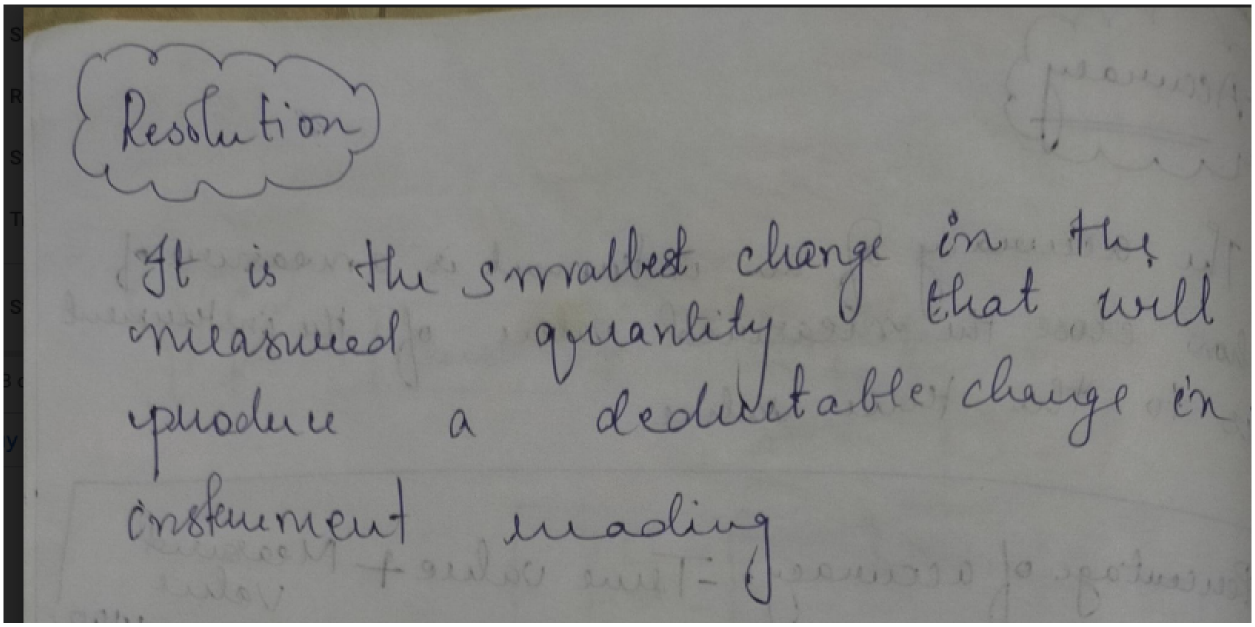
Sensors and Transducers All CT answers

4marks

Explain the following

i) Resolution



Resolution

It is the smallest change in the measured quantity that will produce a dedictable change in instrument reading

ii) Minimum Detectable Signal(MDS)

The minimum detectable signal (MDS) is the smallest signal that a sensor can detect with a specified level of confidence. This value is determined by the sensitivity of the sensor, the noise in the system, and the desired level of confidence in the measurement.

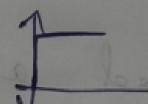
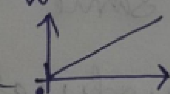
the MDS is important because it determines the ability of the sensor to detect weak signals in the presence of noise. This is particularly important in applications where the signal of interest is very small or the noise level is high, such as in medical imaging or astronomical observations.

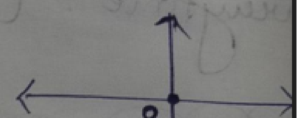
To improve the MDS of a sensor, designers can use a more sensitive sensor, reduce the noise in the system, or increase the signal-to-noise ratio of the measurement.

2) Dynamic Characterisitics of Sensor

II. Dynamic Characterstics

A set of criteria which varies with time is called dynamic characterstics

* Step change 
* Linear change/Ramp 

* Impulse change  
* Sinusoidal change 
* Speed of response
* Fidelity
* Lag
* Dynamic Error

(i) Speed of response

It gives the information about how fast the system reacts to the changes in input.

(ii) Fidelity (without error how a system will output)

It is defined as the degree to which an instrument indicates the changes in the measured variable without dynamic error

(iii) Lag : delay in the response of the system

(iv) Dynamic error : difference b/w true value of the variable to be measured changing with time and the value indicated by the measurement system assuming zero error.

12 marks

1) Explain the working principles of RTD along with the necessary equations and its different types of detail

RTD (Resistance Temperature Detector)

→ The value of resistance changes with change in temperature

$$R_T = R_0(1+\alpha T)$$

↳ Temperature Co-efficient of resistance

+ve temperature co-efficient

PTC - Temp ↑ R ↑

NTC - Temp ↑ R ↓

↓

-ve temperature co-efficient

Mostly platinum

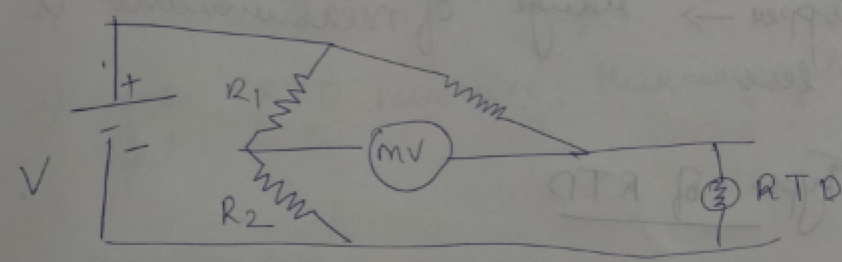
Others are copper, initial

Eg

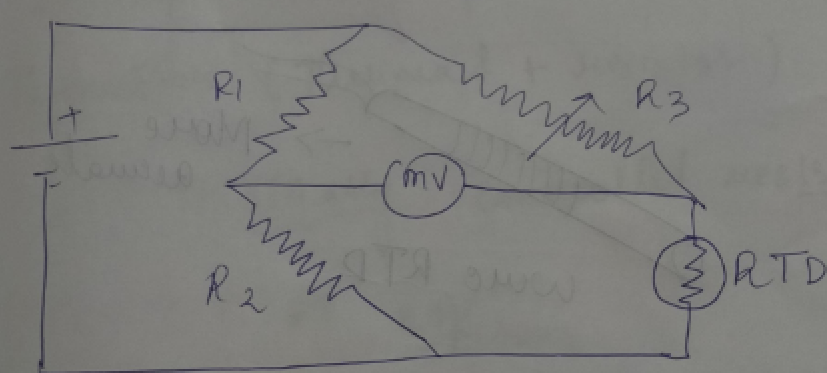
Used in Industries to monitor temperature of stream flowing in a pipeline

* RTD inserted in pipeline

* PT100 ⇒ 0°c → 100 Ω
  1°c → 200 Ω



cheap, simple, but lower accuracy.



Materials used in RTD:

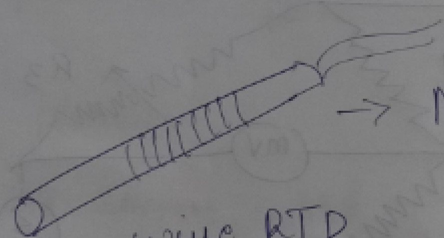
platinum → most common type RTD
→ Excellent corrosion resistance
→ " longterm stability

