display and management of multiple systems, and the hundreds of systems that are fitted to aircraft to perform individual functions.
- Avionics grew in 1950's and 1960 as electronic devices which replaces the mechanical or analog equipment in the aircraft.
- Avionics equipment on a modern military or civil aircraft account for around; 30% of the total cost of the aircraft.

# Avionics Contd…

## Need for Avionics:

- To enable the flight crew to carry out the aircraft mission safely and efficiently. For civil airliner the mission is carrying passengers to their destination. For military aircraft the mission is intercepting a hostile aircraft, attacking a ground target, reconnaissance or maritime patrol.

## Advantages of Avionics:

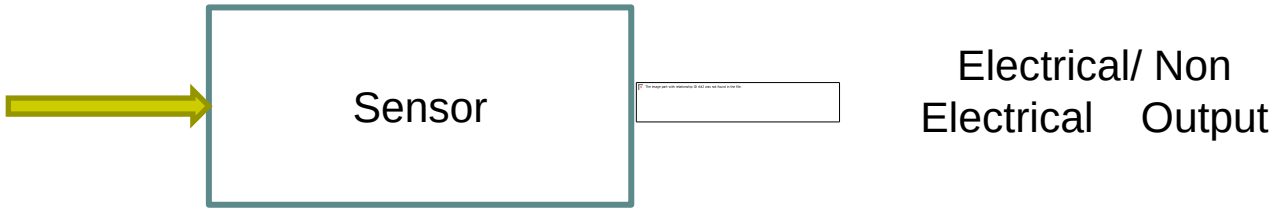
- Increased safety
- Air traffic control requirements
- All weather operation
- Reduction in fuel consumption
- Improved aircraft performance and control and handling and reduction in maintenance costs

# Lecture No. 37

# Sensors and Transducers

## Sensors:

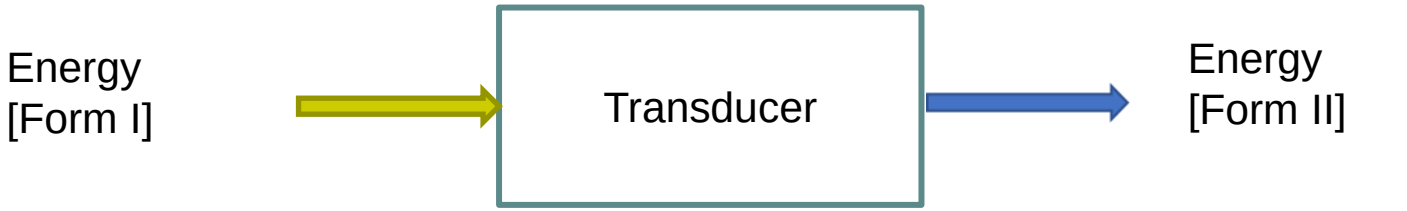
- A sensor is a device which senses the change and make it readable(output is not guaranteed to be electrical).




**Example:**


## Transducers:

- The transducer is a device which converts non electrical quantity into electrical quantity.

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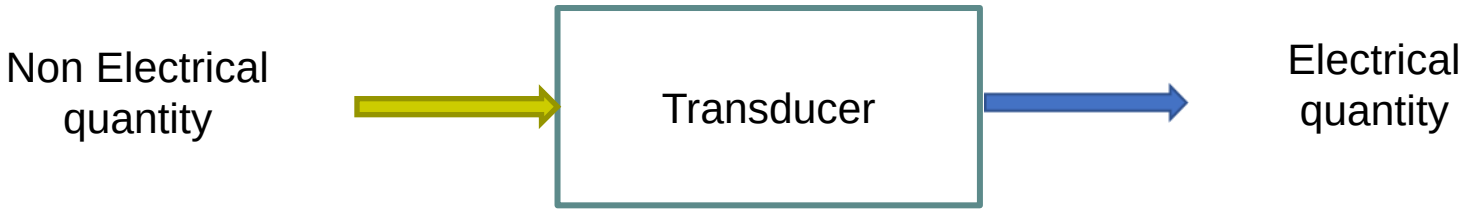



**Example:**

# Types of Sensors

- The following is a list of different types of sensors that are commonly used in various applications.
  - Temperature Sensor
  - Proximity Sensor
  - Accelerometer
  - IR Sensor (Infrared Sensor)
  - Pressure Sensor
  - Light Sensor
  - Ultrasonic Sensor
  - Smoke, Gas and Alcohol Sensor
  - Touch Sensor, colour sensor
  - Humidity Sensor
  - Flow and Level Sensor

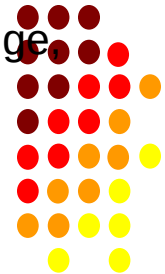
# Types of Transducers

There are of many different types of transducer, they can be classified based on various criteria as:

1. Transducer based on Quantity to be Measured:
   - Temperature Transducers (e.g thermocouple)
   - Pressure transducers (e.g. a diaphragm)
   - Displacement transducers (e.g. LVDT)
   - Oscillator transducers
   - Flow transducers

2. Transducer based on the Principle of Operation:
   - Capacitive
   - Inductive
   - Resistive
   - Photoelectric
   - Chemical

3. Transducer based on need of an External Power Source
   - **Active Transducer:** Active transducers are those which do not require any power source for their operation. For example, a thermocouple, thermometer etc.
   - **Passive Transducer:** Transducers which require an external power source for their operation is called as a passive transducer**.** For example, a strain gauge, thermistor etc.



# Comparison Between a Sensor and Transducer

| | Sensor | Transducer |
|---|---|---|
| **Working principle** | Senses a physical measurement and makes it readable for the user but keeps it in the same format | Senses the physical measurement and converts it from one form to another - ex: Non- electrical to electrical. |
| **Examples** | Thermistor, motion sensor, pressure switch | Microphones, pressure transducer, linear transducer. |
| **Uses / applications** | Patient monitoring, infrared toilet flushes, liquid dispensing in drinks machines. | HVAC monitoring, engine controls, steering systems, ramp and bridge lifting systems. |

# Characteristics of Sensors and Transducers

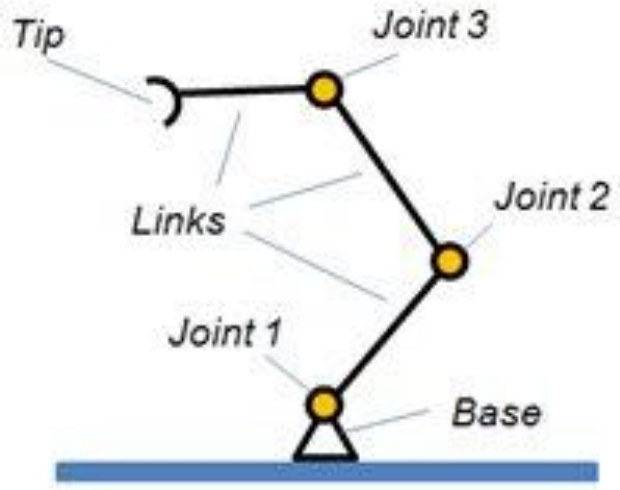
The performance characteristics are mainly divided into two categories: i) Static characteristics ii) Dynamic characteristics

