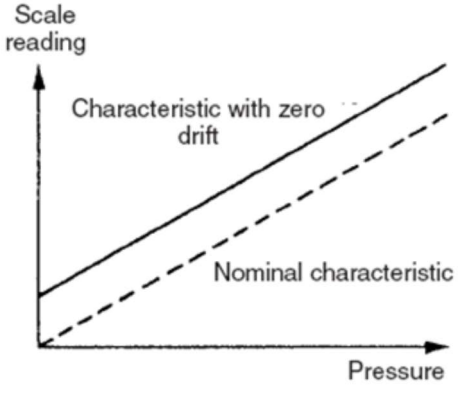
Important suggestions to examiners:

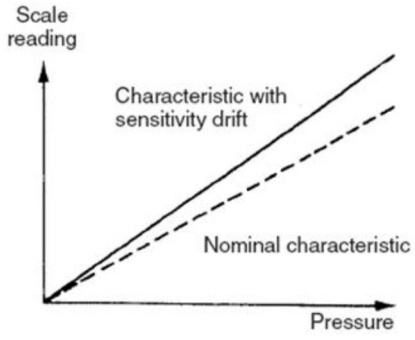
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and communication skills)
4) While assessing figures, examiner may give credit for principle components indicated in a figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case some questions credit may be given by judgment on part of examiner of relevant answer based on candidate understands.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q.1	**Attempt any TEN of the following :** **20 Marks**
a)	**Define : (i) Accuracy (ii) Precision**
Ans:	**i) Accuracy:** **(1 Mark)** The degree of exactness (closeness) of a measurement compared to the expected (desired) value. **OR** Closeness with which the instrument reading approaches the true value of the quantity being measured is known as accuracy **(ii) Precision:** **(1 Mark)** It is the measure of consistency or reproducibility of measurements. i.e successive readings do not defer. **OR** It prescribes the ability of the instrument to reproduce its readings over and over again for a constant input signal
b)	**Define Stress and Strain.**
Ans:	**(i) Stress:** **(1 Mark)** **It** is defined as the force experienced per unit area **OR**

	The amount of push and pull force applied over a cross sectional area right angle to the action of force is called stress. **(ii) Strain:** **(1 Mark)** **It** is defined as the ratio of change in length to original length **OR** The ratio of change in dimension to the original dimension is called strain **OR** The deformation due to the effect of applied force is called Strain.
c)	**List different types of thermistor.**
Ans:	There are two types of thermistors: 1. Negative Temperature Coefficient (NTC) and 2. Positive Temperature Coefficient (PTC). With an NTC thermistor, when the temperature increases, resistance decreases. Conversely, when temperature decreases, resistance increases. This type of thermistor is used the most. A PTC thermistor works a little differently. When temperature increases, the resistance increases, and when temperature decreases, resistance decreases. This type of thermistor is generally used as a fuse.
d)	**Define Slew rate and output voltage swing.**
Ans:	**i) Slew rate:** **(1 Mark)** The slew rate of an op amp or any amplifier circuit is the rate of change in the output voltage caused by a step change on the input. OR -The maximum rate at which an amplifier can respond to an abrupt change of input level It is measured as a voltage change in a given time. **ii) Output Voltage Swing:** **(1 Mark)** It is defined as the maximum unclipped peak to peak **output voltage** that an OPAMP can produce. Since the quiescent **output** is ideally zero, the ac **output voltage**

e)	**Define Hall effect.**
Ans:	**Hall Effect:** **(2 Marks)** If a strip of conducting material carries current in the presence of a transverse magnetic field, An emf is produced between the two edges of conductor. This phenomenon is called Hall Effect. The magnitude of the voltage depends upon the current, flux density and the property of conductor.
f)	**State principle of calibration.**
Ans:	**Principle of calibration:** **(2 Marks)** The process of deriving the value of a quantity by comparing that quantity with a standard quantity is called as calibration. OR Calibration is nothing but comparing the measuring instrument with standard instrument to find out error in the instrument under test OR Calibration of instrument is done to obtain correct unknown value of each scale reading on measuring instrument. There are 3 main reasons for having instrument calibration: ➢ To ensure reading from an instrument are consistent with other measurements. ➢ To determine the accuracy of the instrument reading. ➢ To establish the reliability of the instrument i.e. it can be trusted.
g)	**Draw input output characteristics of zero drift and sensitivity drift.**
Ans:	**Characteristics of Zero drift :** **(1 Marks)** 

Characteristics of Sensitivity drift: **(1 Marks)**



or equivalent figure

h) State any four objectives of DAS.

Ans:

Objectives of DAS: **(Each objective: 1/2 Marks, Total : 2 Marks)**

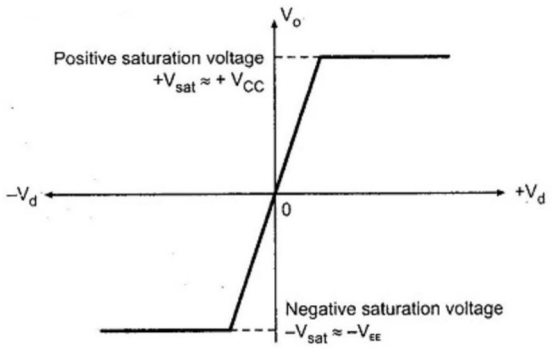
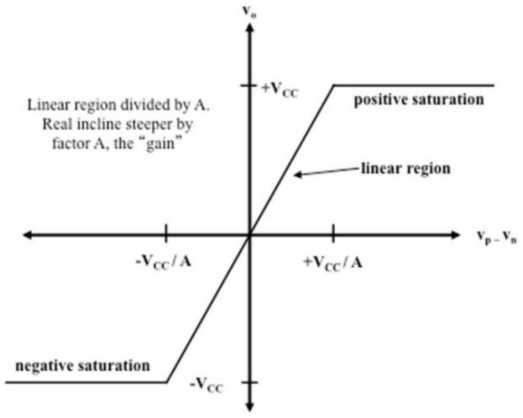
1. To Acquire Data From physical Systems and devices.
2. To transmit it.
3. To Record the real time data to provide necessary signal conditioning.
4. To provide supervisory control whenever required.

i) Compare Active and Passive transducer.

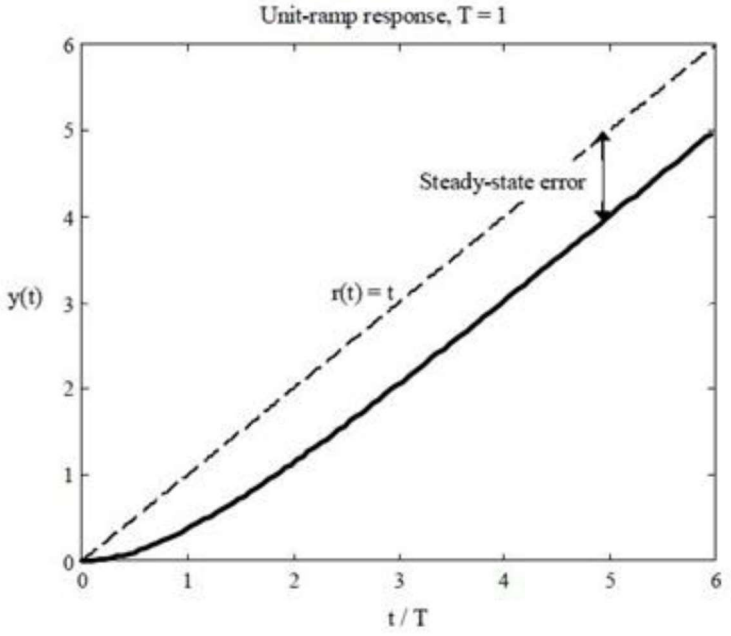
Ans:

(Any Two point expected: 1 Mark each, Total 2 Marks)

S.No.	Active transducer	Passive transducer
1	Don't require external power for operation	Require external power supply for operation
2	It is also called self- generating transducer	It is also called extremely-powered transducer
3	Circuit is simple	Circuit is complex
4	Active bridge is not required	Active bridge is required
5	Operate under energy conversion principle	Operate under controlling principle
6	E.g. thermocouple, piezoelectric	E.g. Thermistor, Stain Gauge

j)	**Draw ideal voltage transfer curve.**
Ans:	**Ideal voltage transfer curve:** **(2 Marks)**  **OR**  **OR Equivalent Curve**
k)	**Define (i) Dynamic error, (ii) Settling time.**
Ans:	**i) Dynamic error:** **(1 Mark)** It is the difference between the true value of the quantity (under measurement) changing with time and the value indicated by the measurement system if no static error is assumed. **ii) Settling time:** **(1 Mark)** It is the time required for the output of any system to reach and stay within a specified tolerance band.
l)	**State the hysteresis effect on instrument.**
Ans:	**Hysteresis effect :** **(2 Marks)** Hysteresis effect is due to magnetic effects of the metals. It gives the relation between field current and the output voltage. The magnetization of ferromagnetic substances due to a varying magnetic field lags behind the field. This effect is called hysteresis, and the term is used to describe any system in whose response depends not only on its current state, but also upon its past history.
Q.2	**Attempt any FOUR of the following :** **16 Marks**
a)	**Describe the response of first order system with Ramp input.**

Ans: **The response of first order system with Ramp input** : **(4 Marks)**



or equivalent figure

Response is exponential with a permanent steady state error.