Nickel → less expensive
→ good corrosion replacement
→ less accuracy

Copper → range of measurement is less

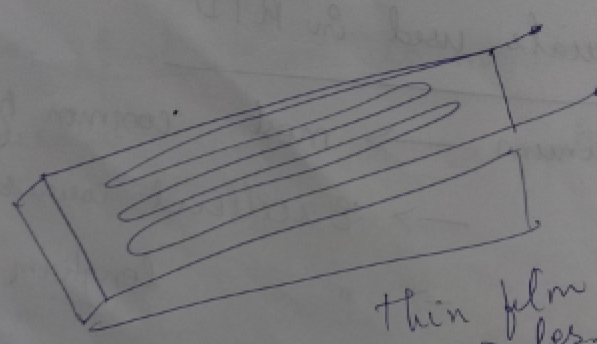
Types of RTD

1) Wire type RTD
2) Film type RTD

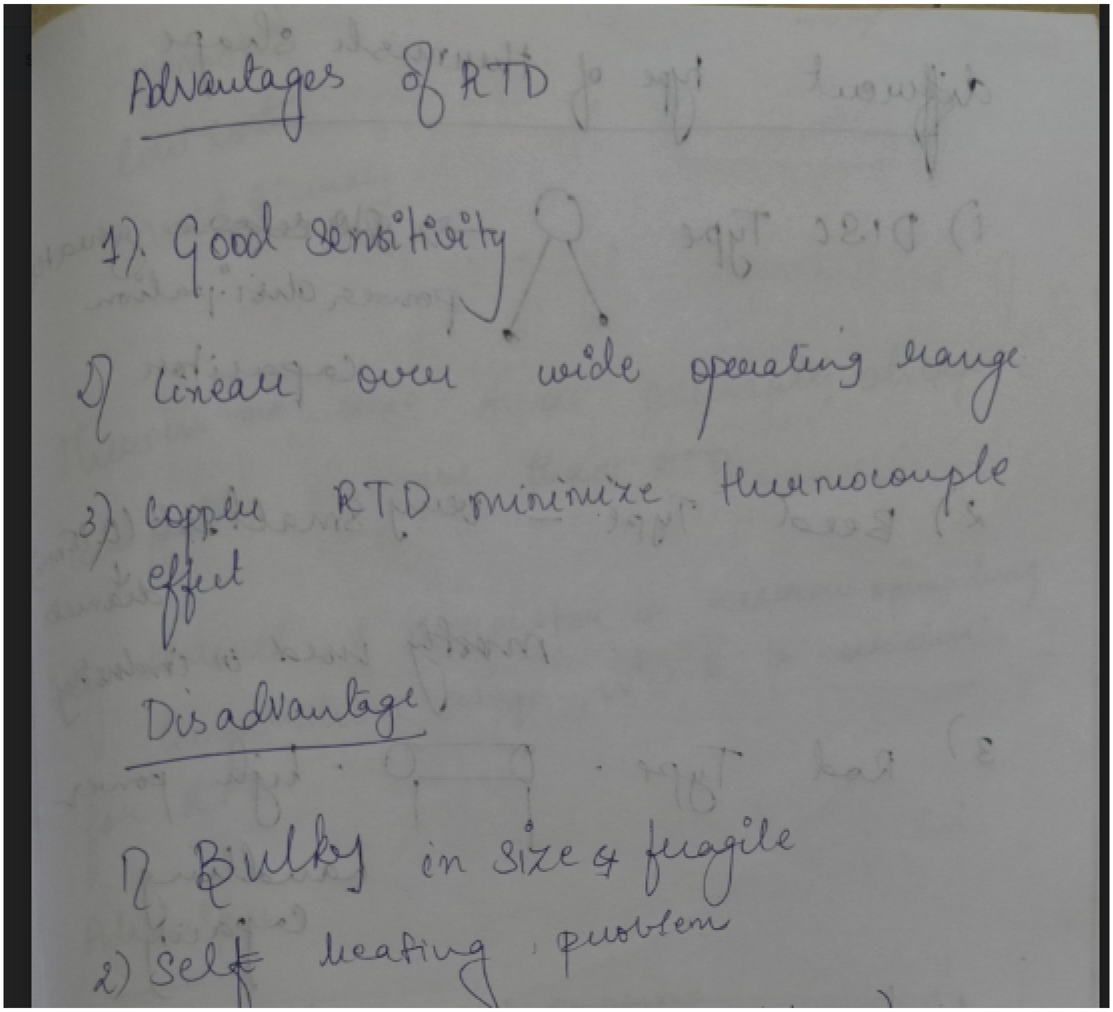


→ More accurate

wire RTD



thin film
→ less accurate
→ less expensive



Advantages of RTD

1). Good sensitivity

2) Linear over wide operating range

3) copper RTD minimize thermocouple effect

Disadvantage

1) Bulky in size & fragile

2) Self heating problem

2) Briefly Describe sensors and classify it based on measurands and technology
A sensor is a device that is used to measure a physical quantity, such as temperature, pressure, or light intensity. Sensors can be classified based on the type of quantity they measure (the measurand) and the technology they use to make the measurement.

Measurand-based classification:

- Temperature sensors: measure temperature
- Pressure sensors: measure pressure
- Light sensors: measure light intensity
- Motion sensors: measure motion or movement
- Chemical sensors: measure the concentration of a chemical species

Technology-based classification:

- Mechanical sensors: use mechanical mechanisms to make the measurement
- Electrical sensors: use electrical signals or currents to make the measurement
- Optical sensors: use light to make the measurement

- Magnetic sensors: use magnetism to make the measurement
- Radiofrequency sensors: use radio waves to make the measurement

These are just some of the ways that sensors can be classified. There are many other types of sensors that measure a wide variety of physical quantities, and the classification methods described here are not exhaustive.

Ct 2

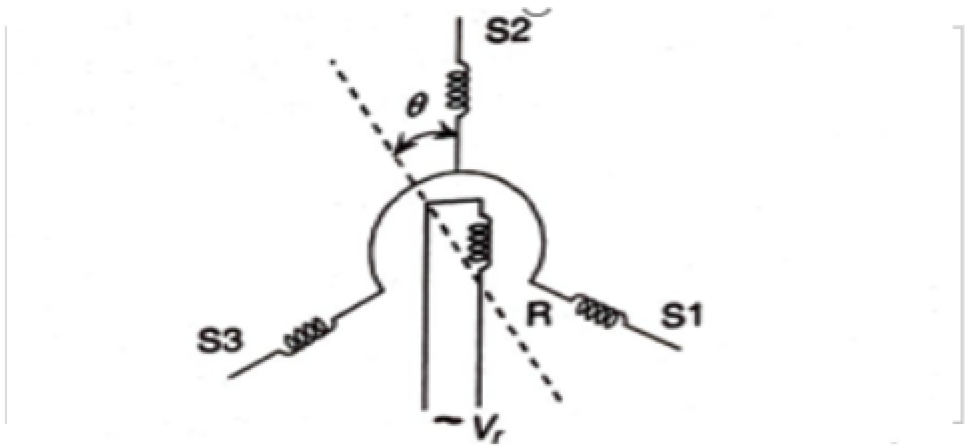
4 marks

1) Write short notes on construction and working of synchros Transducer

Synchros are electromechanical devices which produce an output voltage depending on angular position of the rotor and not on rotor speed and it is different from a DC generator.

Synchros typically consist of a rotor and a stator, with the rotor having three electrical windings and the stator having three pairs of magnetic cores. The rotor and stator are mechanically or electrically coupled, and as the rotor rotates, it generates an electrical signal that is proportional to its position or orientation. This signal can then be transmitted over the mechanical or electrical link to a remote location, where it can be used to control a device or process.

Synchros are highly accurate and reliable, and they are able to transmit signals over long distances without significant loss of signal quality.



2) Explain the Effect of thickness in working of capacivie transducers with necessary equation and diagram.

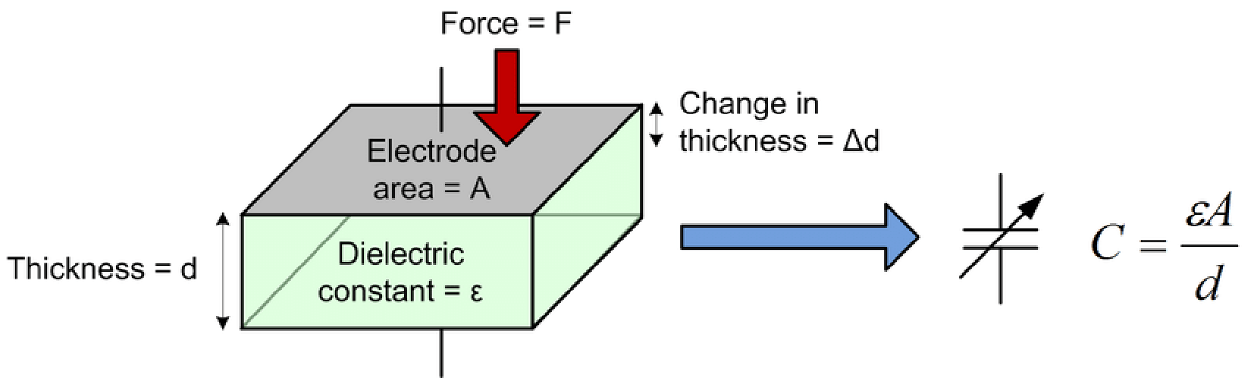
The capacitance of a capacitor is directly proportional to the area of its plates and inversely proportional to the distance between them. This means that, for a given area of the plates, the capacitance will increase as the distance between the plates is reduced. In a capacitive transducer, the thickness of the dielectric material between the plates is a key factor in determining the capacitance of the transducer. As the thickness of the dielectric material is reduced, the capacitance of the transducer will increase.

The relationship between the capacitance and the thickness of the dielectric material can be described by the following equation:

$C = \varepsilon A/t$

where C is the capacitance, ε is the permittivity of the dielectric material, A is the area of the plates, and t is the thickness of the dielectric material.

In practical terms, this means that, for a given area of the plates and permittivity of the dielectric material, the capacitance of the transducer will increase as the thickness of the dielectric material is reduced. This effect can be used to increase the sensitivity of the transducer to changes in the measurand, such as pressure or temperature. However, if the thickness of the dielectric material is reduced too much, the transducer may become unstable or prone to electrical breakdown.



3) How capacitor microphone works. Explain?

A capacitor microphone, also known as a condenser microphone, is a type of microphone that uses a capacitor to convert sound waves into an electrical signal. It consists of two metal plates, one of which is fixed and the other of which is attached to a flexible diaphragm. When sound waves hit the diaphragm, it vibrates, causing the distance between the two plates to change. This changes the capacitance of the capacitor, which in turn generates an electrical signal.

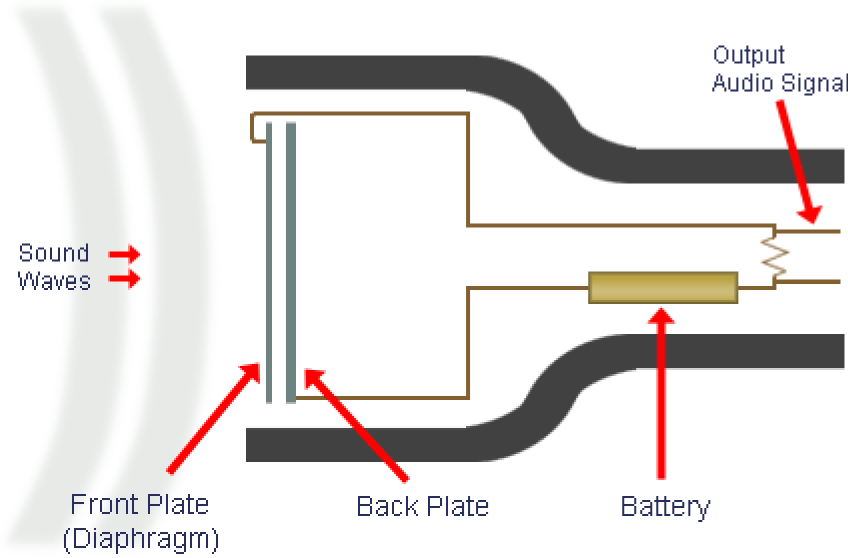
The operation of a capacitor microphone can be explained using the following steps:

- Sound waves hit the diaphragm of the microphone, causing it to vibrate.

