

Q-1 Draw block diagram representation of generalized measurement system. Identify the various elements and point out the function performed by each element.

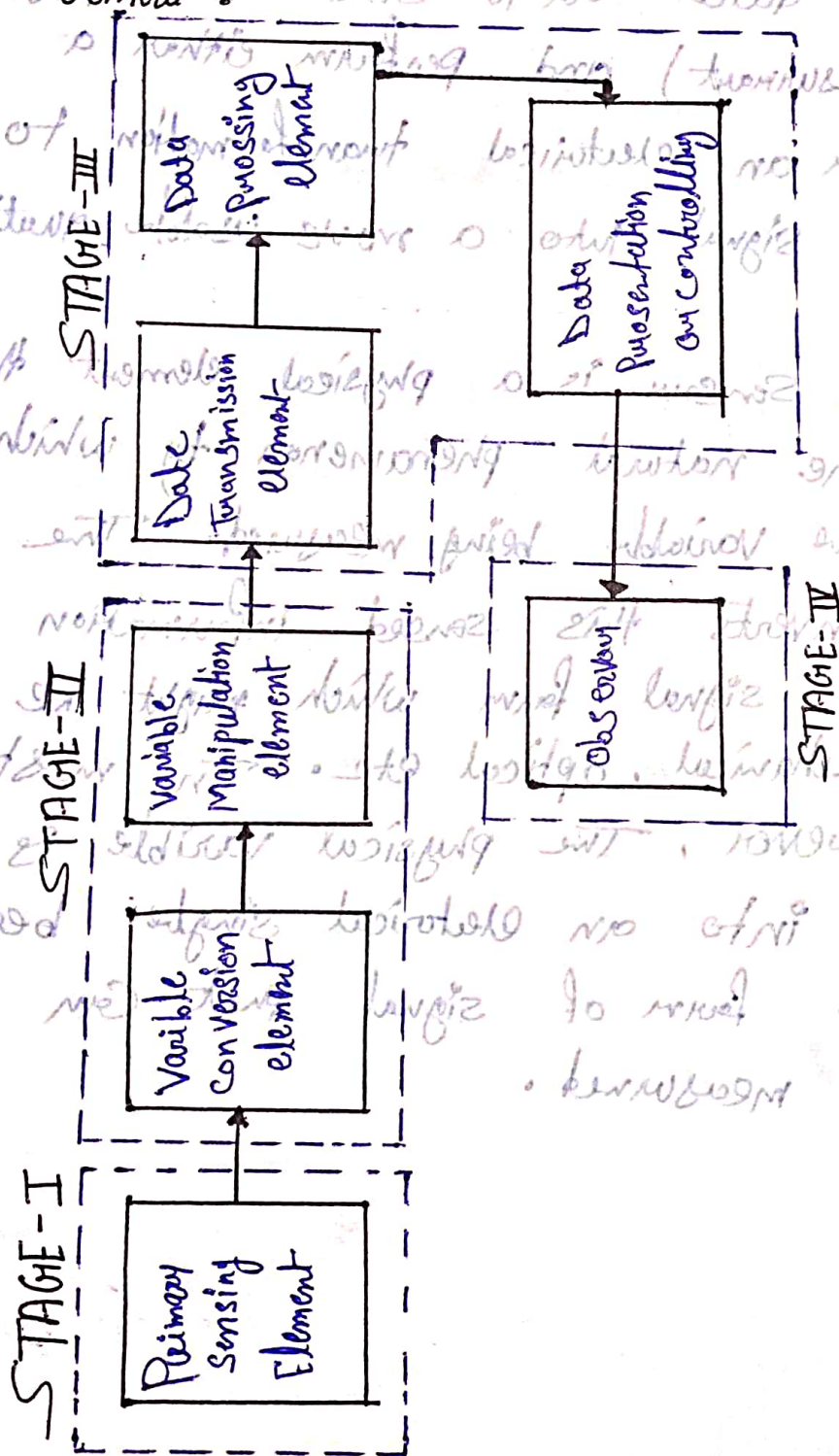


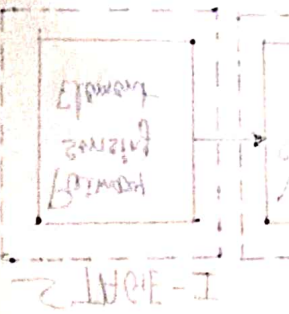
Fig.:- Schematic Diagram of generalised measurement system.

Stage-I → Input signal (Detection transducer)
 Stage-II → Intermediate modifying
 Stage-III → Terminating stage / Data controlling
 Stage-IV → Output stage / feedback stage.

Stage-I → Input signal (Detachable transducer)

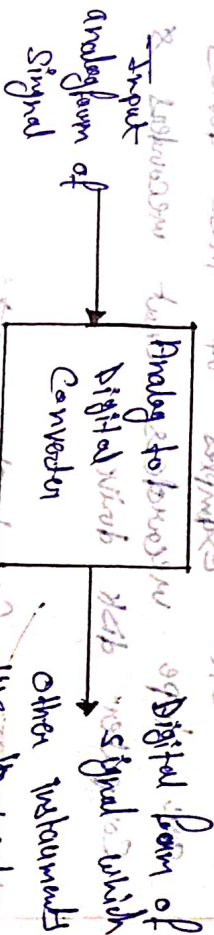
The primary function of the 1st stage is to detect or to sense the physical variable (measurement) and perform either a mechanical or an electrical transformation to convert the signal into a more usable quantity.

The sensor is a physical element that employs some natural phenomenon by which it senses the variable being measured. The transducer converts this sensed information into a detectable signal form which might be detected mechanically, optically etc. In most cases however, the physical variable is transformed into an electrical signal because this is the form of signal that can be easily measured.



Stage-II → Intermediate modifying

The purpose of the 2nd stage is to take the transducer signal and modify by amplification, filtering or other means so that a desirable output is available.



Note → During this stage is lost but only conversion modification takes place.

During this stage is lost but only conversion modification takes place. This stage is used for converting the analog signal into a digital signal which can be used by other instruments.

Stage - III

→ Terminating Information

- Provides an indication of the value that has been measured. The output equipment might be a simple readout display, a metered scale, or may contain devices that can record the signal that can be analyzed later on. Examples of these devices are tape recorders that record & computer disk drive.
- Stage - IV → Control Stage →

The measurement systems that involve process control make up the 4th stage which is the feedback control stage. This usually contains a controller that interprets the measured signal and takes a decision regarding the control of the process. This decision results in the change of the process parameters that effects the magnitude of the sensed variable.

It is pretty much important to realize that the accuracy of the measurement can be any better than the accuracy of the measurement of the control variable. Therefore one must be able to measure a physical variable accurately before one can hope to control that variable.

As we know, the accuracy of the measurement is directly related to the accuracy of the control variable. Therefore, the accuracy of the measurement must be better than the accuracy of the control variable. This is the basic principle of process control.

Q.2 Explain the characteristics of good measurement of

System.

Ans → There are the good characteristics of

measurement system.

1. True value → The value of a quality to be

measured may be defined as

the Average of an Infinite number of measured value when the average deviation to the various contributing factors tends to zero.

The reason for this is that the positive deviation from the true value do not equal to the negative deviation and hence do not cancel each other.

2.

Accuracy → Accuracy as the closeness with

approaches to true value of the quantity being measured.

These Accuracy of a measurement means conformity of truth.

3.

Precision →

It is a measure of the Reproducibility of the measurement.

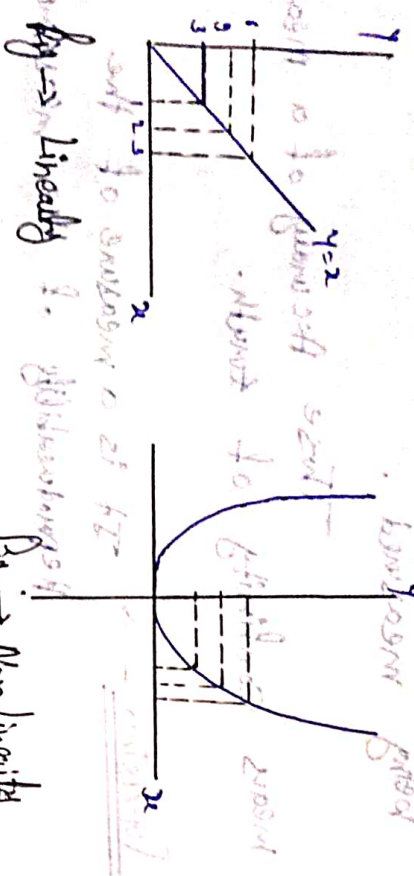
1.

Linearity → (i) → A measurement system is considered

to be linear if the output is linearly varying nonlinearly proportional to the input. where are some of the system which are non linearly calibrated are compute with non linear calibration equation.

(ii) → Linearity is an indicator of the consistency of measurement over the entire range of measurement in simple terms linearity

tells us how well the Instrument measurement corresponds to reality.



5. Static Sensitivity $\rightarrow$ The static sensitivity of an instrument or an instrumentation system is the ratio of the magnitude of the output quantity (Response) to the magnitude of input quantity being measured.

Static Sensitivity $\rightarrow$ infinitesimal change in output / infinitesimal change in input.

Q3 $\rightarrow$ Explain in during $\rightarrow$

- (1) Sensitivity (2) Accuracy (3) Precision (4) Linearity (5) Threshold (6) Resolution (7) Measurement.

Ans $\rightarrow$ (1) Sensitivity $\rightarrow$ The static sensitivity of an instrumentation system is the ratio of the magnitude of the output quantity (Response) to the magnitude of input quantity being measured.

(2) Accuracy $\rightarrow$ Accuracy is the closeness with which an instrument reading corresponds to true value of the quantity being measured.

These accuracy of a measurement means finiteness of truth.
 with smaller error measurement $\rightarrow$ more accurate $\rightarrow$ better result

(3) Precision → It is a measure of the reproducibility of the measurement.

(4) Linearity → Linearity is an indication of the consistency of measurements over the entire range of measurement. In simple terms linearity tells us how well the instrument measurement corresponds to reality.

(5) Threshold → If the instrumented input is increase very gradually from zero then there will be a some minimum value below which no output change will be detected. This minimum value defines the threshold of the instrument.

(6) Resolution → If the input is slowly increase from some arbitrary random (Non-zero) input value it will again be found that output does not change at all until a certain increment is exceeded.

Resolution → This increment is known as resolution.

(7) Measurement → Comparison of measured with standard is known as measurement.

- During measurement, before measurement to beginning of experiment no known standards are used to calibrate the instrument. After starting a constant shift changes to included with errors arise with substituted with old bridge set and half with two of these errors results in a measurement of different magnitude when bridge turned.

Q-4 How to transducer classified? Explain them in brief -

(1) Induction (2) Resistive (3) Capacity

(4) Piezoelectric.

(1) Inductive Transducer →

* Introduction → It is the self generating type otherwise the passive type transducer the 1st type of self generating use the principle of fundamental electrical generation.

The electrical generated on principle is when a motion among a conductor as well as magnetic field induces a voltage with the conductor the motion among the conductor and the field can be supplied by transducer is an electrical device used to convert physical motion into modifying within inductor.

→ It is a type of Displacement transducer.

→ It is an inductive type transducer physical quantity of measurement is converted into electrical quantity.

→ It is a transducer which is both active and passive type.

→ It is a electrical transducer i.e. there conversion of physical quantity takes place into voltage.

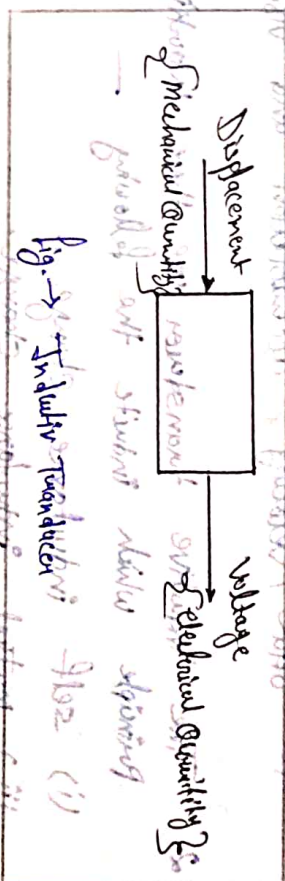


Fig. → Inductive Transducer

→ It works on the principle of Faraday's law of electromagnetic induction.

→ 1st law → When ever a conductor cut's the flux

→ 2nd law → The quantity of induced emf is directly proportional to the rate of change of flux linkage.

* Principle of working of Inductive Transducers $\rightarrow$ AC

1. In Inductive transducers the basic principle is that self-inductance of a single coil or the mutual inductance b/w two coils is change by a quantity to be measured i.e. measured. usually the measured could be a change in linear displacement, force, pressure, torque, velocity, acceleration and vibration.

2. The inductive transducer use three working principle which induce the following —

- (i) self inductance change.
- (ii) mutual inductance change.
- (iii) eddy current production.

* Advantage of inductive transducers $\rightarrow$

- Energy efficient $\rightarrow$ low power consumption make them suitable for portable power tools and battery powered applications.

- Versatile $\rightarrow$ Can detect a wide range of ferrous metals including ferrous and non-ferrous method.

- Safe $\rightarrow$ Non-radiating and safe to use in surgical application.

* Disadvantage of Induction transducers $\rightarrow$

- Limited Sensing range $\rightarrow$ Sensing range is limited to a few millimetres to a few centimetres.

- Can only detect metallic object $\rightarrow$ Not suitable for non-metallic object.

- Interference from other metals $\rightarrow$ Other metals can interfere with the sensing range.

