MODEL ANSWER

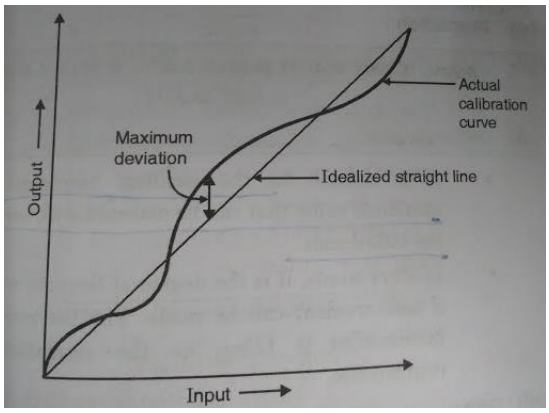
WINTER– 17 EXAMINATION

Subject Title: Industrial Instrumentation **Subject Code:** 17414

Important Instructions 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 principal components indicated in the 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 of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q.N.	Answer	Marking Scheme
Q.1	**(A)**	**Attempt any THREE:**	**20-Total Marks**
	a)	**Define** **i) Sensitivity and** **ii) Resolution**	**2M**
	Ans:	**i. Sensitivity:** The ratio of change in output of an instrument to the change in input is known as sensitivity. Sensitivity = Change in output/ Change in input **ii)Resolution:-** Resolution is defined as smallest increment in input (quantity being measured) which can be detected with certainty by an instrument . **OR** The smallest change in a measured variable to which an instrument will respond is called resolution.	**1 M for each definition**
	b)	**State the static and dynamic characteristics of instruments.**	**2M**
	Ans:	**Static characteristics:** i. Accuracy ii. Sensitivity iii.Reproducibility iv. Drift v.Static error vi. Dead zone	**Any four static characteristi**

		vii. Repeatability viii. Precision ix Linearity **Dynamic characteristics**: i. Speed of response ii. Measuring lag iii. Fidelity iv. Dynamic error	**cs 01 M** **4 dynamic characteristics 1M**
	c)	**Define linearity of instrument and draw linearity curve**	**2M**
	Ans	**Linearity :** It is defined as the ability of an instrument to reproduce the input characteristics linearly and symmetrically. **(or)** It is defined as maximum deviation of calibration curve from a straight line drawn between no load and full load output, expressed as percentage of full scale output and measured on increasing load only. **Linearity curve**  	**Definition 1M** **Linearity curve 1M**
	d)	**Differentiate between zero drift and sensitivity drift (Any two points)**	**2M**
	Ans:	**Zero drift** / **Sensitivity drift** If the whole calibration gradually shifts due to slippage, permanent set or due to undue warning of a electronic circuit, / A shift in calibration curve to change the sensitivity is called sensitivity drift. In this case there is a proportional change in	**01 M each**

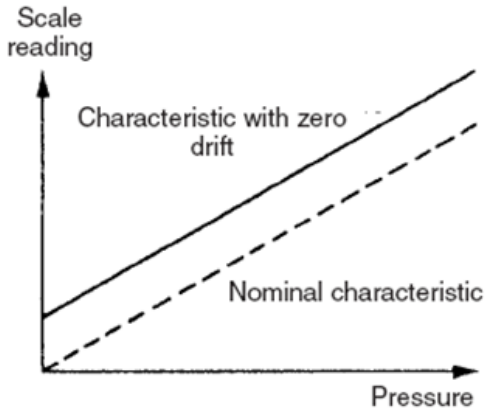
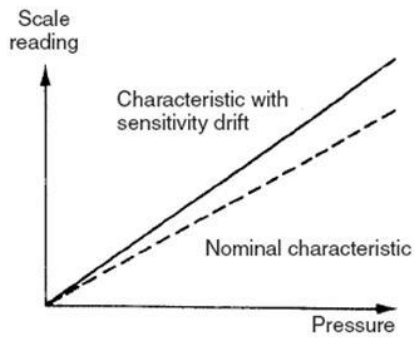
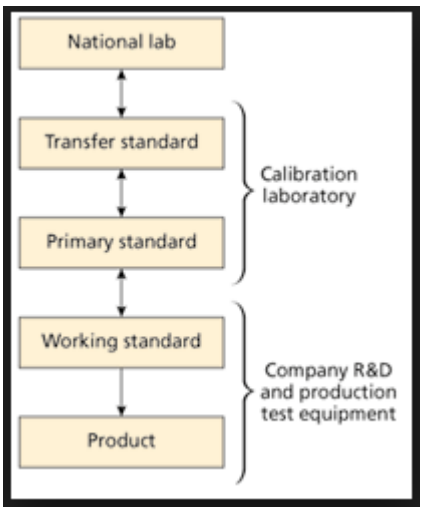
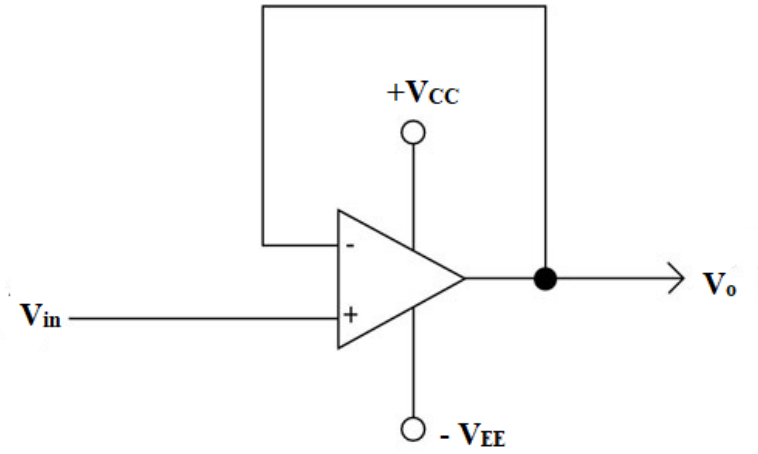
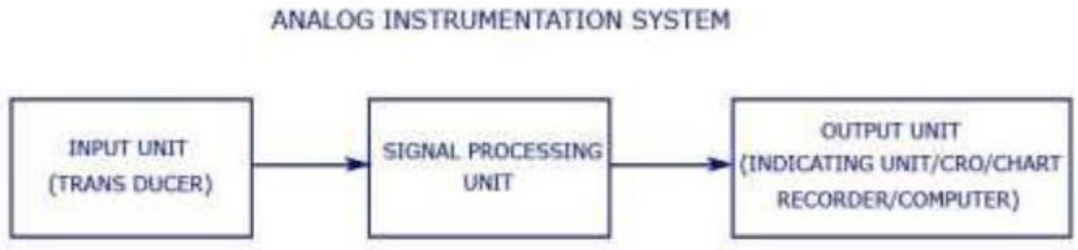
		zero drift sets in the instrument. 	the indication all along the upward scale. 
	e)	**Define dynamic error and settling time**	**2M**
	Ans	**Dynamic error:** It is the difference between the true value of the quantity (under measurement) changing with time and the value indicated by the measurement system if no static error is assumed. **Settling time:** It is the time required for the output of any system to reach and stay within a specified tolerance band. .	**1 M for each definition**
	f)	**Draw the calibration chain.**	**2M**
	Ans:	**(Any other relevant example may also be considered).** 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)	**2M**

		Figure below represents the block diagram of calibration chain and traceability.  	
	g)	**Define stress and strain.**	**2M**
	Ans:	**Stress** 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. **Strain** 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.	**1 M for each definition**
	h)	**State the working principle of thermistors**	**2M**
	Ans:	A thermisto**r** is a type of resistor whose resistance is dependent on temperature. Working principle: Whenever there is a change in temperature, the resistance of some semiconductors change . In case of PTC type, the resistance of the thermistor increases with increase in temperature. In case of NTC type, the resistance of the thermistor decreases with increase in temperature.	**2M**

	i)	**Define gauge pressure and differential pressure**	**2M**
	Ans:	**(i) Gauge pressure:** Gauge pressure is defined as the difference between absolute pressure and atmospheric pressure. Gauge pressure= Pabsolute – Patmospheric **(ii) Differential pressure:** Differential pressure is a pressure that is measured relative to the pressure in the atmosphere around it. Differential pressure is defined as the difference of pressure measurements between two points in a system	**1 M for each definition**
	j	**Give any two advantages of platinum resistance thermometer**	**2M**
	Ans:	1. The resistance temperature characteristic of RTDs is linear. 2 They have a wide operating temperature range: from minus 200 to plus 650°C. 3. They have high degree of accuracy and long term stability. 4. RTDs can be easily installed and replaced. 5. Quick response. The response time is around 2 to 10 seconds. 6. They can be used to measure differential pressure also. 7. No compensation circuit required.	**1 M for each advantage**
	k	**Define :** **i) Input offset voltage** **ii) Differential input resistance**	**2M**
	Ans:	**i. Input offset voltage**: When an op-amp is used as a dc amplifier, it is seen that there is some output dc voltage even though the input dc voltage is zero. Input offset voltage is defined as the voltage that must be applied between two i/p terminals of an op-amp to make its output voltage zero. ii. **Differential input resistance** is defined as the equivalent resistance that can be measured at either inverting or non-inverting input terminals with the other terminal	**01 M for each definition**

		connected to ground.	
	l	**Draw the circuit diagram of unity gain amplifier and state its use**	**2M**
	Ans:	**Diagram:**  The amplifier is a unity gain buffer; also known as a **voltage follower** because the **output voltage** follows or tracks the input voltage. **Use :** As buffer amplifier for matching the impedance of high impedance source to low impedance load.	**Diagram1M** **Use 1M**
Q 2		**Attempt any four:**	**16M**
	(a)	**Draw a neat block diagram of generalized instrumentation system and state function of each block.**	**4M**
	Ans:	 	**Block diagram 2 M**