The vibration of the diaphragm causes the distance between the two plates of the capacitor to change.

- The change in the distance between the plates changes the capacitance of the capacitor.
- The change in capacitance generates an electrical signal that is proportional to the original sound wave.
- The electrical signal is amplified and sent to a sound system or recording device.

Capacitor microphones are highly sensitive and are able to capture a wide range of frequencies. They are commonly used in applications where high-quality sound recording is required, such as in recording studios and for live music performances.



4) With the help of neat sketch explain the working of pyroelectric thermal sensors?

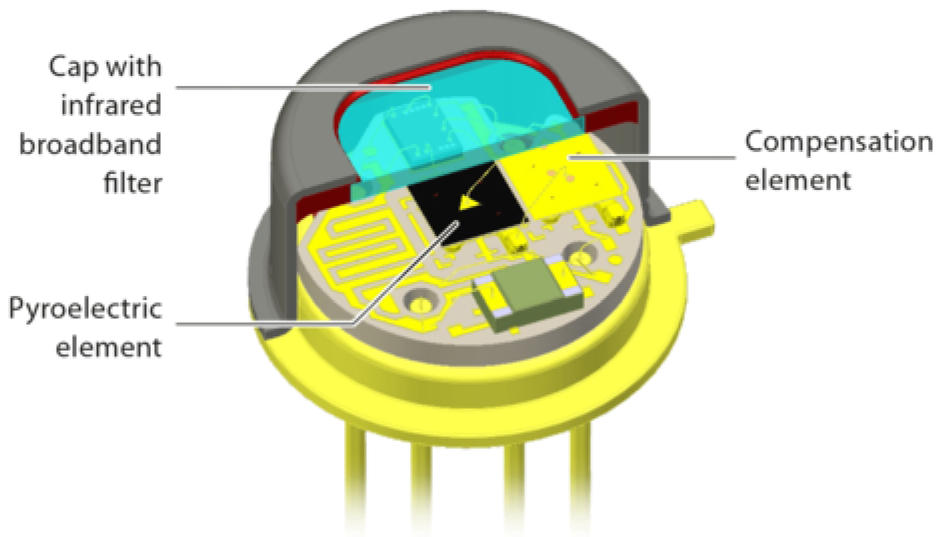
Pyroelectric sensors are generally used to detect weak infrared irradiation due to their high sensitivities at room temperature. However, they require the use of metallic packages to insulate the sensitive element from thermal disturbances and electromagnetic noise, making their miniaturization difficult.

Pyroelectric thermal sensors are sensors that use the pyroelectric effect to detect changes in temperature. The pyroelectric effect is the ability of certain materials to generate an electric charge when they are subjected to a change in temperature. This electric charge can be measured and used to determine the temperature of the material.

The operation of a pyroelectric thermal sensor can be explained using the following steps:

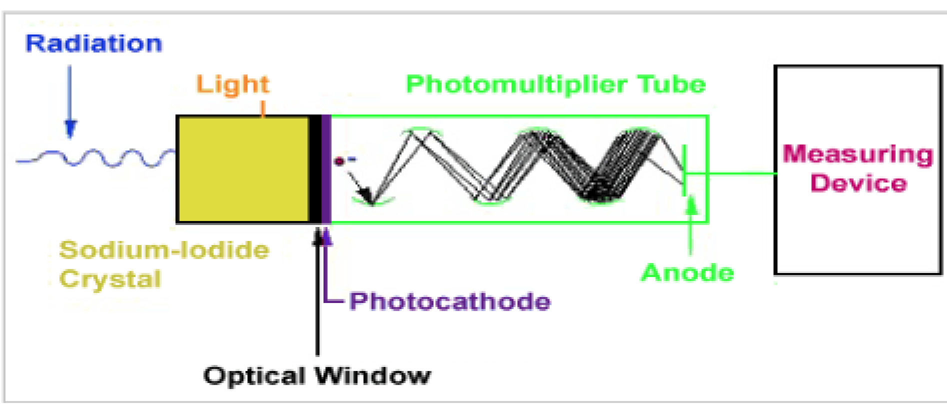
- The sensor consists of a pyroelectric material, such as lithium tantalate or lithium niobate, that is attached to a pair of electrodes.
- The pyroelectric material is maintained at a constant temperature, and no electric charge is generated.
- When the temperature of the pyroelectric material changes, the pyroelectric effect is triggered, and an electric charge is generated.
- The electric charge is measured by the electrodes, and the magnitude of the charge is proportional to the temperature change.
- The measured electric charge is then used to calculate the temperature of the pyroelectric material.
- Pyroelectric thermal sensors are commonly used in applications where high sensitivity and fast response time are required, such as in

temperature control systems and in thermal imaging cameras. They are also used in medical imaging, security systems, and other applications where temperature detection is important.



5) Write short note about scintillation detectors.
Certain single crystals of organic or inorganic materials, activated glasses/liquids or plastic fluors have the property that when they receive high energy radiation, they produce very short duration light pulses or flashes called “Scintillations”.

These materials are known as Scintillators.



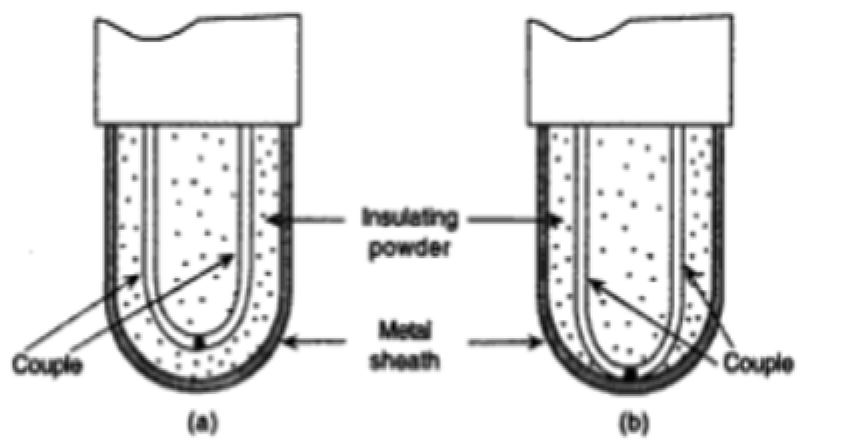
Scintillation detectors are sensors that use scintillating materials to detect and measure ionizing radiation. Scintillation is the process by which certain materials emit light when they are excited by ionizing radiation. Scintillation detectors consist of a scintillating material, such as sodium iodide or plastic, that is attached to a photosensitive element, such as a photomultiplier tube or a photodiode. When ionizing radiation hits the scintillating material, it causes the material to emit light, which is then detected by the photosensitive element. The amount of light detected is proportional to the amount of ionizing radiation that was absorbed by the scintillating material.

Scintillation detectors are commonly used in applications where the detection and measurement of ionizing radiation is important, such as in medical imaging, nuclear power plants, and radiation detection systems. They are highly sensitive and able to detect a wide range of ionizing radiation, including alpha particles, beta particles, and gamma rays.

6) Draw and explain the construction of thermocouple?

Thermocouple

- A thermocouple is a **device for measuring temperature**.
- It comprises two dissimilar metallic wires joined together to form a junction.
- When the junction is heated or cooled, a small voltage is generated in the electrical circuit of the thermocouple which can be measured, and this corresponds to temperature.



lg. 3.28 The MI thermocouples: (a) the usual design, and (b) design with the junction in contact with the sheath.

A thermocouple is a temperature sensor that consists of two wires made of different types of metal. The two wires are joined at one end to form the sensing junction, and the other end is connected to a measurement instrument, such as a thermometer or a temperature controller. The principle behind the operation of a thermocouple is the fact

that two wires made of different metals will produce a voltage when they are at different temperatures. This voltage is known as the thermoelectric voltage or the Seebeck voltage, and it is proportional to the temperature difference between the two wires.
The construction of a thermocouple typically involves the following steps:

- Two wires made of different types of metal are selected. The most common types of metals used in thermocouples are iron, nickel, and copper.
- The two wires are joined at one end to form the sensing junction. This is typically done by welding or brazing the wires together.
- The other end of the wires is connected to a measurement instrument, such as a thermometer or a temperature controller.
- The sensing junction of the thermocouple is placed in the area where the temperature is to be measured.
- The measurement instrument measures the thermoelectric voltage generated by the thermocouple and uses this information to calculate the temperature of the sensing junction.

Thermocouples are widely used in a variety of applications because they are simple to construct, reliable, and able to measure a wide range of temperatures. They are commonly used in industrial, scientific, and medical applications.

10marks

1) With necessary equations deduce the characteristic transfer matrix equation for electromagnetic transducers. *

The characteristic transfer matrix equation for electromagnetic transducers describes the relationship between the input and output of the transducer. This equation is commonly used to analyze the performance of electromagnetic transducers, such as microphones and speakers, and to design and optimize these devices.

The characteristic transfer matrix equation for an electromagnetic transducer is given by:

$H(\omega) = Z1(\omega) / Z2(\omega)$

where $H(\omega)$ is the transfer function of the transducer, $Z1(\omega)$ is the input impedance of the transducer, and $Z2(\omega)$ is the output impedance of the transducer. The transfer function describes how the transducer responds to an input signal, and it is typically expressed as a complex number. The input and output impedances are also complex numbers that describe the electrical properties of the transducer.

The characteristic transfer matrix equation can be used to analyze the frequency response of the transducer, which is the relationship between the input and output amplitudes as a function of frequency. This can be done by evaluating the transfer function at various frequencies and plotting the resulting amplitudes on a graph. The frequency response of the transducer can then be used to predict its performance in different applications and to optimize its design.