Output y (t) = t – T + T $e^{-t/T}$

$Input \quad , r\ (t) = t, 1\ (t),$

Laplace transform R (s) = $1/S^2$

Output C (S) = R (S) /1+TS = $1/S^2$ (1+TS) = $1/S^2$+ T/S +T/ (1+TS)

where 'T' I s the time constant

Taking the inverse Laplace transform gives the response C (t)

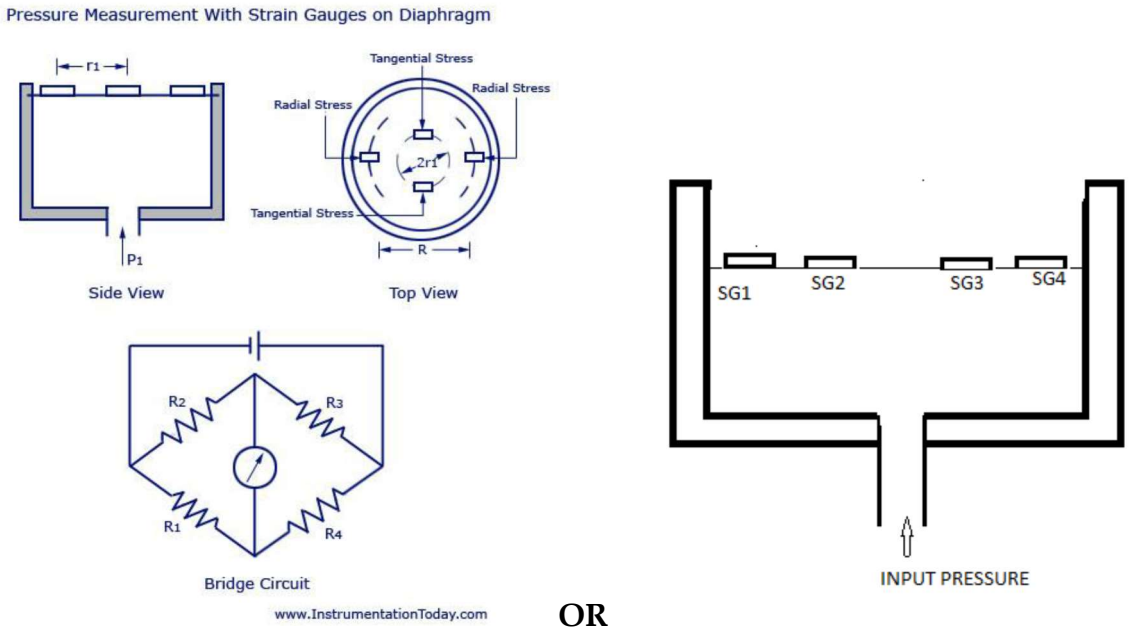
c (t) = t-T +Te $^{1/T}$ for t > 0

Ion the steady-state the output lags the input by a time equal to the time constant

b) **Explain operation of resistive strain gauge.**

Ans: **Diagram of resistive strain gauge:**

(Diagram: 2 Mark & Explanation: 2 Mark, Total : 4 Marks)

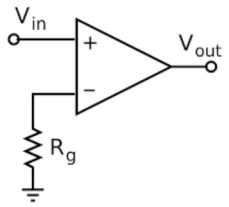
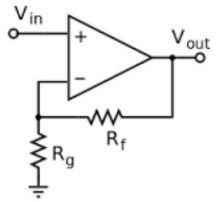


OR

Operation of resistive strain gauge :

- The sensing element is typically a diaphragm or tube whose internal volume contains the applied pressure.
- The pressure causes the element to deflect in a predictable manner causing surface strains as well as an applied force.
- Depending on design, the strain gages can be bonded to the non-pressurized face of the sensing element and respond to the surface strains.
- The strain gages can be bonded to a separate structure, usually a cantilever beam, driven by the force input of the diaphragm.
- In this case the strain gages respond to the surface strains of the beam.
- The strain gages change resistance in response to the surface strains they sense.
- The relationship between strain and resistance is expressed by the gage factor (G.F.) of the strain gage foil

c)	**Compare open loop and closed loop configuration of op-Amp with neat**
Ans:	**(Any four point expected: 1 Mark each, Total 4 Mark)**

S.No.	Point	open loop configuration of Op-Amp	closed loop configuration of Op-Amp
1	Circuit diagram		
2	Gain	Voltage gain is very high. Gain is uncontrollable	Voltage gain is low as compared to open. Gain is controllable & depends on external passive components.
3	Bandwidth	bandwidth is low	bandwidth is high
4	Application	Comparator, Square wave generator, wave shaping circuit, zero crossing detection	It is used ac, dc signal amplifier, oscillator, Instrument amplifier circuits etc
5	Feedback signal	No feedback is taken from output	A feedback signal is taken from the output

d) Draw and explain block diagram of instrumentation system.

Ans: **Block diagram of instrumentation system : (Figure: 2 Mark & Explanation :2 Mark)**

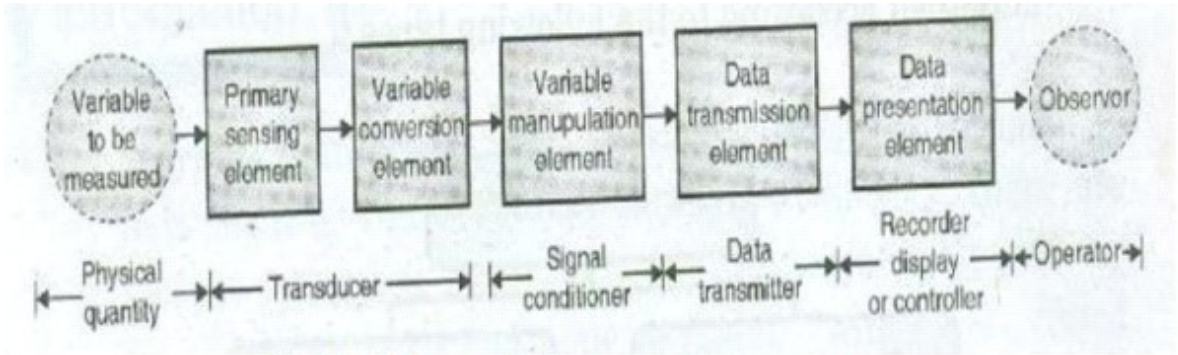


Fig: Block diagram of instrumentation system.

or equivalent figure

1. Primary Sensing Element:

Primary sensing element of system is that which first receives energy from the measured medium and produces an output depending in some way on the value of measured quantity.

2. Variable Conversion Element:

A variable conversion element merely converts the output signal of the primary sensing element into a more suitable variable or condition useful to the function of the instruments.

3. Variable Manipulation Element:

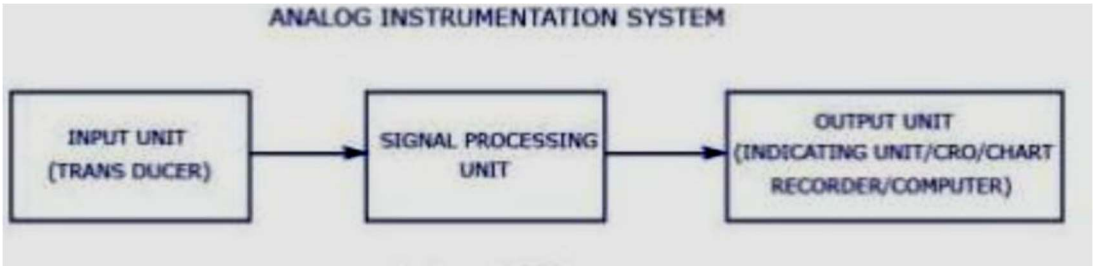
It manipulates the signal represented by some physical variable, to perform the intended task of an instrument. In the manipulation process, the physical nature of the signal is preserved.

4. Data Transmission Element: It transmits the data from one element to other element.

5. Data presentation Element:

It performs the translation function, such as the simple indication of a pointer moving over a scale or recording of a pen moving over a chart.

OR



or equivalent figure

1. The Primary Element/Transducer:

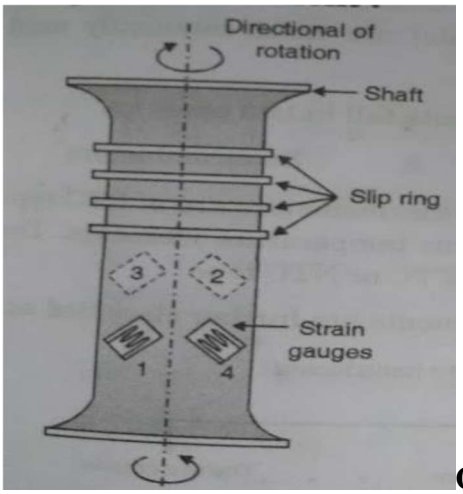
The input receives the quantity whose value is to be measured and is converted into its proportional incremental electrical signal such as voltage, current, resistance change, inductance or even capacitance. Thus, the changed variable contains the information of the measured variable. Such a functional element or device is called a transducer.

2. The Secondary Element/Signal Processing Unit :

The output of the transducer is provided to the input of the signal processing unit. This unit amplifies the weak transducer output and is filtered and modified to a form that is acceptable by the output unit. Thus this unit may have devices like: amplifiers, filters, analog to digital converters, and so on.

