



**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. 01 a) Attempt any three**

**4marks each**

**1. Define (each definition one mark each)**

**Threshold:** It is defined as the minimum value of the input which is necessary to cause a detectable change from zero output i. e. when the input signal of an instrument is gradually increased from zero, there will be some minimum value of input before which the instrument will not detect any output change.

**Resolution:** It is defined as the smallest change of input for which there will be change in output. When the input signal is increased from non zero value, one observes that the instrument output does not change until a certain input increment is exceeded. This increment is termed as resolution or discrimination.

**Repeatability:** The repeatability of a measuring instrument may be defined as the closeness among the no of consecutive measurement of the input, under the same operating conditions, approaching the measurement from the same direction. It is random of nature.



**Reproducibility:** It is the closeness among repeated measurement of the output for the same value of input made under the same operating conditions over a period of time, approaching from both directions. Perfect reproducibility means that the instrument has no drift.

**II) Comparison Accuracy and Precision (any four points one mark each)**

Accuracy	Precision
It is the closeness with which an instrument reading approaches to the true value of the quantity being measured.	It is the degree of reproducibility among several independent reading of the same true value under specified condition.
It is expressed as the limit of error of a measuring device	It is composed of two characteristics, conformity and no of significant digits.
Accuracy of measurement means conformity of the truth.	Precision refers to degree of agreement within group of measurement.
Expressed on the basis of % actual scale or full scale reading. Accuracy necessarily is with precision.	Precision in measurement does not guaranties accuracy.
Measurements are dependent on the systematic errors	Measurements are dependent on the random errors
Determined by proper calibration	Determined by statistical analysis

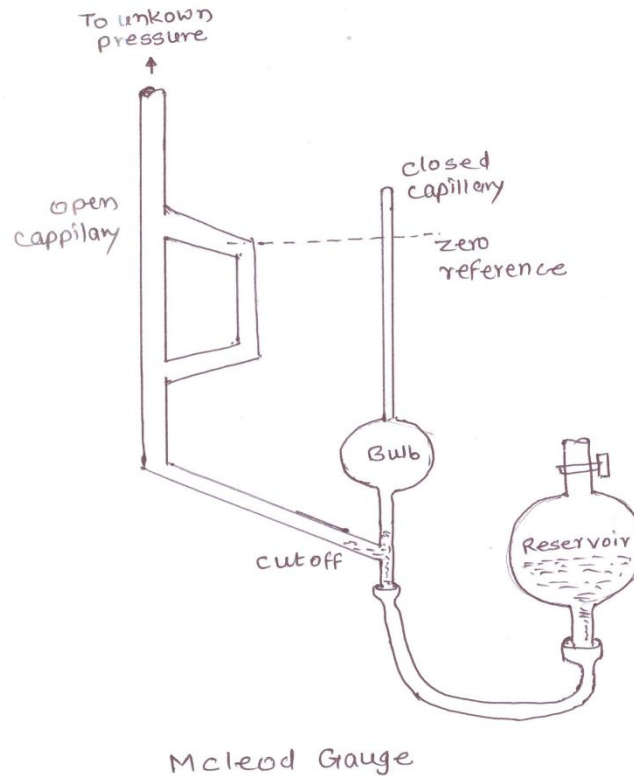
**III) Low pressure measurement ( list of low pressure gauges 2 mark+ 2 marks explanation of nay one low pressure gauge)**

Vacuum pressures are those which are below atmospheric pressure. These pressure gauges measure low pressure ranging  $10^{-3}$  to  $10^{-6}$  mm of hg. Following are the gauges which measures low pressure.

The low pressure gauges are as follows

1. Capsule Gauge,
2. McLeod Gauge,

3. Thermal conductivity Gauge,
4. Pirani Gauge.



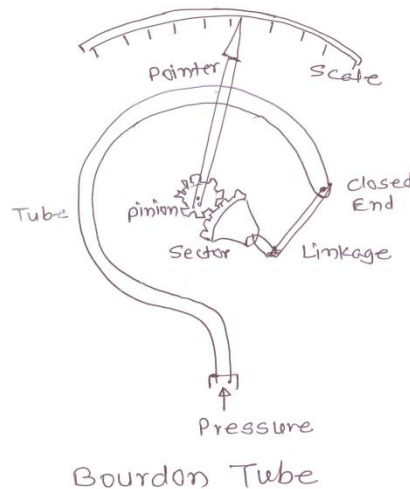
The gas enters the gauge through the open capillary tube and fills the tubes down to the level of mercury in the reservoir. The pressure is equal through the tubes and the bulb. Mercury is pumped up from the reservoir. As the mercury raises the cut-off, it traps the gas inside the bulb. The mercury is then pumped higher in the open end capillary tube until all the gas in the bulb is compressed into the bulb. Operator allows the mercury to rise until it reaches zero reference line on the closed capillary tube. The mercury rises faster in the open capillary tube.