* Inductive Transducer circuit $\rightarrow$

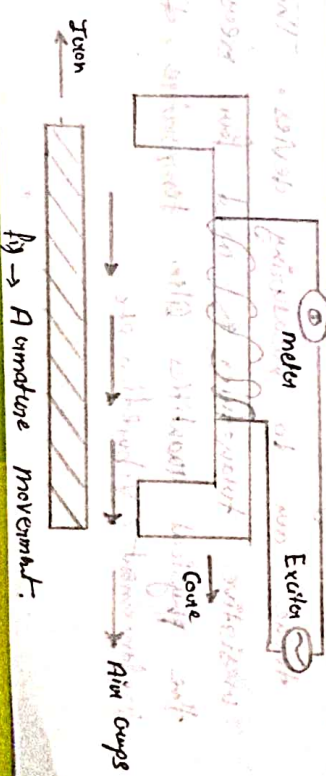


Fig $\rightarrow$ A core type movement.

* Application $\rightarrow$ The most common application of inductive transducer is as proximity switch / sensor which is used in that equipment as safety devices like cranes, elevators etc.

(a) Resistive Transducer $\rightarrow$

Introduction $\rightarrow$

1. $\rightarrow$ The transducer whose resistance varies because of the environment effect & such type of transducer is known as the resistive transducer.

2. $\rightarrow$ The change in resistance is measured by these on to measuring devices. The resistive transducer is used for measuring the physical quantities like temperature, displacement, vibration etc.

* Principle of working $\rightarrow$

1. $\rightarrow$ The resistive transducer element works on the principle that the resistance of the element is directly proportional to the length of the conductor and inversely proportional to the area of the conductor.

$$2. \rightarrow R = \rho L / A$$

Here, R = Resistance in ohms

A = Cross-section area of the conductor in m^2 .

L = Length of the conductor in meter

* Advantage $\rightarrow$

- Both AC & DC current or voltage is appropriate for the measurement of variable resistance.
- It gives faster response.
- It is a variable in various size & having a wide range of resistance.

* Disadvantage →

- A lot of work is wasted moving the slider.
- Sliding contact and produce a lot of noise.

P = The resistivity of the conductor in metallic ohm meter.

- The resistive transducer is designed by considering the variation of the length and resistivity of the metal.

* Positive Resistive Transducer Circuit →

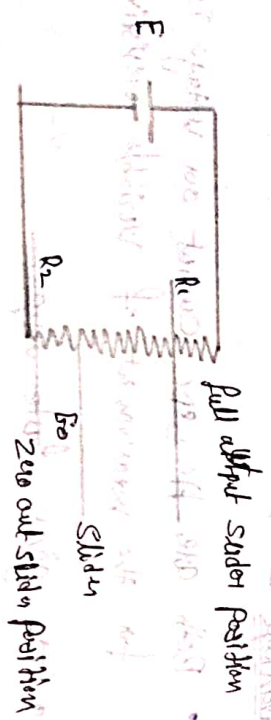


Fig. → Sliding Resistive Transducer.

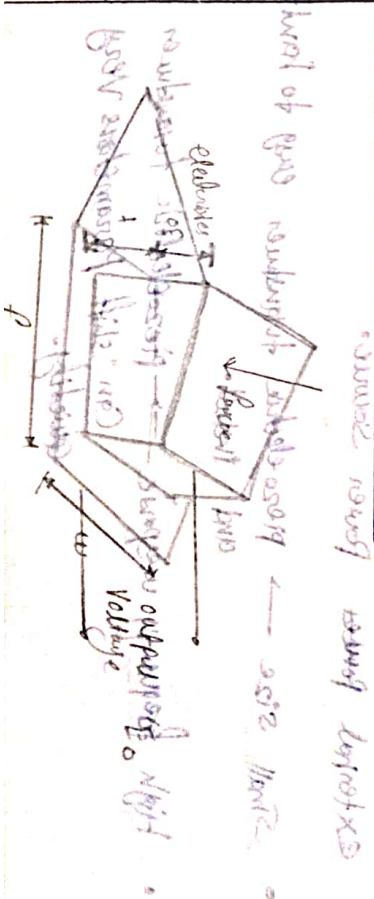
* Application →

1. Potentiometer
2. Strain gauge
3. Resistance Thermometer
4. Thermistor.

(3) Piezoelectric Transducer →

The piezoelectric transducer is an electromechanical transducer used for conversion of pressure or mechanical stress into an alternating electrical force. It is used for measuring the physical quantity like force, pressure, stress etc. which is directly not possible to measure.

* Sketch of Piezoelectric Transducer →



* Working Principle →

1. → Piezoelectric Transducer works with the principle of piezoelectricity. The faces of piezoelectric material, usual quartz, is coated with thin layer of conducting material such.

applied when mechanical stress has applied then under surface of (charge contacts) in the material move towards one of the conducting surface while moving from the other.

$$Q_d = P_2 + 5H ; Q_{cat} 2.$$

* Advantage →

- Self-powered → Piezoelectric transducers can generate voltage without can external power source.
- Small size → Piezoelectric transducers easy to handle and install.
- High frequency response → Piezoelectric transducers can shift parameters very quickly.

* Disadvantage →

- Low output → Piezoelectric transducer often generate very low voltage or outputs.
- High temperature sensitivity → Piezoelectric transducers affected by temperature. Piezoelectric transducers are not suitable for static measurements.

* Application →

- They are used in seismographs to measure vibration in works.
- In strain gauges to measure force, stress, vibrations etc.
- used by automotive industries to measure detonations in engines.

measuring strain with ultrasonic

*) Capacitive Transducer →

*) Introduction → It is used for measuring the displacement, pressure and other physical quantities. It is a passive transducer that means it uses external power for operation.

The capacitive transducer works on the principle of variable capacitance.

*) Sketch of Capacitive Transducer →

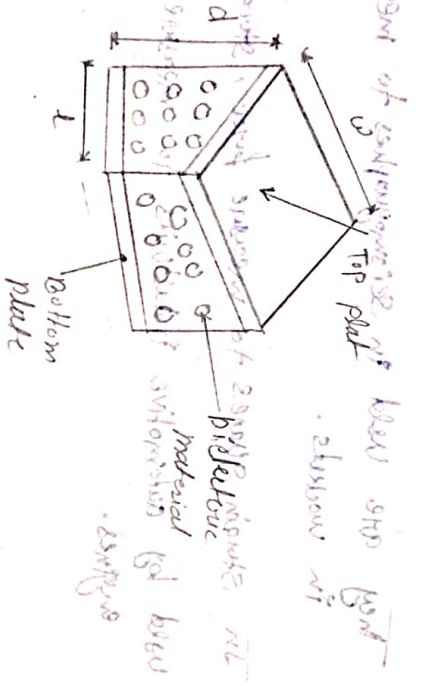


Fig → Parallel plate Capacitive Transducer.

*) Principle →

1. → The equation below expresses the capacitance b/w the plates of a capacitor for capacitive

$$C = \frac{\epsilon A}{d}$$

$$C = \epsilon_r \epsilon_0 \frac{A}{d}$$

Here — A = overlapping area of plate in material.

d = The distance b/w two plate in meter.

ϵ_0 = Permittivity of medium in p/m

ϵ_r = relative permittivity

ϵ_0 = the permittivity of free space.

2. → The change in capacitance occurs because of the physical variable like displacement of the force, pressure, etc. The capacitance of the transducer also changes by the variation in fluid levels constant which is usually becomes of the measurement of liquid or gas level.

* Advantage →

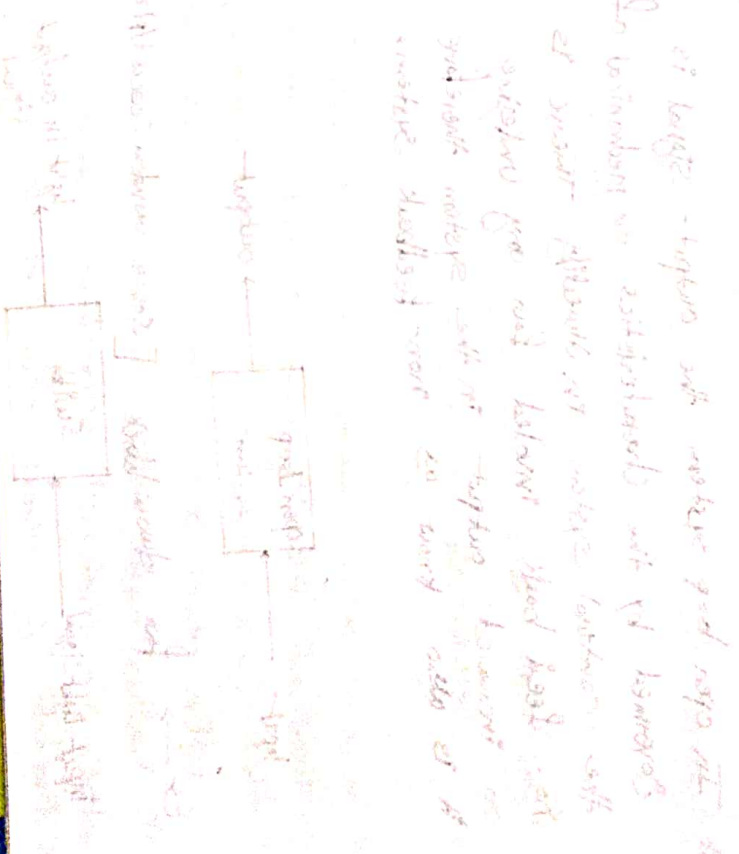
- These transducers offer high input impedance. i.e. the loading effects value will be low.
- The frequency response of these transducer is extremely high.
- These transducer are high sensitive.

* Disadvantage →

- These transducer exhibit non-linear behaviours due to edge effects.
- These are temp. dependant. The external temp. value can effect this transducer capacitance value.

* Application →

- The Capacitive transducer uses for measurement on both the linear and angular displacement. It is extremely sensitive and used for the measurement of very small distance.
- The humidity in gases is measured through the capacitive transducer.



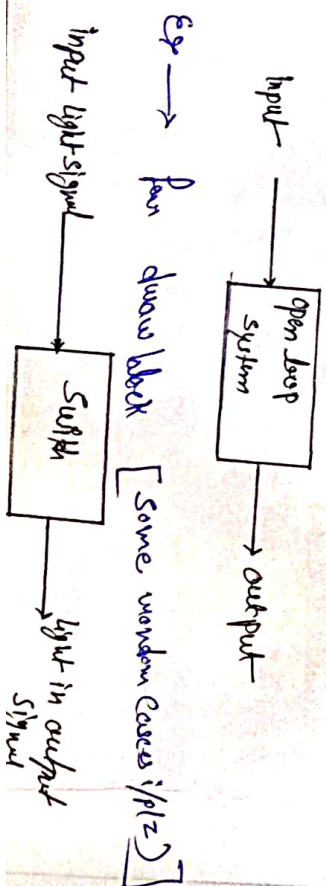
Unit-2 (Control System)

Q1.) What is Control system.

Ans → A system which consists of no. of components connected together to perform a specific function in which the output is controlled by input.

Q2.) Explain 'open loop' Control system" with diagram state the advantage & disadvantages of open loop control system Draw block diagram with an example.

Ans → In open loop system the output signal is determined by the characteristics or mechanical of the control system. In directly there is no feedback involved. For any undesirable or incorrect output in the system therefore it is also known as non-feedback system.



Example → ① Traffic control signals
② Automatic washing machine
③ Bread toaster

Advantage → ① simple and economical
② easier to construct
③ easy maintenance
④ stable & generally stable.

Disadvantage → ① In accurate
② changes in the output are not corrected automatically.

Q3.) Explain the closed loop control system with an example also write the advantage and disadvantage.

Ans → A closed loop control system measures the system output compares it with the input and determines the error (if it is there) which is then used in controlling the system output to get the desired value. As feedback is taken into consideration in closed loop system therefore it is also known as feedback system.

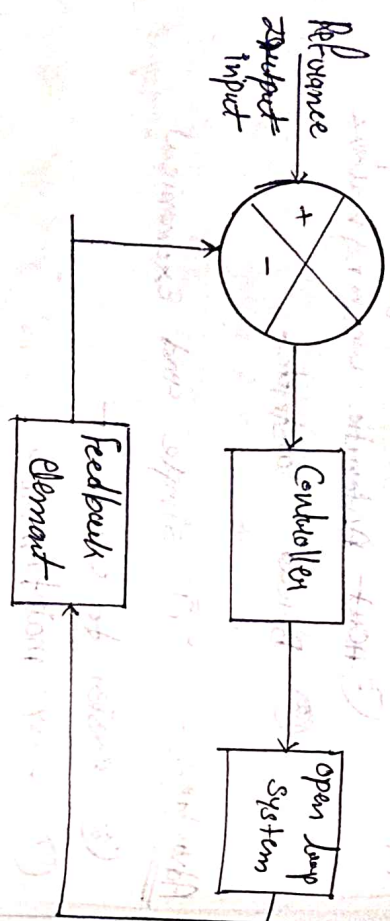


Fig → Closed loop System.

Exp → ① Automatic electric iron

② Crookman etc.

Advantages → ① more accurate

② less affected by noise

Disadvantage → ① Complex & costly

② feedback reduces the overall gain of the system.

③ stability is the major problem.

Q.11

Explain difference b/w open loop & closed loop control system.

Open loop system	Closed loop system
① open loop system are simple and economical.	① closed loop system are complex and costlier.
② These systems are inaccurate and unreliable.	② These system are accurate.
③ open loop system are stable.	③ stability is a major problem in closed loop system.
④ The open loop system are easier to construct.	④ The closed loop system are taught to construct.
⑤ Error detection is absent.	⑤ Error detection is there.