2) What is meant by LVDT and explain its construction and working with the help of the a diagram?

Linear Variable Differential Transformer (LVDT).

→ Modified version of plunger type sensors

→ arranged with two sets of coils, one as the primary and the other set as secondary having two coils connected differentially for providing the o/p.

→ The coupling between primary and secondaries varies with the core plunger moving linearly.

→ An alternating supply V_i and frequency f is impressed across the primary coil and depending on the position of the core w.r.to primary and two secondaries, an o/p voltage V_o is obtained from the secondaries.

→ The induction in one secondary coil, according to the law is

$$V_{os} = -\frac{n\,d\phi}{dt} = -M\frac{di_p}{dt} \quad -(1)$$

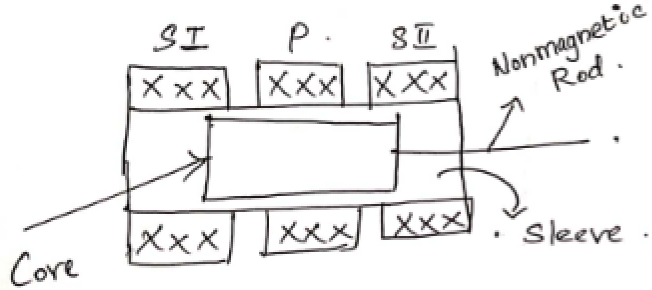
n → no of turns in the coil of secondary

ϕ → magnetic flux

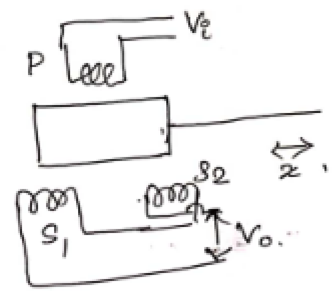
M → Mutual Inductance b/w primary & secondary

i_p → primary current.

Scheme of an LVDT



equivalent model



For the two coils diffeerentially connected,

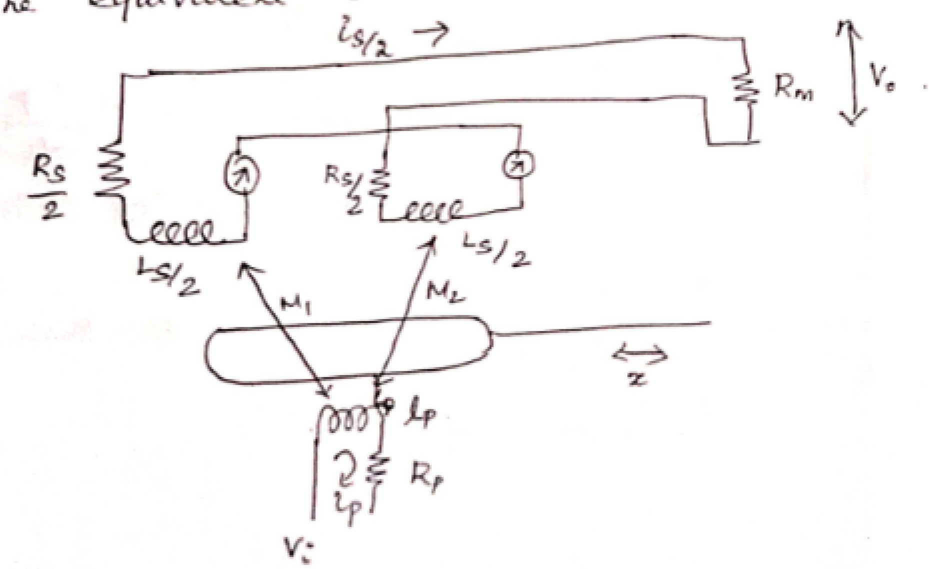
$$V_o = V_{os1} - V_{os2} = (M_1 - M_2)\frac{di_p}{dt} \quad -②$$

Both M_1 & M_2 being functions of x, $M_1 - M_2 = M(x)$. If the function is linear over a certain range, $M(x) = kx$ so that

$$x = \frac{V_o}{k\left(\frac{di_p}{dt}\right)} \quad —③$$

Loss components are to be considered for obtaining o/p V_o per unit displacement of the core. ~~The~~ When arranged in a bridge in a differential manner, loss components be compensated by appropriate circuit components.

The equivalent circuit of LVDT is



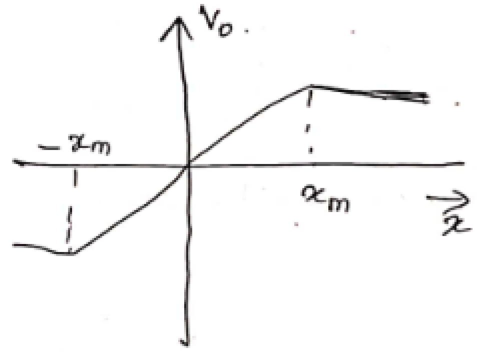
Solving for the magnitude ratio per unit displacement $\left|\frac{V_o}{V_i}\right| / x$, angle by which the o/p voltage V_o, lags the i/p voltage V_i at $f = \frac{\omega}{2\pi}$ and if the meter load is R_m, we get.

$$\left|\frac{V_o}{V_i}\right| \frac{1}{x} = \frac{K \omega R_m / \{(R_s + R_m) R_p\}}{\sqrt{[\{1 - \omega^2(\tau_m^2 + \tau_p \tau_s)\}^2 + \omega^2(\tau_p + \tau_s)^2]}}$$

$$\phi = 90^\circ - \tan^{-1} \frac{\omega(\tau_p + \tau_s)}{1 - \omega^2(\tau_m^2 + \tau_p \tau_s)}$$

Where $\tau_m = \frac{M_1 - M_2}{\sqrt{(R_s + R_m) R_p}}$ $\quad \tau_p = \frac{L_p}{R_p}$ $\quad \tau_s = \frac{L_s}{R_s + R_m}$

The phase rectified secondary o/p voltage V_o with x is shown in fig.



For a given V_i, linear range limits is are indicated by $\pm x_m$. This limitation is inherent in all differential systems.

An LVDT (Linear Variable Differential Transformer) is a type of transducer that is used to measure linear displacement. It consists of a primary coil, a secondary coil, and a movable core that is attached to the object whose displacement is being measured. The operation of an LVDT is based on the principle of electromagnetic induction, in which a changing magnetic field generates an electrical current in a coil.

The construction of an LVDT typically involves the following components:

- A primary coil: This is a coil of wire that is connected to an AC voltage source. When the AC voltage is applied to the primary coil, it generates a changing magnetic field.
- A secondary coil: This is a coil of wire that is wound around a central core, which is the movable part of the LVDT. The secondary coil is positioned next to the primary coil, and it is connected to an output amplifier.
- A central core: This is the movable part of the LVDT, and it is attached to the object whose displacement is being measured. The core is made of a ferromagnetic material, such as iron or steel, and it is positioned between the primary and secondary coils.
- An output amplifier: This is an electronic circuit that is connected to the secondary coil and is used to amplify the output signal of the LVDT.

The working of an LVDT can be explained using the following steps:

1. An AC voltage is applied to the primary coil, which generates a changing magnetic field.
2. The changing magnetic field induces an electrical current in the secondary coil.
3. As the core moves, the amount of electrical current in the secondary coil changes, which is detected by the output amplifier.
4. The output amplifier amplifies the detected current and produces an output signal that is proportional to the displacement of the core.

LVDTs are widely used in a variety of applications where linear displacement needs to be measured, such as in industrial machinery and in scientific instruments. They are highly accurate and reliable, and they are able to measure small displacements with high precision.

3) Discuss in detail about the various types of thermocouples based on material used and temperature of operation?

Thermocouples are temperature sensors that consist of two wires made of different types of metal. The temperature of the sensing junction, where the two wires are joined, is determined by measuring the thermoelectric voltage, or Seebeck voltage, generated by the wires. The type of thermocouple used depends on the temperature range to be measured and the materials used for the wires.

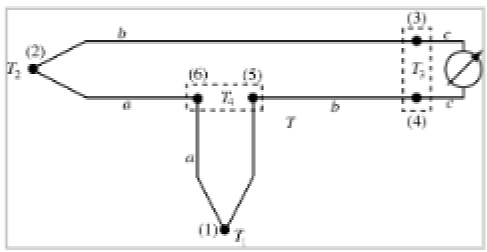
There are several types of thermocouples based on the materials used for the wires and the temperature range of operation. Some of the most common types are:

- Iron-constantan thermocouple: This type of thermocouple uses iron and constantan as the materials for the wires. It is commonly used to measure temperatures in the range of -200°C to 600°C.
- Chromel-alumel thermocouple: This type of thermocouple uses chromel and alumel as the materials for the wires. It is commonly used to measure temperatures in the range of 0°C to 1200°C.
- Copper-constantan thermocouple: This type of thermocouple uses copper and constantan as the materials for the wires. It is commonly used to measure temperatures in the range of -200°C to 400°C.
- Platinum-rhodium thermocouple: This type of thermocouple uses platinum and rhodium as the materials for the wires. It is commonly used to measure temperatures in the range of 0°C to 1600°C.

In addition to these types, there are other specialized thermocouples that are used in specific applications, such as in high-temperature or high-pressure environments. These thermocouples may use other combinations of materials or have different temperature ranges of operation.

Thermocouples: connection

- Based on the thermoelectric laws:
- Usually connected in pairs
  - One junction for sensing
  - One junction for reference
  - Reference temperature can be lower or higher than sensing temperature



Thermocouples (cont.)