The Primary Element/Transducer :

The primary element which is a transducer receives the quantity whose value is to be measured and converts it into an equivalent electrical signal such as voltage, current, resistance change, inductance or even capacitance.

The Secondary Element/Signal Processing Unit :

This unit is made up of various networks like amplifiers, filters, analog to digital converters, etc. The output of the transducer is applied to the input of the signal processing unit. This unit amplifies transducer output, filters and modifies it such that it is acceptable by the output unit.to a form that is acceptable by the output unit.

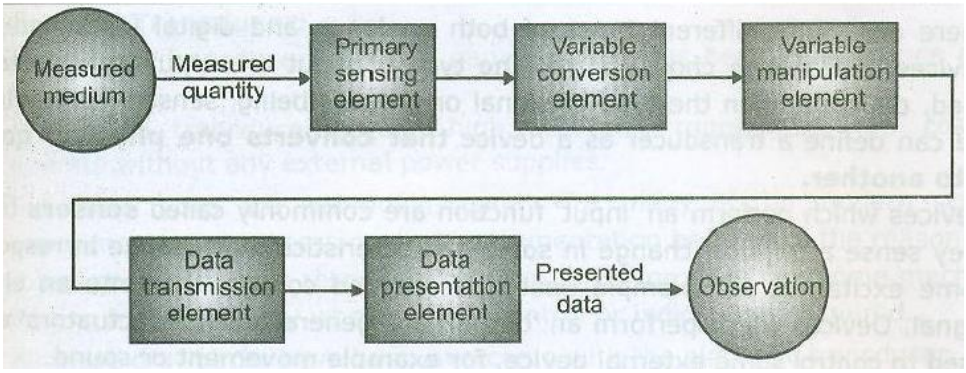
Functions 2M

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, etc.

(OR)

Block diagram of Instrumentation system



Block diagram 2 M

- **Primary Sensing Element:** It receives energy from the measurand medium and produces an output depending in some way on the value of measured quantity.
- **Variable Conversion Element:** This element converts the output signal of the primary sensing element into a more suitable variable which is useful to the function of the instruments.
- **Variable Manipulation Element:** It manipulates the signal represented by some

Functions 2M

physical variable, to perform the intended task of an instrument. In the manipulation process, the physical nature of the signal is preserved.

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

(b) Compare between accuracy and precision (any four points) **4M**

Ans:

Sr no	Accuracy	Precision
1	It is the closeness which an instrument reading approaches the true value of the quantity being measured. **OR** The degree of exactness of a measurement compared to the expected value.	It is the ability of the instrument to reproduce a certain set of readings with a given accuracy. **OR** A measure of the consistency of measurements, i.e successive readings do not defer.
2	It represents the nearness of the measurement with actual value.	Precision represents the nearness of an individual measurement with those of others
3	It is a measure of statistical bias	It is a measure of statistical variability.
4	It is based on single factor	based on multiple factors
5	It is concerned with systematic error that is error due to problems in instrument.	It is concerned with random error which occurs periodically with no recognizable pattern.

1 mark for each point

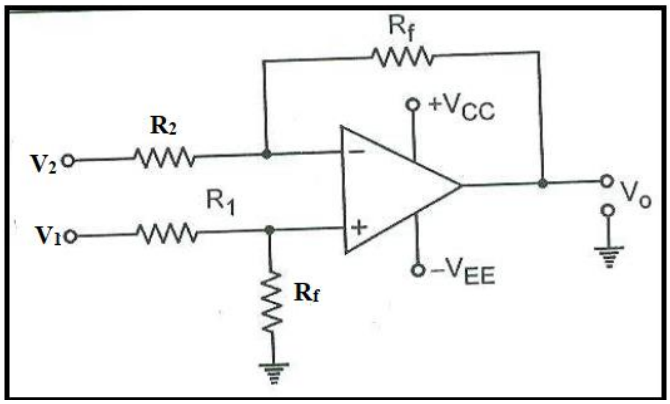
		6	Example : The accuracy of a thermometer having a range of 500^0C may be expressed as ±0.5% of scale range. This means that the accuracy of the thermometer when the reading is 500^0C is ± 0.5%.	Example: Consider the measurement of a known voltage of 100V with a voltmeter. Five readings are taken, and the indicated values are 104,103,105,103 and 105V. From these values, it is seen that the instrument has a precision of ±1% since the maximum deviation from the mean reading of 104V is only 1.0V.	
	(c)	**Explain in brief the working principle of strain gauge. Define gauge factor and list out types of strain gauges.**		**4M**
	Ans:	If a metal conductor is stretched or compressed, the resistance changes as both length and diameter change. There is a change in the value of resistivity of the conductor also when it is strained and this property is called Piezoresistive effect. Strain gauges work on the principle of "Piezoresistive effect". When a strain gauge is subjected to positive strain, its length increases and area of cross section decreases. As resistance R is directly proportional to its length L and inversely proportional to the area of cross section A, the resistance of the conductor increases with positive strain. But this change is greater than that due to change in dimensions. As R =(ρ L)÷A, where ρ = resistivity of the conductor, the extra change in dimensions is due to change in resistivity of the conductor when strained. This property is piezoresistive effect. **Gauge Factor**: It is the defined as the ratio of per unit change in resistance to per unit change in length. $G_f = \frac{\Delta R/R}{\Delta L/L}$	**Working principle 2 M** **Definition 1 M**

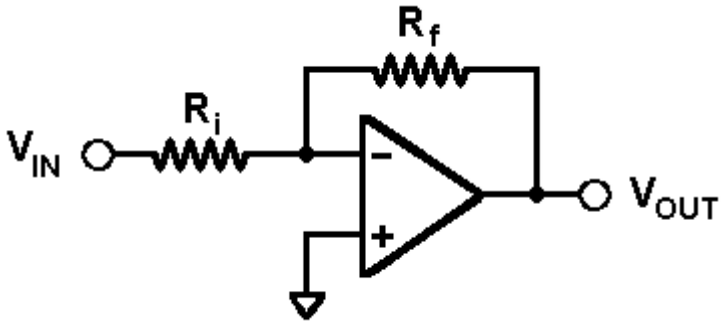
		Types of strain gauges 1. Unbonded metal strain gauges 2. Bonded metal wire strain gauges 3. Bonded metal foil strain gauges 4. Bonded semiconductor strain gauges 5.Vacuum deposited metal film strain gauges 6. Diffused metal strain gauges 7. Sputter deposited thin metal strain gauge	**Any 4 types 1 M**
	(d)	**State the working principle and specification of LVDT**	**4M**
	Ans:	**Working principle:** It works on the principle of mutual induction.to convert linear displacement into equivalent voltage. LVDT has a single primary winding P and two secondary windings S_1 and S_2 wound on a cylindrical former. S_1 and S_2 have equal number of turns and are connected in series opposition. A movable soft iron core is placed inside the cylindrical former. When a.c. supply is given to the primary winding, voltages are induced in both the secondary windings. When a displacement is applied to the movable core the flux linking with both the secondary winding changes and produces output voltage which is proportional to the displacement applied. The output voltage is $Vo = (V_{S1} - V_{S2})$ where V_{S1} is voltage induced in S_1 and V_{S2} is voltage induced in S_2. **Specifications of LVDT** High sensitivity Very good linearity Ruggedness Less friction Low hysteresis Low power consumption	**Principle 2 M** **Any four specifications 2M**