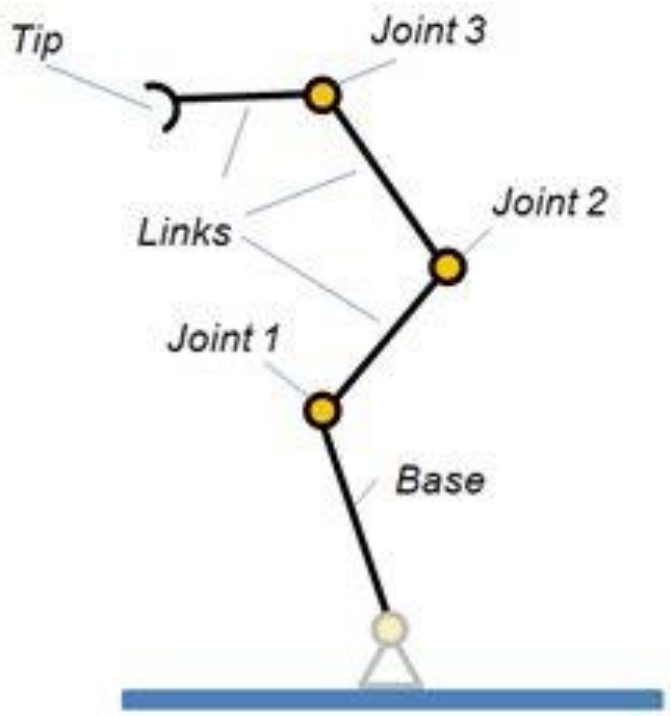
1. **Static characteristics:** Static characteristics refer to the characteristics of the system when the input is either held constant or varying very slowly. Range, sensitivity, linearity, resolution, accuracy, precision, response time etc are important static characteristics.
2. **Dynamic characteristics:** Dynamic characteristics refer to the performance of the instrument when the input variable is changing rapidly with time. For example, human eye cannot detect any event whose duration is more than one-tenth of a second; thus, the dynamic performance of human eye cannot be said to be very satisfactory. Few important dynamics characteristics are dynamic error, speed of response, fidelity and lag.

# Lecture No. 38

# Kinematic Chains

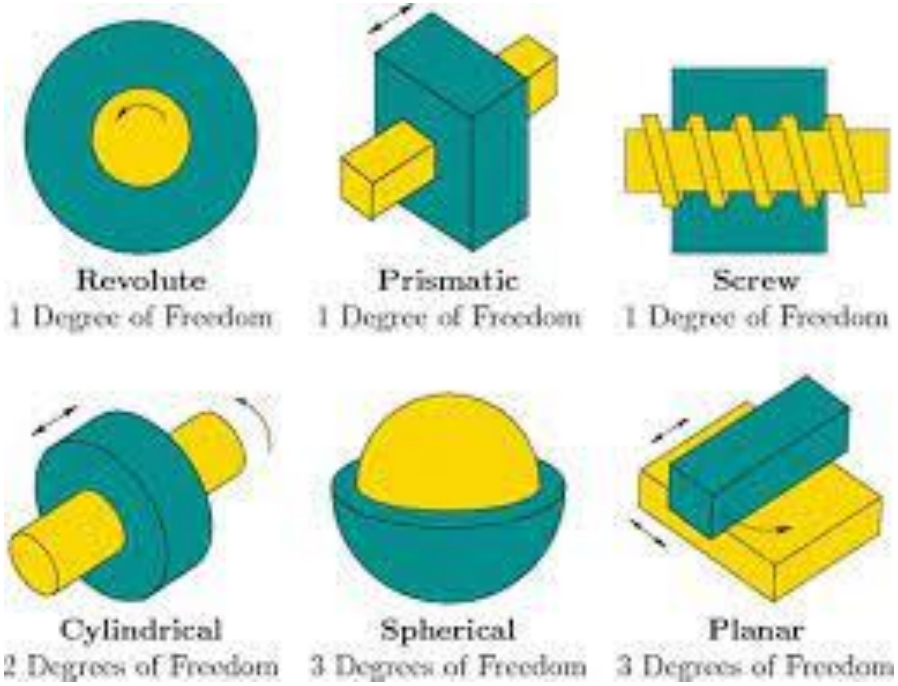
- **Kinematic Link:** A kinematic link or element or link is a resistant body that constitutes part of the machine, connecting other parts which have motion relative to it. Example: Piston rod.



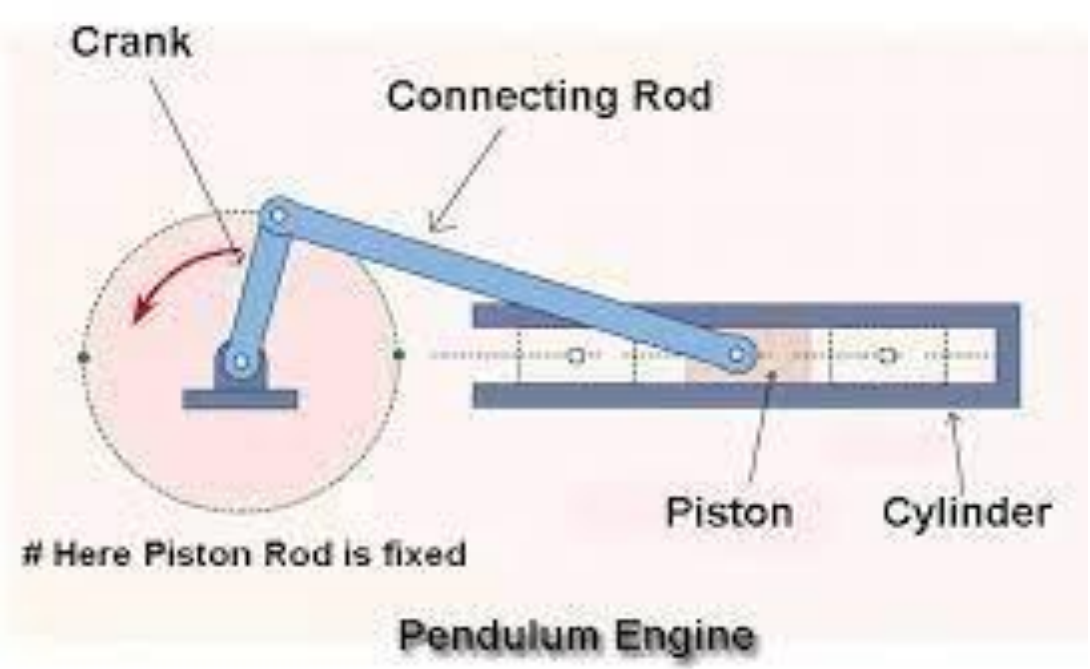
# Kinematic Chains Contd…

- **Kinematic Pair:** Kinematic pair is defined as the two links or elements of a machine when in contact with each other are said to form a pair. If the relative motion between them is completely or successfully constrained in a definite direction, the pair is known as the Kinematic pair. Example: Piston and Cylinder