Exp → fan with a without regulator

Exp → Automatic traffic control system.

Q5 Write about any two of the following -

PD Controller, - PID Controller - ON/OFF Controller -
 Stopper motor - PI Controller.

Ans (i) Proportional (P) Controller → In Proportional Controller

The control action in a control system is proportional to the error signal therefore the system is called Proportional controller system.

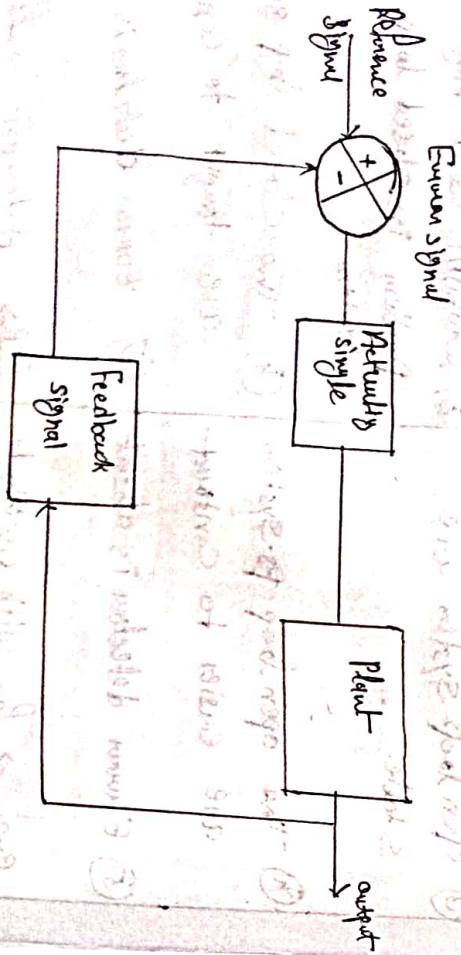


Fig. → Proportional Controller.

Controller output i.e. actuating signal $P = \text{function of error}$

$P \propto e$

~~$P \propto K_p$~~

$$P = K_p e$$

$$P(s) = K_p E(s)$$

$K_p = \text{Proportional gain constant}$

(ii) Integral (I) Controller (Reset mode) →

In integral Controller the actuating signal for the control action in a control system is proportional to the integral of the error signal therefore the system is called integral control system.

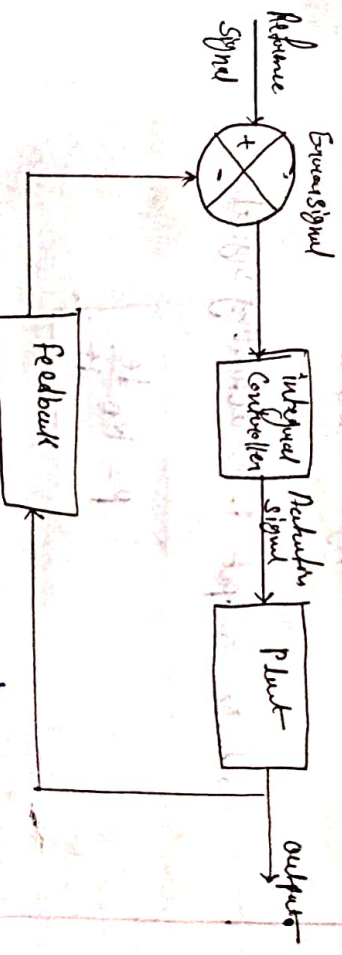
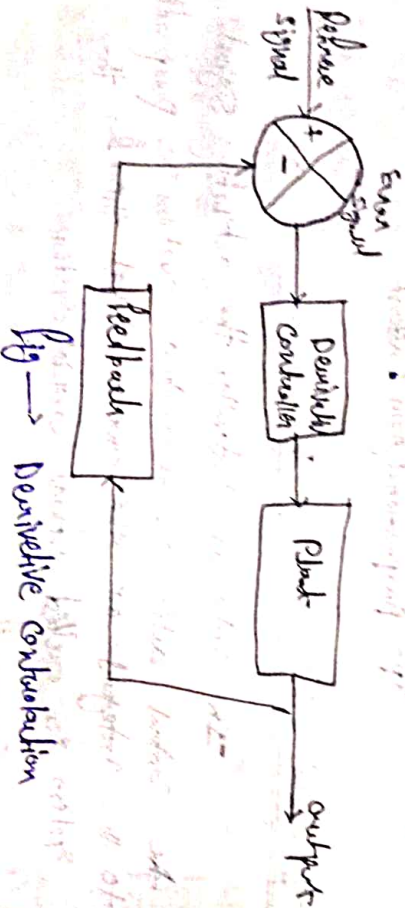


Fig. - integral control action. → Controller output i.e. actuating signal.

$$P = K_i \int e \, dt = \frac{1}{T_i} \int e \, dt$$

(iii) Derivation (D) Controller (Rate mode)

In derivation controller the actuating signal in the control action in a control system is proportional to the derivative of the error signal therefore the system is called derivative control system.



→ Controller output i.e. actuating signal

$$P = K_D \frac{de}{dt}$$

(iv) Proportional Integral Derivative (P-I-D) Controller

- It is used for improving both transient and steady state response characteristics
- It is similar to lag-lead compensation.
- It increases the stability of the system.

It is composite of proportional integral and derivative controllers.



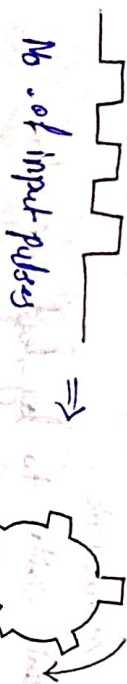
$$P_s = K_P \left(1 + \frac{1}{sT_i} + sT_d \right) E_s$$

(v)

Stepper motor

→ It is an electro mechanical digital device if activates a train

of step movements in response to train of input pulses. Stepper motor is output (shaft encoder displacement) is completely determined by the number of input pulses.



→ The step movement can be angular or linear and it can be either in clockwise

→ Each pulse input produces one step movement

→ The step size of a stepper motor is typically between 15° to 30° .

(vi) On/off Controller → An on/off controller refers

to a simple control system that

only has two states on and off. This type of controller is commonly used in various systems for basic regulation or switching tasks.

Q1. How are industrial controller classified? Explain briefly pneumatic control system state its advantage & disadvantages?

disadvantages?

⇒ Control System → A system which consists of No. of components connected together to perform a specific function in with the output is controlled by input.

Control system is two types —

- ① open loop system
- ② closed loop system.

① open loop system → In open loop system the output signal is governed by the characteristic or mechanics other the control system directly.

② closed loop system → A closed loop control system compares it with the input and determines the compares it with the input is then used in controlling.

→ Explain any two type with working principle, operation and advantage and disadvantages —

(i) LVDT, (ii) RVDT, (iii) Optical Encoder.

→ (i) LVDT →

LVDT "Linear Variable Differential Transformer"

Its working principle is same as Transformer (I.e. Mutual induction Principle) it is an electromechanical type inductive transducer that converts mechanical displacement into the AC electrical signal.

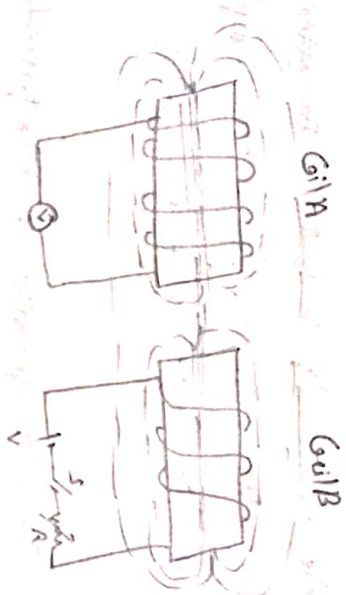
The physical quantities such as force, weight, Tension, Pressure, etc. are first converted into displacement by a primary transducer and that LVDT is used to measure it in terms of the corresponding electrical signal. Hence LVDT is used as "secondary transducer".

* Construction →

- The transformer consists of one primary coil (winding) P and two secondary coils S_1 and S_2 wound on a cylindrical core.
- Both the secondary windings have an equal number of turns and they are placed on either side of primary winding.
- The primary winding is connected to an AC source which produces a flux in the air gap and voltage are induced in secondary.
- 
- Removable soft iron core is placed inside the frames and arm is connected to the core.

* Working Principle →

- The movable core also is laminated in order to reduce the eddy current losses. The displacement to be measured is attached to this movable soft iron core.
- The iron core is generally of high permeability which helps in reducing hysteresis and high sensitivity of LDT.
- The working principle of LDT is based on the mutual induction principle.
- The emf induced in one coil by the change of current in the other coil is called as mutually induced emf.
- Consider two coils A and B lying close to each other. When switch S is closed, current flows through coil B and flux is developed.
- Part of this flux cuts the coil A as shown.
- Emf induced in coil B is self-induced emf induced



* Working →

Case-1 → When the Core is at null position (No displacement)

The Secondary winding is equal so the induced emf is equal in both the winding

$$\therefore V_0 = 0$$

Case-2 → When the Core is moved toward S_1
The magnitude of E_1 will be more as that of E_2

$$\therefore V_0 = E_1 - E_2 \text{ will be positive (+)}$$

Case-3 → When the Core is moved toward S_2
The magnitude of E_2 will be more as that of E_1

$$\therefore V_0 = E_1 - E_2 \text{ be Negative}$$

* Output Characteristics →

→ When the Core is at null position ($V_0 = 0$)

→ When the Core is moved toward S_1 ($V_0 = \text{Positive}$)

→ When the Core is moved toward S_2 ($V_0 = \text{Negative}$)

* Advantages →

(i) Small and wide range of operation → LVDT has a very wide range of measurement of displacement it can measure displacement ranging from 1.25 mm to 250 mm.

(ii) Low Hysteresis losses → LVDT gives low hysteresis losses hence repeatability is excellent under all the conditions.

(iii) Low Friction losses $\rightarrow$ As the core move in a hollow former so there is no concept of friction losses. Hence it gives an accurate output value.

(iv) Lower Power Consumption $\rightarrow$ LVDT consumes very low power of approx 100 during its operation.

(v) Rugged operation $\rightarrow$ It can tolerate a high degree of shock and vibration especially when the core is loaded with spring.

Disadvantage $\rightarrow$

(i) LVDT is inductive Transducer so it sensitive to stray magnetic field. Hence an extra setup is required to protect it from stray magnetic field.

(ii) it also gets affected by the vibration and temperature variation.

(ii) RVD T

$\Rightarrow$ A "Rotary Variable Differential Transducer" (RVD T) is an electromechanical transducer that provides a variable alternating current (AC) output voltage that is linearly proportional to the angular displacement of its linearly input shaft.

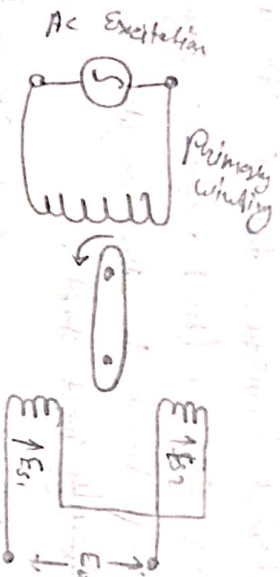
when energized with a fixed AC source the output signal is linear within a specified range over the angular displacement.

Construction $\rightarrow$

$\rightarrow$ Like every other transducer RVD T has two types of winding i.e. primary winding and secondary winding. The primary and secondary winding are wound on former.

$\rightarrow$ There are two secondary winding having equal number of turns. These winding are placed on either side of ~~these~~ ~~two~~ primary winding identically.

→ A can shaped magnetic core made of soft iron is connected to a shaft. This magnetic core can be thus be rotated in between the winding



Differential output

$$E_o = E_{s1} - E_{s2}$$

* Working Principle →

→ The reluctance seen by the primary m.m.f changes with the rotation of cam shaft. This results in change in the magnetic flux with rotation of the cam shaft.

→ Due to this change in magnetic flux with rotation of cam the flux linkage of secondary winding also change. Therefore as per the transformer action an emf is induced in secondary winding.

→ The magnitude of induced emf will depend on the rate of change of rotation. The more the rate of change of rotation the more the emf will be induced.

* Advantage →

- The consistency of RDFT is high
- The accuracy of RDFT is high
- The lifespan is long
- The performance is repeated
- Durability
- Low cost
- Linearity is excellent.

* Disadvantage →

- The contact among the measuring extension as well as the nozzle is not possible for all time.
- The output of the RDFT is linear (about two or two degrees) so it restricts the usability.

* Application →

- Fuel valves as well as hydraulic
- modern machine tools
- Controls Cockpit
- Controls Fuel
- Aircraft and Avionics
- Process Control industry.

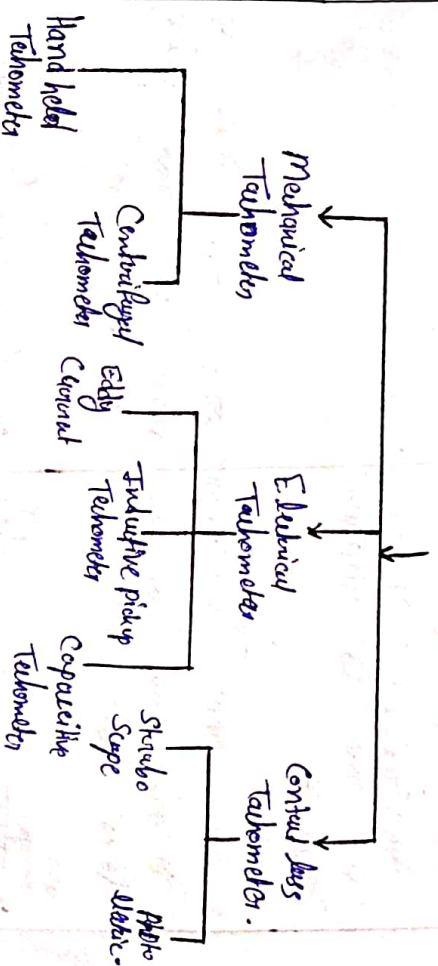
Q2 → Difference b/w AC Tachometer & DC Tachometer.
what is Tachometer & its classification.