MODEL ANSWER

WINTER– 17 EXAMINATION

Subject Title: Industrial Instrumentation **Subject Code:** 17414

	(e)	**Draw and explain the Op-amp based subtractor**	**4M**
	Ans:	 **Working** The subtractor circuit is a basic op-amp circuit whose output voltage is the difference between two input voltages. In the above circuit, the two input voltages are V_1 and V_2. The op amp is used in inverting mode, so gain of the amplifier is R_f / R Output due to V_2 alone = - R_f / R_2 Output due to V_1 alone = - R_f / R_1 The output of the differential amplifier =Vo = - $(R_f / R)(V_1 - V_2)$ if $R_1 = R_2 = R$. When differential gain is 1, ie $R_f = R$, the output voltage is **$Vo = (V_2 – V_1)$.**	**Diagram 2M** **Explanation 2 M**
	(f)	**Draw the circuit diagram of inverting and non- inverting amplifiers and write their voltage gain equation**	**4M**
	Ans	**Inverting amplifier**	**Diagram 1M** **Gain**

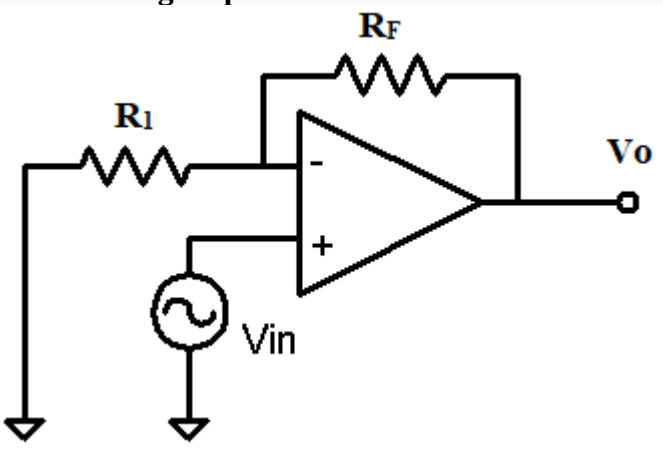


expression 1M

Diagram 1M

Gain of inverting amplifier = (R_f / $R_{1)}$

Non inverting amplifier:



Gain expression 1M

Gain of noninverting amplifier = (1 + R_F /$R_{1)}$

MODEL ANSWER

WINTER– 17 EXAMINATION

Subject Title: Industrial Instrumentation **Subject Code:** 17414

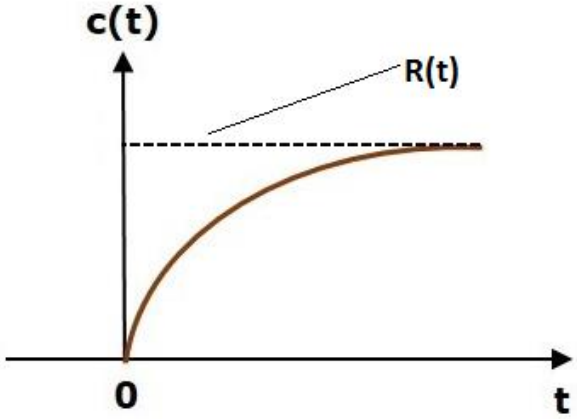
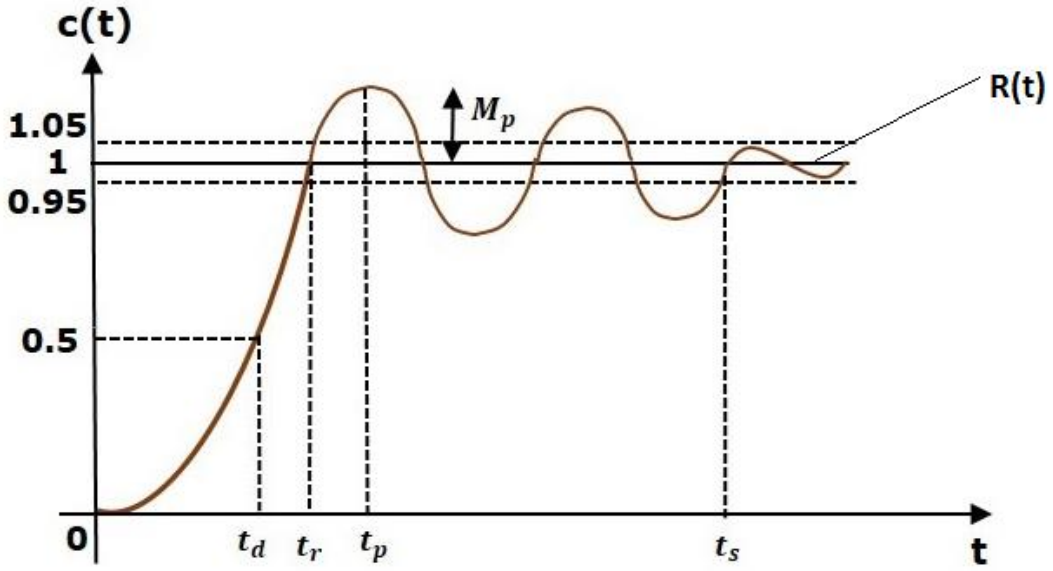
Q. No.	Sub. Q. No	Answer	Marking Scheme
3		**Attempt any four**	**16M**
	a	**Draw and explain the response of first order and second order instruments to the step input.**	**4 M**
	Ans.	**First order instrument response to step input:** The time equation for the step response of a first order instrument is exponential in nature and is given by the equation, $c(t) = 1-e^{-t/\tau}$.	**1 M**
		Where, τ is called the time constant of the system. It shows that, the value of the **unit step response, c(t)** is zero at t = 0 and for all negative values of t. It is gradually increasing from zero value and finally reaches steady state. The steady state value depends on the magnitude of the input.	
			**1M**
		Step response of first order instrument	
		Second order instrument response to step input: The step response of the second order instrument is oscillatory in nature. Depending upon the value of damping ratio, it may be over, under or critically damped or even un- damped.	**1M**

		Fig. below shows the response for an under- damped case. The response up to the settling time is known as transient response and the response after the settling time is known as steady state response. Analysis of such a system is done by calculating different parameters called time response specifications.  **Step response of second order instrument**	**1M**
	b	**State the Seeback and Peltier effects of thermocouple.**	**4 M**
	Ans.	**Seebeck effect**: is a phenomenon in which a temperature difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between the two substances. If the two conductors or semiconductors are connected together through an electrical circuit, direct current (DC) flows through that circuit. **Peltier effect:** The Peltier effect is a temperature difference created by applying a voltage between two electrodes connected to a sample of semiconductor material. This phenomenon can be useful	**2M** **2M**

<table>
<tr><td></td><td></td><td>when it is necessary to transfer heat from one medium to another on a small scale.</td><td></td></tr>
<tr><td></td><td>c</td><td>Differentiate between mass flow rate and volumetric flow rate.</td><td>4 M</td></tr>
<tr><td></td><td>Ans.</td><td>
<table>
<tr><td>Sr No.</td><td>Volumetric flow rate</td><td>Mass flow rate</td></tr>
<tr><td>1</td><td>Volumetric flow is the measure of a substance moving through a device over time.</td><td>Mass flow rate is the amount of Mass moving through an instrument over time</td></tr>
<tr><td>2</td><td>Units of measure for volumetric Flow rate are meter^3 /second, liters/second or feet^3/hour</td><td>The unit of measure is mass per unit of time. It can be expressed as pounds /hour or kilogram/second</td></tr>
<tr><td>3</td><td>To measure Volumetric flow rate, positive displacement meters, turbine flow meters are used.</td><td>To measure mass flow rate, Coriolis flow meters, thermal mass flow meters etc. are used.</td></tr>
<tr><td>4</td><td>Volumetric flow rate = Velocity of flowing fluid x Area.</td><td>Mass flow rate = volumetric flow rate x density</td></tr>
</table>
</td><td>1 M each</td></tr>
<tr><td></td><td>d</td><td>State Hall effect. Explain in brief operation of hall effect transducer with its suitable applications.</td><td>4 M</td></tr>
<tr><td></td><td>Ans.</td><td>Hall Effect:
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.</td><td>1M</td></tr>
</table>

Diagram of hall Effect transducer:

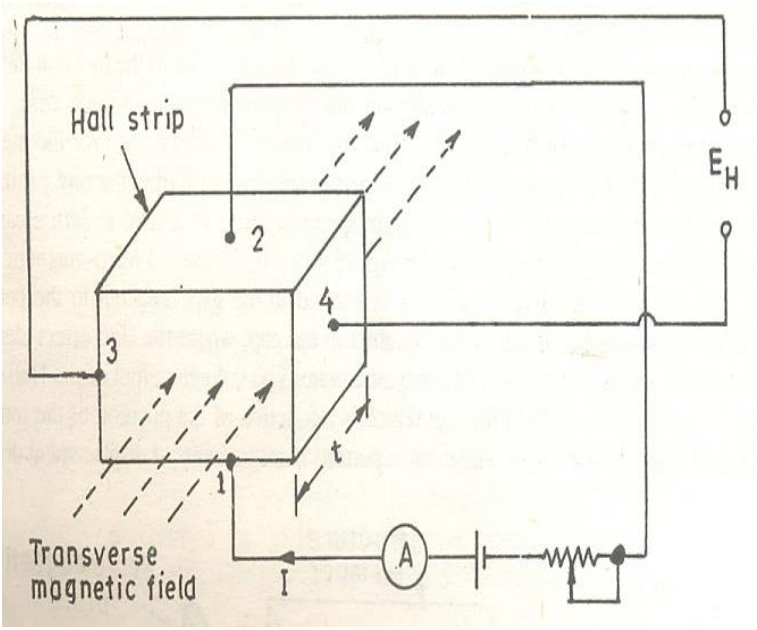


Fig. above shows a Hall Effect element/transducer. Current is passed through leads 1 and 2 of the strip. The output leads connected to edges 3 and 4 are at the same potential when there is no transverse magnetic field passing through the strip. When a transverse magnetic field passes through the strip,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

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

Where,

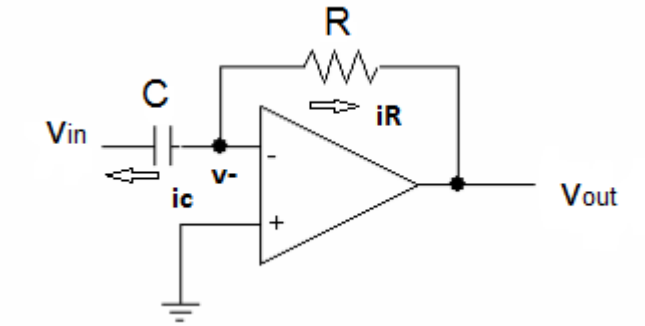
K_H = Hall Effect coefficient

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.

		Applications: 1) Magnetic to Electric transducer 2) Measurement of displacement 3) Measurement of current 4) Measurement of power **(marks may be given for explanation of hall effect transducer for specific example)**	**1M** **(any one)**
	e	**Draw and explain the circuit diagram of differentiator.**	**4 M**
	Ans:	**Diagram:**  **Explanation:** Fig. shows the circuit diagram of differntiator, which provides an output voltage equal to differential of input voltage as given below. Apply KCL at A, we get $i_c = i_R$ i.e, $c\frac{d}{dt(v_- - v_1)} = \frac{v_0 - v_-}{R}$ when $v_- = 0$, $-c\frac{d}{dt}(v_1) = \frac{v_0}{R}$, $v_0 = -RC\frac{d}{dt}(v_1)$	**2M** **2M**

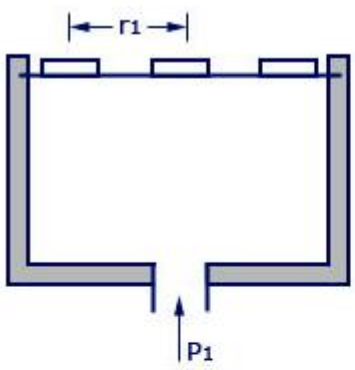
MODEL ANSWER

WINTER– 17 EXAMINATION

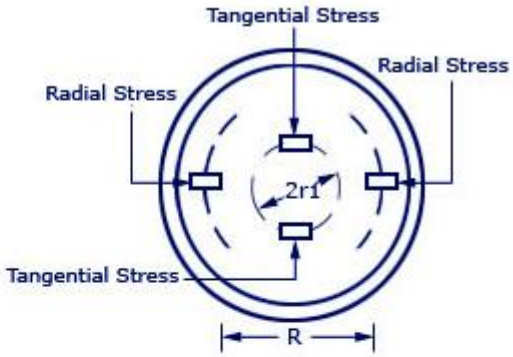
Subject Title: Industrial Instrumentation **Subject Code:** 17414

	f	**List any six criteria for selecting a proper transducer for an application.**	**4M**
	Ans:	**Criteria for selecting a transducer for an application:** 1. Electrical output of transducer (Current/voltage) 2. Range of measurement i.e maximum and minimum values of parameter to be measured. 3. Static operating condition of a transducer. 4. Electrical Noise level. 5. Temperature at which transducer is operating. 6. Dynamic protection housing (IP Protection) 7. Type of mounting required for transducer. 8. Accuracy required. 9. Operating principle suited for application. 10. Sensitivity of transducer. 11. Loading effect. 12. Stability & Reliability of transducer 13. Cost and availability	**Any six-4M**
4	**A**	**Attempt any FOUR:**	**16M**
	a	**Draw and explain the operation of pressure transducer having diaphragm as a primary sensor and four strain gauges as secondary sensors.**	**4 M**
	Ans	**Pressure measurement with strain gauges on diaphragm:**	**2M for correct diagram (any relev-ant dia. May be**

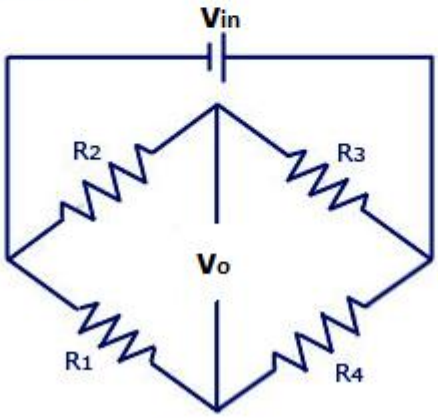
considered)



Side View



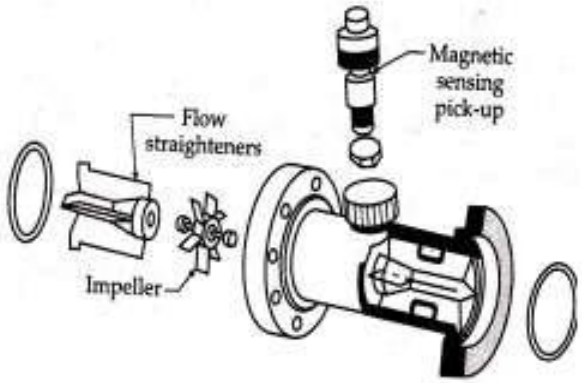
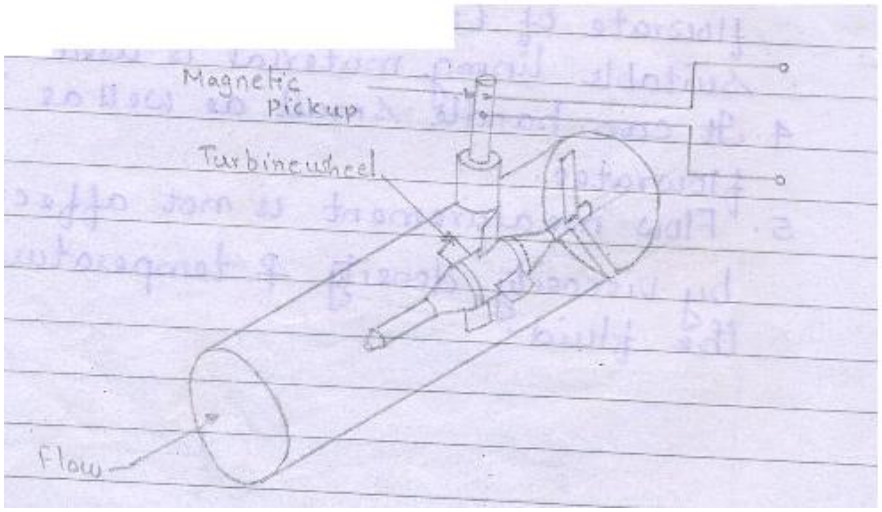
Top View