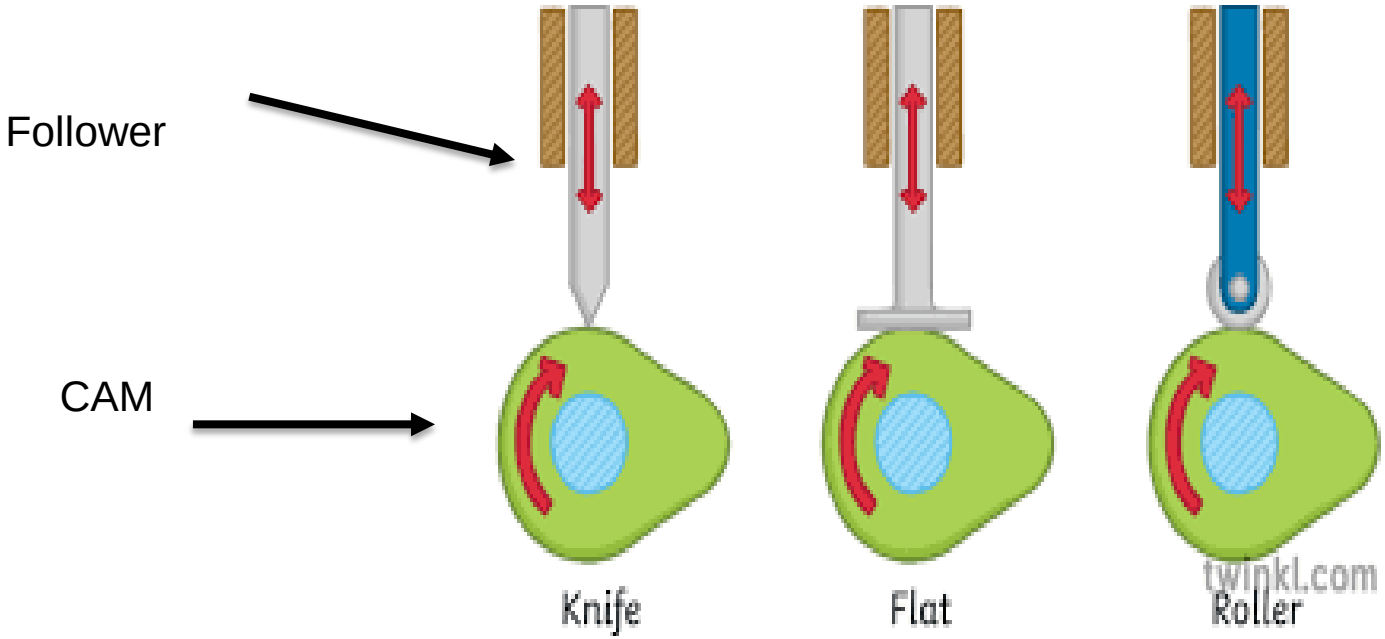
# Kinematic Chains Contd…

- **Kinematic Chain:** When **two or more kinematic pairs are joined together**, they form kinematic chain. Example: 4-Bar mechanism



# CAM

- A CAM is a rotating or sliding piece in a mechanical linkage used especially in transforming rotary motion into linear motion.



# CAM Contd…

- **Types of CAM**

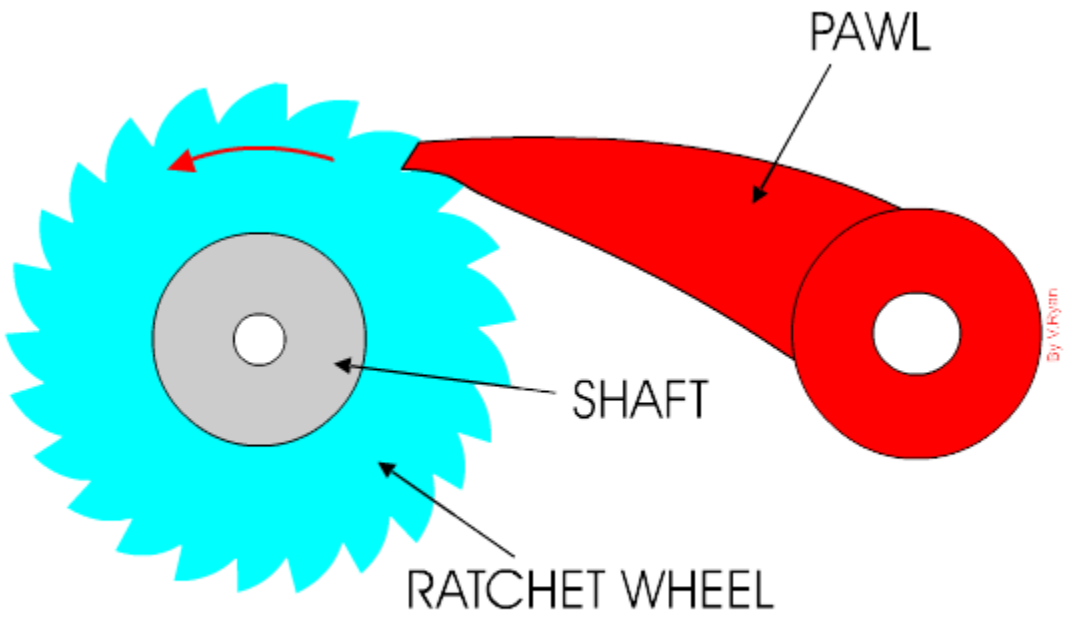
1. Radial or Disc CAM
2. Cylindrical CAM
3. Translation or Wedge CAM
4. Conjugate CAM
5. Globoidal CAM
6. Spherical CAM

- **Types of Follower**

1. Knife edged follower
2. Roller follower
3. Flat faced follower
4. Spherical faced follower.

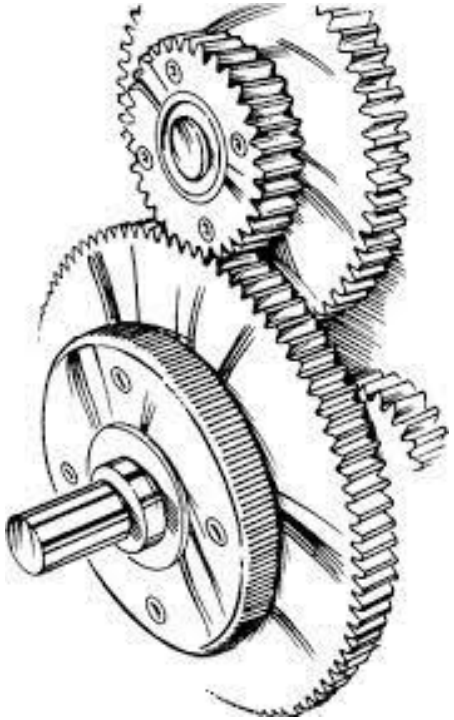
# Train Ratchet Mechanism

- A ratchet mechanism is based on a wheel that has teeth cut out of it and a pawl that follows as the wheel turns. See the diagram we will see that as the ratchet wheel turns and the pawl falls into the 'dip' between the teeth. The ratchet wheel can only turn in one direction - in this case anticlockwise.



# Gears

- **Definition of Gears:** Gears are mechanical parts with cut teeth designed to fit with teeth on another part so as to transmit or receive force and motion. Gears are also sometimes called toothed wheels or cogged wheels or cogs. The cut teeth are also sometimes called cogs.



# Types of Gears

- Gears are of Various types as following:

Helical Gear

Spur Gear

Rack & Pinion Gear

Worm Gears

Bevel Gear

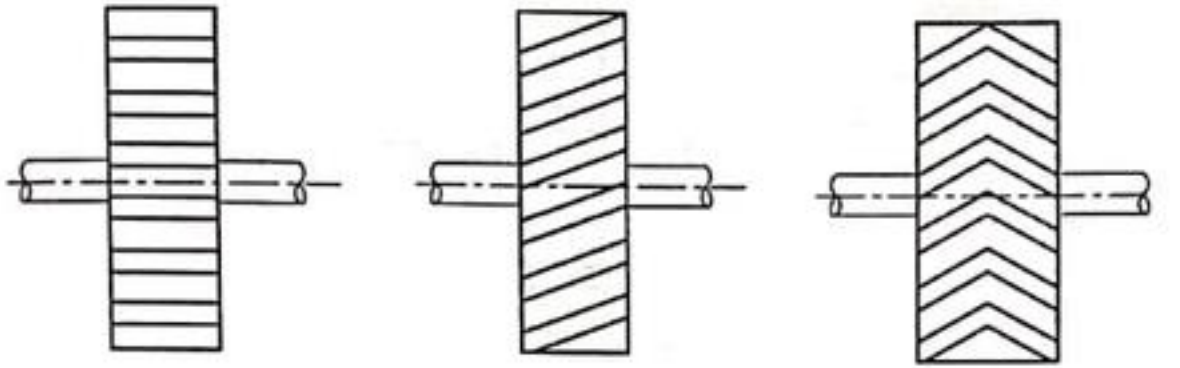
Sprockets Gear

# Types of Gears Contd…

1. **Spur Gears:** Spur gears transmit power through shafts that are parallel. The teeth of the spur gears are parallel to the shaft axis.