The compression of gas in closed capillary tube makes the pressure of trapped gas higher than the measured pressure. This pressure difference causes difference in the mercury level in the two tubes. Mathematically pressure is calculated as

$$P = KHH_0(1 - KH)$$

**Note:-Explanation of any low pressure gauge should be considered.**

**IV) Bourdon Tube (sketch 2 marks+ 2 marks explanation)**



Fluid under pressure enters the bourdon tube it tries to change the section of the tube from oval to circular and this tends to straighten out tube. The resulting movement of the free end of the tube causes the pointer to move over a calibrated scale. This happens through the mechanical linkages and gear and sector arrangement at the closed end of tube.

Bourdon tube is made of number of materials depending on fluid and the pressure for which it is used such as alloy steel, phosphor bronze, monel metal, beryllium copper etc. These must have adequate elastic and spring characteristics.

**b) Any one of the following**

**06 marks**

**I) Transducer:** Transducer is an element which converts energy from one form to another. Usually a transducer converts non electrical quantity into electrical signal. Many physical parameters such as heat, light, flow rate, pressure, humidity may be converted into electrical signal. Example thermocouple converts heat energy into electrical voltage. ( 2 marks)

**Classification (2 marks)**

- 1) On the basis principle used : Resistive/inductive/ capacitive
- 2) Active and Passive transducer as power source.
- 3) Primary and Secondary transducer
- 4) Analog and digital transducer

5) Input output transducer

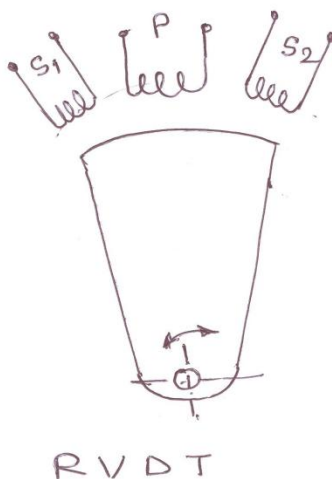
Thermo resistive transducer

The resistance of the conductor changes when its temperature is changed. This property is used for measurement of temperature. Resistance temperature detector RTD and thermister is the example of this type of transducer. In RTD resistance changes with temperature in proportional manner where as in thermister it is having negative resistance temperature coefficient.

Example: LVDT, Photoelectric, resistive (any one example 2 marks)

## II) Working of RVDT (sketch 2 marks+ 4 marks explanation)

This is called as rotary variable differential transformer and is used for measurement of angular displacement. Iron core is having angular motion and is having windings. Two secondary and one primary winding is used in RVDT. Input supply is given to primary winding and output is taken across secondary winding. Output is the difference of voltage across two secondary windings. This output depends on the movement of central iron cores angular displacement. Fig shows working principle and electrical diagram for RVDT.



Applications:-

- To measure angular position or displacement

**Q. No 2 Attempt any two****Definition 01 mark, Sketches 01, error types 06 marks**

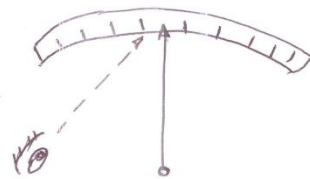
a) **Error** It is the difference between observed value and true value.

Errors arise from different sources are classified as

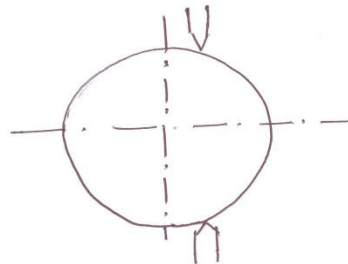
**Gross Error:** These arise due to involvement of human in the experiment. These are human errors and observational errors. Operational Errors due to misalignment error and excessive pressure by operator

Observational errors are due to wrong readings taken can be avoided by taking no of readings. Tendency to read high or low also cause error. Lack of experience is also affecting on this type of error. Parallax error.

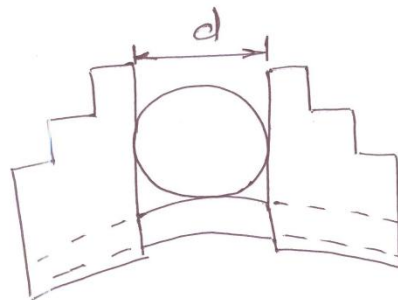
**Systematic Error:** Also called as known error these is due to



Parallax Error



Misalignment



Excessive pressure.

Instrumental error: Zero error or calibration error also leads to the errors in the reading.

Environmental errors: These are due to effect of change of different parameters due to environment. A change in room temperature may affect on resistance of any arm in the circuit and give misleading results. These type of errors can be avoided or corrected by compensating.