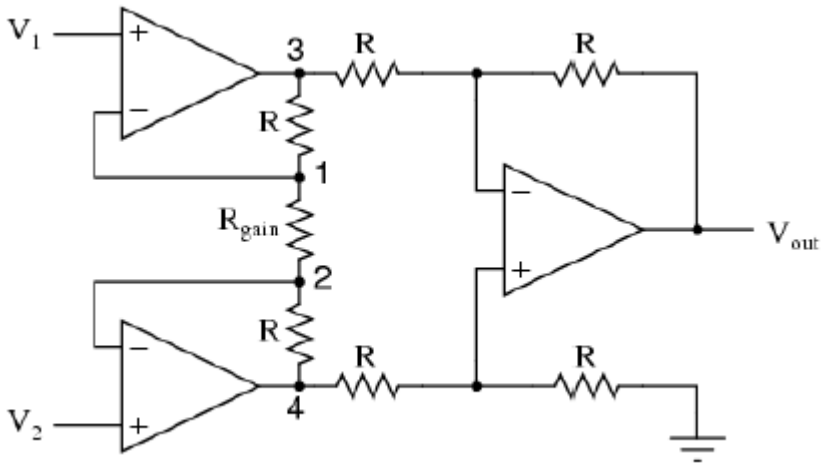


Bridge Circuit

Description:

This method uses the principle of converting pressure into a displacement by elastic elements which act as primary transducers. The displacement created is converted into an electrical parameter by secondary transducers. The figure above shows an arrangement of pressure measurement using four strain gauges mounted on a flat diaphragm. The gauges are electrically connected in a bridge circuit as shown in the figure. The diaphragm act as primary transducer and bonded strain gauges as secondary transducers. As pressure is applied, the diaphragm deflects causing radial and tangential stresses on the strain gauges. The stress cause strain on the gauges, changing the resistance of strain gauges. The change in resistances produce unbalance in the bridge circuit, producing an

		output voltage proportional to the applied pressure.	**2M**
	b	**Draw and explain the working principle of turbine type flow meter. Mention its Application area.**	**4 M**
	Ans	**Diagram:**  **(OR)**  	**2 M for Diagram**

		Working Principle: The flow of liquid past the wheel causes the wheel to rotate at a rate which is proportional to the velocity of the fluid. A voltage pulse is induced in the coil as each blade on the turbine wheel moves past it and these pulses are measured by a pulse counter. **Application Area:** 1) Can be used at high temperature and pressure 2) Suitable for low viscosity high flow measurements 3) Used in petrochemical industries, in Aerospace applications etc.	**1M** **1M**
	c	**Draw the circuit diagram for Instrumentation amplifier using three OP-AMPs. State its advantages and applications.**	**4 M**
	Ans.	 **Application:** 1. Noise eliminator in precision DAS 2. In Medical instrumentation, Navigation, Radar instrumentation e.t.c 3. In Audio applications involving low amplitude audio signals in noisy environments	**2M** **1M**

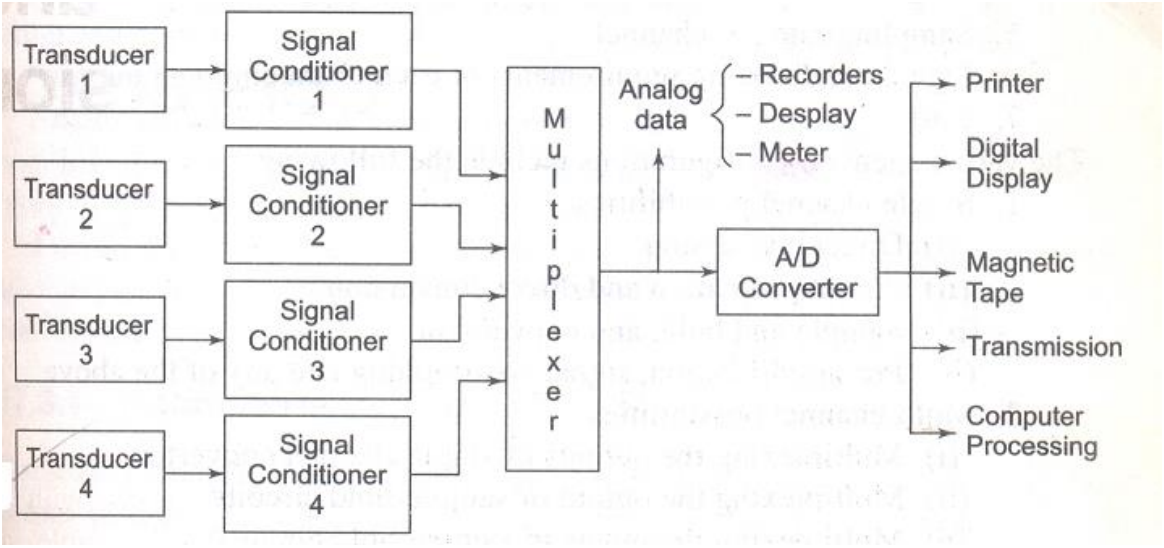
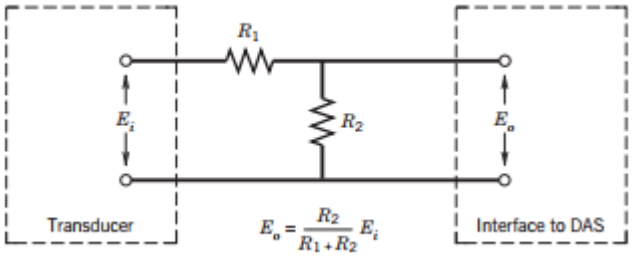
		to improve the signal to noise ratio; 4. High-speed signal conditioning for video data acquisition and imaging 5. High frequency signal amplification in cable RF systems. **Advantages:** i) Low DC OFF- set ii) High open loop gain iii) High CMRR ratio iv) High stability of gain with low temperature coefficient v) Selectable gain with high accuracy and linearity vi) Low output impedance vii) High input impedance	**1M**
	d	**Draw and explain neat labeled block diagram of generalized Data Acquisition System (DAS).**	**4 M**
	Ans.	**Diagram:**  **Description:**	**2M**

		Fig. above shows the block diagram of generalized Data Acquisition System (DAS). It Consists of transducers, signal conditioners, multiplexer, A/D converter and output devices such as display, recorder and printer. Transducers are used for translating physical parameters into electrical signals. The Output of the transducer is given to signal conditioning circuit where the signal is modified to the required level of A/D converter. The analog multiplexer selects the inputs sequentially, one at a time. These are further converted to digital signals by the A/D converter. The processed data is further given for display/ transmission/ printing/recording/computer processing.	**2M**
	e	**List the different techniques used for signal conditioning in DAS. Explain in brief Any one signal conditioning technique.**	**4M**
	Ans:	**Types of Signal Conditioning techniques in DAS:** **1) Attenuation** 2) **Amplification** 3) **Linearization** 4) **Filtering** 5) **Ratiometric conversion** 6) **Logarithmic conversion** **Attenuation:** An attenuator is used to scale down the input gains to match the level of input signal to the converter's full scale range. Most data-acquisition systems contain on-board instrumentation amplifiers as part of the signal conditioning stage with selectable gains ranging from less than to greater than unity. Gain is varied either by a resistor jumper or by logic switches set by software, which effectively reset resistor ratios across OPAMPs. Voltages can also be attenuated using a voltage divider circuit as shown below.	**Listing 2 M** **Explana-tion of any one-2M**



Voltage divider circuit for signal amplitude attenuation.

Amplification:

Amplification increases a voltage signal to a level suitable for digitization by the DAQ equipment. Typically a data acquisition device is calibrated for input voltages in the 0 to 10 V range. A small voltage, such as that coming from a thermocouple or strain gauge bridge may need to be amplified 1000 times to make it between 0 and 10 V.

Linearization:

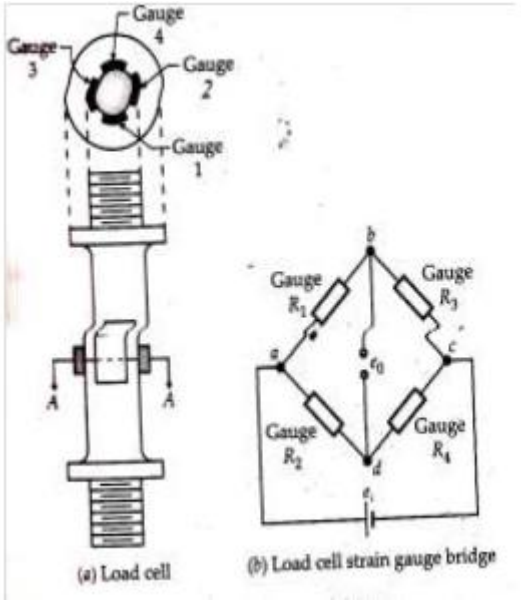
Linearization is required when the signals produced by a sensor don't have a linear relationship with the physical measurement, as is the case when using thermocouples to measure temperature. In this case linearization is performed by analog techniques using either linear approximation or smooth series approximation using IC amplifier. It can also be done digitally after A to D conversion.