2. **Helical Gears:** Helical gears have teeth that are oriented at an angle to the shaft, unlike spur gears which are parallel.

3. **Herringbone Gears:** Herringbone gears are very similar to the double helical gear, but they do not have a gap separating the two helical faces.



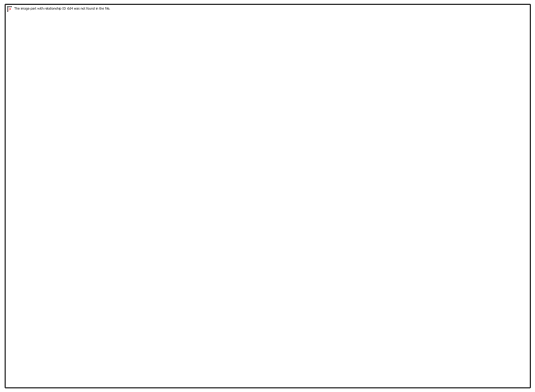
(a) Spur gear (b) Helical gear (c) Double helical gear

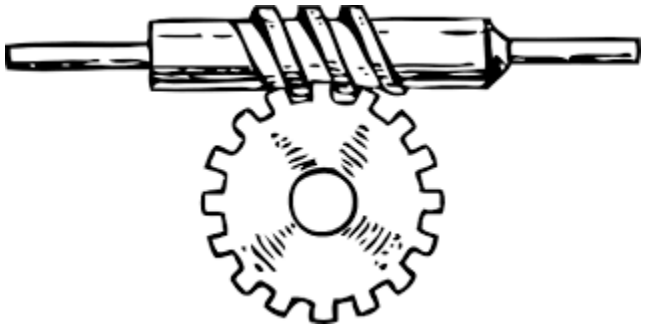
# Types of Gears Contd…

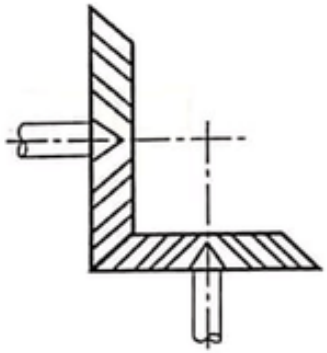
4. **Rack and Pinon Gears:** A rack and pinion is a type of linear actuator that comprises a circular gear (the pinion) engaging a linear gear (the rack), which operate to translate rotational motion into linear motion.

5. **Worm Gears:** Worm gears transmit power through right angles on non-intersecting shafts. Worm gears produce thrust load and are good for high shock load applications but offer very low efficiency in comparison to the other gears.

6. **Bevel Gears:** Bevel gears are most commonly used to transmit power between shafts that intersect at a 90-degree angle. They are used in applications where a right-angle gear drive is required. Bevel gears are generally more costly.







Bevel gears

# Belt

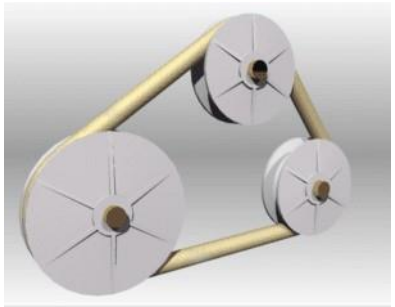
- A belt is a loop of flexible material used to link two or more rotating shafts mechanically, most often parallel. Belts may be used as a source of motion, to transmit power efficiently or to track relative movement. Belts are looped over pulleys and may have a twist between the pulleys, and the shafts need not be parallel.

# Types of Belt

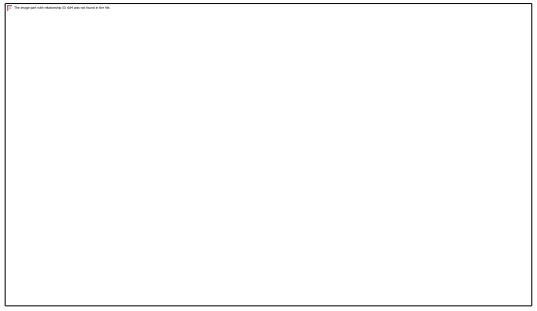
1. **Flat Belt**

2. **V- Shape Belt**

3. **Rope**



4. **Toothed Belt**



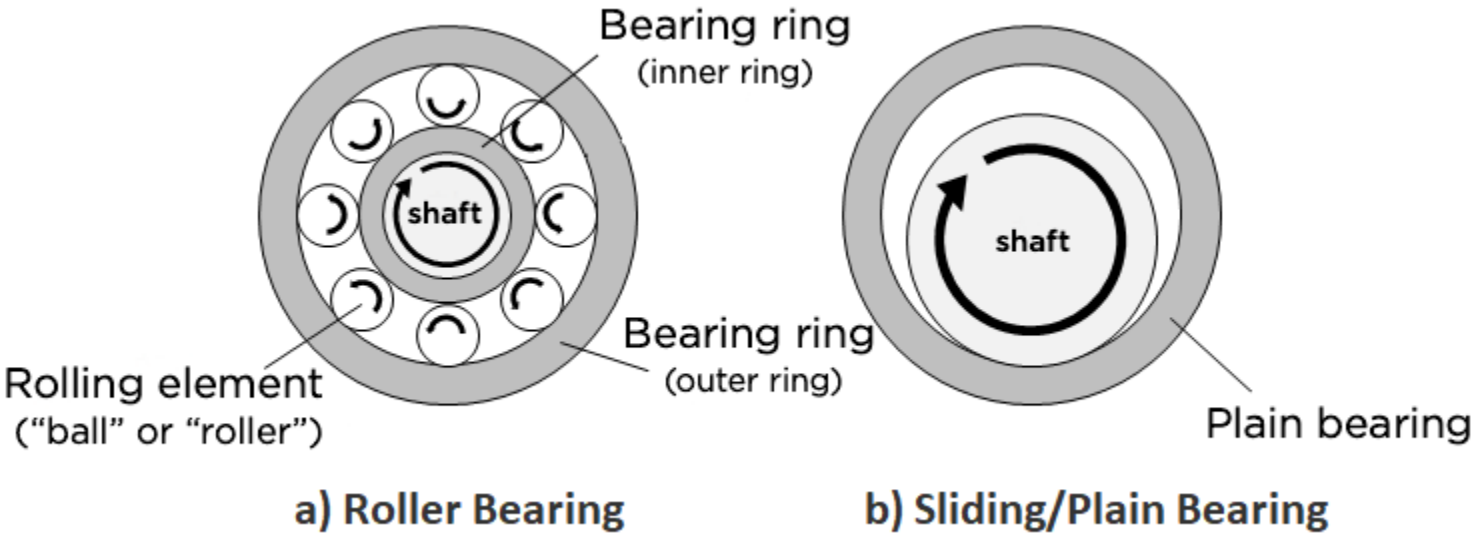
# Bearings

- **Definition of Bearing:** Bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts.