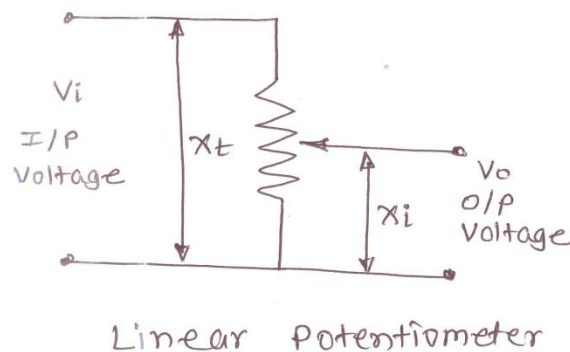
**Random Error:** By taking all care still we can not reach towards true value and the error exists for unknown reasons are called random error.

**Translational and signal transmission error:** The instrument may not translate the measurement effect with complete fidelity. The error may also result from unwanted disturbances such as noise, line pick up, ripple etc.

**b) Linear potentiometer:**

(Sketch 02 mark , working of potentiometer 04 mark , Application 02 marks)

It is a passive transducer since it requires external power source for its operation. It is used for measurement of linear displacement. A potentiometer is used for voltage division and it is also called as POT. The voltage divider circuit for potentiometer is as shown in circuit.



The movement of slider against the potentiometer resistance element results in variation in resistance and the corresponding variation in the output voltage. When the slider is in lowest position the output voltage is minimum and when the slider is in topmost position the output voltage is maximum.

Mathematically displacement is found by equation  $V_o/V_i = X_i/X_t$

Displacement  $X_i = (V_o/V_i) * X_t$

**Application**

1. For measurement of displacement
2. Regulating fan speed.
3. For sensing the vibrations
4. Regulating the required the power supply.

**Q.2.C Temperature Measurement**

## 1. Non Electrical methods

Liquid in glass thermometer

Bimetallic thermometer

Thermo electric type thermometer

Pyrometry type thermometer

## 2. Electric methods

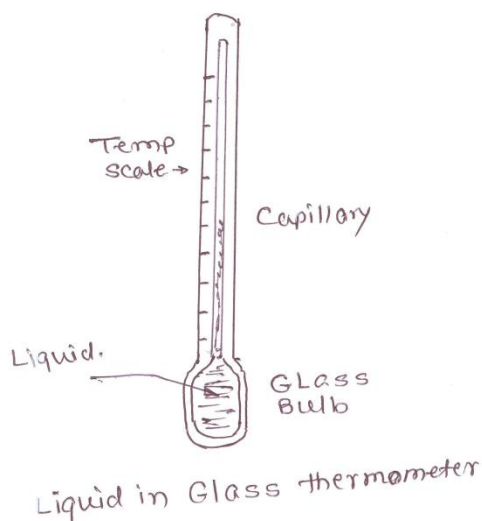
Electric Resistance type thermometer

RTD Resistance temperature detector

**02 marks**

Thermistors

Liquid in Glass thermometer

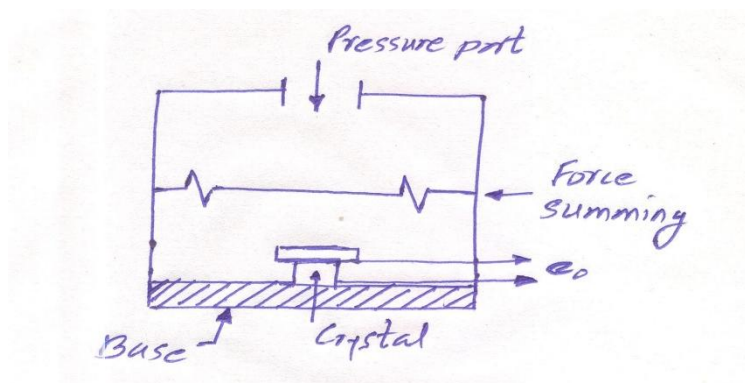
**02 marks**

It is one of the most common temperature measuring device. It works on the principle of expansion of liquid under application of heat. The expansion is volumetric and is proportional to the temperature of hot body. This volumetric expansion is converted into linear scale. The construction of liquid in glass thermometer is as shown in fig. It consists of thick walled glass tube with a capillary bore and a spherical



or cylindrical bulb filled with liquid. The two parts are fused together and upper end of capillary tube is sealed.

When the thermometer is placed at a point of temperature measurement of a hot body the responsive liquid expands. it causes liquid to rise in capillary tube. As the area of capillary tube is very small change in liquid volume will result in significant liquid rise in it. The laboratory thermometers have scale engraved on glass tube. The liquid in glass tube is usually filled with mercury. It has got linear coefficient of expansion. Other liquid like Alkohol, pentane, toluene, creosote are also used for various temperature ranges. Range of these thermometers is between  $-80^{\circ}\text{C}$  to  $200^{\circ}\text{C}$ .