3. The Final Element/Output Unit:

	The output from the signal processing unit is fed to the input of the output unit. The output unit measures the signal and indicates the value to the reader. The indication may be either through: an indicating instrument, a CRO, digital computer, and so on
e)	**Explain measurement of torque by using torque cell.**
Ans:	**(Any one type may be considered, Diagram : 2 Mark & Explanation: 2 Mark)**



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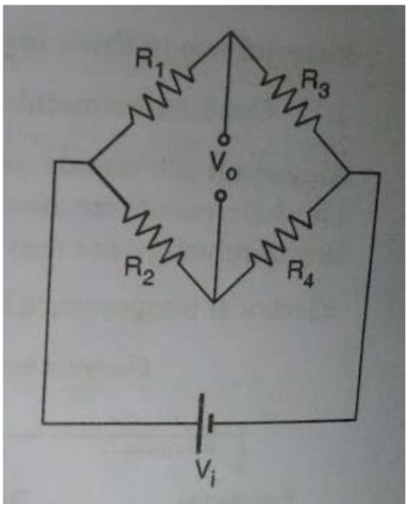
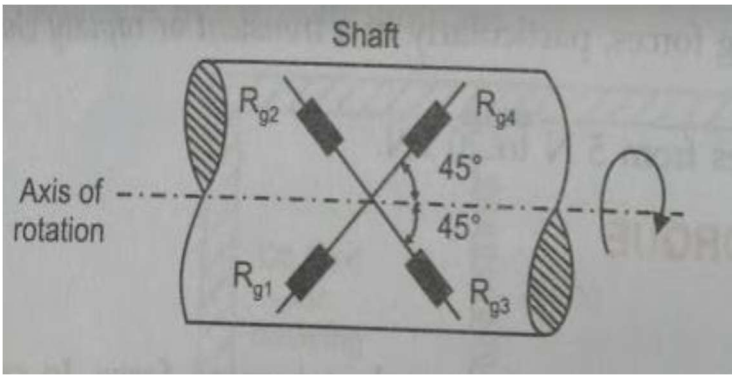


or equivalent figure

- Figure a shows the construction of load cell used to measure torque using strain gauges connected to the rotating shaft. Figure b represents the bridge arrangement to measure torque. The strain gauges are fixed at 450 with the shaft axis. Two strain gauges are subjected to tensile stresses while the other two experience compressive stress. Slip rings are used for connectivity with the bridge.
- When torque is applied to the shaft, the strain gauges change their properties and the strain is measured by the bridge circuit. Output of the bridge network will be proportional to the torque.

OR



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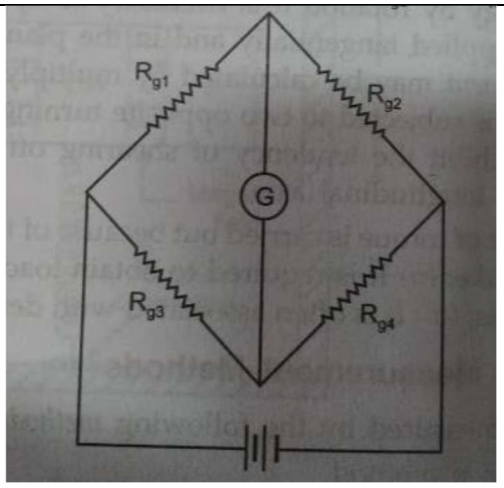


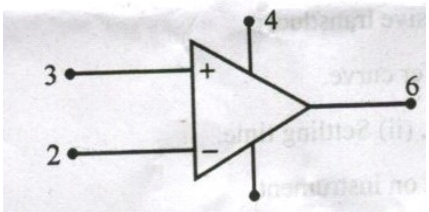
Figure above represents a strain gauge bridge circuit used for torque measurement.

Four bonded wire strain gauges are mounted on a 450 helix with the axis of rotation.

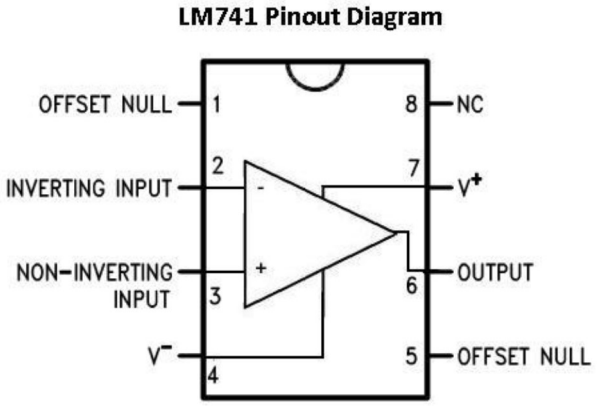
They are placed in pairs diametrically opposite. When the gauges are accurately placed and have matched characteristics, the system is temperature compensated and insensitive to bending and thrust.

Working: When the shaft is under torsion, gauges 1 and 4 will elongate as a result of the tensile component of a pure shear stress on one diagonal axis while gauges 2 and 3 will contract due to the compressive component on the other diagonal axis. The Wheatstone bridge output is proportional to torsion and hence the torque.

f) **Label the pin no. 2, 3, 4 and 6 in the following dia of IC-741.**



Ans: **Labelled pin diagram for IC 741:** **(4 Marks)**



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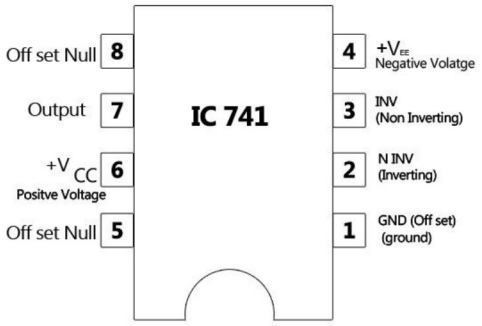
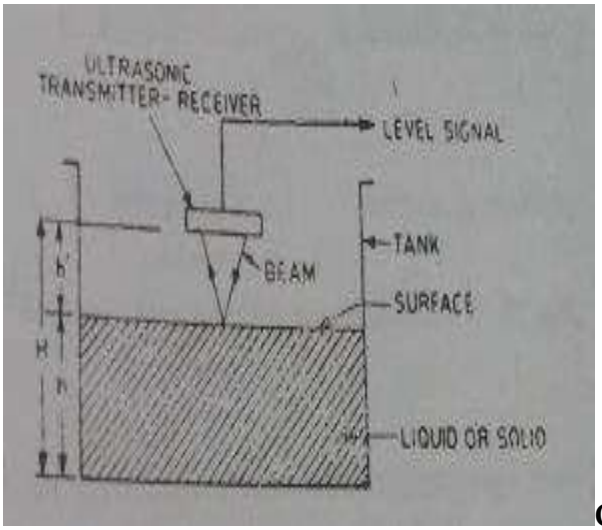


OR equivalent diagram

Q.3	**Attempt any FOUR of the following : 16 Marks**
a)	**Draw a neat diagram of ultrasonic level measurement and state its working principle.**

Ans: **Diagram of ultrasonic level measurement:**

(Diagram : 2 Mark & Working Principle: 2 Marks, Total 4 Marks)



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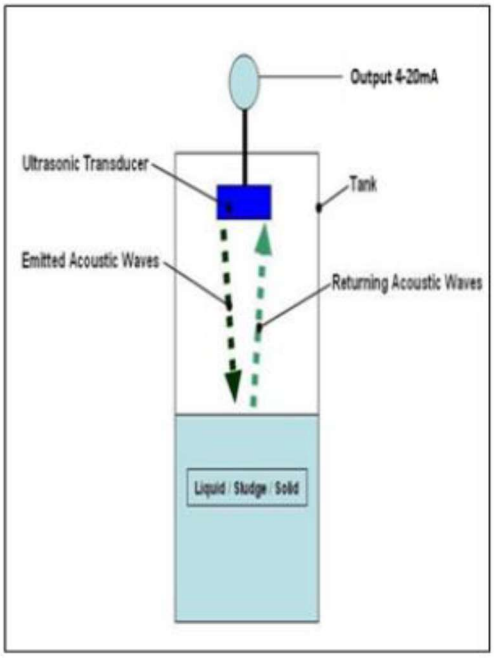


Working principle:

1. It operates by generating an ultrasonic wave or pulse and measuring a time it takes for the echo to return.
2. There are two way of measurement of liquid level:

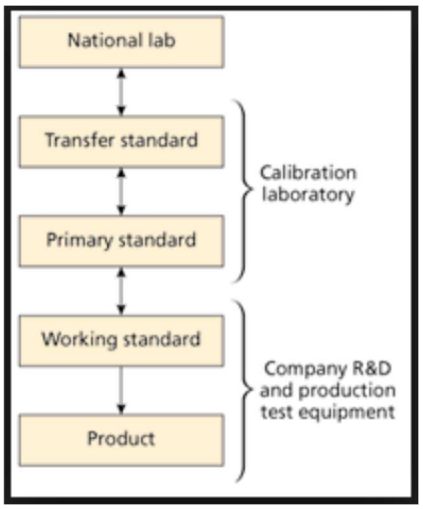
- Doppler Type
- Time difference type

3. The ultrasonic waves generated by transmitter and directed towards the liquid surface in the tank which is to be measure.
4. These waves get reflected from the surface of the liquid and are received by the receiver.
5. The time take by the wave is a measure of the distance travelled by the wave. Therefore the time't' between transmitting and receiving a wave is proportional to the distance 'd' between ultrasonic set and surface of the liquid in the tank.
6. As the distance 'H' between ultrasonic set and the bottom of the tank is fixed time 't' is measure of level 'l'

b) State and explain calibration chain and traceability.

Ans: **Diagram of calibration chain and traceability: (Diagram: 2 Mark & Explanation: 2 Marks)**

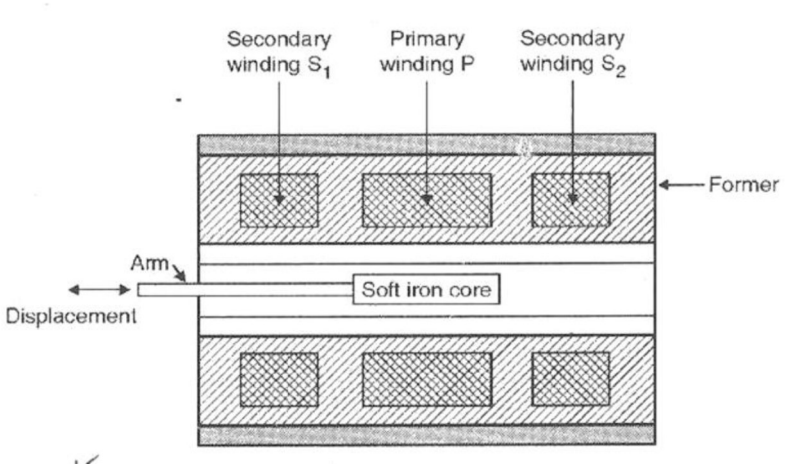
(Any other relevant example may also be considered).