Filtering:

Filtering reduces noise errors in the signal. For most applications a low-pass filter is used. This allows the lower frequency components but attenuates the higher frequencies. The cut-off frequency must be compatible with the frequencies present in the actual signal and the sampling rate used for the A-D conversion.

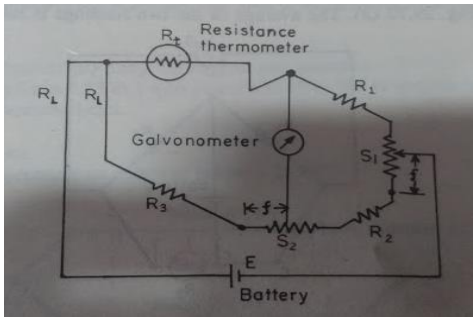
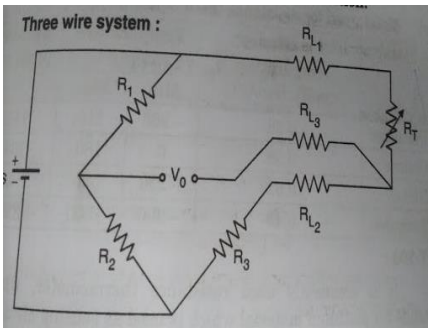
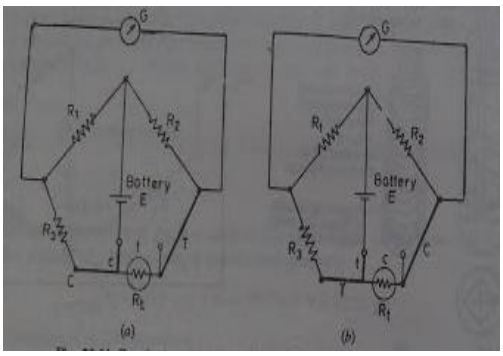
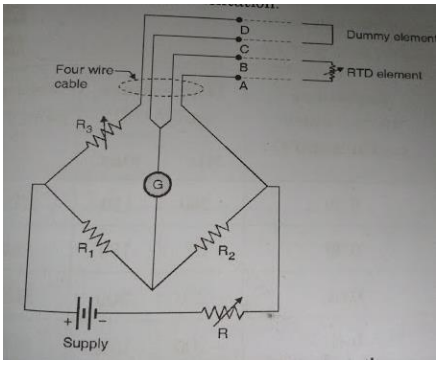
Ratiometric conversion:

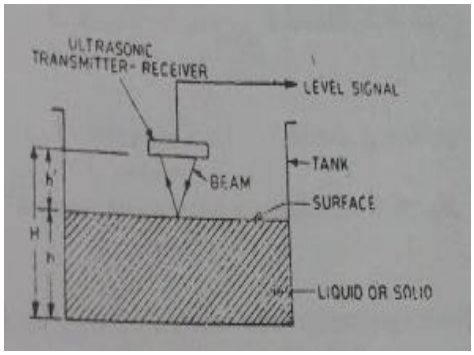
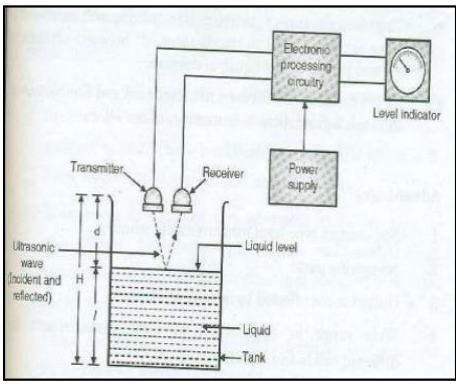
It is a method used along with ADC to improve accuracy of a system having a bridge circuit connected with RTD or strain gauge sensors. The bridge output voltage is a function of each arm resistance and excitation supply. So to make the system accurate, the system sensitivity

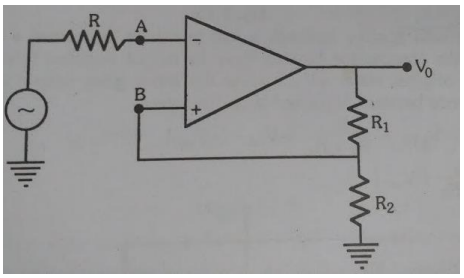
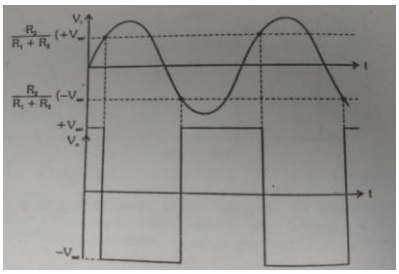
		should be made independent of the supply fluctuations. This can be achieved using a ratiometric conversion circuit. Here the bridge excitation voltage is fed to the ADC as an external reference voltage. Now the conversion factor (Vo/Vi) of ADC is inversely proportional to the reference voltage, making the system sensitivity independent of excitation supply fluctuations. **Logarithmic conversion:** Logarithmic signal compression is a method of signal conditioning for compressing wide dynamic range input signals to a range of an output device. A log amplifier compresses signals by offering equal output amplitude changes in response to a given ratio of input amplitude increase. Such conditioning can be used, where moderate accuracy is expected over a wide range of inputs like in medical investigatory circuits, photo detectors, ionizing radiation detectors and ultrasound receivers etc.	
	f	**Draw and explain force or weight measurement using load cell.**	**4M**
	Ans:	**Diagram:**  	**2M**

		Description: Load cells utilize an elastic member as the primary transducer and strain gauges as secondary transducers. Strain gauges may be attached to any elastic member, on which there exists a, suitable plane area to accommodate them. This arrangement may then be used to measure loads applied to deform or deflect the elastic member, provided that the resultant strain is large enough to produce detectible outputs. Fig. above shows a column type load cell mounted with four strain gauges on its periphery. The output voltage measured across the four arm Wheatstone bridge circuit, is a measure of the weight being applied.	**2M**

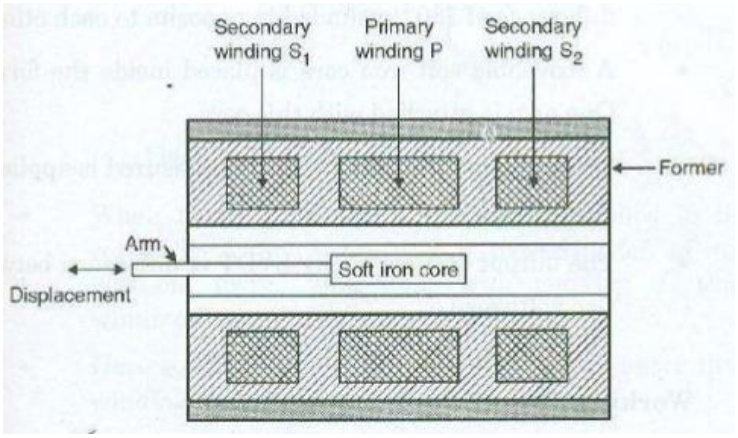
Q. No.	Sub Q.N.	Answer	Marking Scheme
Q.5		**Attempt any FOUR:**	**16M**
	a)	**State the working principle of RTD. List RTD fabrication materials. Draw either 3-wire or 4-wireRTD measurement configuration.**	**4M**
	Ans:	**Working principle of RTD:** The resistance of a conductor changes when its temperature is changed. The variation of resistance R of a metal with the temperature T can be represented by the following relationship: $R_t = R_0(1+\alpha_1 T +\alpha_2 T^2 +\alpha_n T^n + ----)$ where R_0 = resistance of the conductor at temperature T = 0 $\alpha_1, \alpha_{2,---} \alpha_n$ = constants. **Materials used to fabricate RTD :**	**Principle 1M** **Materials**

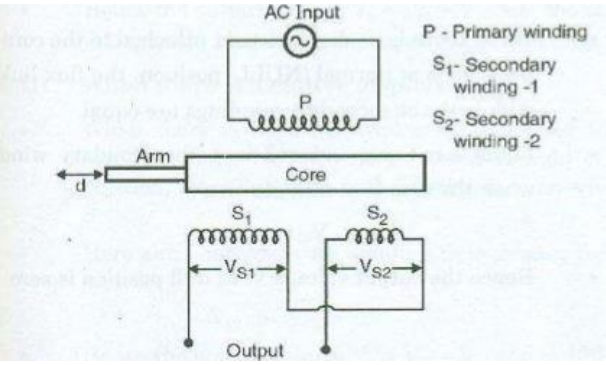
		Platinum, Copper, Nickel and Tungsten **3-wire RTD measurement configuration:**  **(or)**  **(OR)** **4-wire RTD measurement configuration:**  **(OR)**  	**used 1M** **Any one diagram 2M**
	b)	**Draw and explain the operation of ultrasonic level measurement.**	**4M**