Ans

Tachometer → A Tachometer is a device that

measures the rotational speed of a machine or vehicle, typically in revolution per minute (RPM). It is commonly used to measure the speed of engines, pumps, and other rotating machine.

Classification of Tachometer.



Q3 → Explain to following instruments with the help of

(a) magnétive tachometer (b) Stroboscopic tachometer
(c) Photoelectric tachometer. (d) Potentiometer, etc.

(c) photoelastic tomography. (d) potentiometric sils are.

(a) Magnitude Pickup truck models (b) Stratiotic truck models

(c) photoelastic tomography. (d) potentiometric sils are.

A simple hand-drawn sketch of a building with a chimney. The building is represented by a rectangle with a small square on top, and a chimney is shown as a vertical line extending from the roof.

part of

✱

The sensor consists of a permanent magnet and a coil of wire. As a rotating gear on shaft with metallic teeth passes near the sensor it disturbs the magnetic field.

(ii) Detection of Rotational speed $\longrightarrow$

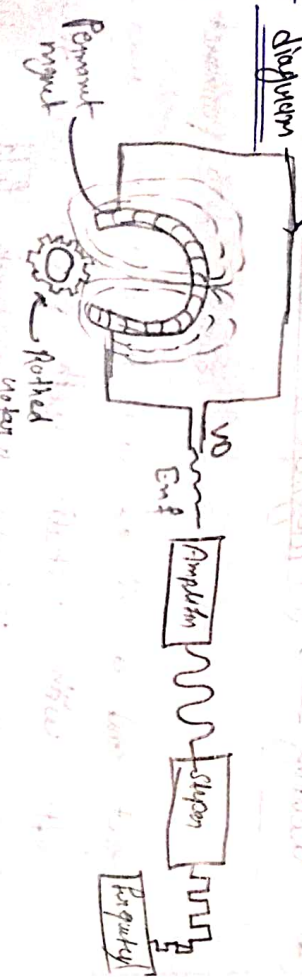
As the gear teeth or other metallic parts pass the sensor they disturb the magnetic field. This disturbance induces a small voltage pulses in the coil due to electromagnetic induction.

(iii) signal Processing $\longrightarrow$

Each passing tooth generates a pulse. The frequency of these pulses is proportional to rotational speed (RPM).

A tachometer (or Control System) processes these pulses to display an actual speed.

Diagram



Advantages $\longrightarrow$

- (i) Non-contact measurement.
- (ii) Suitable in harsh environments.
- (iii) Accurate and fast response time.
- (iv) Works well with high speed rotating part.

Applications $\longrightarrow$

- (i) Engine RPM monitoring in diesel and gasoline engines.
- (ii) Industrial machines and turbines.
- (iii) speed measurement in vehicles and aircraft.
- (iv) monitoring rotational speed in generators and motors.

(B) Stroboscopic tachometer

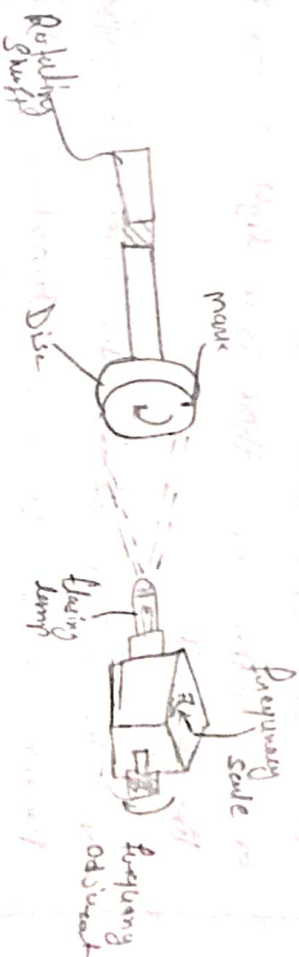
⇒ A Stroboscopic tachometer is a device used to measure the rotational speed of an object such as motor shaft or fan blade without making physical contact. It operates based on the Stroboscopic effect which makes moving object appear stationary when illuminated with a flashing light at a ~~meat~~ matching frequency —

* Principle of operation —

- (i) Stroboscopic effect → The device emits controlled frequency. when this flashing rate matches the rotational speed of the object appears stationary to the observer.
- (ii) Adjustable Flash Rate → The frequency of the Strobe light is adjusted until the rotating object seems to stop moving.

(ii) speed Calculation → The flashing frequency at which the object appears stationary corresponds to the actual rotational speed in revolution per minute (RPM)

* diagram —



* Advantage —

- (i) Non-Contact measurement No need for physical contact with the rotating part.
- (ii) Accurate and quick reading
- (iii) Can measure high speed rotations without affecting the object.

* Application —

- (i) Measuring the speed of motors, fans, and turbines.
- (ii) Checking machinery vibration and imbalance.
- (iii) used in industrial maintenance and quality control.

1C) Photoelectric Tachometer

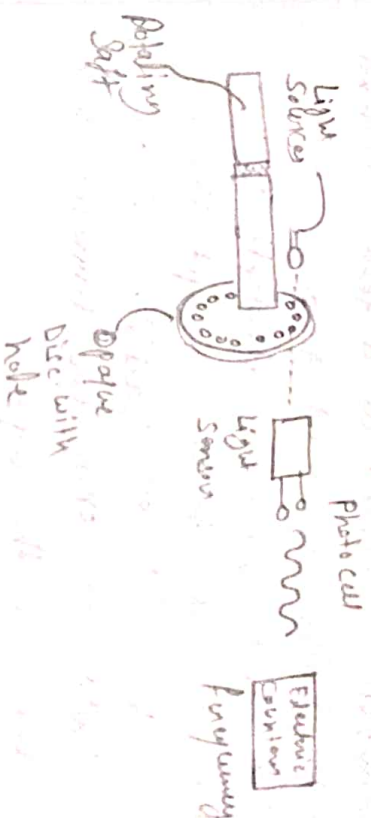
⇒ It consists of a opaque disc mounted on the shaft whose speed is to be measured. The disc has a number of equidistant holes around the periphery on one side of the disc there is a source of the light (L) while on the other side there is a light sensor in line with it.

→ On the rotation of the disc holes and opaque portions of the disc come alternately in between the light source and the light sensor.

→ Thus whenever a hole comes in line with the light source and sensor a pulse is generated. These pulses are counted / measured through an electronic counter.

→ The number of pulses generated depends upon the following factors.

- (i) The number of holes in the disc
- (ii) the shaft speed.



* Advantage →

(i) The output format is digital and this means that if the tachometer is part of a digital instrumentation system no analogy to digital conversion is necessary.

(ii) The pulse amplitudes are constant this simplifies the electronic circuitry.

* Disadvantage →

(i) A disadvantage is that light source must be replaced from time to time. A typical life of light source is 50,000 hours.

1D) Potentiometer - Tautometer

⇒ Potentiometer is defined as a three-terminal resistor having either sliding or rotating contact that forms an adjustable voltage divider in order to use the potentiometer as a wiretap or variable resistor. It should have only two terminals with one end and the wiper.

Construction and working Principle

The Potentiometer consists of a wire which is a long resistive wire and a battery of known EMF V whose voltage is assumed a primary circuit arrangement by connecting the two ends of L to the battery terminals one end of the primary circuit is connected to the cell whose EMF E is to be measured and the other end is connected to potentiometer W .

This circuit is assumed to be a Secondary circuit.

The working principle depends on the potential across any portion of the wire which is directly proportional to the length of the wire. It has a uniform cross-section area and current flow is constant.

$$V = IR \text{ (Ohm's law)}$$

→ The contacts tend to deflect a disk which is mounted on the shaft and restrained by a spring, through a certain angle.

→ The deflection of the disk which is rigidly connected to a point is indicated on a dial.

* Advantage $\rightarrow$

1. $\rightarrow$ A linear relationship b/w the output voltage and speed is obtained if the carrier frequency is 5 to 10 times.
2. $\rightarrow$ The ~~things~~ does cap type tachometers are rugged and are in expensive Also they require little maintenance.
3. $\rightarrow$ In some situation these tachometers are very useful since they give a ripple free output.

* Disadvantage $\rightarrow$

1. These tachometers are hard to calibrate.
2. At high speed there exists a non-linear relationship.
- 3.

Q11 $\rightarrow$ Explain any two of the following with working principle & application & use with diagram.

- WDT, - Photoelectric tachometer, - Optical encoder
- Eddy current, drag cap tachometer

Ans $\rightarrow$

(1) Optical encoder

$\rightarrow$ An optical encoder is a sensor that converts motion (linear or rotary) into an electrical signal using light. It consists of a light source (LED) a disk or strip with transparent and opaque section and a photodetector. As the disk or strip moves the light is interrupted generating pulses that represent position, speed or direction.

Working Principle $\rightarrow$

An optical encoder consists of three main components —

1. $\rightarrow$ Light Source
2. $\rightarrow$ Optical Disk or strip
3. $\rightarrow$ Photodetector.

Working →

- The LED emits light towards the optical disk on strip.
- As the disk on strip moves the transparent and opaque sections allow or block light.
- The photodiode senses the changes in light and converts them into electrical pulses.
- These pulses are processed to determine motion parameters like position, speed and direction.

Diagram →

Application →

- Robotics
- CNC machines
- Industrial automation
- Motor Control System.

← (B) Eddy current / drag cup tachometer →

An eddy current tachometer uses the interaction of the magnetic fields generated by a permanent magnet and a rotor whose speed of rotation is proportional to the eddy current generated.

- The current tends to deflect a disk which is mounted on the shaft and restrained by a spring through a certain angle.

- The deflection of the disk, which is rigidly connected to a pointer is indicated on a dial.

Advantage →

- A linear relationship b/w the output voltage and speed is obtained if the carrier frequency is 5 to 10 times.
- The drag cup type tachometer are rugged and are in expensive. Also they require little maintenance.
- In some situations these tachometers are very useful since they give a ripple free output.

Disadvantage →

- These tachometer are hard to calibrate.
- At high speed there exists a non-linear relationship b/w output voltage and the input speed.

Unit-4 (Temperature Measurements)

Q1 → Explain with sketch the construction & working, principle of thermocouple and advantage & disadv.

⇒ Thermocouple device which is used for the measurement of temperature variations.

if the Active Transducer and Thermo-electric sensor -

Principle → Thermocouple is composed of at least two metals joined together at form two (known temperature) Junction. (unknown body).

(A) Seebeck effect →

* This effect states that when two different or unlike metals are joined together at two Junction an electromotive force (EMF) is generated at the two Junctions.

* The amount of EMF generated is different for different combinations of the metals.

(B) Peltier effects $\longrightarrow$

* when two dissimilar metals are joined together to form two junction, emf is generated wh. within the circuit due to the different temperatures of the two junction of the circuit.

(C) Thomson effect $\longrightarrow$

* when two unlike metals are joined together to form two junction, the potential axis within the circuit due to temperature gradient along the entire length of the conduction within the circuit.

Working →

* Thermocouple measurement. The voltage generated b/w the two junction.

* The emf produced in the thermocouple is given by →

$$E = a(\Delta\theta) + b(\Delta\theta)^2$$

$\Delta\theta \rightarrow$ difference in temp^y b/w the two junction (°C).

$a, b \rightarrow$ Constants

$$E = a\Delta\theta$$

$$\Delta\theta = \frac{E}{a}$$

* In thermocouple temp^y measuring circuit the emf setup is measured by sending a current through a moving coil instrument the deflection being directly proportional to the emf.

* The reference junction is usually at 0°C.

* Thermo Couples $\rightarrow$ up to 1100°C

* Combination of metals used for thermocouple should always produce a linear rise

in emf $E_0 = a\Delta\theta$
 $b \rightarrow$ neglected

$$E = a\Delta\theta + b(\Delta\theta)^2$$

if $b \rightarrow 0$ then $E = a\Delta\theta$
if $b \neq 0$ then $E = a\Delta\theta + b(\Delta\theta)^2$

$$E = a\Delta\theta$$

$$\frac{E}{\Delta\theta} = a$$

Chromel + Constantan

Chromel + Alumel

Rhodium + Iridium

Tungsten + Rhodium

Copper + Constantan

* temperature range to be measure.

* kind of atmosphere.

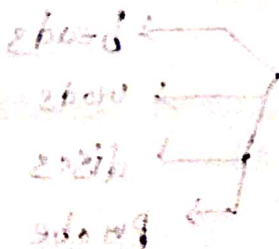
* Active Transducer $\rightarrow$ self generating transducer.

Advantage $\rightarrow$

- (i) follow the temperature changes with a small time.
- (ii) Convenient for measuring the temp. at one particular point in a piece of apparatus.

Disadvantage $\rightarrow$

- (i) No accuracy against contamination.
- (ii) Should be protect to ensure long-life.
- (iii) placed remote from measuring devices.



Q-2 → what is Thermistor? Explain its working principle in with neat sketch advantage & disadvantage & application also.