# Types of Bearings

- **Bearings**l are classified into following types**:**

1. Ball Bearings
2. Roller Bearings
3. Mounted Bearings
4. Linear Bearings
5. Slide Bearings
6. Jewel Bearings
7. Frictionless Bearings



# Lecture No. 39

# Control valves

- One of the most important functions in any fluid power system is control. If control components are not properly selected, the entire system will fail to deliver the required output. Elements for the control of energy and other control in fluid power system are generally called “Valves”.

- **There are 3 basic types of valves**

1. Directional control valves
2. Pressure control valves
3. Flow control valves

https://www.youtube.com/watch?v=qLSl9ZGIl0A

# Directional control valves

- Directional control valves perform only three functions:
  - stop fluid flow
  - allow fluid flow, and
  - change direction of fluid flow.
- These three functions usually operate in combination.

- **Directional control valves can be classified in a number of ways**:

1. According to type of construction:
   - Poppet valves
   - Spool valves
2. According to number of working ports:
   - Two- way valves
   - Three – way valves
   - Four- way valves.
3. According to number of Switching position:
   - Two – position
   - Three – position

# Pressure control valves

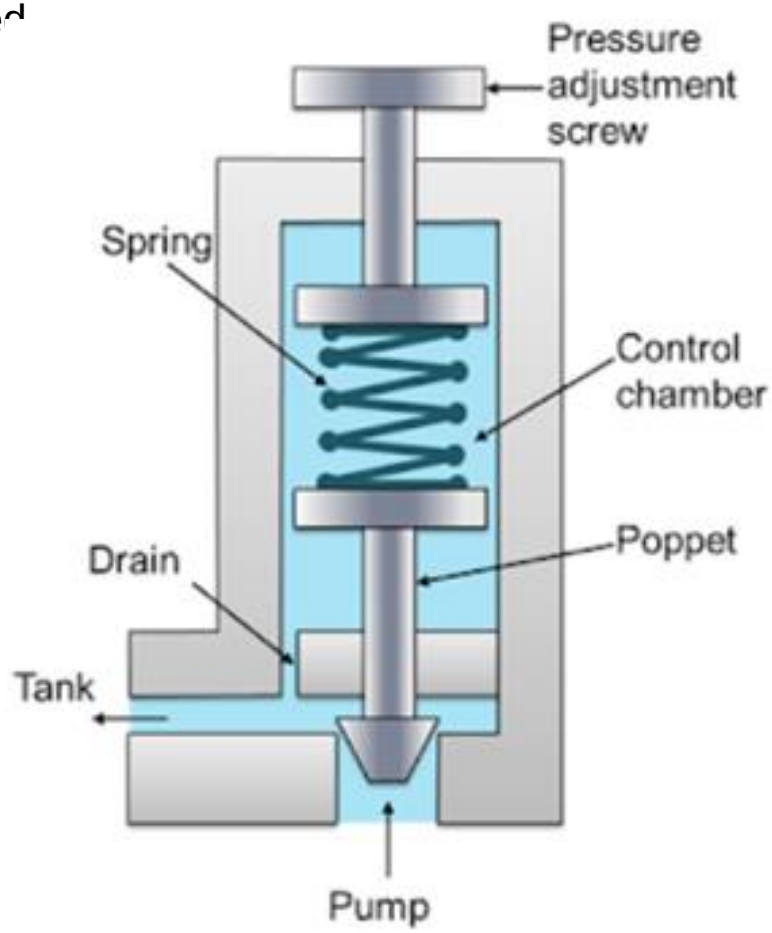
- These are the units ensuring the control of pressure. A throttling orifice is present in the valve and by variation of orifice, the pressure level can be controlled or at a particular pressure, a switching action can be influenced.
- The most common valves for controlling pressure include relief, reducing, sequence, counterbalance, and unloading valves.

- **Pressure relief valve:** The pressure relief valve is an important type of safety valve. A pressure relief valve protects motors, pumps and actuators from becoming damaged from high pressure. The valve remains closed for normal operation. And no water passes through the valve. When the pressure in the loop exceeds the limit the valve opens, and the relief the excess pressure. Thus, protects the expensive machinery.

- Pressure-relief valves limit the maximum pressure in a hydraulic circuit by providing an alternate path for fluid flow when the pressure reaches a pre-set level.

# Pressure control valves Contd…

- **There are two different designs of relief valves in use:**
  1. Direct-acting
  2. Pilot-operated



# Actuators

- Actuators are output devices which convert energy from pressurized hydraulic oil or compressed air into the required type of action or motion. In general, hydraulic or pneumatic systems are used for gripping and/or moving operations in industry. These operations are carried out by using actuators.

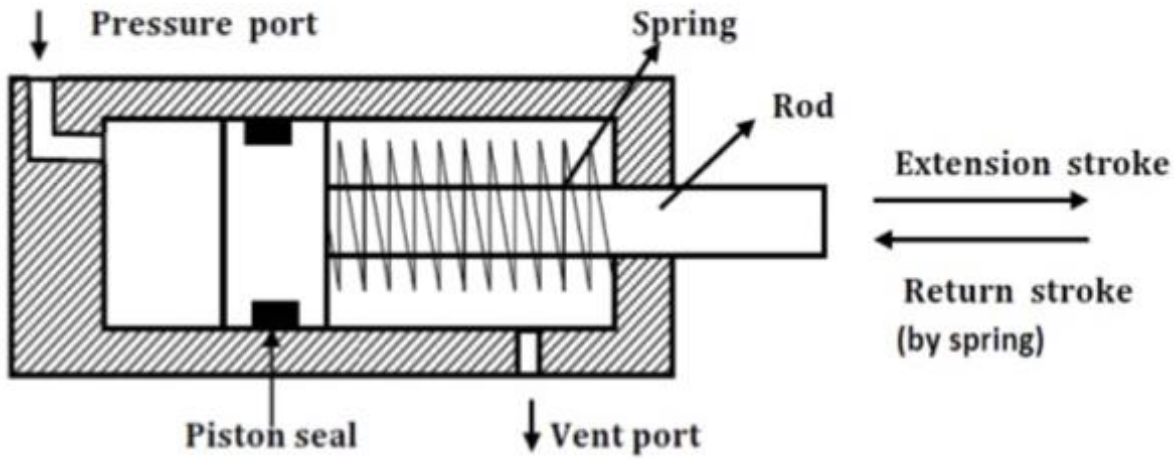
- **Actuators can be classified into two types.**

1. Linear actuators: These devices convert hydraulic/pneumatic energy into linear motion.
2. Rotary actuators: These devices convert hydraulic/pneumatic energy into rotary motion.

# Linear actuators (cylinders)

- All hydraulic cylinders create linear movement, but there are different varieties which have their own unique effects. Below we will outline some of the most common types of hydraulic cylinders.

1. **Single acting hydraulic cylinder:** Single acting cylinders operate in one direction only. They have a single port at one end of the cylinder, so when the fluid is pumped into the port it pushes the rod, causing it to extend. The rod returns because of an external force such as the load or a spring.