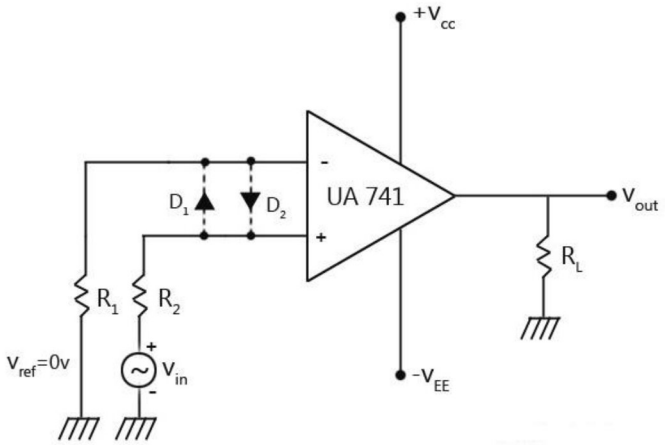
or equivalent figure

Explanation:

Field instruments are calibrated using master instruments. Master instruments are instruments with more accuracy and greater repeatability. Master instruments are

	calibrated periodically at external laboratories. And the instruments in these labs too are calibrated at another place. Such a chain is called calibration chain. Identification is provided on all these of the instrument used to calibrate it and that is called traceability. In India, mostly instruments are calibrated and are traceable to NPL (National Physics Laboratory)
c)	**Explain the working principle of LVDT.**
Ans:	**Constitutional diagram of LVDT:** **(Diagram: 2 Mark & Working: 2 Mark, Total 4 Marks)**  **or equivalent diagram** **Working Principle:** It works on the principle of variable inductance. The inductance is varied according to the displacement. This is achieved either by varying the mutual inductance between the two coils. It is having a primary & two secondary windings wound over a hollow former and a soft iron core slides inside the hollow former. The position of movable core determines the flux linkage between the AC excited primary winding and each of the secondary winding.
d)	**Draw the circuit diagram and input output waveform of zero crossing detector.**
Ans:	**(Diagram: 1 Mark, Explanation: 2 Mark & Waveform : 1 Mark, Total 4 Marks)** **Circuit diagram of zero crossing detector: (1 Mark)**

Zero Crossing Detector Using UA 741 op-amp IC



or equivalent figure

Explanation: **(2 Mark)**

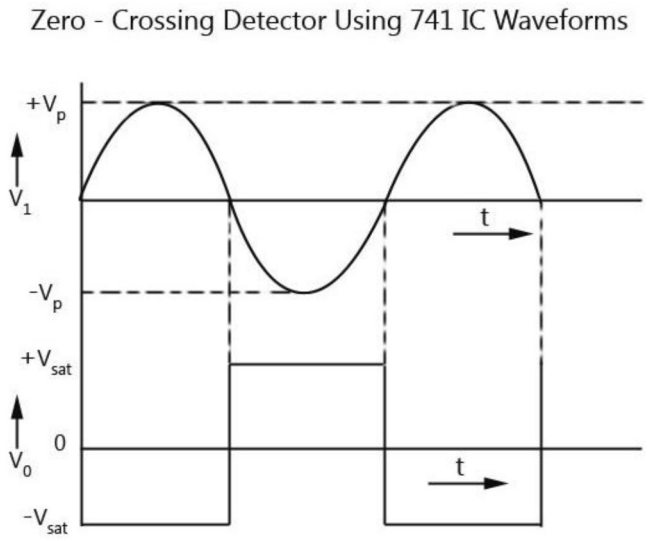
The zero crossing detector circuit is an important application of the op-amp comparator circuit. It can also be called as the sine to square wave converter. Anyone of the inverting or non-inverting comparators can be used as a zero-crossing detector. The reference voltage with which the input voltage is to be compared, must be made zero (Vref = 0V). An input sine wave is given as Vin. These are shown in the circuit diagram and input and output waveforms of an inverting comparator with a 0V reference voltage.

As shown in the waveform, for a reference voltage 0V, when the input sine wave passes through zero and goes in positive direction, the output voltage Vout is driven into negative saturation. Similarly, when the input voltage passes through zero and goes in the negative direction, the output voltage is driven to positive saturation. The diodes D1 and D2 are also called clamp diodes. They are used to protect the op-amp from damage due to increase in input voltage. They clamp the differential input voltages to either +0.7V or -0.7V.

In certain applications, the input voltage may be a low frequency waveform. This means that the waveform only changes slowly. This causes a delay in time for

the input voltage to cross the zero-level. This causes further delay for the output voltage to switch between the upper and lower saturation levels. At the same time, the input noises in the op-amp may cause the output voltage to switch between the saturation levels. Thus zero crossing are detected for noise voltages in addition to the input voltage. These difficulties can be removed by using a regenerative feedback circuit with a positive feedback that causes

Input output waveform of zero crossing detector: **(1 Mark)**

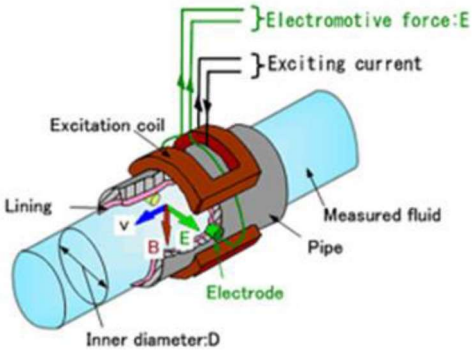


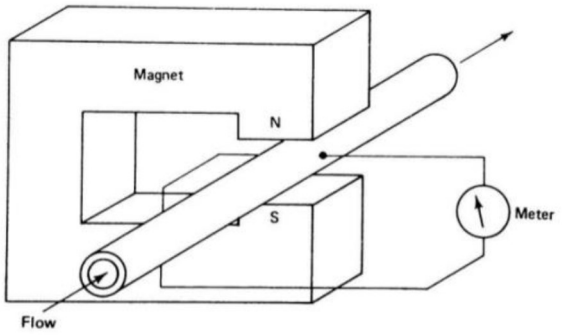
or equivalent figure

e) Describe construction and working principle of electromagnetic flow meter.

Ans: Diagram of electromagnetic flow meter

(Diagram: 2 Mark & Construction & Working; 2 Mark. Total 4 Marks)





OR

or equivalent figure

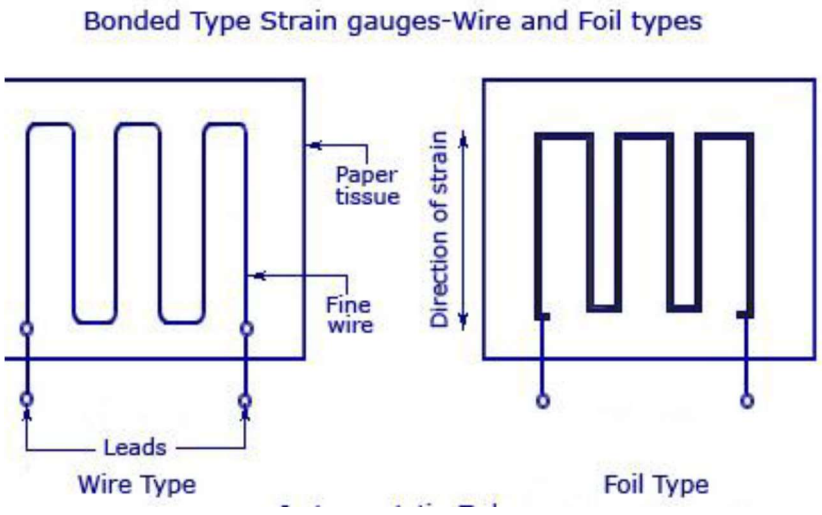
Construction and Working Principle:

- The electromagnetic flow meter uses Faraday's Law of electromagnetic induction to measure the process flow.
- When an electrically conductive fluid flows in the pipe, an electrode voltage E is induced between a pair of electrodes placed at right angles to the direction of magnetic field. Under Faraday's law of induction, moving conductive liquids inside of a magnetic field generates an electromotive force (voltage) in which the pipe inner diameter, magnetic field strength, and average flow velocity are all proportional. In other words, the flow velocity of liquid moving in a magnetic field is converted into electricity.
- (E is proportional to V × B × D)
- The electrode voltage E is directly proportional to the average fluid velocity (V).

f) Explain with neat diagram construction and working principle of bonded strain gauge.

Ans: Diagram of bonded strain gauge:

(Diagram: 2 Mark & Explanation: 2 Mark, Total: 4 Marks)



or equivalent diagram

Explanation:-

In this type, the spreading of wire permits a uniform distribution of stress over the grid. The carrier is bonded with an adhesive material to file specimen under study. This permits a good transfer of strain from carrier to grid of wires. The wires cannot buckle as they are embedded in a matrix of cement and hence faithfully follow both the tensile and compressive strains of the specimen.

Foil type gauges have a much greater heat dissipation capacity as compared with wire wound strain gauges on account of their greater surface area for the same volume. For this reason, they can be used for higher operating temperature range.