⇒ Thermal and Resistance opposes the flow of current is called by "Thermistor" is Negative temp. Co-efficient (NTC) -

(Temp ↑ - resistance ↓)

Thermistor is a special type of resistor whose resistance changes with the change in temperature.

Thermistor are used for precision temp measurement control and compensation. Thermistor are highly sensitive but have a non-linear characteristic of resistance versus temp.

Construction →

* Manganese, nickel, Cobalt, Copper, iron and uranium.

* Sizes and Shapes

- beads
- rods
- discs
- probe

Classification of Colloidal Dispersions

1) Dispersions - (i)

(ii) Colloids - (ii)

(iii) Suspensions - (iii)

Classification of Colloidal Dispersions

(i) Bead → Smallest is size size diameter of 0.15 mm to 1.25 mm.

(ii) Cross Probes → diameter of 2.5 mm, length varies from 6 mm to 50 mm

(iii) Disc → Made by pressing material under high pressure into cylindrical shape with diameter 2.5 mm to 25 mm

Characteristics of Thermistors →

- (i) Resistance — Temperature
- (ii) Voltage — Current
- (iii) Current — Time.

(i) Resistance — Temperature characteristics →

* The mathematical expression for the relation b/w the resistance of a thermistor and temperature is —

$$R_{T_1} = R_{T_2} \exp \left[B \left(\frac{1}{T_1} - \frac{1}{T_2} \right) \right]$$

$R_{T_1} - R_{T_2}$ → Resistance of thermistor at Temp^y $T_1 - T_2$

B → Constant depending upon the material of thermistor.

(ii) Voltage current characteristics →

- * The Voltage drop a thermistor increase with increasing current until it reaches a peak value.
- * After peak value the voltage drop decreases with increase in current.

(iii) Current - Time characteristic →

- * When the heating effect occurs in a thermistor a certain finite time is required for the thermistor to heat and the current to build up to a maximum steady state value.

Application →

- (i) Measurement of Temp^{re}
- (ii) Control of Temp^{re}
- (iii) Temp^{re} Compensation.
- (iv) Vacuum meas.
- (v) Providing time delay.
- (vi) meas. of thermal conductivity.
- (vii) meas. of level, flow, pressure.
- (viii) meas. of power at high frequencies.

Advantage →

- (i) Compact, rugged and inexpensive.
- (ii) good stability, highly sensitive.
- (iii) response time is fast.
- (iv) Not affected by stray magnetic and electric fields.

Q3 → Explain the following temperature measurement devices with the help of a neat figure →

(i) Bimetallic (ii) Resistance thermometer (iii) Radiation pyrometer

⇒ (i) Bimetallic

A bimetallic thermometer is a temperature measuring device which converts the temperature into the mechanical displacement. The metals used in the bimetallic thermometer are Copper, Steel & brass.

Working →

The working of the bimetallic device depends on the thermal expansion of the metal. It consists of two flat strips of different metals (metal-A & metal-B) which are welded together.

when the temperature rise the metal strip turns in the direction of the less temperature coefficient metal and when the temperature decrease then the strip turns in the direction of high - Temperature Coefficient metal. This change the pointer deflect on graduated scale and indicated temperature.

Advantage $\rightarrow$ (i) The bimetallic thermometer is easily installed.
(ii) Wide temperature ranges are available.
(iii) The bimetallic thermometer has good accuracy.

Disadvantage $\rightarrow$ (i) It is suitable at local mounting only.

(ii) Indicators are used to display.

(ii) Resistance Thermometers

Also known as resistance temperature detector (RTD), used for measurement of the temperature.

Principle $\rightarrow$

* The resistance of a conductor changes when the temperature is changed.

* The variation of resistance R with temp. $T(^{\circ}K)$ can be represented by $\rightarrow$

$$R = R_0 (1 + \alpha_1 T + \alpha_2 T^2 + \dots + \alpha_n T^n)$$

* Resistance thermometer use the change in electrical resistance of conductors to determine the temperature.

Construction $\rightarrow$

* positive temperature coefficient.

* Platinum $\begin{cases} \rightarrow \text{withstand high temp.} \\ \rightarrow \text{excellent stability} \\ \rightarrow \text{less susceptible to contamination.} \end{cases}$

Requirement of a Conduction material to be used
in RTD $\rightarrow$

(i) Change in resistance of material per unit change in temperature should be as large as possible.

(ii) Material should have high value of resistivity so that minimum volume of material is used.

(iii) Resistance of material should have a continuous and stable relationship with temp.

$$R = R_0 [1 + \alpha (T - T_0)]$$

(iii) Radiation Pyrometer

- * Used for very high temp. measurement
- * used to measure temp. of hot boiling vapours or liquids and also corrosive liquids that can damage other temp. measuring devices.
- * used for measuring temp. which are above the range of thermocouple.
- * used to measure temperature of rapidly moving objects

Principle & working →

- * Every object when heated, radiates or emit some amount of energy or heat.
- * Thermal radiation is electromagnetic radiation emitted as a result of temp.
- * Have wavelength in the range from 0.1 to $100 \mu m$
- * limited band of radiation energy.

* The total radiation emitted by a band is given by $\rightarrow \boxed{q_b = \sigma T^4 \text{ w/m}^2}$

To what types of Radiation Pyrometer $\rightarrow$

(i) Total Radiation Pyrometer

(ii) or selection (Partial) Radiation Pyrometer.

Advantage $\rightarrow$

* Measure very high temp. without direct contact with the hot source.

* objective (optical lens) can be adjusted to measure temp. of objects.

* High output signal

- * moderate cost
- * fast response

Disadvantage →

- * Non-Linear scale.
- * Error can occur.
- * Emissivity of target materials can affect Temp^y measurement

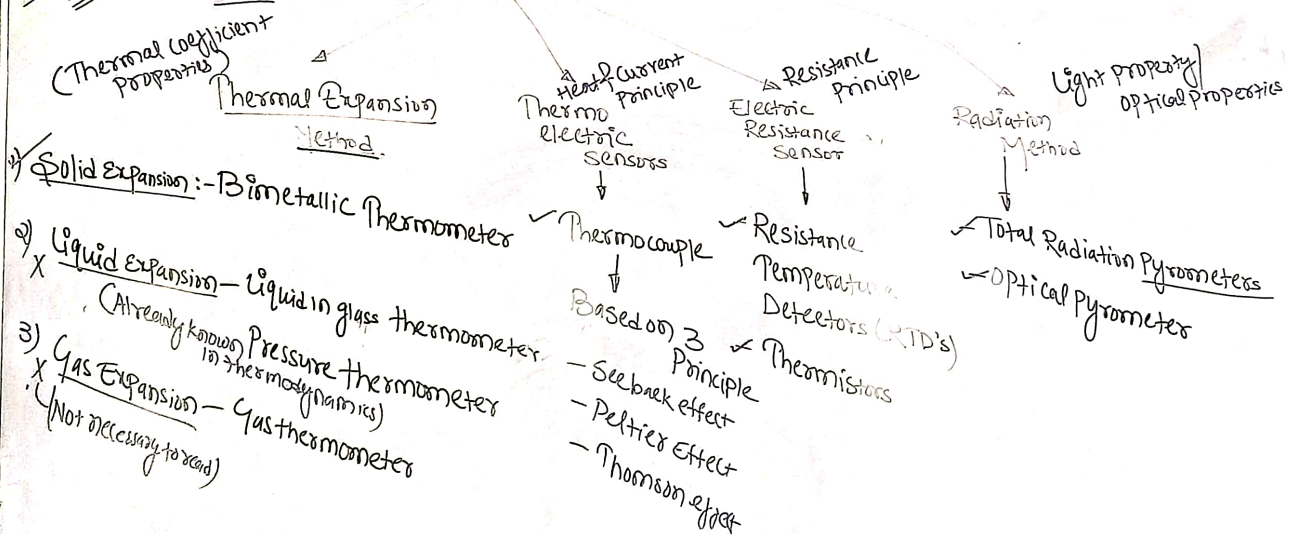
Application →

- * high temp^y measurements.
- * moving object.
- * target where physical contact is not possible.
- * measure ^{infrared} ~~infrared~~ energy from radiation.

29/03/25
MC

U.4. Temperature Measurement

→ Error in temperature measurement {list topic}



Q. → write Short Notes on the following topics -
in a construction, working or use.

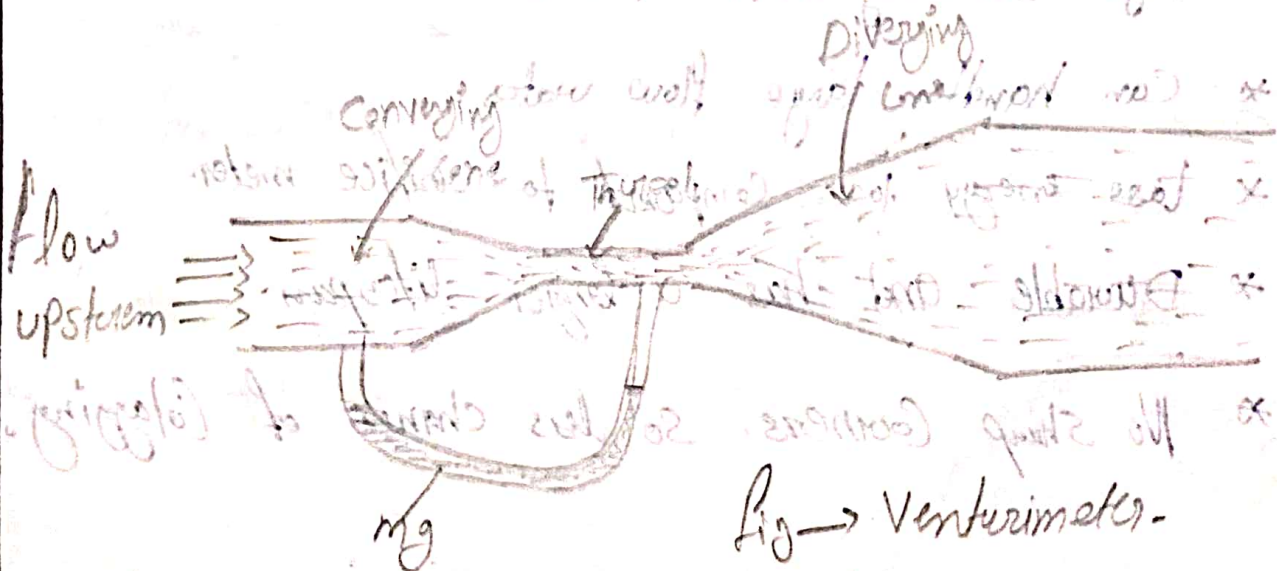
- (i) orifice (ii) Venturimeter (iii) flow nozzle
(iv) pitot tube

(i) Venturimeter

A Venturimeter is a device used to measure the flow rate (discharge) of a fluid (liquid or gas) through a pipeline. It works on the principle of Bernoulli's theorem.

Flowing through a pipe at constant of three parts →

- (i) Converging part (ii) Throat part (iii) diverging part.



Working Process →

- * Fluid enters the converging section where velocity increases and pressure decreases.
- * At the throat the pressure is at its lowest and velocity is highest.
- * This pressure difference b/w the inlet and throat is measured using a manometer or differential pressure gauge.
- * Using Bernoulli's on the flow rate is calculated based on this pressure difference.

Advantage →

- * High accuracy in flow measurement.
- * Can handle large flow rates.
- * Less energy loss compared to orifice meter.
- * Durable and has a longer lifespan.
- * No sharp corners. So less chance of clogging.

Disadvantage →

- * Costly compared to orifice meter
- * Bulky and heavy needs more space.
- * Difficult to clean if the fluid is dirty or sticky.

(ii) Orifice meter.

An orifice meter is a device used of measuring the rate of flow of fluid (discharge) through a pipe.

It is a cheap device as compare to Venturi meter it also working on a same principle as that of Venturi meter.

Construction →

i) Orifice plate → A thin flat plate with a hole (orifice) in the middle. It is placed perpendicular to the flow inside the pipeline.

(ii) Pipe Flanges → Used to fix the orifice plate
between two sections of the pipe.

(iii) Pressure Taps → Two pressure taps are
installed:
one upstream (before the orifice plate) one downstream
(after the orifice plate).

(iv) Manometer or Differential Pressure Gauge →

Connected to the pressure taps to
measure the pressure difference.