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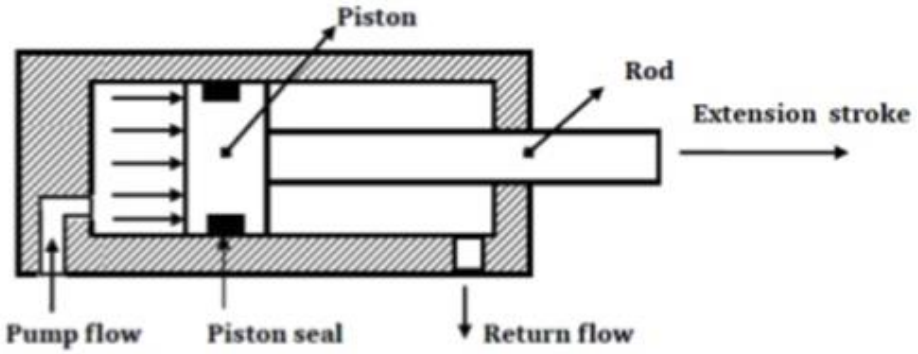
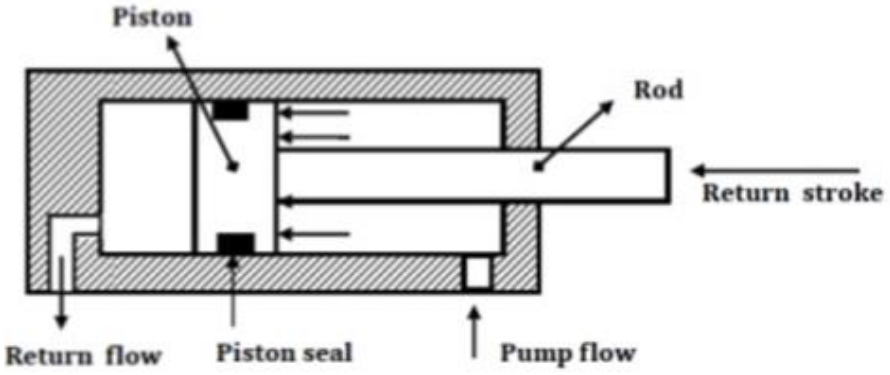
# Linear actuators (cylinders) Contd…

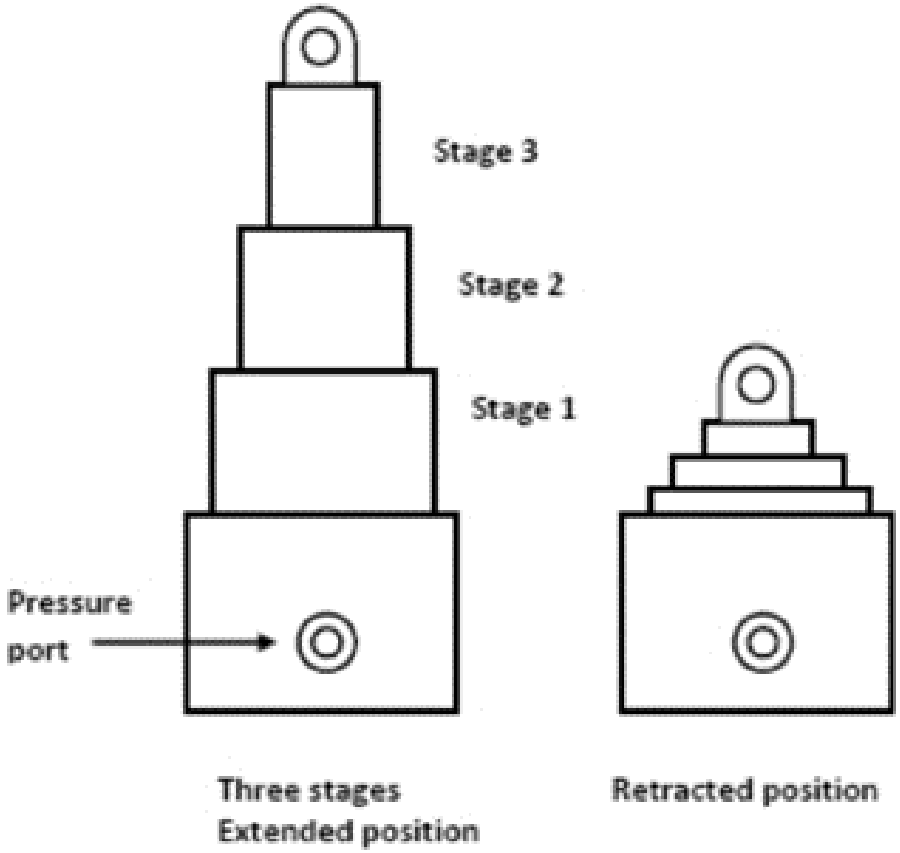
2. **Double acting hydraulic cylinder:** Unlike single acting cylinders which can only push or pull, double acting cylinders do both. They have ports both ends of the cylinder so that when oil is pumped into the head port, the piston moves and extends the rod. Oil in the rod end of the cylinder is pushed out into a reservoir. To achieve the opposite movement and retract the rod, the oil flow is reversed.



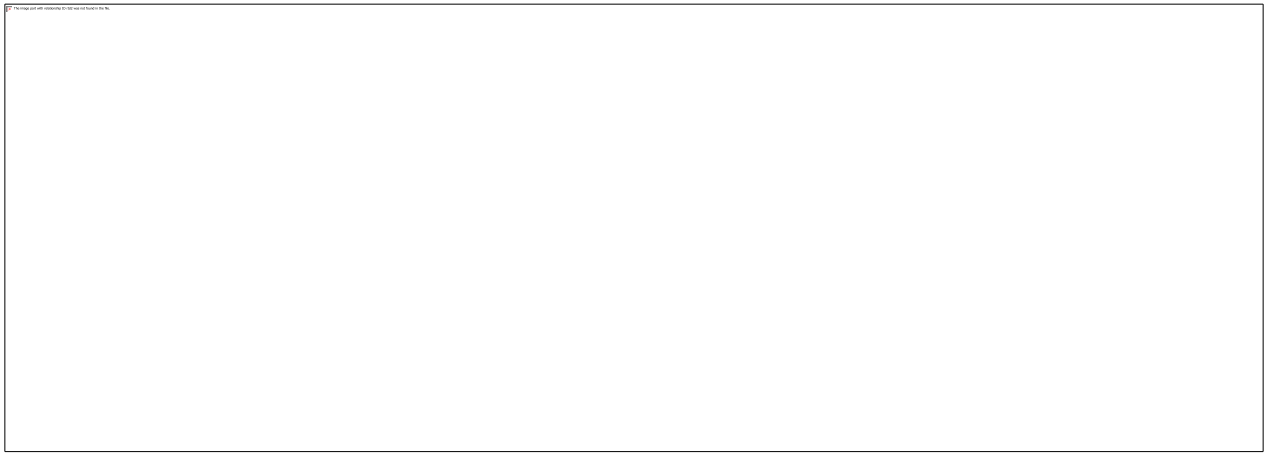
# Linear actuators (cylinders) Contd…

3. **Telescopic hydraulic cylinder:** Telescopic cylinders are, as their name suggests, a series of rams inside one another like a telescope. This means they can achieve a comparatively long stroke when all the rams are extended. These types of cylinders can be single or double acting.