- Any connection in the circuit between dissimilar materials adds an emf due to that junction.
- Any pair of junctions at identical temperatures may be added without changing the output.
  - Junctions 3 and 4 are identical (one between material *b* and *c* and one between material *c* and *b* and their temperature is the same. No net emf due to this pair
  - Junctions (5) and (6) also produce zero field

- Each connection adds two junctions.
- The strategy in sensing is:
  - For any junction that is not sensed or is not a reference junction:
    - Either each pair of junctions between dissimilar materials are held at the same temperature (any temperature) or:
    - Junctions must be between identical materials.
    - Also: use unbroken wires leading from the sensor to the reference junction or to the measuring instrument.
    - If splicing is necessary to extend the length, identical wires must be used to avoid additional emfs.

Connection without reference

- The connection to a voltmeter creates two junctions
  - Both are kept at temperature T_1
  - Net emf due to these junctions is zero
  - Net emf sensed is that due to junction (2)
  - This is commonly the method used

4) Explain the construction and working of semiconductor-based sensor for measuring temperature

Semiconductor-based sensors are sensors that use semiconductor materials to measure temperature. These sensors are commonly used in a wide range of applications, such as in automotive, industrial, and consumer electronics.

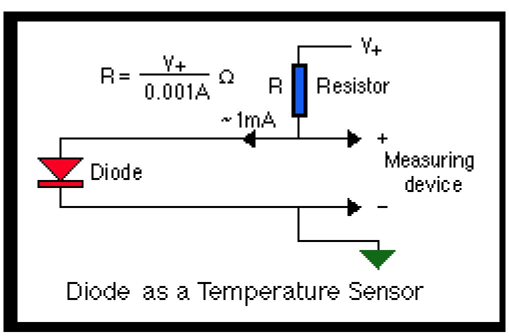
The construction of a semiconductor-based temperature sensor typically involves the following steps:

- A semiconductor material, such as silicon or germanium, is selected based on the temperature range to be measured.
- The semiconductor material is doped with impurities, such as phosphorus or boron, to create a P-N junction.
- The P-N junction is connected to a circuit that measures the voltage across the junction.
- The temperature of the semiconductor material is measured by detecting the change in voltage across the P-N junction.

The working of a semiconductor-based temperature sensor can be explained using the following steps:

- The P-N junction is maintained at a constant temperature, and no voltage is detected across the junction.
- When the temperature of the semiconductor material changes, the voltage across the P-N junction changes due to the temperature-dependent behavior of the semiconductor material.
- The change in voltage is detected by the circuit, and the magnitude of the voltage is proportional to the temperature change.
- The measured voltage is then used to calculate the temperature of the semiconductor material.

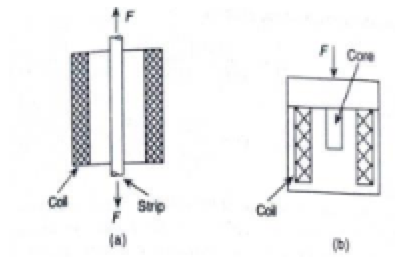
Semiconductor-based temperature sensors are highly accurate and have fast response times. They are commonly used in applications where precise temperature measurement is required, such as in temperature control systems and in medical devices.



Ct 3:
4marks
1) Illustrate the three basic types of magneto elastic sensors designed based on the principle of villari effect with neat sketch and give its equation.

VILLARI EFFECT

- Based on Villari effect, **three basic types** of magnetoelastic sensors may be designed.

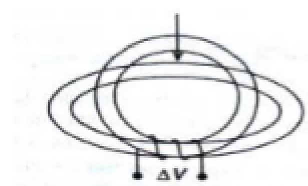


TYPE 1:

The mechanical loading is unidirectional so as to produce compression or tension and this changes the inductance or permeability with the specimen having predefined magnetic flux path, as in choke or coil type design.

TYPE 2:

- Mechanical loading changes the flux in 2 directions or in a plane as in circular rings or laminated cores.
- Circular ring is deformed into elliptical form and change in inductance of the ring or change in voltage in the secondary winding ΔV gives the value of the load.
- In case of laminated core load cells, isotropic magnetic materials are used which becomes anisotropic under stress due to varying deformation in longitudinal and transverse directions relative to load axis and change in voltage can be derived in ring type design.



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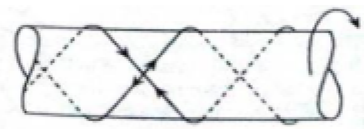


g. 4.8 Stress directions in hollow cylindrical shaft.

TYPE 3:

- Loading changes the flux spatially, that is 3 dimensionally in torque transducers for shafts.
- If the shaft material does not have the requisite magnetic properties such as magnetostriction, an additional magnetic coating on the shaft surface produces the desired mechanical stress on this surface that is to be measured.
- In solid or hollow cylindrical shaft, stress develops in two principal orthogonal directions, one compressive and other tensile, each at angle ±45° with shaft axis in screw like fashion around the shaft (as shown in fig).

- For a hollow shaft of inner and outer diameters Di and Do, the angle of torsion ϕ, the legth of shaft l, torque produced is given by

$$T = \frac{C\pi\phi}{32l}(D_o^4 - D_i^4)$$

The n ximum stress on the surface of the shaft is

$$S_m = \frac{16D_oT}{\pi(D_o^4 - D_i^4)}$$

and maximum strain ε_m is

$$\varepsilon_m = \frac{S_m}{Y}(1 + \nu) = \frac{16D_o(1 + \nu)}{\pi(D_o^4 - D_i^4)Y}T$$

where ν = Poisson ratio.

2) List out the (i) the preparation steps involved in thick film sensors
(ii) Techniques involved in preparation of thin film sensor

8.2.1 Thick Film Sensors

Thick film deposition is a mature technique and there has not been substantial improvement whilst thin films are being developed almost at the same pace as microelectronics incorporating latest technology. It is to be noted that thick film process had been in use for producing capacitor, resistor, and conductors—and has subsequently been adopted in sensor development. The processing of a sensor can be expressed schematically as

Step 1: Selection and preparation of a substrate.

Step 2: Preparation of the initial coating material in paste or paint form.

Step 3: Pasting or painting the substrate by the coating material or screen printing it.

Step 4: Firing the sample produced in step 3 in an oxidising atmosphere at a programmed temperature format.

Thick film sensors are sensors that use thick film technology to measure a physical quantity, such as temperature, pressure, or strain. Thick film sensors are commonly used in a wide range of applications, such as in automotive, industrial, and medical devices.

The preparation of a thick film sensor typically involves the following steps:

1. A substrate material, such as ceramic or glass, is selected based on the application and the operating environment of the sensor.
2. The substrate is cleaned and prepared to ensure that it is free of contaminants and defects.
3. A layer of conductive material, such as gold or silver, is deposited on the substrate to form the electrodes of the sensor.
4. A layer of insulating material, such as glass or ceramic, is deposited on the electrodes to isolate them from each other.
5. A layer of thick film material, such as a resistive or piezoelectric material, is deposited on the insulating layer. This layer is the active sensing element of the sensor.
6. The thick film material is patterned and etched to form the desired sensor geometry, such as a resistor or a capacitor.
7. The sensor is tested to ensure that it is functioning properly and meets the required specifications.

Once the preparation of the thick film sensor is complete, it is ready to be integrated into a device or system for measurement of the desired physical quantity.

8.2.2 Thin Film Sensors

Thin film sensor processing differs from thick film technology mainly in the film deposition techniques. This technology is similar to that used in silicon micromechanics. A number of techniques are used for thin film deposition, such as:

(a) Thermal evaporation
    (i) resistive heating
    (ii) electron beam heating

(b) Sputter deposition
    (i) DC with magnetron
    (ii) RF with magnetron

(c) Chemical vapour deposition (CVD)

(d) Plasma enhanced chemical vapour deposition (PECVD)

(e) Metallo-organic deposition (MOD)

(f) Langmuir–Blodgett technique of monolayer deposition.

Of these, the thermal evaporation and sputter deposition are decades old. However, in the sputter deposition technique, magnetron sputtering is an improved form where a magnetic field perpendicular to the applied electric field is applied. This increases the ionization probability of the electrons as the Lorentz force **E** × **B** restricts the primary electrons near the cathode. As a result, sputtering efficiency is also enhanced.

Thin film sensors are sensors that use thin film technology to measure a physical quantity, such as temperature, pressure, or strain. Thin film sensors are commonly used in a wide range of applications, such as in automotive, industrial, and medical devices.

The preparation of a thin film sensor typically involves the following steps:

1. A substrate material, such as glass or silicon, is selected based on the application and the operating environment of the sensor.
2. The substrate is cleaned and prepared to ensure that it is free of contaminants and defects.
3. A layer of thin film material, such as a metallic or semiconductor material, is deposited on the substrate using a technique such as sputtering or evaporation. This layer is the active sensing element of the sensor.
4. The thin film material is patterned and etched to form the desired sensor geometry, such as a resistor or a capacitor.
5. The sensor is tested to ensure that it is functioning properly and meets the required specifications.

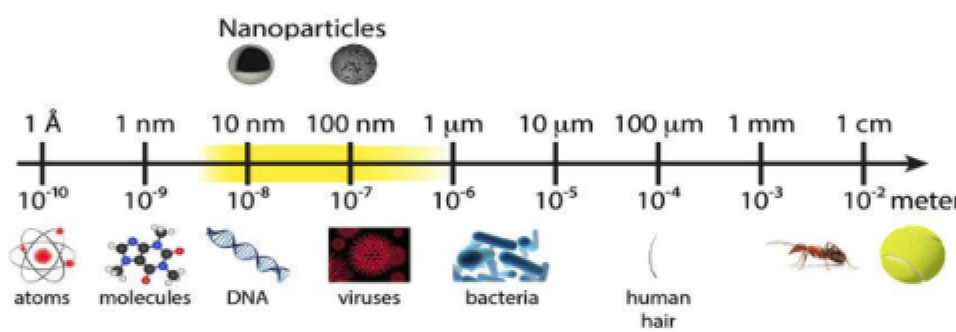
Once the preparation of the thin film sensor is complete, it is ready to be integrated into a device or system for measurement of the desired physical quantity.