Q.4 Attempt any FOUR of the following : 16 Marks

a) Compare RTD and thermistor. (any 4 points)

Ans: **(Any four point expected: 1 Mark each, Total 4 Mark)**

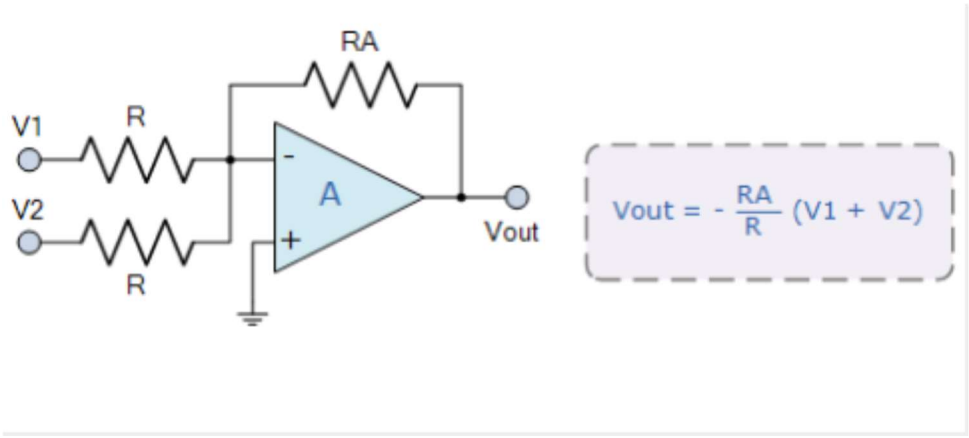
S.No.	RTD	thermistor
1	Made of metals like copper, platinum, nickel and tungsten	Made of metallic oxides such as cobalt, manganese, nickel etc.
2	Have positive temperature coefficient of resistance that is their resistance increases as the temperature increases.	Thermistors of both positive and negative temperature coefficient of resistance are available but thermistors having NTC are used, that is, their resistance will decrease as the temperature increases.
3	Temperature range: -100 C to 650 C.	Temperature range: -50 C to 300 C
4	Temperature versus resistance characteristics are linear.	Temperature versus resistance characteristics are nonlinear.
5	Less sensitive to temperature than thermistor	Thermistors are more sensitive to temperature in the specified range than RTDs
6	Cost is high	Less costlier than RTD
7	They have better reproducibility and low hysteresis.	They have less reproducibility and more hysteresis.

	8	Relatively bigger in size.	Thermistors are quite small in size and in shapes like washer, bead, probe, disc, etc. .

b) Derive the output equation of adder with neat diagram.

Ans: **Output equation of adder with neat diagram:**

(Diagram : 2 Mark & Explanation: 2 Mark, Total 4 Mark)



or equivalent diagram

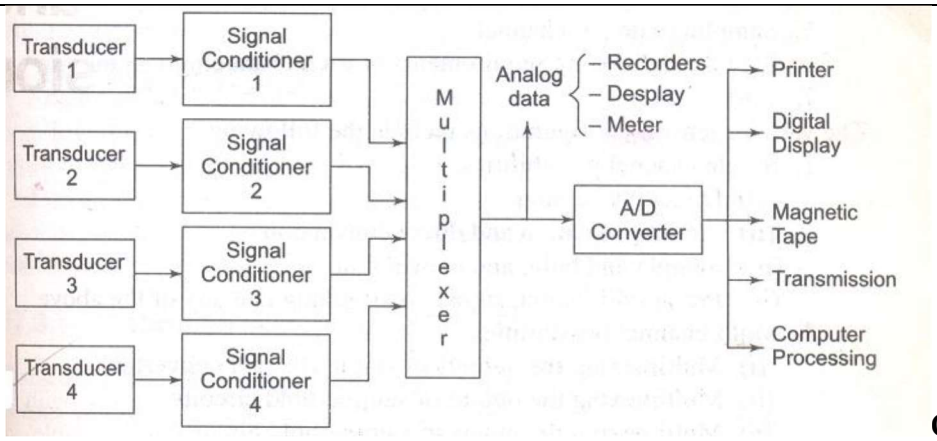
Explanation :

The Adder, also called a summing amplifier, produces an inverted output voltage which is proportional to the sum of the input voltages V1 and V2. More inputs can be summed. If the input resistors are equal in value (R1 = R2 = R) then the summed output voltage is as given and the gain is $\frac{RA}{R}$. If the input resistors are unequal then the output voltage is a weighted sum and becomes:

$$Vout = -(V1(\frac{RA}{R1}) + V2(\frac{RA}{R2}))$$

c) Draw and explain block diagram of generalized DAS.

Ans: **Block diagram of generalized DAS.**



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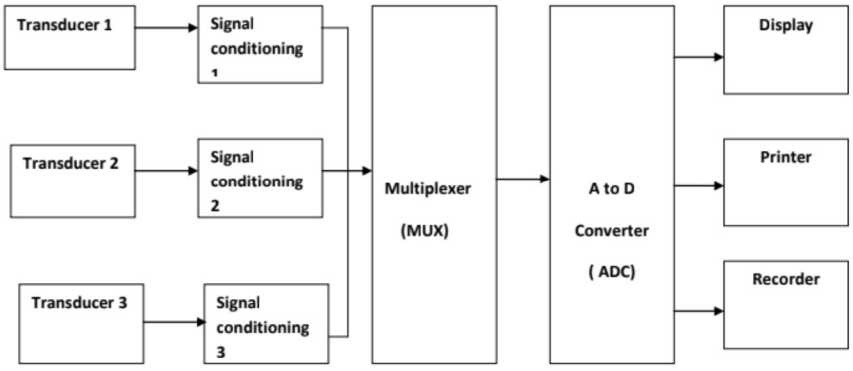


or equivalent figure

Working:

1. Transducer:-

A transducer is used to convert the physical parameters corning from the field into electrical signals or it is used to measure directly the electrical quantities such as resistance, voltage, frequency, etc.

2. Signal Conditioner:-

Usually the output signals of the transducer will be of very low level (weak) signals which cannot be used for further processing. In order to make the signals strong enough to drive the other elements signal conditioners are used such as amplifiers, modifiers, filters etc.

3. Multiplexer:-

The function of the multiplexer is to accept multiple analog inputs (after signal conditioning) and provide a single output sequentially according to the requirements.

4. A/D Converter:-

The analog-to-digital (A/D) converter is generally used to convert the analog data into digital form. The digital data is used for the purpose of easy processing, transmission, digital display and storage. Processing involves various operations on data such as comparison, mathematical manipulations, data is collected, converted into useful form and utilized for various purposes like for control operation and display etc.

The transmission of data in digital form is possible over short distances as well as long distances of and has advantages over transmission in analog form. The data can be stored permanently or temporarily and can be displayed on a CRT or digital panel.

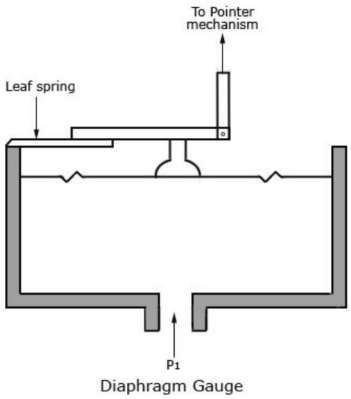
5. Recorders and Display Devices:-

In display devices the data is displayed in a suitable form in order to monitor the input signals. Examples of display devices are oscilloscopes, numerical displays, panel meters, etc.

d) Explain measurement of pressure using diaphragm with neat diagram.

Ans: **Diagram of pressure measurement using diaphragm:**

(Diagram: 2 Mark & explanation with working: 2 mark, Total 4 Marks)



or equivalent figure

Explanation:

A diaphragm type pressure transducer is used for low pressure measurement. They are commercially available in two types: Metallic and Non-metallic.

Working:

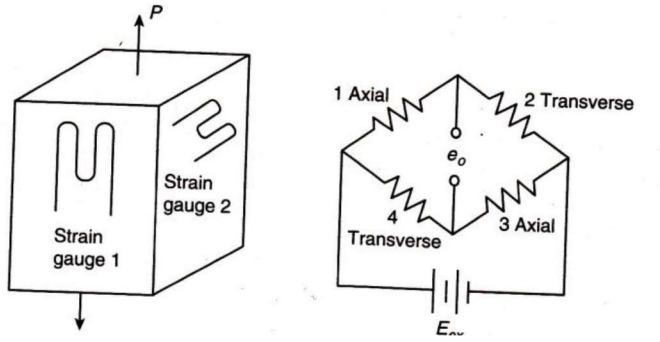
The diagram of diaphragm pressure gauge is shown in the figure. When a force acts against a thin stretched diaphragm, it causes a deflection of the diaphragm with its center deflecting the most.

If the pointer or mechanical movement is connected to the LVDT or other secondary transducer then it converts mechanical action into electrical output.

e) Describe the method of force measurement using load cell. (column type)

Ans: **Diagram of force measurement using load cell :**

(Diagram : 2 Mark & Explanation: 2 Mark, Total 4 Marks)



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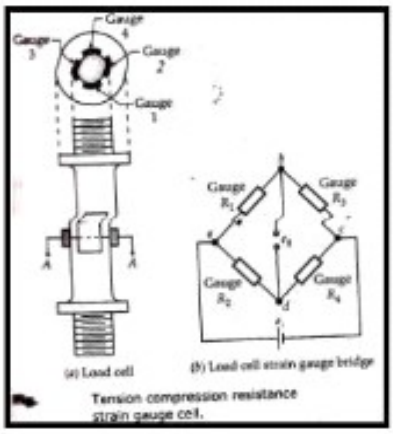


OR equivalent figure

Explanation :

- Load cell is an elastic member as the primary transducer and strain gauge is the secondary transducer.
- When this combination is used, it is called load cell. In this case an axial compressive load causes a negative strain in vertical gauges.
- The two strains are not equal in this case. These are related to each other by Poisson's ratio and a force is measured.