# Linear actuators (cylinders) Contd…

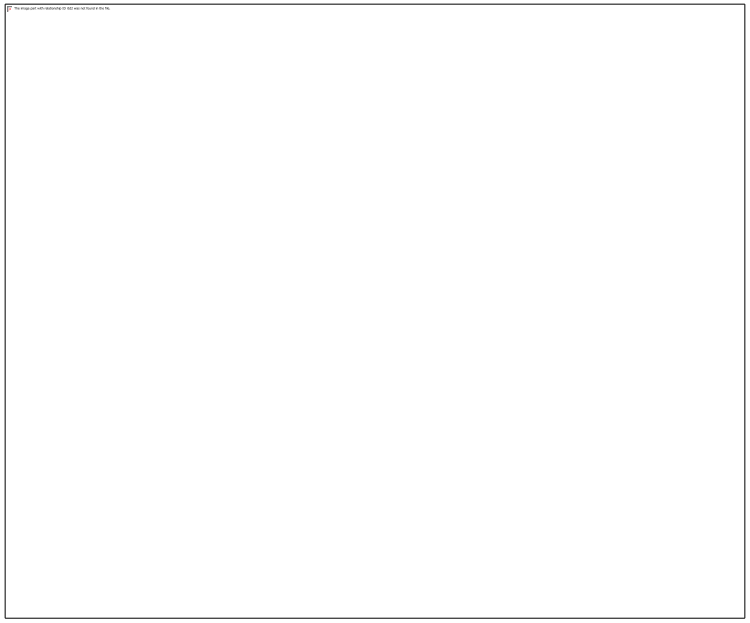
4. **Tandem hydraulic cylinder:** In a tandem hydraulic cylinder, two interconnected cylinders operate together to generate a greater force than one cylinder would be able to create on its own. The two cylinders are supplied by different hydraulic systems, but they are connected mechanically so that the rod of the first cylinder enters the second cylinder, pushing its base.



# Rotary actuators

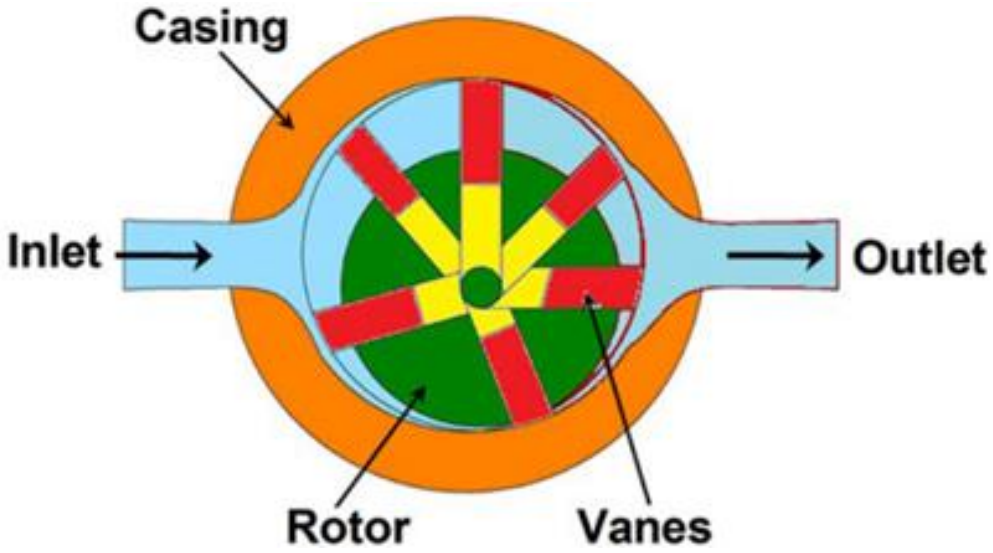
- Rotary actuators convert energy of pressurized fluid into rotary motion. Rotary actuators are similar to electric motors but are run on hydraulic or pneumatic power.

1. **Gear motor:** It consists of two inter meshing gears inside a housing with one gear attached to the drive shaft. Figure shows a schematic diagram of Gear motor. The air enters from the inlet, causes the rotation of the meshing gear due to difference in the pressure and produces the torque. The air exists from the exhaust port. Gear motors tend to leak at low speed, hence are generally used for medium speed applications.



# Rotary actuators Contd…

2. **Vane motor:** A rotary vane motor consists of a rotor with sliding vanes in the slots provided on the rotor (Fig.). The rotor is placed eccentrically with the housing. Air enters from the inlet port, rotates the rotor and thus torque is produced. Air is then released from the exhaust port (outlet).

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# Lecture No. 40

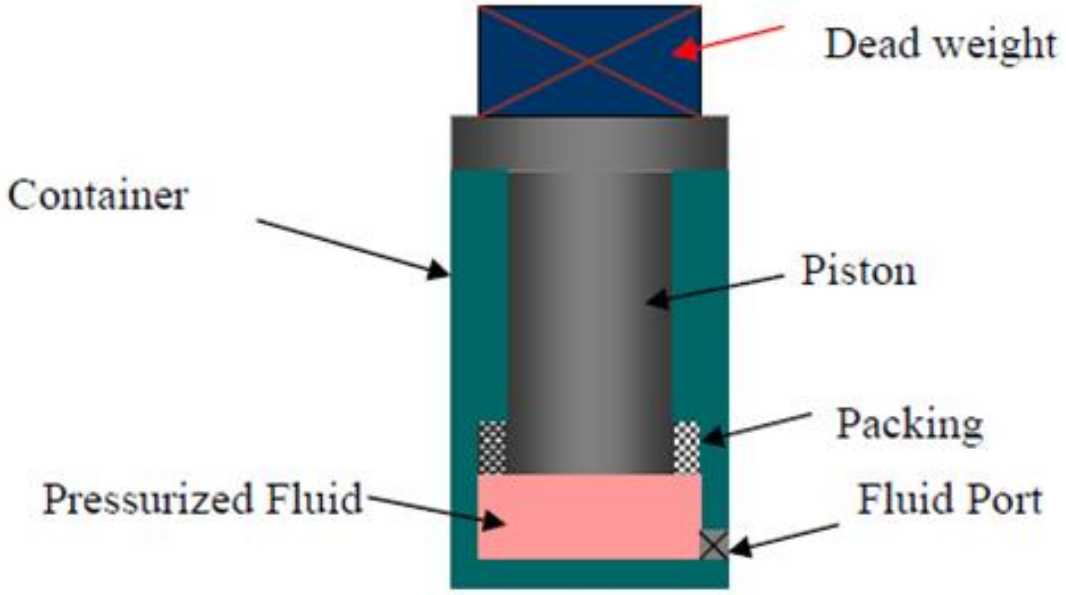
# Accumulator

- A hydraulic accumulator is a device that stores the potential energy of an incompressible fluid held under pressure by an external source against some dynamic force.
- The stored potential energy in the accumulator is a quick secondary source of fluid power capable of doing useful work as required by the system.

- There are three basic types of accumulator used in hydraulic system. They are:
  1. Weight – Loaded, or gravity, type
  2. Spring -Loaded type
  3. Gas – Loaded type

# Weight – Loaded Accumulator

- This type consists of a vertical, heavy- wall steel cylinder, which incorporates a piston with packing to pressure leakage as shown in figure. A dead weight is attached to the top of the piston. The force of gravity of the dead weight provides the potential energy in the accumulator.
- This type of accumulator creates a constant fluid pressure throughout the full volume output of the unit regardless of the rate and quantity of output. The main disadvantage of this type of accumulator is extremely large size and heavy weight which makes it unsuitable for mobile equipment