3) discuss the need of nano sensors and explain proximity nano sensor with neat sketch.

Nano Sensors

- Particles that are smaller than the characteristic lengths associated with the specific phenomena often display new chemistry and new physics that lead to new properties that depend on size
- When the size of the structure is decreased, surface to volume ratio increases considerably and the surface phenomena predominate over the chemistry and physics in the bulk
- The reduction in the size of the sensing part and/or the transducer in a sensor is important in order to better miniaturize the devices
- Science of nano materials deals with new phenomena, and new sensor devices are being built that take advantage of these phenomena
- Sensitivity can increase due to better conduction properties, the limits of detection can be lower, very small quantities of samples can be analysed, direct detection is possible without using labels, and some reagents can be eliminated.

SIZE AND COMPATIBILITY

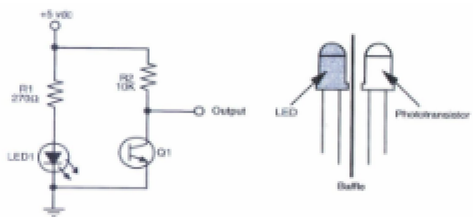


The need for nano sensors arises from the fact that many phenomena and processes occur at the nanoscale, and these phenomena and processes cannot be accurately measured using conventional sensors. For example, in medicine, the detection and diagnosis of diseases often require measurements of biological molecules and processes at the nanoscale. In environmental monitoring, the detection of pollutants and contaminants often requires measurements of chemical and physical quantities at the nanoscale. In industrial processes, the control and optimization of processes often require measurements of physical quantities at the nanoscale.

Nano sensors are able to provide the high sensitivity and precision needed to accurately measure physical, chemical, and biological quantities at the nanoscale. They are also able to operate in challenging environments, such as in the human body or in harsh industrial environments. This makes them essential tools for a wide range of applications where accurate measurement at the nanoscale is required.

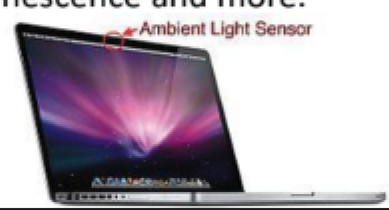
Optical Sensors- Proximity Sensors

- ✓ Proximity sensors are designed for use in detecting the presence of an object or motion detection in various industrial, mobile, electronic appliances and retail automations.
- ✓ Examples of proximity sensor usage include the detection of an out-of-paper condition in a printer or a mobile phone screen that dims to save battery life when placed near a face.

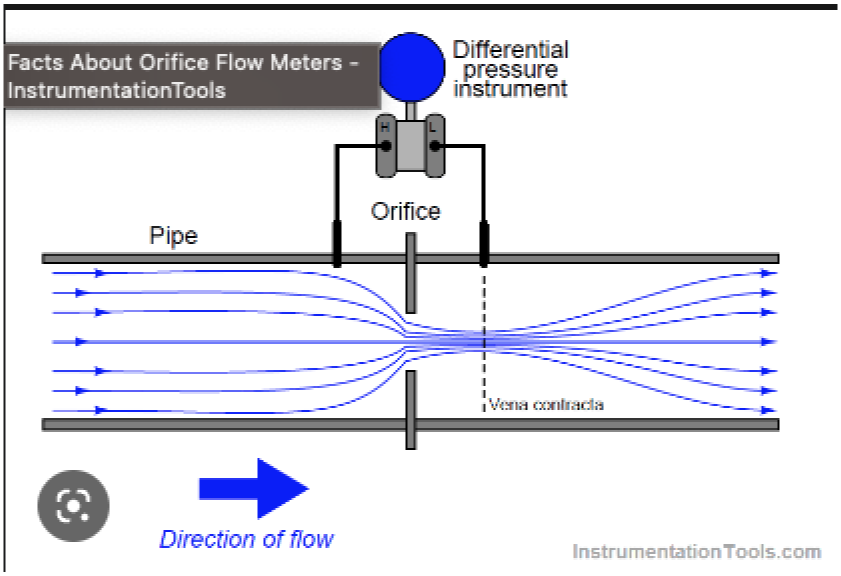


The basic design of the infrared proximity sensor.

- ✓ Ambient light sensors provide precise light detection for a wide range of ambient brightness and are commonly used in LCD backlight control in mobile phones, LCD TV/panel, and notebook applications.
- ✓ One way to convert the optical signal is by using electro-optical sensors - electronic detectors that convert light, or a change in light, into an electronic signal. Light has many components that can be sensed, such as the wavelength, the intensity, the polarization and the phase. The interaction of light with matter can be quantified by measuring absorbance, reflectance, luminescence and more.



4) Discuss the construction and working of flow meter using (I) orifice plate and (ii) Venturimeter


Facts About Orifice Flow Meters - InstrumentationTools
Differential pressure instrument
H
L
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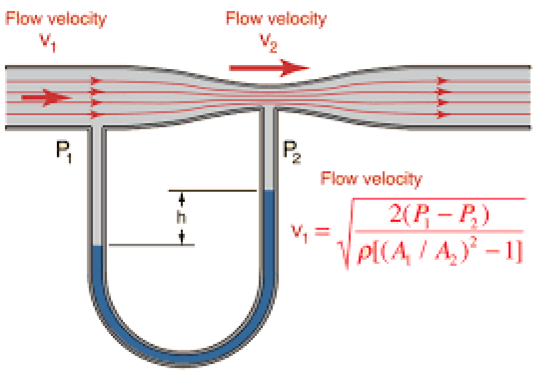
Direction of flow
InstrumentationTools.com


Flow velocity v_1
Flow velocity v_2
P_1
P_2
h
Flow velocity
$v_1 = \sqrt{\frac{2(P_1 - P_2)}{\rho[(A_1 / A_2)^2 - 1]}}$

A flow meter is a device used to measure the flow rate of a fluid, such as a gas or a liquid. There are several different types of flow meters, each using a different principle of operation. Two common types of flow meters are the orifice plate flow meter and the venturimeter.

The construction of an orifice plate flow meter typically involves the following steps:

1. A pipe, through which the fluid is flowing, is selected based on the operating conditions and the type of fluid.
2. An orifice plate, which is a thin metal plate with a hole in the center, is inserted into the pipe. The orifice plate is typically made of stainless steel or another corrosion-resistant material.
3. Two pressure taps, one on either side of the orifice plate, are installed in the pipe to measure the pressure of the fluid.
4. The pressure taps are connected to a differential pressure transmitter, which measures the difference in pressure across the orifice plate.
5. The differential pressure transmitter is connected to a flow meter, which calculates the flow rate of the fluid based on the measured pressure difference and the known geometry of the orifice plate.

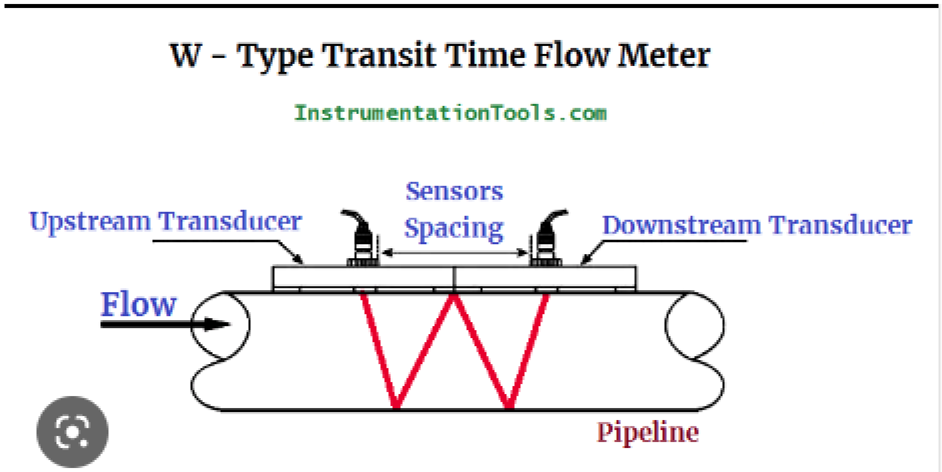
The working of an orifice plate flow meter can be explained using the following steps:

1. The fluid flows through the pipe and encounters the orifice plate, which creates a constriction in the flow.
2. The constriction in the flow causes a pressure drop across the orifice plate, which is measured by the pressure taps.
3. The differential pressure transmitter converts the measured pressure difference into an electrical signal, which is sent to the flow meter.
4. The flow meter uses the known geometry of the orifice plate and the measured pressure difference to calculate the flow rate of the fluid.