OR

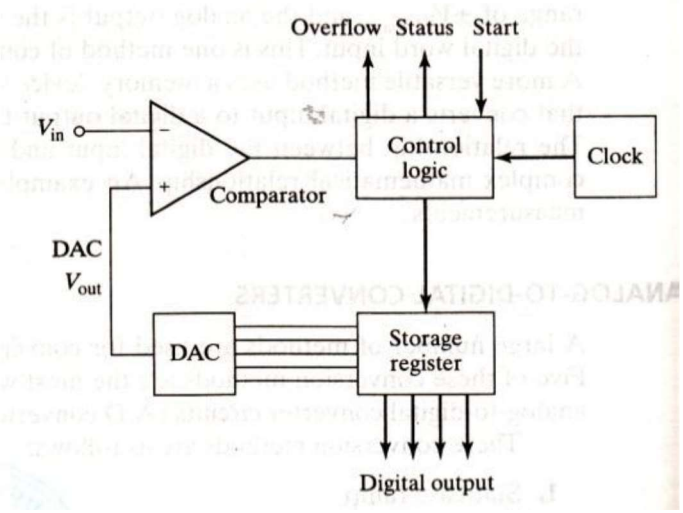
1. Load cells utilize an elastic member as the primary transducer and strain gauges as secondary transducers.

2. Strain gauges may be attached to any elastic member, on which there exists a, suitable plane area to accommodate them.
3. This arrangement may then be used to measure loads applied to deform or deflect the member, provided that the resultant strain is large enough to produce detectible outputs.
4. When the strain gauge –elastic member combination is used for weighing it is called a load-cell.

f) Explain working principle of successive approximation type A to D convertor.

Ans: **Diagram of successive approximation type A to D convertor:**

(Diagram : 2 Marks & Working : 2 Marks, Total 4 Marks)



or equivalent figure

Working principle of Successive approximation type A to D converter:

- It uses an efficient code search strategy to complete n bit conversion in n clock periods. It consists of a DAC, an output register, a comparator and control circuit.
- Here the comparator compares the analog input with DAC reference voltage that is successively divided in half. The reference voltage is repeatedly divided for successive approximation till the divided voltage is almost equal to the unknown input voltage level.

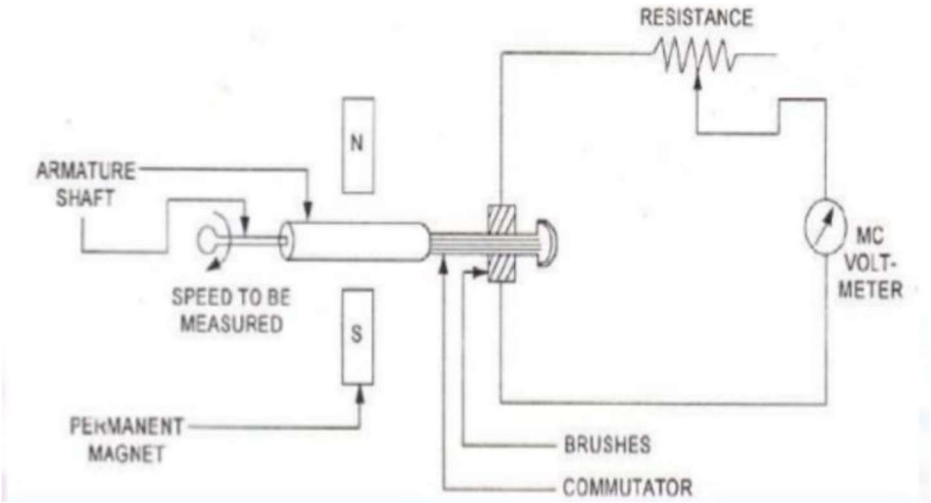
- When each bit of the DAC is enabled one at a time starting from MSB, the comparator produces an output that indicates whether the analog input voltage is greater or less than the output of the DAC.
- If DAC output is greater than the analog input voltage, comparator output is LOW, so bit in the control register is reset.
- If DAC output is less than the analog input voltage, comparator output is HIGH, so bit is retained in the control register.
- After all the bits of the DAC are tried, the conversion process is complete and the register indicates the end of conversion.

Q.5 Attempt any FOUR of the following : 16 Marks

a) Explain working principle of DC tacho-generator with neat diagram.

Ans: **(Diagram : 2 Marks & Working principle : 2 Marks, Total: 4 Marks)**

Diagram of DC tacho-generator



Working principle of DC tacho-generator :

The D.C Tacho generators is a type of electrical type's tacho generators which can also be used for speed measurement. The D.C tacho generator is shown in above figure. The armature of the D.C Tacho generator is kept in the permanent magnetic field. The armature of the tacho generator is coupled to the machine whose speed is to be measured. When the shaft of the machine revolves, the armature of the tacho generator revolves in

the magnetic field producing e.m.f. which is proportional to the product of the flux and speed to be measured.

Now as the field of the permanent field is fixed, the e.m.f generated is proportional to the speed directly. The e.m.f induced is measured using moving coil voltmeter with uniform scale calibrated in speed directly. The series resistance is used to limit the current under output short circuit condition. The polarity of output voltage indicates the direction of rotation. The commutator collects current from armature conductors and converts internally induced a.c e.m.f into d.c (unidirectional) e.m.f. while the brushes are used to collect current from commutator and make it available to external circuitry of the d.c tacho generator.

b) Draw and explain instrumentation amplifier by using 3 op-Amp.

Ans: **Diagram of Instrumentation amplifier in three Op-Amp:** **(2 Marks)**

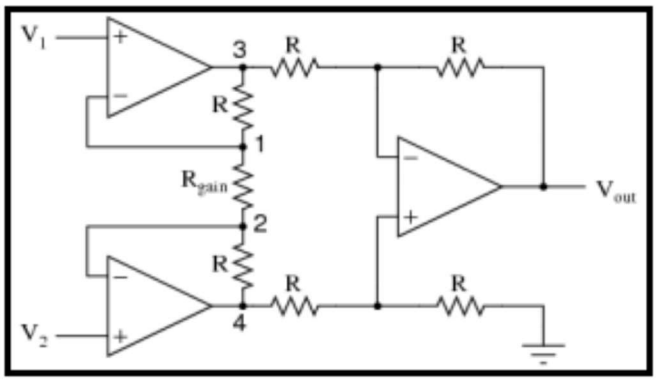


Figure:- Instrumentation amplifier

or equivalent diagram

Explanation of Instrumentation amplifier in three Op-Amp: **(2 Marks)**

It is beneficial to be able to adjust the gain of the amplifier circuit without having to change more than one resistor value, as is necessary with the previous design of differential amplifier. The so-called instrumentation builds on the last version of differential amplifier to give us that capability:

This intimidating circuit is constructed from a buffered differential amplifier stage with three new resistors linking the two buffer circuits together. Consider all

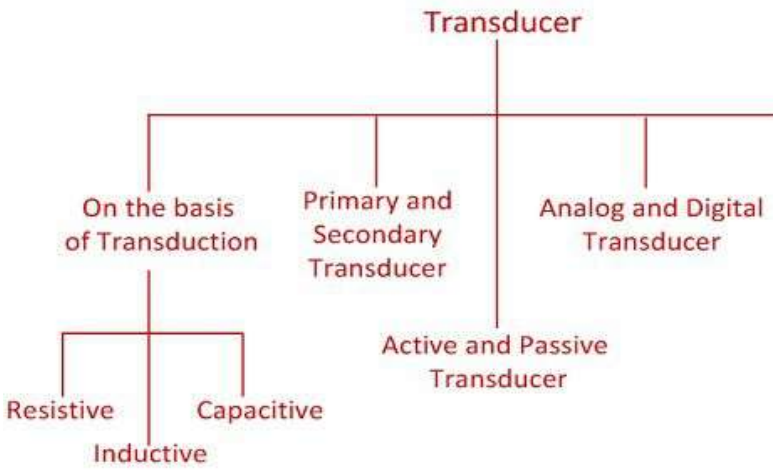
resistors to be of equal value except for R gain. The negative feedback of the upper-left op-amp causes the voltage at point 1 (top of R gain) to be equal to V1. Likewise, the voltage at point 2 (bottom of R gain) is held to a value equal to V2. This establishes a voltage drop across R gain equal to the voltage difference between V1 and V2. That voltage drop causes a current through R gain, and since the feedback loops of the two input op amps draw no current, that same amount of current through R gain must be going through the two "R" resistors above and below it. This produces a voltage drop between points 3 and 4 equal to:

$$V_{3-4} = (V_2 - V_1)(1 + \frac{2R}{R_{gain}})$$

The regular differential amplifier on the right-hand side of the circuit then takes this voltage drop between points 3 and4, and amplifies it by a gain of 1 (assuming again that all "R" resistors are of equal value). Though this looks like cumber some way to build a differential amplifier, it has the distinct advantages of possessing extremely high input impedances on the V1 and V2 inputs (because they connect straight into the non-inverting inputs of their respective op amps),and adjustable gain that can be set by a single resistor. Manipulating the above formula a bit, we have a general expression for overall voltage gain in the instrumentation amplifier:

$$A_V = (1 + \frac{2R}{R_{gain}})$$

Though it may not be obvious by looking at the schematic, we can change the differential gain of the instrumentation amplifier simply by changing the value of one resistor: R gain. Yes, we could still change the overall gain by changing the values of some of the other resistors, but this would necessitate balanced resistor value changes for the circuit to remain symmetrical. Please note that the lowest gain possible with the above circuit is obtained with R gain completely open (infinite resistance), and that gain value is 1.