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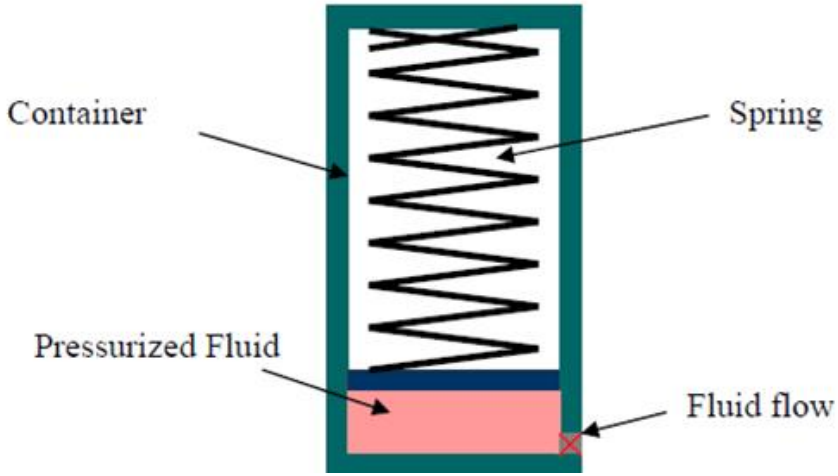
# Spring – Loaded Accumulator

- A spring loaded accumulator is similar to the weight – loaded type except that the piston is preloaded with a spring as shown in figure. The spring is the source of energy that acts against the piston, forcing the fluid into hydraulic system. The pressure generated by this type of accumulator depends on the size and pre-loading of the spring. In addition, the pressure exerted on the fluid is not a constant.
- The spring- loaded accumulator typically delivers a relatively small volume of oil at low pressures. Thus, they tend to be heavy and large for high- pressure, large – volume systems. This type of accumulator should not be used for applications requiring high cycle rates because the spring will fatigue and lose its elasticity. The result is an inoperative accumulator.

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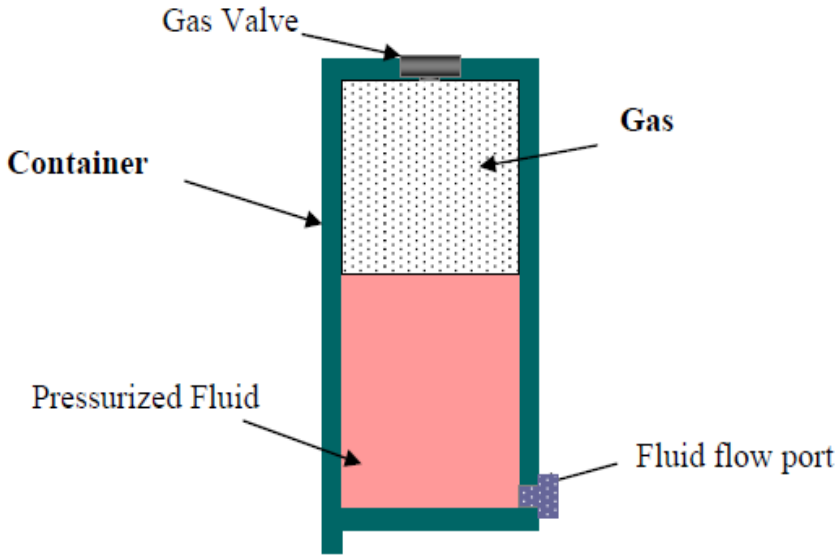
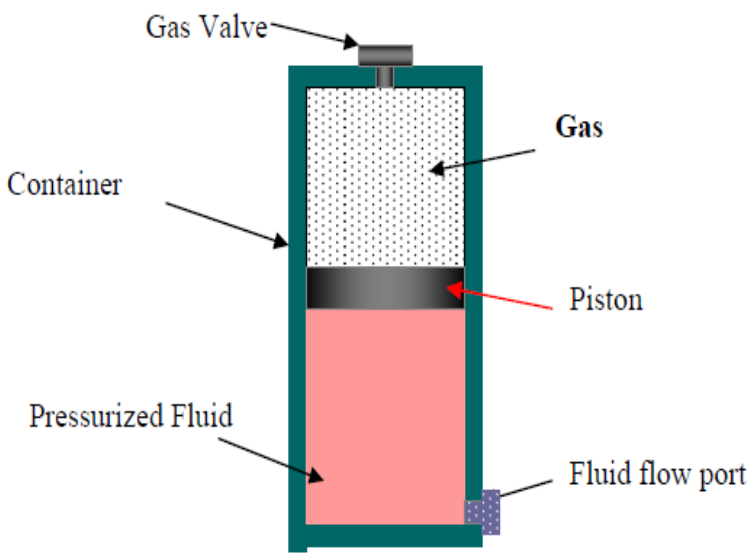
# Gas Loaded Accumulator

a) **Non separator- Type Accumulator**: The non-separator type of accumulator as shown in figure consists of a fully enclosed shell containing an oil port on the bottom and a gas charging valve on the top. The gas is confined in the top and the oil at the bottom of the shell. There is no physical separator between the gas and oil and thus the gas pushes directly on oil.

b) **Separator – Type Accumulator**: The commonly accepted design of gas loaded accumulators is the separator type. In this type there is a physical barrier between the gas and the oil.



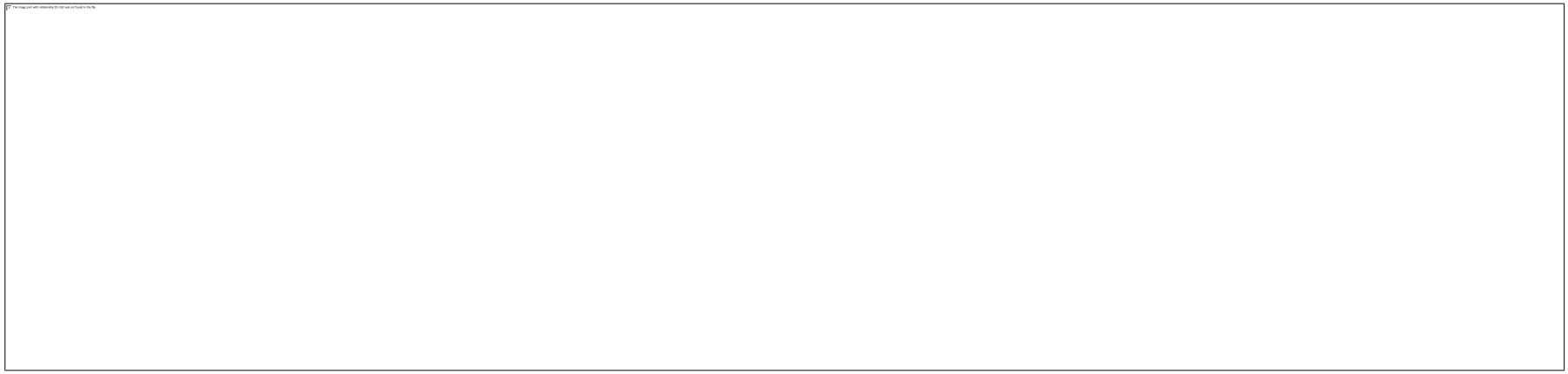



# Amplifier

- An **amplifier**, **electronic amplifier** or (informally) **amp** is an electronic device that can increase the power of a signal (a time-varying voltage or current).
- It is a two-port electronic circuit that uses electric power from a power supply to increase the amplitude of a signal applied to its input terminals, producing a proportionally greater amplitude signal at its output.
- The amount of amplification provided by an amplifier is measured by its gain: the ratio of output voltage, current, or power to input. An amplifier is a circuit that has a power gain greater than one.

# Pneumatic Sequence

- The number of ports on a directional control valve (DCV) is usually identified by the term “ way”.
  1. A valve with 2 service ports and 2 switching positions is designated as 2 / 2 way valve.
  2. A valve with 3 service ports and 2 position is designated as 2 / 3 way valve.
  3. A valve with 4 service ports and 2 position is designated as 2 / 4 way valve



**2/2 way valve** **2/3 way valve** **2/4 way valve**

# THANK YOU