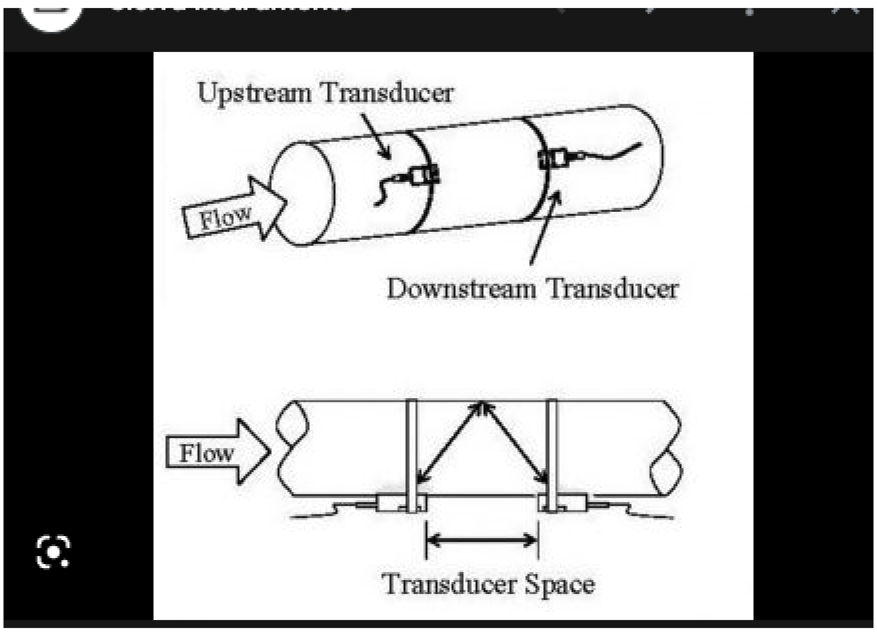
The construction and working of a venturimeter are similar to those of an orifice plate flow meter. The main difference is that a venturimeter uses a converging-diverging nozzle, instead of an orifice plate, to create the constriction in the flow. This causes a pressure drop across the nozzle, which is measured by pressure taps and used to calculate the flow rate

5) With a neat sketch, discuss why Transit-time flow meters are better that ultrasonic flow meter. Give the flow rate equation for both type.

Transit-time flow meters



Ultrasonic flow meter



Transit-time flow meters and ultrasonic flow meters are both types of flow meters that use ultrasonic waves to measure the flow rate of a fluid. However, transit-time flow meters are generally considered to be more accurate and reliable than ultrasonic flow meters. This is because transit-time flow meters use the difference in transit time of ultrasonic waves traveling in opposite directions, whereas ultrasonic flow meters use the average transit time of ultrasonic waves traveling in one direction.

The flow rate equation for a transit-time flow meter is given by:

$$Q = V * A * \Delta t / 2$$

where Q is the flow rate, V is the velocity of the fluid, A is the cross-sectional area of the flow meter, and Δt is the difference in transit time of the ultrasonic waves traveling in opposite directions.

The flow rate equation for an ultrasonic flow meter is given by:

$$Q = V * A * t$$

where Q is the flow rate, V is the velocity of the fluid, A is the cross-sectional area of the flow meter, and t is the average transit time of the ultrasonic waves traveling in one direction.

The main advantage of transit-time flow meters over ultrasonic flow meters is that they are more accurate. This is because the difference in transit time of ultrasonic waves traveling in opposite directions is less affected by noise and other sources of error than the average transit time of ultrasonic waves traveling in one direction. This makes transit-time flow meters more suitable for applications where high accuracy is required, such as in the oil and gas industry.

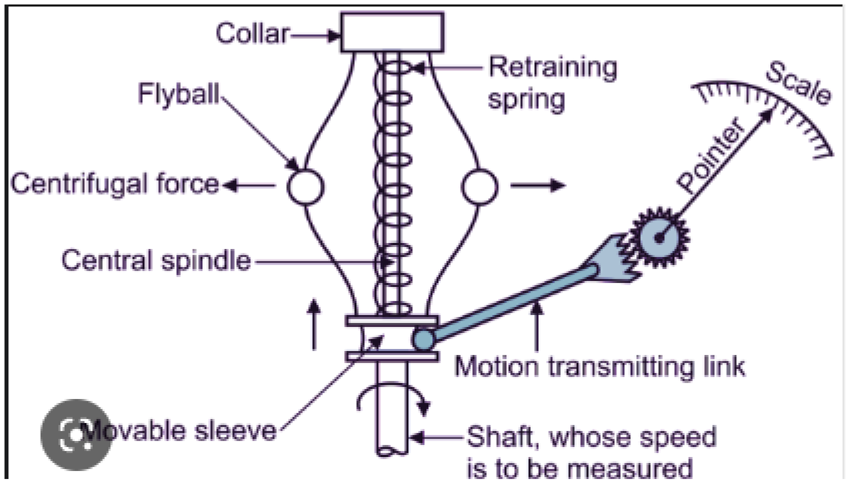
6) What are the types of mechanical Tachometer? Explain Centrifugal tachometer.

A tachometer is a device used to measure the speed of a rotating object, such as a motor or a shaft. There are several different types of tachometers, each using a different principle of operation. Some of the most common types of tachometers are:

- Contact tachometers: These tachometers use physical contact with the rotating object to measure its speed. They typically use a spinning wheel or a rotating blade to touch the object and measure its speed by counting the number of rotations per unit time.
- Optical tachometers: These tachometers use a light source and a photoelectric sensor to measure the speed of the rotating object. They typically use a light-emitting diode (LED) as the light source and a photodiode or a phototransistor as the sensor. The light source is directed at the rotating object, and the sensor detects the change in light intensity caused by the rotation.
- Laser tachometers: These tachometers use a laser beam and a photodetector to measure the speed of the rotating object. They typically use a laser diode as the light source and a photodiode or a phototransistor as the sensor. The laser beam is directed at the rotating object, and the sensor detects the change in light intensity caused by the rotation.

In addition to these types, there are other specialized tachometers that are used in specific applications, such as in high-speed or high-precision environments. These tachometers may use other principles of operation or have different features to suit the specific requirements of the application.

Centrifugal tachometer



A centrifugal tachometer is a type of tachometer that uses the centrifugal force of a rotating object to measure its speed. It consists of a rotating element, such as a flywheel or a rotor, that is attached to the object to be measured. The centrifugal force generated by the rotation of the element causes a corresponding displacement of a pointer or a dial, which is used to measure the speed of the object.

The working of a centrifugal tachometer can be explained using the following steps:

1. The rotating element is attached to the object to be measured, such as a motor shaft or a turbine blade.
2. The rotation of the object causes the rotating element to spin, generating a centrifugal force.
3. The centrifugal force causes a corresponding displacement of the pointer or the dial, which is proportional to the speed of the object.
4. The displacement of the pointer or the dial is measured using a scale or a dial, and the speed of the object is calculated based on the measured displacement and the known geometry of the tachometer.

Centrifugal tachometers are commonly used in applications where direct contact with the rotating object is not possible or desirable. They are also used in applications where high accuracy and precision are required, such as in turbine and engine testing.

10marks

1) Explain Hall effect with necessary Equation.

Hall effect

- Its also called as Galvanomagnetic effect sensor.

- Observed in metals and semiconductors.

- When a current is sent through a very long strip of extrinsic homogenous semiconductor in the x direction and across the plane xy perpendicular to it, a magnetic field is applied to produce a flux density Bz, then an electric field Ey in the direction of y is produced which is called Hall field.

Cont…

- With electrodes across the strip in y direction, a voltage VH called the Hall voltage, can be collected with approximately is given by

$$V_H \approx B_z I_x \tag{4.33}$$

- Galvanomagnetic effects, arise because of Lorentz force on the charge carrier transport phenomena in condensed medium. Lorentz force is

$$\mathbf{F} = e\mathbf{E} + e[\mathbf{v} \times \mathbf{B}] \tag{4.34}$$

where

e is the charge of the carrier,
E is the electrical field,
v is carrier velocity, and
B is the magnetic induction.

If **J** is the total current density, then the carrier transport equation is

Cont…

- μH – Hall mobility
- Jo- current density due to electric field E
- Carrier concentration Δn
- A magnetic field also affect the electric field potential and carrier concentration and hence it is not justified to write J=J0 and B=0

$$\mathbf{J} = \mathbf{J}_0 + \mu_H[\mathbf{J}_0 \times \mathbf{B}] \tag{4.35}$$

Cont…

- σ- conductivity
- D – diffusion coefficient

$$J_0 = \sigma E - eD\nabla n \qquad (4.36)$$

- Drift – Ist term, Diffusion –IInd term, transverse transport caused by magnetic field – IInd term of eq. 4.35

Cont…

- The transport coefficients μH, σ, D are dependent on electric and magnetic field and are determined by carrier scattering process.
- Hall mobility μH is the product of drift mobility of the carrier μ and hall scattering factor r, which is given by appropriate ratio of relaxation time averages of their energy distribution, thus

$$r = \frac{\langle \tau^2 \rangle}{\langle \tau \rangle^2} \qquad (4.37a)$$

$$\mu_H = r\mu \qquad (4.37b)$$

2) Explain in detail the construction of Bucket Coveyor and Slat conveyor.

CONVEYING SYSTEMS

A **conveyor system** is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy or bulky materials.

Gravity wheel conveyor

- These can be used as pusher units set horizontally or inclined for gravity flow.
- They are highly standardized and are usually sold in 1.5- or 3-m (5- or 10-ft) sections; special lengths are available at extra charge
- Gravity skate wheel will convey lightweight loads that have firm flat bottoms such as cartons, totes, cases, etc. Skate wheel conveyor "rolls" more easily than roller conveyor allowing for lighter packages and less slope.
- Since wheel units are relatively light, they have relatively low inertia, and loads may be started and stopped quite easily
- Metal plates or projecting hardwood slats are commonly used as stops on conveyor lines.

Roller conveyor

- Gravity rollers are considerably heavier than the wheels on wheel conveyors,
- Non-powered roller conveyors or Gravity Conveyors are the most economical and common method of conveying unit loads. The conveyors are typically mounted on a slight decline angle, therefore using gravity to assist product movement, especially for long distances. They can also be used in applications where the conveyor is level and operators can push the product along to its final destination, allowing for multiple workstations, if needed.
- As with gravity wheel conveyors, roller units are highly standardized and auxiliary equipment is available for supporting the line from ceiling or floor. Many special rollers are available for retarding containers if speed becomes too great for safe handling.