	Ans:	**Diagram**  **(OR)**  In this method, an ultrasonic transmitter receiver is mounted on top of the tank for measurement of level. The ultrasonic beam generated by transmitter is projected downwards towards the liquid surface in the tank which is to be measured. This beam is reflected from the surface of the liquid and is received by the receiver. The time taken by the beam is a measure of the distance travelled by the beam. Therefore the time 't' between transmitting and receiving a pressure pulse is proportional to the distance 'h' between ultrasonic set and surface of the liquid in the tank. Or $t \alpha (H - h)$ where H = distance between ultrasonic set and the bottom of the tank As H is fixed, time't' is measure of level.	**Diagram 2M** **Explanation 2M**
	c)	**Draw and explain the working of Schmitt trigger.**	**4M**
	Ans:	A Schmitt trigger converts an irregular shaped waveform into a square wave. It is a special type of comparator in which the output changes from one saturation level to another saturation level depending on differential input voltage. **Working**:	**Working 2M**

		Consider the circuit shown below to which an a.c. voltage is applied. The potential at B is positive and at point A is zero. The differential voltage is positive, so the output voltage is driven to + $V_{sat.}$ At this instant, the potential at B is: $V_B = R_2/(R_1 + R_2)*(+V_{sat.})$.This voltage is called upper trigger point (V_{UTP}).When input becomes more positive than V_{UTP}, the differential input is negative. Therefore the output is driven to – V_{SAT}. Now the potential at B is: $V_B = R_2/(R_1 + R_2)*(-V_{sat.})$ This voltage is called lower trigger point (V_{LTP}).The output remains at $-V_{sat}$ until input voltage becomes more negative than V_{LTP}.When input becomes more negative thanV_{LTP}, the differential input is again positive. Therefore the output is driven to + V_{SAT}. the circuit diagram and waveforms are as shown.   **Circuit diagram** **Waveforms**	**Diagram 2M**
	d)	**List the types of ADCs. Explain working principle of any one type of ADC.**	**4M**
	Ans:	**Types :** 1. Successive approximation type A/D converter or Potentiometric type 2.Voltage to time or ramp type A/D converter 3.Voltage to frequency or integrating type A/D converter 4.Dual slope integrating type A/D converter **Working Principle of:** **1.Successive approximation type A/D converter:** It uses an efficient code search strategy to complete n bit conversion in n clock	**Types : 1M**

		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. **2.Voltage to time A/D converter:** This type of ADC utilizes digital counter techniques to measure the time required for a voltage ramp to rise from zero to the input voltage level. The ramp can be either positive going or negative going. The ramp voltage is applied to a comparator where it is compared with the analog voltage from the sensor. The time consumed by the ramp voltage to increase to the value of sensor voltage depends upon the size of the sampled analog voltage. When the ramp voltage starts a gate is opened which starts a binary counter counting the regular pulses from a clock. When both voltages are equal, the gate closes and the word indicated by the counter is the digital representation of the sampled voltage . **3. Voltage to frequency or integrating type A/D converter :** An analog voltage can be converted to digital form, by producing pulses whose	**Working principle of any one ADC -3M**

		frequency is proportional to the analog voltage. These pulses are counted by a counter for a fixed duration and the reading of the counter will be proportional to the frequency of the pulses and hence, to the analog voltage. **Dual slope Integration A/D converter** In this ADC , an unknown analog voltage and a known reference voltage are converted into equivalent time periods using an integrator, These time periods are measured by the counter. This circuit is called dual slope ADC because the analog voltage and reference voltage are converted to ramp signals of different slopes by the integrator.	
	e)	**Draw and explain the displacement measurement system using LVDT.**	
	Ans:	 **(Or)**	**Any one diagram 2M**



Explanation 2M

LVDT has a single primary winding P and two secondary windings S_1 and S_2 wound on a cylindrical former. S_1 and S_2 have equal number of turns and are connected in series opposition. A movable soft iron core is placed inside the cylindrical former. When a.c. supply is given to the primary winding, voltages are induced in both the secondary windings. When a displacement is applied to the movable core, the flux linking with both the secondary winding changes and produces output voltage which is proportional to the displacement applied.

The output voltage is $Vo = (V_{S1} - V_{S2})$

where V_{S1} is voltage induced in S_1 and V_{S2} is voltage induced in S_2.

Working:

Case I: **When there is no displacement.** When no displacement is applied to the core, the core is at normal position. The flux linking with both the secondary windings is equal. Equal e.m.f. is induced in both secondary windings or $V_{S1}=V_{S2}$

So, $Vo = V_{S1} - V_{S2} = 0$

The output voltage Vo at null position is zero.

Case II: When the core moves to the left due to some displacement:

When the core is moved to left of null position due to some displacement applied, more flux links with winding S_1 than winding S_2

Hence e.m.f. induced in S_1 is greater than the e.m.f. in S_2, that is $V_{S1}>V_{S2}$
The output voltage Vo = V_{S1}-V_{S2} and is in phase with the input primary voltage.

Case III: When the core moves to the right due to some displacement: When the core is moved to right of null position due to applied displacement, more flux links with winding S_2 than winding S_1. So e.m.f. induced with winding S_2 is greater than S_1.that is $V_{S2}>V_{S1}$
Hence the output voltage Vo= V_{S1}-V_{S2} and is 180^0 out of phase with the input primary voltage.
In this way any physical displacement of core causes the voltage of one secondary winding to increase while simultaneously reducing the voltage in the other winding. Output voltage Vo measured is equivalent to the displacement.

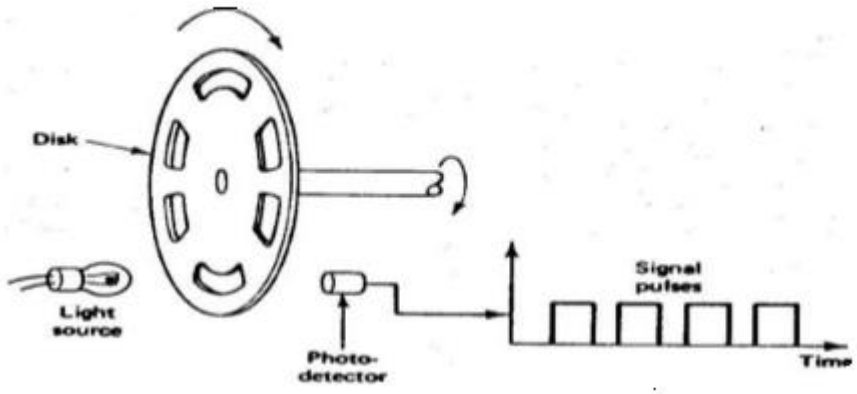
f) Compare between RDTs and Thermistors (Any 4 points) **4M**

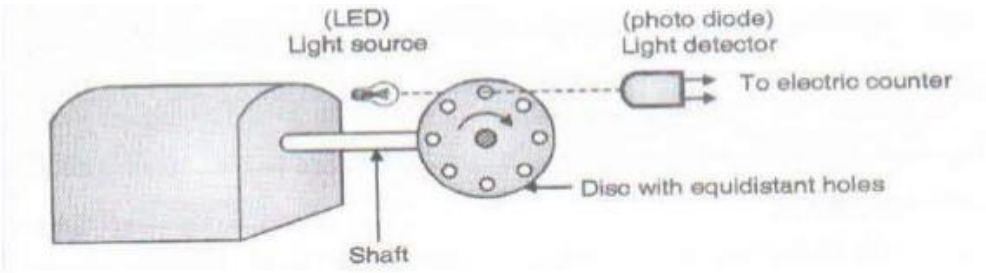
Ans

Sr 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
	Temperature versus	Temperature versus resistance

One mark for each valid point

			4	resistance characteristics are linear.	characteristics are nonlinear.	
			5	Less sensitive to temperature than theristor	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. .	
Q.6		**Attempt any FOUR:**				**16M**
	a)	**What is encoder? Draw and explain an optical encoder operation for rotary motion measurement.**				**4M**
	Ans:	**Definition:** Digital encoders convert analog motion (rotary or linear) to a digital output form. An optical encoder is an electromechanical device which has an electrical output in digital form proportional to the angular position of the input shaft. Optical encoders enable an angular displacement to be converted directly into a digital form.				**Definition 1M**

		Diagram:  **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.	**Diagram 1M** **Explanation 2M**
	b)	**Draw and explain in brief speed measurement using non-contact type transducer.**	**4M**
	Ans:	**(Note: Any one type may be considered.)** **i) Photoelectric Tachometer:**	



Diagram

2M

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.