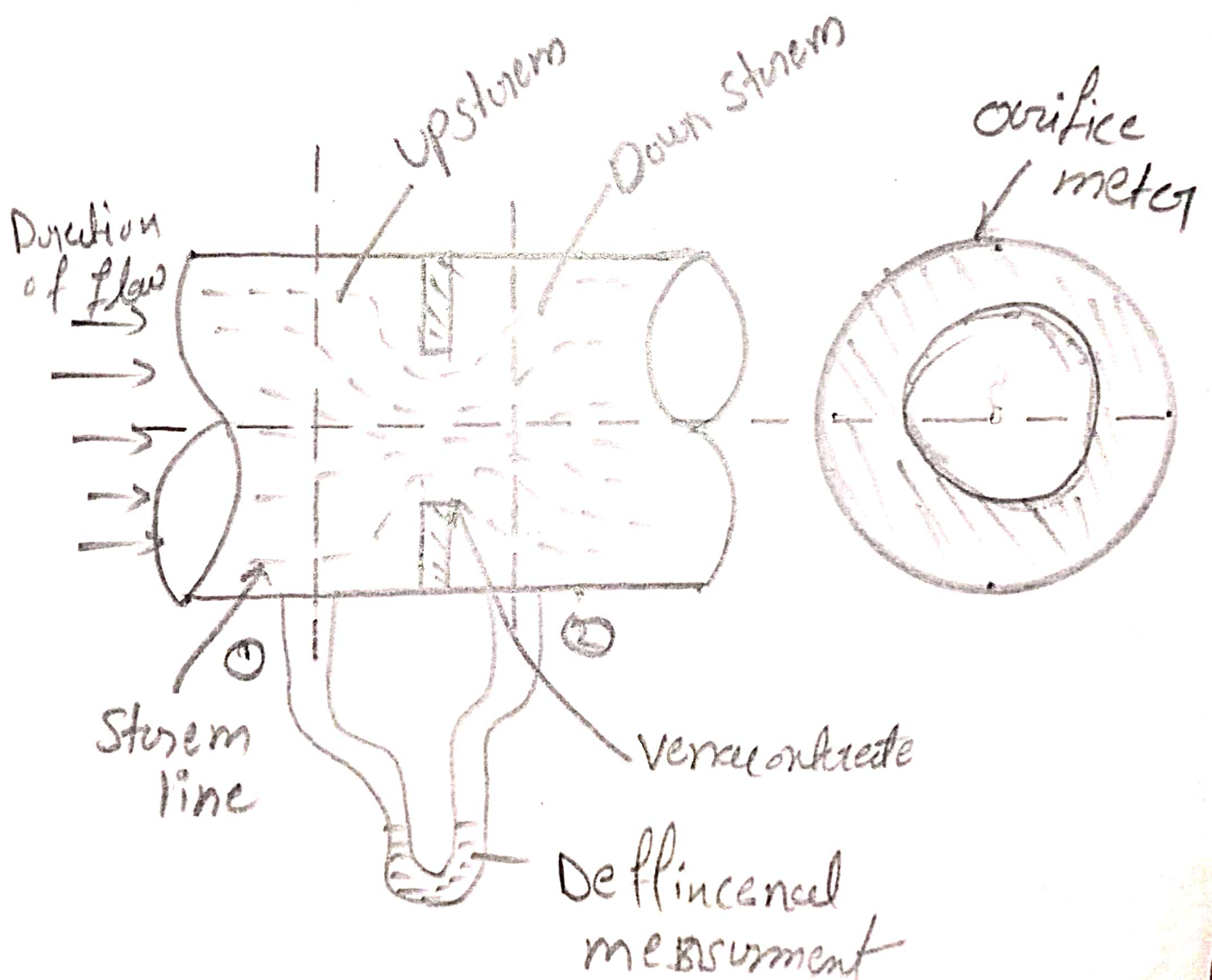
Working →

* The fluid flows through the pipeline and encounters
the orifice plate.

* The flow area suddenly decreases at the orifice
causing an increase in velocity and drop in
pressure.

* According to Bernoulli's principle this pressure drop
is related to the flow rate.

Fig → orifice meter



* The differential pressure is measured using a manometer or pressure sensor.

* Using this pressure difference the flow rate is calculated with standard formula.

Advantage →

- (i) Simple and inexpensive construction.
- (ii) Easy to install and maintain.
- (iii) Suitable for a wide range of fluids (liquid, gas, steam).
- (iv) Requires no moving parts so its durable.

Disadvantage →

- (i) Pressure loss is permanent ~~due to~~.
- (ii) Accuracy can be affected by wear and tear of the orifice plate.
- (iii) Not ideal for dirty or viscous fluids.
- (iv) Required straight pipe lengths upstream and downstream of accurate results.

(iii) Flow Nozzles

Types of Flow rate Measuring device which measure flow rate of liquids and gas flowing in a pipe.

Act as an obstruction in the path of the fluid causing a change in pressure.

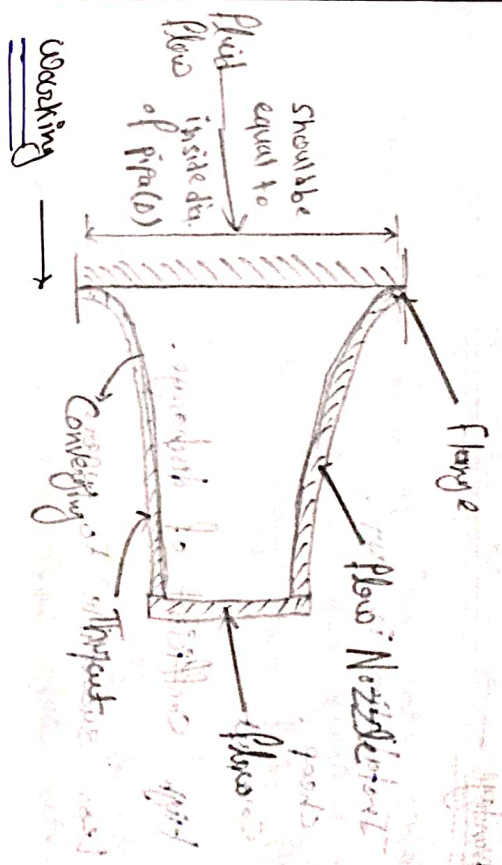
The change in pressure is dependent on the flow rate of liquid.

Construction

* Flow Nozzle is having b/w the 4 flanges of pipes carrying the fluid where flow rate is the measured.

* Flow Nozzle Throat minimum area.

* Two measuring U-tube manometers

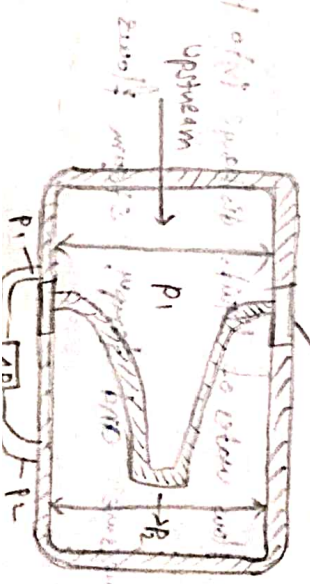


Working

* Based on Bernoulli's principle as fluid passes through the nozzle it accelerates causing a drop in pressure.

* The pressure difference b/w the inlet and the throat is used to calculate the flow rate.

* The higher the flow rate the greater the pressure.



Advantage →

- * Installation is easy.
- * Cheap.
- * Compact.
- * High coefficient of discharge.
- * Less susceptible to wear.

Disadvantage →

- * No divergent outlet and hence low pressure recovery.
- * Cannot be used in low pressure head.
- * Maintenance is high.
- * Cannot be used for fluids having solid particles.

Application →

- * Used to measure flow rates of liquids discharge into free atmosphere.
- * Used for high pressure and temp. steam flows.

(iv) Pitot tube

Most common form of flow rate measuring devices which work on the principle of converting the kinetic energy in a fluid flow to potential energy.

Pitot tube is named after the scientist Henri Pitot who used a glass tube to measure velocities in a river. Very simple devices with no moving parts.

Bernoulli's eqn → Stagnation = static + Dynamic pressure

Operating Principle →

Based on the fact that when a solid body is kept centrally and stationary in a pipe line with a fluid streaming down the velocity of the fluid starts diminishing due to the pressure of the body till it is reduced to zero directly in front of the body.

This point is known as STAGNATION POINT

- * As the kinetic head is lost by the fluid it gain a static head.
- * Ans by measuring the difference b/w pressure at normal flow line and that at stagnation point the velocity is determined.

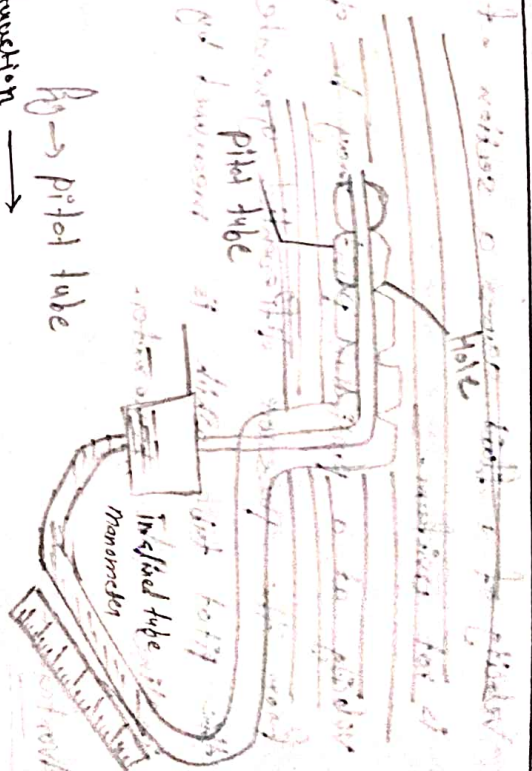
Stagnation pressure $\rightarrow$ static + dynamic pressure

$$P = P_0 + \frac{1}{2} \rho V^2$$

$$P - P_0 = \frac{1}{2} \rho V^2$$

$$V^2 = \frac{2(P - P_0)}{\rho}$$

$$V = \sqrt{\frac{2(P - P_0)}{\rho}}$$



Construction $\rightarrow$

- * Tube consists of two concentric tube -
 - (i) Inner tube
 - (ii) outer tube
- * The open end of inner tube faces the incoming fluid.
- * The outer tube has a closed end and has holes in its wall.
- * Both tubes contain same fluid as is flowing in the main pipe line.
- * Outer tube - Static pressure
- * Inner tube - Total pressure

* Velocity of a fluid across a section of pipe is not uniform.

* Velocity at a particular point may be determined from the pressure differential generated by the pitot tube which is measured by an inclined tube manometer.

Advantage →

- * No. Moving Parts.
- * No Process loss nature (in solid state) is
- * Economical to install.
- * Easily removed from the pipeline.
- * Cost is much smaller.

Disadvantage →

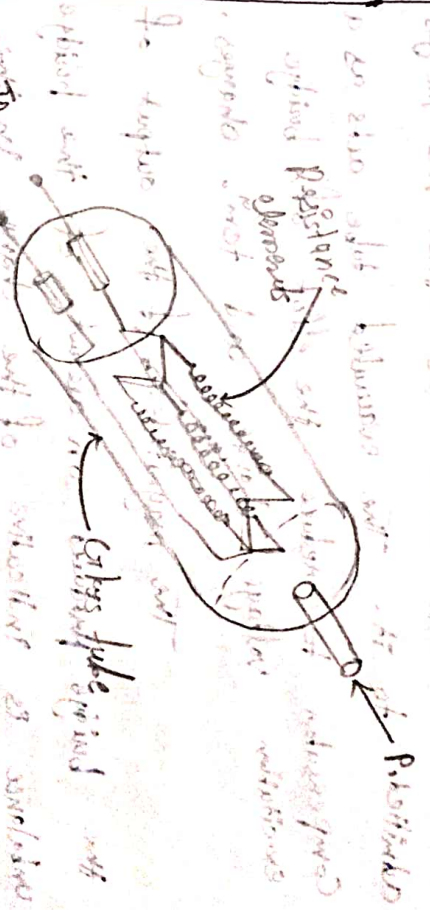
- * Poor accuracy.
- * unsuitable for dirty sticky fluids.
- * Produce a low differential head on account of low sensitivity.

Describe briefly the construction and working of a Pirani gauge write its application advantage & disadvantage.

⇒ Pirani Gauge

The Pirani Gauge like thermocouple gauge, is a device that measures the pressure through change in thermal conductivity of a gas which changes the temperature of a heated element.

Unlike in the case of a thermocouple gauge the functions of heating and temperature measurement are combined in a single element.



As → Pirani gauge is used for

Working

The coil surface is the gas tube. The Pirani gauge is connected in one of the arms of a Wheatstone bridge for the measurement of the resistance of its heater element.

Two identical Pirani tubes generally are connected in the bridge circuit one of the tubes is evacuated to a very low pressure and then sealed off while the other has the gas admitted to it. The evacuated tube acts as a compensation to reduce the effect of bridge excitation voltage change and temp. changes.

The magnitude of the output of the bridge produced on account of the bridge unbalance is indicative of the change in the value of resistance of the heater element and hence of the pressure.

Advantage

(i) Pirani gauge are rugged inexpensive and usually more accurate than thermocouple gauge.

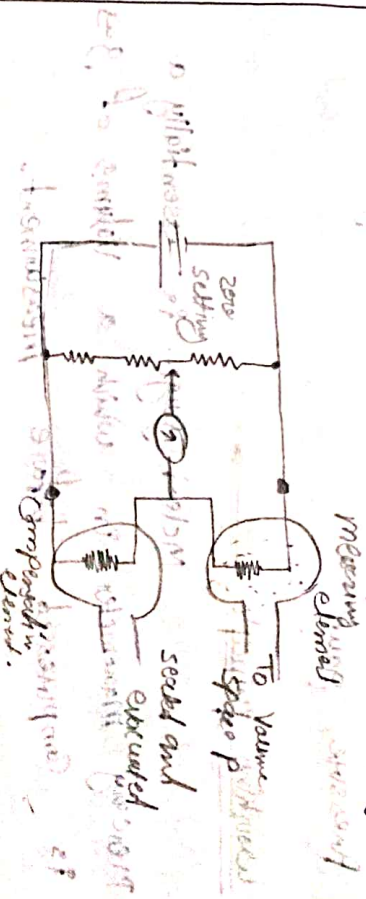
(ii) They are useful for measuring pressure ranging from 10×10^{-6} to 1 torr. However, their

Disadvantage

(i) Pirani gauge require calibration against some pressure standards.

(ii) Calibration pressure is nonlinear and varies from one gas to another.

(iii) The transient response of Pirani gauge is poor.



Q.14 → Describe in construction, working & theory of McLeod gauge for measurement of vacuum its advantage & disadvantage.