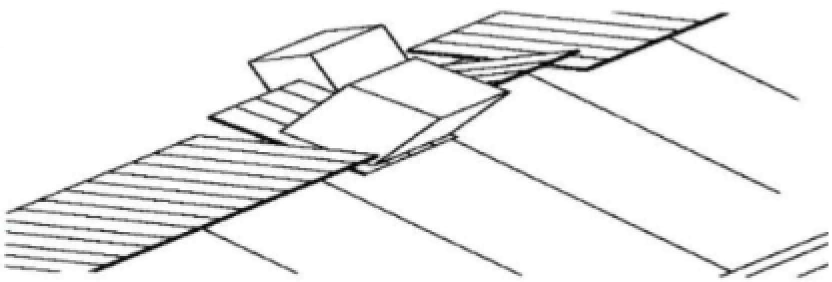
BELT CONVEYOR

Working principle

Belt conveyor is composed by two pulleys and a closed conveyor belt. The pulley that drives conveyor belt is called drive pulley ; the other one-only used to change conveyor belt movement direction-is called bend pulley. Drive pulley is driven by the motor ,. The drive pulleys are generally installed at the discharge end. Material is fed on the feed-side and landed on the rotating conveyor belt.

Slat conveyors

- Uses discretely spaced slats connected to a chain.
- The slats are either of wood or flanged metal.
- Unit being transported retains its position (like a belt conveyor).
- Orientation and placement of the load is controlled.



Working

- Slat Conveyors are conveyors employing one or more endless chains to which non-overlapping, non-interlocking, spaced slats are attached.
- Slat conveyors consist of endless chains, driven by electric motors operating through reduction gears and sprockets, with attached spaced slats to carry objects that would damage a belt because of sharp edges or heavy weights.

A bucket conveyor is a type of conveyor system that uses buckets attached to a moving chain or belt to transport materials. It is commonly used in a wide range of applications, such as in mining, construction, and manufacturing.

The construction of a bucket conveyor typically involves the following steps:

1. A framework, typically made of steel or aluminum, is selected based on the size and weight of the materials to be transported and the operating environment of the conveyor.
2. The framework is assembled to form the structure of the conveyor, including the support legs, the drive and drive-support systems, and the return and take-up systems.
3. A chain or belt, typically made of steel or another strong and durable material, is installed on the framework and attached to the drive and drive-support systems.
4. Buckets, typically made of steel or another strong and durable material, are attached to the chain or belt at regular intervals. The size and shape of the buckets are selected based on the materials to be transported and the desired capacity of the conveyor.
5. The chain or belt is tensioned and aligned to ensure that it is operating properly and that the buckets are moving smoothly.
6. The conveyor is tested to ensure that it is functioning properly and that it meets the required specifications.

Once the construction of the bucket conveyor is complete, it is ready to be used to transport materials. The bucket conveyor operates by moving the chain or belt with the attached buckets, which scoop up the materials and transport them along the conveyor. The materials are discharged at the end of the conveyor, or at intermediate points along the conveyor, depending on the design of the system.

3) List out the methods to measure hydrostatic pressure. Explain any two with neat diagram.

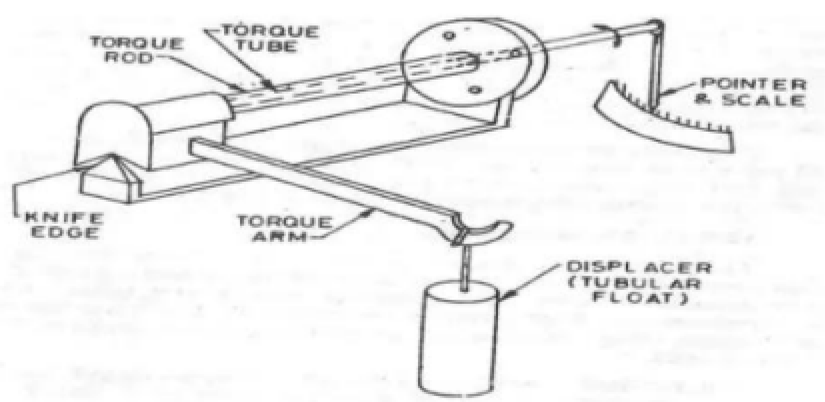
i. HYDROSTATIC PRESSURE TYPE

Hydrostatic pressure methods used for liquid level measurement are listed below.

a. Pressure gauge method
b. Air purge system
c. Diaphragm box type
d. Torque balance type

FLOAT DISPLACEMENT TYPE LEVEL MEASUREMENT

- These instruments work on the Archimedes principle according to which a body when placed in a liquid is buoyed up by a force equal to the weight of the displaced liquid, and the apparent change in weight of the body is directly proportional to the level of liquid in which it is placed.
- Torque tube is the most commonly used device for this purpose.
- The displacer is attached to a torque tube assembly whose rotary motion is used for read out/control.
- Otherwise, this instrument is rugged and simple in construction and reliable in operation. With selection of suitable material for float, float cage, and torque tube, it's possible to use this instrument over a wide range of pressure and for many liquids.



Float Displacement Type Level Measurement

Advantages

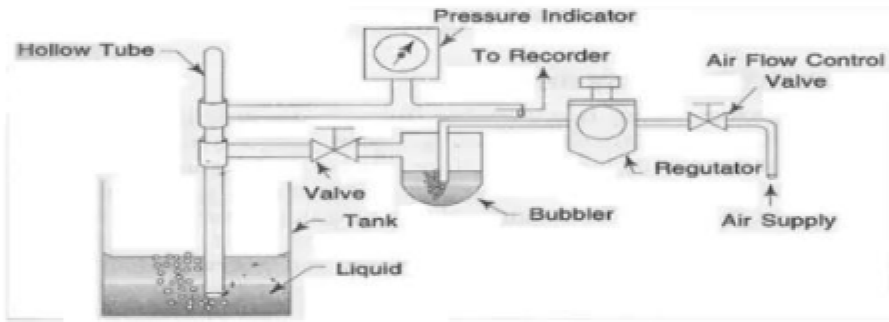
- High accuracy
- Reliable in clean liquids
- Can be mounted internally or externally (external mounted unit can be disconnected for maintenance)
- Adaptable to liquid interface measurement

Disadvantages

- Limited range, devices exceeding 1.2m in length are bulky and difficult to balance
- Cost increases appreciably for externally mounted units as pressure ratings increase
- External units may require stilling chambers

a. Air purge system

Air purge (bubbler tube) is one of the most popular hydrostatic pressure types of liquid measuring system which is suitable for any liquid as shown in fig.

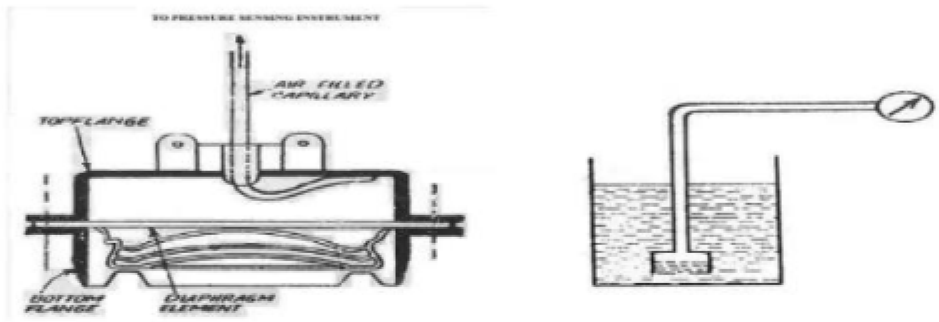


Advantages

- Pressure gauge can be placed above or below the tank level and can be kept as far away as 500 ft (12.7m) from the tank with the help of piping.
- Well - suited for measuring the corrosive/abrasive liquid.

b. DIAPHRAGM BOX METHOD

The diaphragm box liquid level meter is shown in fig. and consist of two flanges in between which is contained a diaphragm element made of rubber or oil resistant synthetic composition.



Advantage

•Where it is necessary to prevent contact b/w liquid and diaphragm, the box may be installed in a well outside the tank and the well is communicated to the tank with an impulse piping. The impulse piping and the well are filled with an inert liquid.

Disadvantage

•The main disadvantage is that the head developed is not sufficient to meet up the line losses as well as for a satisfactory indication. Hence ranges are quite limited.

4) Illustrate the applications of sensors in industries and home appliances

Sensors are devices that are used to measure physical, chemical, or biological quantities and convert them into electrical signals or other forms of output. They are commonly used in a wide range of industries and home appliances to monitor and control various processes and systems.

In industries, sensors are used in a variety of applications, such as:

- In the automotive industry, sensors are used to measure quantities such as temperature, pressure, and strain in engines, transmissions, and other automotive systems. They are also used in safety systems, such as airbags and collision avoidance systems.
- In the aerospace industry, sensors are used to measure quantities such as temperature, pressure, and acceleration in aircraft and spacecraft. They are also used in navigation and control systems, such as in inertial measurement units and global positioning systems.
- In the medical industry, sensors are used to measure quantities such as temperature, pressure, and chemical composition in medical devices and diagnostic instruments. They are also used in medical implants, such as pacemakers and insulin pumps.

In home appliances, sensors are used in a variety of applications, such as:

- In washing machines, sensors are used to measure quantities such as water level and temperature. They are also used in automatic dispensing systems, such as detergent and fabric softener dispensers.
- In refrigerators, sensors are used to measure quantities such as temperature and humidity. They are also used in automatic defrost and ice-making systems.
- In security systems, sensors are used to measure quantities such as motion, temperature, and pressure. They are also used in alarm systems, such as door and window sensors.

Overall, sensors are essential tools in a wide range of industries and home appliances, where they are used to measure and control various processes and systems.