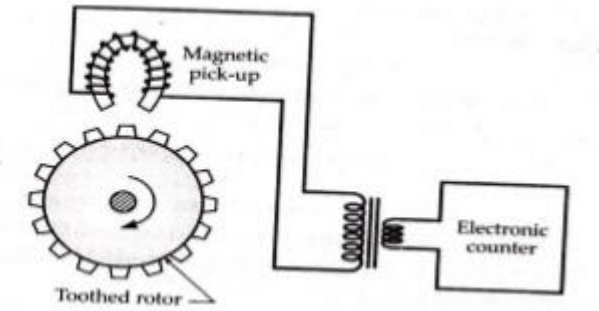
The pulse rate is measured by an electronic counter which is directly calibrated in terms of speed.

Explanation

2M

(OR)

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



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)

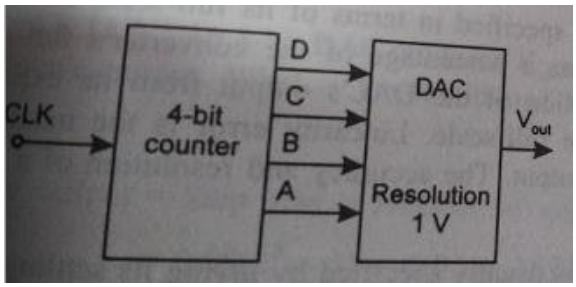
= (P/T) rps = (P/T) *60 rpm.

	c)	**With the help of a neat circuit diagram explain the working principle of Digital to Analog converters.(DAC)**	**4M**
	Ans:	**(Any appropriate circuit and explanation may be considered.)**	

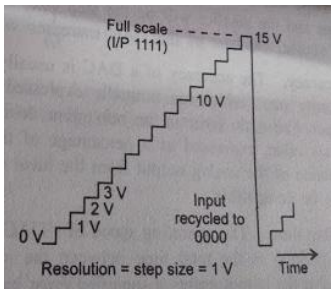
Digital-to-Analog Converters:

Diagram

2M



DAC fed by a binary counter



Output waveform of a DAC

D/A conversion is the process of converting a value represented in digital code such as binary or BCD into a voltage or current which is proportional to the digital value.

Fig represents the symbol of a typical 4 bit D/a converter.

Each of the digital inputs A,B,C and D can assume a value 0 or 1, therefore there are2^4 = 16 possible combination of inputs. For each input number, D/A converter outputs a unique value of voltage.

Explanation

2M

The analog output voltage V_{out} is proportional to the input binary number.

So, Analog output = (K *digital input) where K is proportionality factor and is constant for a given DAC.

(Or)

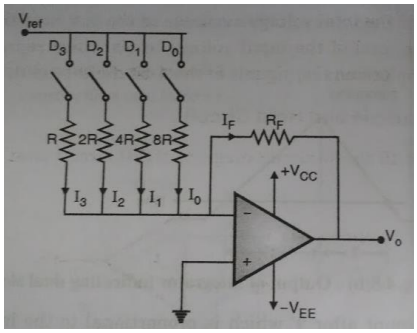
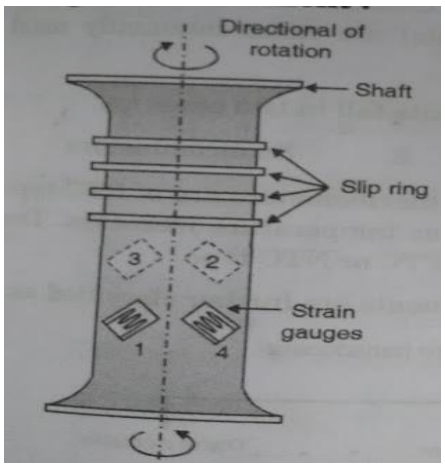
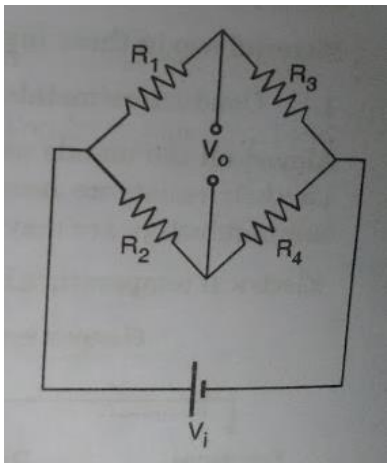
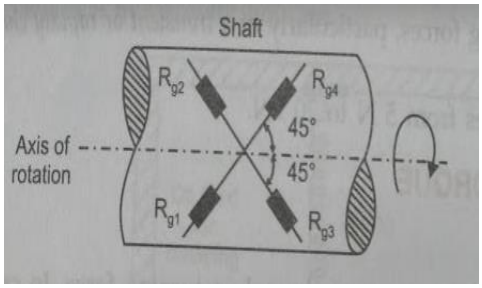
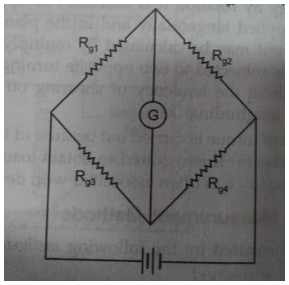
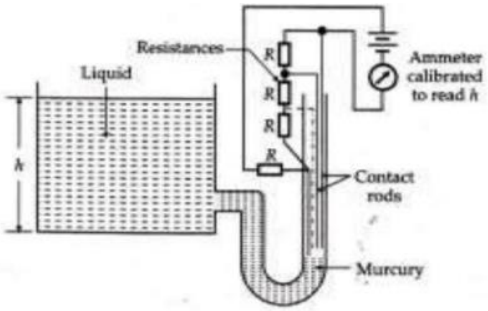
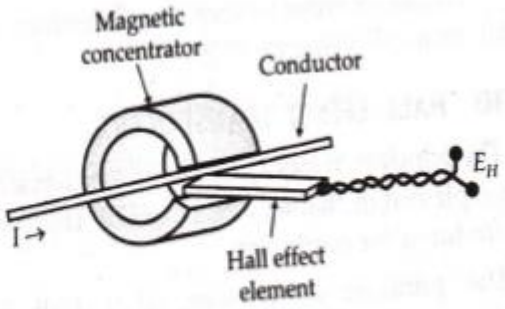


		Figure above represents a DAC using op-amp. The summing amplifier has four input resistances corresponding to four binary inputs D0,D1,D2 and D3.Switches are provided with each input. If a switch is open ,it indicates '0'And for closed switch it indicates '1'. The output of the 4 bit DAC is : $I_{in} = (V_{ref}/R)(D_3+2^{-1}D_2+2^{-2}D_1+2^{-3}D_0$. So the total voltage available at the output of the op-amp is the total of input voltage levels which represents the equivalent analog signals of the 4-bit digital input.	
	d)	**Draw and explain the measurement of torque using Torque Cell**	**4M**
	Ans:	**(Any one type may be considered.)**   Fig a fig b 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 45^0 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	**Diagram 2M** **Explanation 2M**

		strain is measured by the bridge circuit. Output of the bridge network will be proportional to the torque . **(Or)**   Figure above represents a strain gauge bridge circuit used for torque measurement. Four bonded wire strain gauges are mounted on a 45^0 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. .	
	e)	**Draw and explain in brief Liquid Level Measurement using Resistive Sensor.**	**4M**
	Ans:	 	**Diagram 2M**

		Working: This method uses mercury as a conductor as shown in the figure. A number of contact rods are placed at various liquid levels. As the level of liquid rises in the tank, head h increases. The level of mercury rises above the datum and 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.	**Explanation 2M**
	f)	**Explain in brief AC Current , RMS Indication using Hall Effect Transducer.**	
	Ans:	 **Measurement of current using Hall Effect transducer.** When an ac current passes through the conductor it sets up a magnetic field around the conductor. This magnetic field is proportional to the current. A Hall Effect Transducer is placed in a slotted ferromagnetic tube which acts as a magnetic concentrator. The voltage produced at the output terminals is proportional to the magnetic field strength and hence is proportional to the current flowing in the conductor. In this way, the current is measured using the Hall effect transducer.	**Diagram 2M** **Explanation 2M**