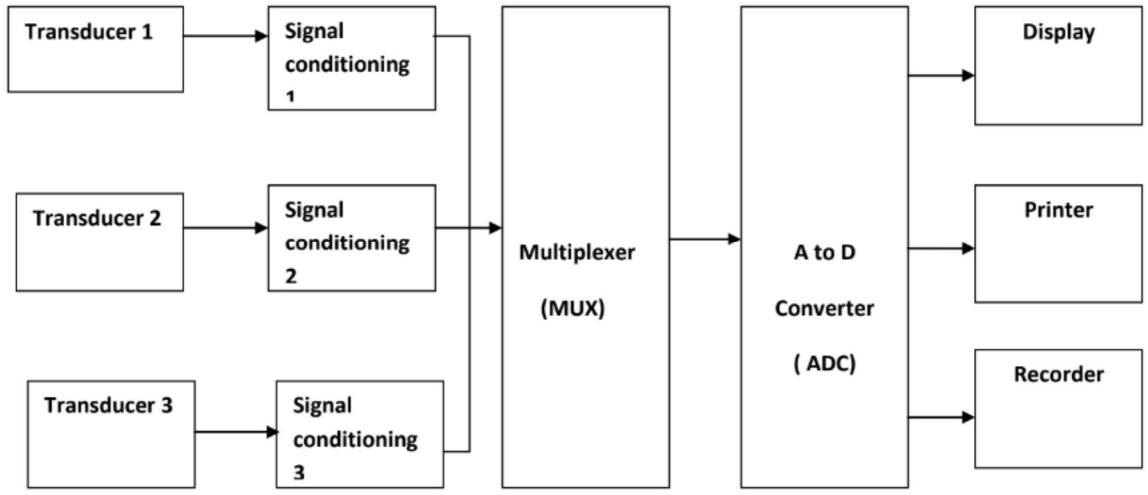
c)	**Classification of electrical transducer in detail.**
Ans:	**Classification of Electrical transducer :** **(4 Marks)** 
d)	**List criteria for selecting a transducer for an application.**
Ans:	Transducer is a device which transforms energy from one form to another. The **following points should be considered while selecting a transducer for particular application.** **(Any Four point expected: 1 Mark each, total 4 Marks)** 1. Operating range: The range of transducer should be appropriate for measurement to get a good resolution. 2. Operating principle: The transducers are selected on the basis of operating principle it may be resistive, inductive, capacitive, optical etc. 3. Sensitivity: The transducer should be more sensitive to produce the output or sensitivity should be as per requirement. 4. Accuracy: The accuracy should be as high as possible or as per the measurement. 5. Frequency response and resonant frequency 6. Errors: The error produced by the transducer should be low as possible. 7. Environmental compatibility: The transducer should maintain input and output characteristic for the selected environmental condition. 8. Usage and ruggedness.: it should be rugged in construction 9. Electrical aspect.

10. Stability and Reliability: Transducer should produce stable and accurate output in any environmental condition.
11. Loading effect: The transducer's input impedance should be high and output impedance should be low to avoid loading effect.

e) Explain multi-channel data acquisition system with neat diagram.

Ans: **Diagram of multi-channel data acquisition system :**

(Diagram: 2 Marks & Explanation: 2 Marks, Total : 4 Marks)



OR equivalent figure

Explanation:

A data acquisition (DAQ) system is used for the measurement and processing of plant Signal data before it is displayed on the operator desk or permanently recorded.

Block diagram of a PC (computer) based data acquisition is shown in figure.

- It consists of individual transducers (sensors) for measurement of physical plant Parameters (such as temperature, pressure, flow, etc.).
- After measurement, the transducer data is fed to the signal conditioning device to bring the signal level up to a sufficient value to make it useful for conversion,

processing, indicating and recording. Signal conditioner is used to amplify, modify or select certain portion of signals.

- The output of the signal conditioner is fed to the multiplexing (telemetry) device With the help of multiplexing all individual signal data (called lower bandwidth
- Communication channels) are combined and transmitted over a higher bandwidth channel. At the receiving end, de-multiplexing recovers the original lower bandwidth channels. It scans across a number of analog signals and time-sharing them sequentially into a single analog output channel.
- The multiplexed data is converted into digital signal with the help of analog-to-Digital converter.
- The converted digital signals are fed to the computer for further processing, Mathematical computation, storage, etc. The final and processed data is either displayed on electronic digital display panel or recorded on magnetic media and/or chart recorders.

f) Describe with neat diagram resistive method for liquid level measurement.

Ans: **Resistive method for liquid level measurement:**

(Diagram: 2 Mark, Explanation: 2 Mark , Total 4 Marks)

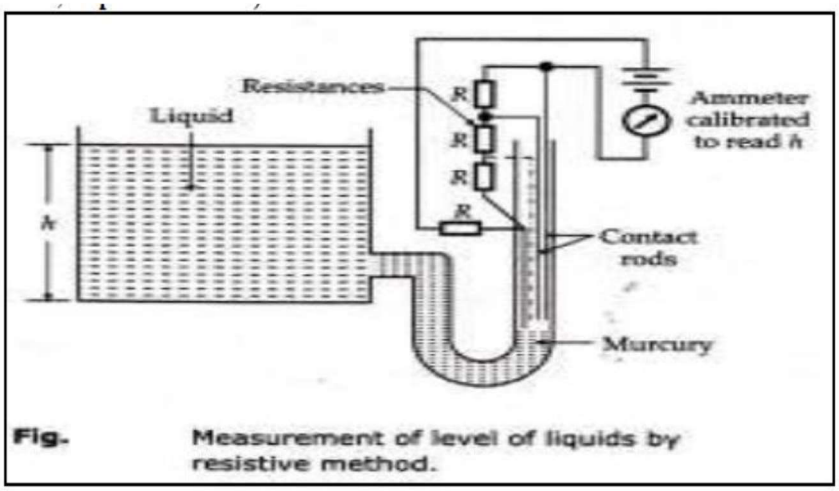
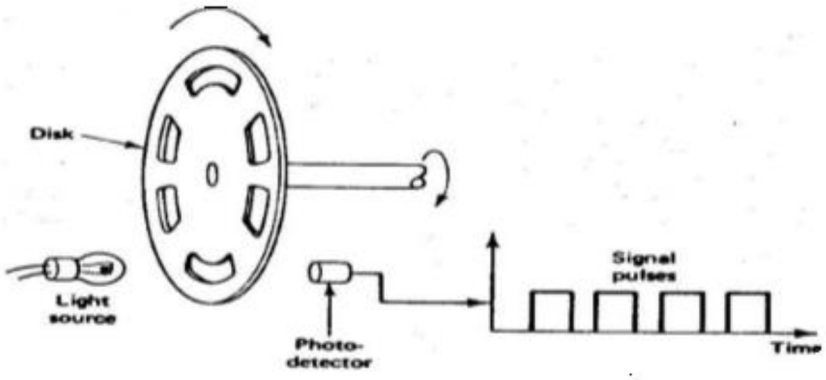


Fig. Measurement of level of liquids by resistive method.

or equivalent figure

	Explanation:- This method uses mercury as a conductor. A number of conduct rods are placed at various liquid levels. As head 'h 'increases, the rising level of mercury above the datum, shorts successive resistors 'R' and increases the value of 'h' directly. The ammeter connected in series is calibrated in terms of the liquid level and indicates the liquid level directly.
Q.6	**Attempt any FOUR of the following : 16 Marks**
a)	**Describe the measurement of rotary motion using optical encoder.**
Ans:	**Diagram of Measurement of rotary motion using optical encoder.** **(Diagram: 2 Marks & Explanation: 2 Marks, Total 4 Marks)**  **or equivalent figure** **Measurement of rotary motion using optical encoder :** ➢ An optical encoder is an angular position sensor. It has a shaft mechanically coupled to an input driver which rotates a disc rigidly fixed to it. A succession of opaque and transparent segments is marked on the surface of the disc. On one side of the disc are ➢ LEDs and on the other side there are photosensitive receivers like photodiodes or photo transistors. ➢ When the disc rotates and opaque segments are between LEDs and receivers, no light reaches the receivers and output is zero.

➢ When the transparent segments are between LEDs and receivers, light is received by the receivers and output signal is obtained. In this way a train of pulses equivalent to the rotation is obtained as shown.

b) Explain with neat labelled diagram of single channel DAS.

Ans:

Diagram for single channel DAS: **(2 Marks)**

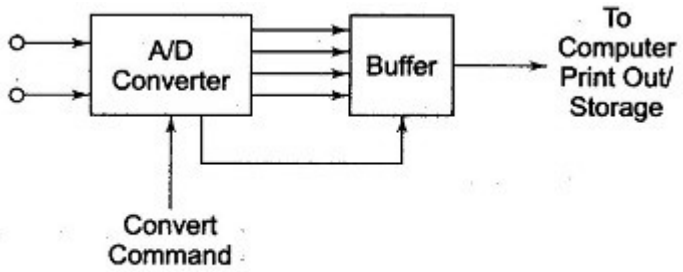


Fig. 17.3 Single Channel DAS

or equivalent diagram

Explanation for single channel DAS: **(2 Marks)**

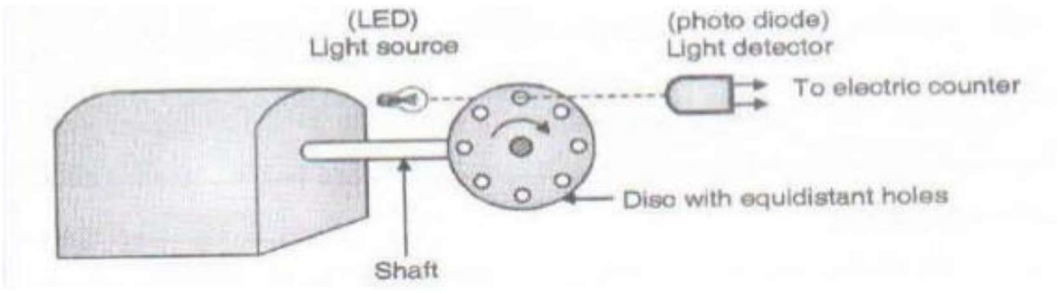
➢ A Single Channel Data Acquisition System consists of a signal conditioner followed by an analog to digital (A/D) converter, performing repetitive conversions at a free running, internally determined rate. The digital outputs are further fed to a storage or printout device, or to a digital computer device, or to a digital computer for analysis.

c) Explain the measurement set up used for speed measurement using non-contact type tachometer.