Ans → McLeod gauge →

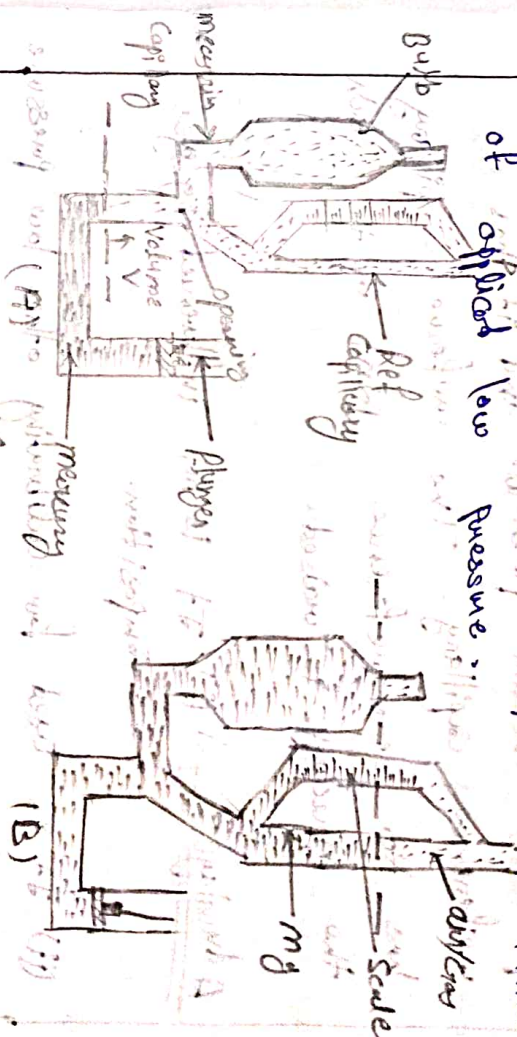
It is the type of low pressure gauge McLeod gauge comprises the low pressure and was developed to extend the range of vacuum measurement significantly.

The McLeod gauge measures the vacuum pressure in the range 10^{-1} to 10^{-5} torr. This can be used as a primary standard device for calibrating other low pressure gauge.

Working Principle →

McLeod gauge is essentially a mercury manometer in which a volume of gas is compressed before measurement.

It operates by compressing a low pressure gas of known volume into a smaller volume so that its pressure is sufficiently higher energy enough to be read. The resultant final volume and pressure provide the indication of applied low pressure.



The McLeod gauge consists of a reservoir containing mercury. A plunger is attached on the top of the reservoir & reservoir which is used to raise or lower the level of mercury into the reference column and bulb. Above the reservoir there is a

containing mercury. A plunger is attached on the top of the reservoir & reservoir which is used to raise or lower the level of mercury into the reference column and bulb. Above the reservoir there is a

bulb. The other end and reference column and the point of connection of bulb and reference column is the opening on cut off point. The other end of the reference column is open to vacuum pressure and it has a reference capillary. The reference capillary has to zero reference point up to which the mercury is raised.

Advantage → (i) It is not influenced by gas composition.

(ii) It is used for calibrating other low pressure measuring gauge.

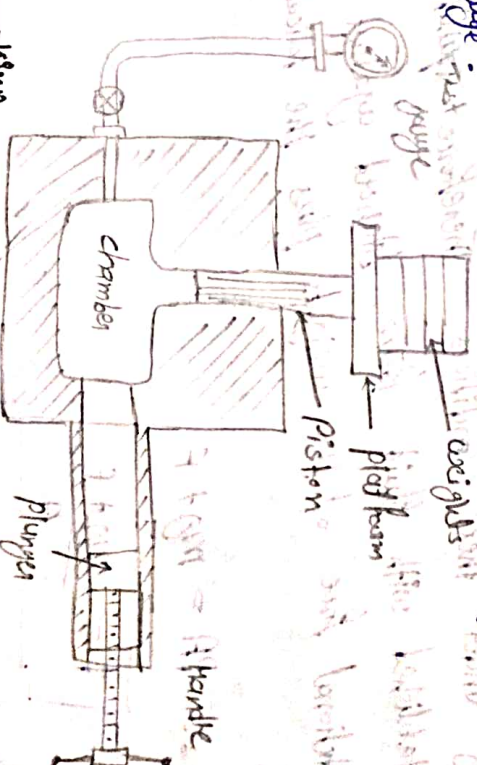
Disadvantage → (i) Condensable gases cannot be used.

(ii) It cannot give continuous output.

(iii) There are chances for the gauge to get contaminated.

Q.1 → What is Dead weight pressure gauge? Explain principle & working in brief. Write its advantage & disadvantage and application.

→ A Dead weight pressure gauge refers to a pressure measuring set up where known weights are placed on a piston of known area generating a precise pressure that is used to calibrate or verify the accuracy of pressure gauge.



working → As dead weight pressure gauge is used to calibrate or verify the accuracy of pressure gauge. A vertical chamber and cylinder of the piston are filled with clean oil. The gauge to be tested is fixed at its appropriate place and piston

is inserted in cylinder. A weight is placed on the piston. The pressure is exerted to get the ~~the~~ fluid and this pressure is transmitted to the gauge deflecting its pointer. The weight may be adjusted to get the desired setting of the gauge pointer. The plunger is forced in by moving the handle thereby varying the pressure. The piston weight combination floats freely under these conditions. Therefore equilibrium is established with fluid force balanced against the gravitational force of the weights plus the friction drag.

$$\therefore PA = mg + F$$

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

$m = \text{mass, kg}$

$g = \text{acceleration due to gravity, m/s}^2$

$F = \text{friction drag, N}$

$A = \text{area of piston cylinder, m}^2$

Advantages →

- * simple construction.
- * Easy to use and maintain.
- * Provides continuous pressure indication.
- * Low cost.

Disadvantage →

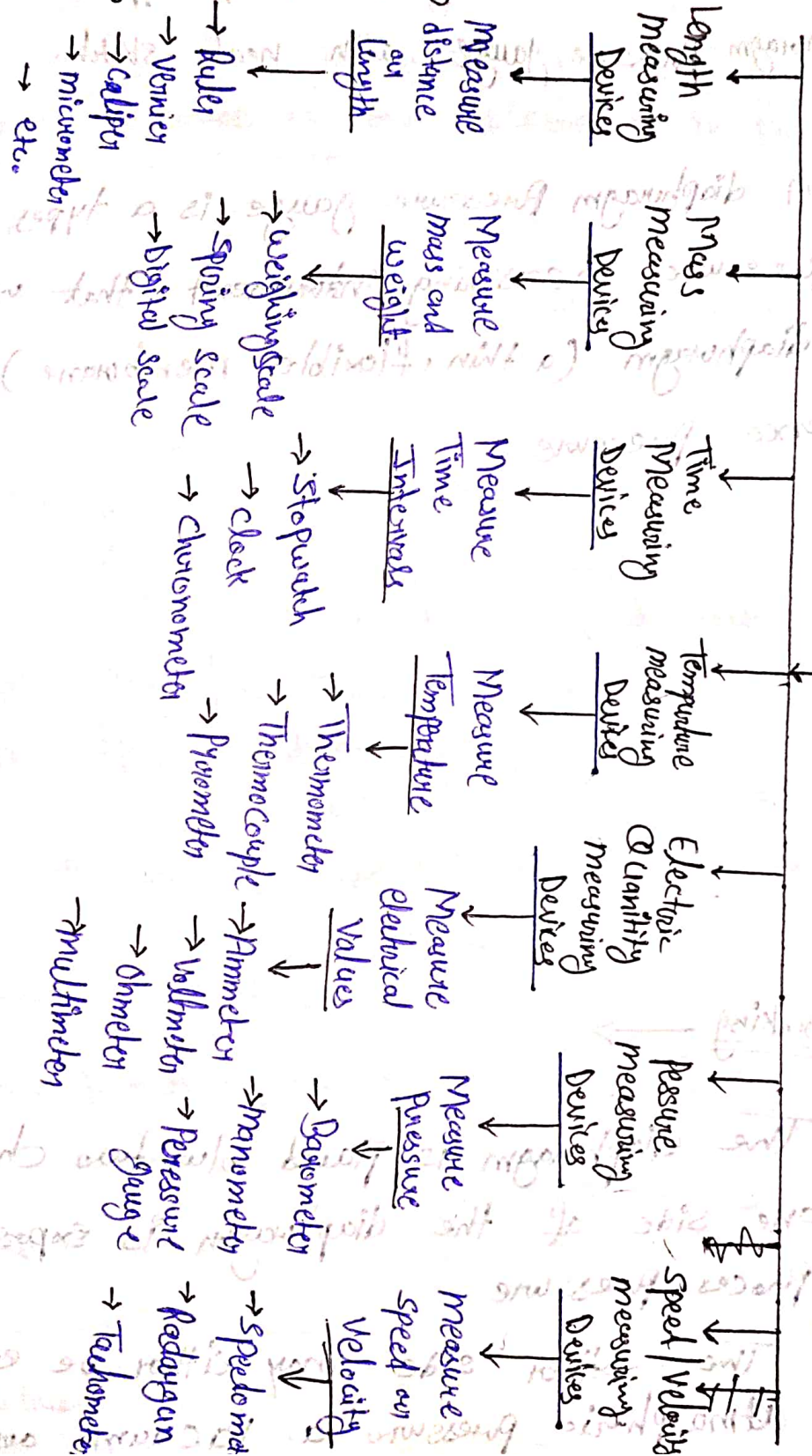
- * limited to low pressure ranges.
- * Accuracy is not very high.
- * Sensitive to vibrations and external disturbance.
- * Temp. changes may affect reading.

Applications →

- * Measuring low gas pressure
- * used in laboratories for experiment set up.
- * Educational tools to demonstrate pressure principle.

Measuring Device

Classify the measuring device with their function :-



Q.2

Measuring Device

Q1 → Write the working principle & application of diaphragm pressure gauge with neat sketch.

Ans → A diaphragm pressure gauge is a type of pressure measuring instrument that uses a diaphragm (a thin, flexible membrane) to sense pressure.

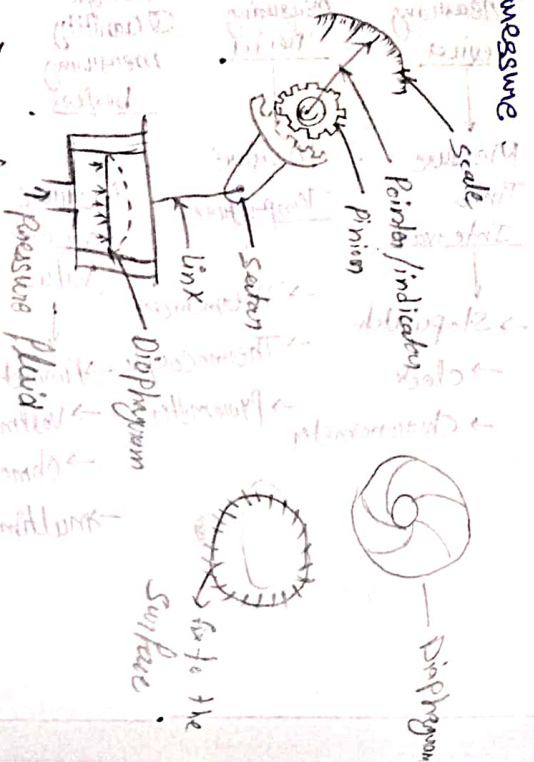


Fig → Diaphragm pressure gauge.

- Working →
- * The diaphragm is placed b/w two chambers.
 - * One side of the diaphragm is exposed to the process pressure.
 - * The other side may either be exposed to atmospheric pressure or a vacuum or another

Pressure source.

- * When pressure is applied, the diaphragm flexes (moves) because of the difference in pressure.

* This small movement is mechanically amplified and moves a pointer on a dial, showing the pressure value.

Advantage →

- (i) Can measure very low pressure accurately.
- (ii) Suitable for corrosive fluids.
- (iii) Good for viscous or dirty media.

Disadvantage → (i) Limited to low and medium pressure ranges.

- (ii) More expensive.
- (iii) Temperature sensitivity.

Application →

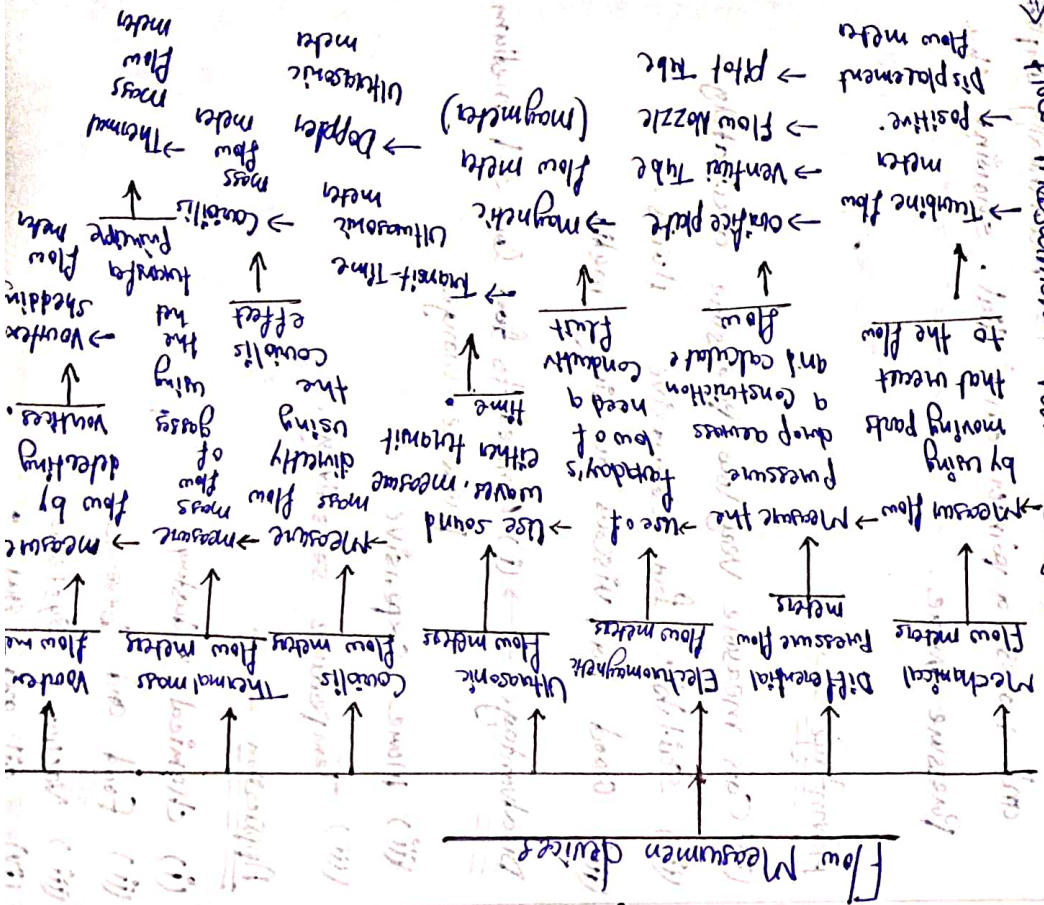
- (i) chemical industry
- (ii) Food and beverage
- (iii) Vacuum systems.
- (iv) oil and gas.

Q.1 → How are flow measurement device classified? Explain

The following special flow meters with a meter station (1, 2a) Electromagnetic flow meter

(b) Hot urine anemometers.

Flow measurement, device $\rightarrow$ Classified



(a) Electromagnetic flow meters $\rightarrow$

An Electromagnetic flow meter is a device that measures the volumetric flow rate of a fluid using "Faraday's law" of electromagnetic induction.

Working →

→ According to Faraday's law when a conductive fluid flows through a magnetic field it generates a voltage.

* The voltage produced is directly proportional to the velocity of the fluid

~~+~~ Electrode placed inside the pipe walls capture this voltage and the meter converts it into flow rate.

Formula →

$$E = k \gamma B \times D \times v$$

$E =$ Induced voltage

$D =$ Diameter of pipe

$k = \text{meter constant}$

$V =$ Fluid velocity.

$B =$ magnetic field strength

48

4

Application →

- (i) water and wastewater treatment
- (ii) chemical processing
- (iii) mining and slurry measurement
- (iv) Pulp and paper industry.

Disadvantage →

- (i) No obstruction to flow
- (ii) Suitable for large pipe size
- (iii) Highly accurate and repeatable

Disadvantage →

- (i) Expensive compared to mechanical meters
- (ii) only works with conductive fluids
- (iii) Requires Power Supply for operation.

(b) Hot wire anemometer →

⇒ A Hot wire Anemometer is a device used to measure the velocity (speed) of a fluid usually air or gas. based on heat transfer principle.

Types of Hot wire anemometer →

- (i) Constant Temperature Anemometer (CTA)
- (ii) Constant Current Anemometer (CCA)

Applications →

- (i) Measuring air velocity in labs and industrial setting.
- (ii) Turbulence studies in wind tunnels
- (iii) HVAC system performance testing.

Formula →

$$H = A + B \sqrt{v}$$

H = heat loss from the wine

v = fluid velocity

A, B, n = constants depending on wine and fluid properties.

Fluid Properties.

Advantage →

(i) Very high sensitivity, especially to small velocity changes.

(ii) Can measure very low flow speeds, accurately.

(iii) Quick response time (good for unsteady, fluctuating flows)

Disadvantages →

(i) Very delicate (wine can easily break).

(ii) Affected by tempⁿ and pressure changes in the fluid.

(iii) Requires careful calibration.

Answer
of May 2008

Q1 → Explain working principle of Bonded and Unbonded type of strain gauge.

Ans ① Bonded strain gauge →

Bonded strain gauge are the most commonly used types of strain gauge. They consist of a sensing element that is bonded directly to the surface of the structure under study using a special adhesive. The adhesive ensuring a strong and reliable bond between the gauge and the material.

Advantages →

- They provide accurate and precise measurement of strain.
- They are suitable for a wide range of material and applications.
- They are widely available and cost effective.

②

Unbonded strain gauge →

Unbonded strain gauge as the name suggests also not require any other for installation. Instead they are mechanically attached to the surface of the material using clamping mechanisms or spot welding techniques.

Advantage →

- They can be easily removed and reinstalled on different test objects.
- They do not introduce the residual strain associated with adhesive bondings.
- They are suitable for application with rapidly changing strain gradients.

Strain gauge → A strain gauge is a device used to measure strain of an object under application forces. They are widely used in various engineering application including structural angle material testing monitoring.

Q2 → What is Load Cell? write application of load cell.

⇒ A Load Cell is a transducer that converts a force or load into an electrical signal. It is commonly used for weighing and force measurement application. Load cell works based on different principle such as strain gauge, hydraulic, pneumatic or capacitive mechanism.

Application of Load Cell →

(i) Weighing Scales → Used in industrial, commercial and household weighing system like digital scale and truck weighbridges.

(ii) Material Testing Machines → measures stress and strain in material to determine their strength.

(iii) Industrial Automation → integrated into making force measurement and control in manufacturing processes.

(iv) Medical Equipment → Applied in Prosthetics, patient lifting systems, and medical testing devices.

(v) Robotics & Automation → Provides force feedback for robotic arms and automated assembly system.

Q3 → Explain briefly with neat diagram →

- (i) Foil Strain gauge (ii) wire wound strain gauge
- (iii) Strain Pot (iv) Resistive strain gauge
- (v) Capacitive strain gauge.

Ans → Foil strain gauge → A foil strain gauge is a

type of resistance strain gauge that is widely used to measure strain or deformation in various engineering applications. It consists of a thin flexible metallic foil (usually made of material like Constantan or Karma) that is bonded to a backing material which is often made of a flexible polymer. The gauge is designed to be attached to the surface of a

Structure on component that need to be tested for strain.

(i) Wire wound gauge $\rightarrow$ A wire wound strain gauge is a type of strain gauge that uses a fine wire usually made of materials like constantan as known wound in a specific pattern to measure strain on deformation in various materials and structures. This type of strain gauge operates based on the principle that the electrical resistance of the wire changes when it undergoes mechanical strain.

(ii) Resistive strain gauge $\rightarrow$ A resistive strain gauge is a sensor used to measure strain (deformation) in a material. It works on the principle that a material's electrical resistance changes when it is stretched or compressed.

(iv) Capacitive strain gauge $\rightarrow$ A capacitive strain sensor that measures strain in a material by detecting changes in capacitance. It operates on the principle that the capacitive plates change when the distance between them varies due to mechanical deformation.

(v) Rosette strain gauge $\rightarrow$ A rosette strain gauge is a configuration of multiple strain gauges arranged in a specific pattern to measure multi-directional strain at a single point. Unlike a single strain gauge which only measures strain along one direction, a rosette strain gauge can determine strain in multiple directions.

Q. → Explain Selection of installation of Strain gauge.

⇒ 1. Selection of a Strain Gauge →

When select a strain gauge consider the following factors →

(A) Types of Strain Gauge →

- Foil strain gauge.
- Semiconductor strain gauge.
- Wire strain gauge.

(B) Gauge length →

- Shorter gauges capture localized strain.
- Longer gauges average strain over a larger area.

(C) Resistance (ohms) →

- Typically 120Ω, 350Ω, 1000Ω.
- Higher resistance reduces heat generation and improves stability.

(D) Sensitivity (Gauge factor) →

- A typical gauge factor (GF) is ~2.0 meaning a 1% strain results in a 2% change in resistances.

(E) Material Compatibility → must match the material of the test specimen to ensure

consistent expansion / contraction.

2. Installation of a Strain Gauge →

Proper installation is critical for accurate results. Follow these steps.

(A) Surface Preparation →

- (i) Clean the surface
- (ii) Abrasion
- (iii) Neutralization.

(B) Strain gauge Positioning →

- (i) Align the gauge.
- (ii) Use Alignment Tools.

(C) Adhesive Application →

- (i) Choose the right Adhesive
- (ii) Apply Evenly

(D) Wiring and Connections →

- (i) Solder or using the wire
- (ii) Use strain relief
- (iii) Shielding

(E) Protective Coating →

- (i) Apply a protective layer
- (ii) Environmental Sealing

Q5 → Explain strain measurement. Write relation b/w stress strain & types of strain gauge.

⇒ Strain measurement →

Strain is defined as the change in length at a line segment b/w two points divided by the original length of the line. For the strain measurement it is the usual practice to make measurement.

Relation b/w stress & strain →

The relationship b/w stress and strain is given by "Hooke's law" which states that -

Stress & Strain

For a linear elastic material this relationship is expressed as

$$\sigma = E \cdot \epsilon$$

where →

• σ = Stress (force per unit area in pascals)

• ϵ = Strain (Dimensionless, change in length per unit length)

• E = Young's modulus (Elastic modulus in pascals).

Types of Strain gauge →

- (i) Electrical Resistance strain gauge
- (ii) Optical strain gauge
- (iii) Mechanical strain gauge
- (iv) Semiconductor strain gauge
- (v) Piezoresistive strain gauge
- (vi) Capacitance strain gauge
- (vii) Inductive strain gauge
- (viii) Vibrating wire strain gauge.

Q1 → Describe the procedure for measurement of strain using Resistor strain gauge in detail.

→ Measurement of strain using a Resistance strain gauge →

A resistance strain gauge is a widely used sensor for measuring strain in materials. It operates on the principle that a change in strain leads to a change in electrical resistance which can be measured and correlated to strain.

Principle of operation — The strain gauge consists of a fine wire on a metallic foil arranged in a grid pattern and bonded to a material.

$$\Delta R = K R \epsilon$$

Procedure for measuring strain using a Resistance strain gauge →

The procedure consists of the following steps.

Step-1 → Selection of the strain gauge →

- Choose an appropriate strain gauge based on the type of strain to be measured.
- Consider factors like gauge factor, material compatibility, temperature stability, and resistance.

Step-2 → Surface preparation →

- The surface where the strain gauge is to be attached must be smooth, clean, and dry.
- The surface is then degreased using acetone or alcohol.

Step-3 → Mounting the strain gauge →

- The strain gauge is carefully positioned at the desired location.
- The adhesive is allowed to cure properly.
- A thin layer of adhesive is applied to bond the strain gauge to the material.

Step-4 → Wiring and Connection →

- Fine wires are soldered on clamped onto the terminals of the strain gauge.

- The wiring is done to minimize noise and temp effects.

Step-5 → Wheatstone Bridge Circuit Step. →

- The strain gauge is connected in a wheatstone bridge configuration to measure small changes in resistance accurately.

- The bridge can be configured in different ways —

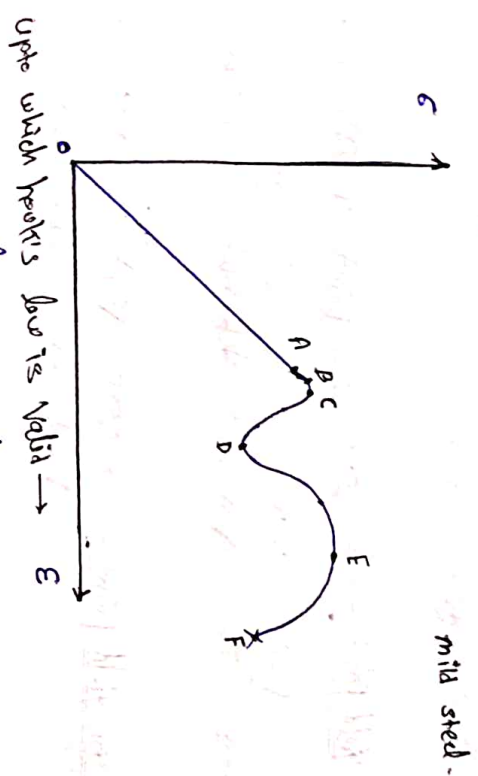
- Quarter-bridge
- Half-bridge
- Full bridge

Step-6 Calibration →

- The system is calibrated by applying known loads and measuring output voltage.
- A zero adjustment is done to eliminate any initial offset.

Q-7. Explain relation b/w strain & stress diagram.

σ-ε diagram for ferrous material →



- A = limit of Proportionality
- B = elastic limit
- C = Upper yield limit
- D = Lower yield limit
- E = Ultimate stress point
- F = Fracture.

(i) Limit of Proportionality → stress proportional to strain
stress is proportional to strain
stress is proportional to strain

(ii) Elastic limit $\rightarrow$ वह स्तर तक जो धातु को छोड़ने पर वापस अपनी मूल आकार में लौटने में सक्षम हो सके।
 यह वह स्तर है जहाँ धातु का विकृति स्थायी नहीं है।
 Elastic limit से ऊपर है।

(iii) Upper yield point $\rightarrow$ स्तर तक जो कि धातु को प्लास्टिक आकार में आने से पहले वह परम शक्ति देवता को देती है।

(iv) Lower yield point $\rightarrow$ स्तर तक जो कि धातु को हार्ड करने में आती है।

(v) Ultimate stress point $\rightarrow$ स्तर तक जो कि धातु का अधिकतम ताकत है।
 यह वह स्तर है जहाँ धातु का ताकत अधिकतम होता है।
 धातु का स्तर है।

(vi) Failure $\rightarrow$ स्तर तक जो कि धातु का टूटने का स्तर है।