Ans:

(Note: Any one type may be considered: **(Diagram : 2 Mark & Explanation: 2 Mark)**

i) Photoelectric Tachometer:

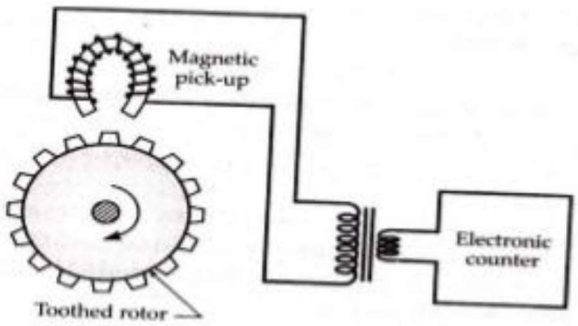


or equivalent figure

- This method of measuring speed consists of mounting an opaque disc on the rotating shaft. The disc has a number of equidistant holes on its periphery. At one side of the disc a light source is fixed. On other side of the disc, and on the line of the light source, a light sensor like phototube or some photosensitive semi-conducting device is placed.
- When the opaque portion of the disc is between the light source and the light sensor, the light sensor is not illuminated and it does not produce any output. When a hole appears between two, the light falling upon the sensor produces an output pulse.
- The frequency at which the pulses are produced depends on the number of holes in the disc and its speed of rotation. As the number of holes is fixed, the pulse rate is a function of speed of rotation.
- The pulse rate is measured by an electronic counter which is directly calibrated in terms of speed.

(OR)

ii) Toothed rotor variable reluctance Tachometer (Magnetic Pick up) :



or equivalent figure

- This tachometer consists of a metallic toothed rotor mounted on the shaft whose speed is to be measured. The magnetic pickup consists of a housing containing a small permanent magnet with a coil wound round it.
- When the rotor rotates, the reluctance of the air gap between pickup and the toothed rotor changes giving rise to the induced e.m.f in the pickup coil. This output is in the

form of pulses. The frequency of the pulses of induced voltage depends upon the number of teeth of the rotor and its speed of rotation.

- As the number of teeth of the rotor is known, the speed of rotation can be determined by measuring the frequency of pulses with an electronic counter.
- If the rotor has T teeth, the speed of rotation is n rps and number of pulses per second is P

Number of pulses per revolution = T

Speed n = (pulses per second /number of teeth)

$$P\,(T)_{rps} = (\frac{P}{T}) \times 60\ rpm$$

d) Suggest suitable thermocouple for following temperature range.
(i) – 250° to 400 °C (ii) 0° to 2100 °C (iii) – 200° to 800 °C (iv) – 0° to 1400 °C

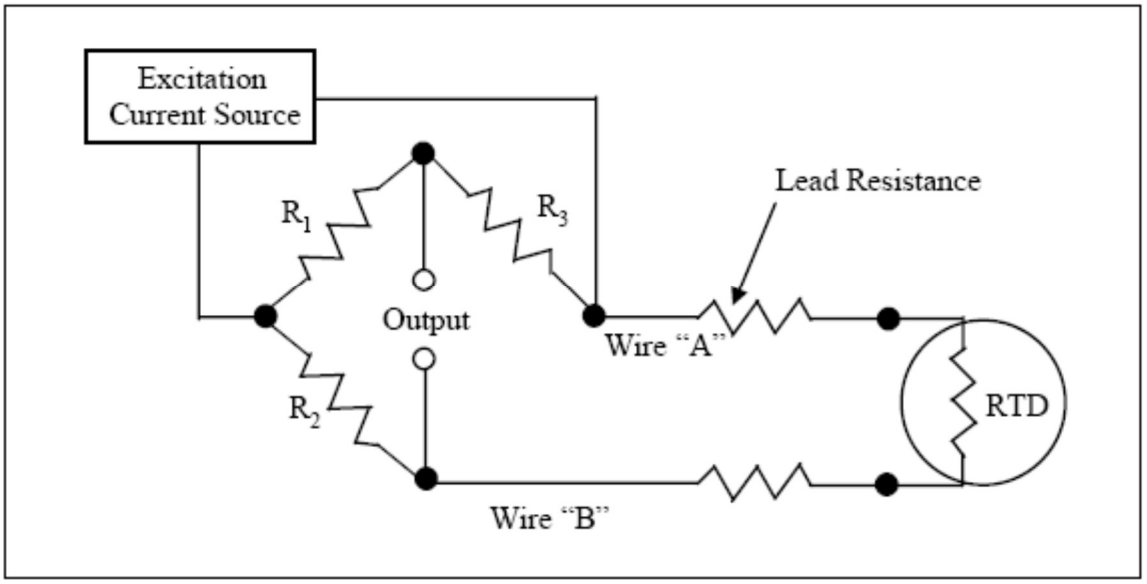
Ans: **Thermocouple for following temperature range:** **(Each transducer: 1 Mark,Total 4Marks)**

S.No.	Temperature Range	Suggest suitable thermocouple
1	– 250° to 400 °C	**T (Copper constantan)**
2	0° to 2100 °C	**R (Platinum Rhodium)**
3	– 200° to 800 °C	**J (Iron Constantan)**
4	– 0° to 1400 °C	**K (Chromel Alumel)**

e) Describe the measurement set up used for temperature measurement using RTD.

Ans: **Diagram of measurement set up used for temperature measurement using RTD:**

(Diagram: 2 Marks & Explanation: 2 Marks, Total 4 Marks)



OR Equivalent Figure

Explanation:

A Resistance Thermometer or Resistance Temperature Detector is a device which used to determine the temperature by measuring the resistance of pure electrical wire. This wire is referred to as a temperature sensor. If we want to measure temperature with high accuracy, RTD is the only one solution in industries. It has good linear characteristics over a wide range of temperature. The variation of resistance of the metal with the variation of the temperature is given as,

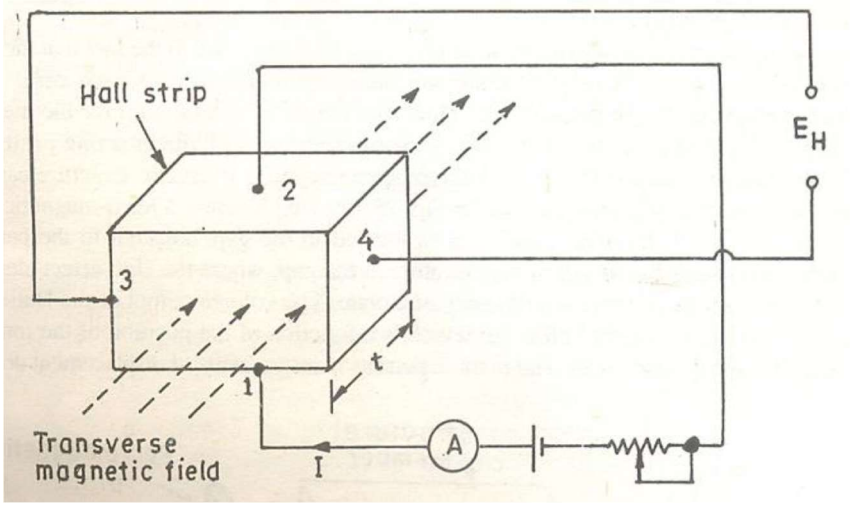
$$R_t = R_0 \left[1 + (t - t_0) + \beta (t - t_0)^2 \ldots\ldots\ldots \right]$$

Where, R_t and R_0 are the resistance values at t ^{0}C and t^{0}C temperatures. α and β are the constants depends on the metals**.**

In this RTD, the change in resistance value is very small with respect to the temperature. So, the RTD value is measured by using a bridge circuit. By supplying the constant electric current to the bridge circuit and measuring the resulting voltage drop across the resistor, the RTD resistance can be calculated. Thereby, the temperature can be also determined. This temperature is determined by converting the RTD resistance value using a calibration expression.

f)	**Describe the working of hall effect transducer for measurement of AC current with neat diagram.**
Ans:	**Diagram of hall effect transducer for measurement of AC current:**

(Diagram : 2 Mark & Working : 2 Mark, Total : 4 Marks)



or equivalent figure

Working of Hall effect Transducer :

Fig. above shows a Hall Effect element/transducer. Current is passed through leads 1 and 2 of the strip. The output leads connected to edges 3 and 4 are at the same potential when there is no transverse magnetic field passing through the strip. When a transverse magnetic field passes through the strip, an output voltage appears across the output leads, given by,

$$E_H = \frac{K_H \ I \ B}{t}$$

Where,

K_H = Hall Effect coefficient, I = current, B = flux density, t = thickness of strip

thus the voltage produced may be used for measurement of either the current I or the magnetic field strength B.

----------END----------