**04 marks****Q. 3. Attempt any FOUR****a) Piezoelectric type transducer (sketch 2m and explanation 2m)****4m**

When certain crystalline substances are subjected to pressure or stresses along specific planes, voltage is generated in them. This effect is called as piezoelectric effect. The piezoelectric effect is direction sensitive i.e. if tension is applied definite voltage polarity will be produced while if compression is applied opposite voltage polarity will be produced.

Construction of piezoelectric type transducer is shown in above figure. Usually a crystal is placed between a solid base and a force summing member. Metal electrodes are plated on to selected faces of piezoelectric material so that lead wires can be attached for bringing in or leading out electric charge. Piezoelectric crystals are insulators. The electrodes become the plates of a capacitor. Thus it can be considered as a charge generator and a capacitor. The salient features of this type transducer as it is having high output up to 30 mV, excellent high frequency response, negligible phase shift, etc.

**b) Wheatstone bridge**

Static sensitivity = Change in output / Change in input

$$= dq_o / dq_i$$

$$= 3 \text{ mm} / 7 \Omega$$

$$= 0.43 \text{ mm} / \Omega$$

Deflection factor = 1/ sensitivity

$$= 7 / 3 = 2.3 \Omega/\text{mm}$$

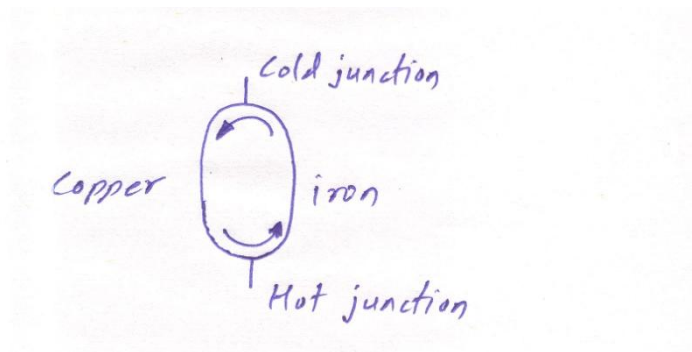
**c) Thermistor (Meaning 1mrks and explanation 3marks)**

**4m**

Thermistor (short form of thermal resistor) is thermally sensitive variable resistor made of ceramic like semiconducting materials. They are available in greater variety of shapes and sizes having cold resistance ranging from a few ohms to mega ohms. The size can range from extremely small bead, thin disc, thin chip or wafer to a large sized rods. Unlike metals thermistors respond negatively to temperature and their coefficient of resistance is of the order of 10 times higher than that of platinum or copper. As the temperature increases the resistance goes down and as the temperature decreases the resistance goes up.

**d) Seebeck and Peltier effect (2marks each)**

**4m**



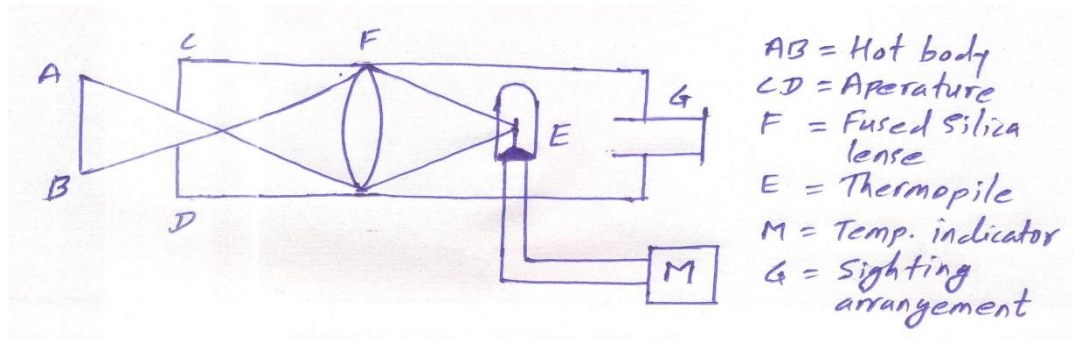
**i) Seebeck effect-** In 1821, the scientist Seebeck discovered that if a closed circuit is formed of 2 dissimilar metals and the two junctions of the metals are at different temperatures an electric current will flow round the circuit. Current flows from copper to iron at hot junction and it flow from iron to copper at cold junction.

**ii) Peltier effect-** In 1834, he discovered that when a loop was formed of 2 dissimilar metals and if externally current was forced to flow through the circuit, one of the junctions was heated while the

other was cooled. Amount of heat liberated or absorbed when unit current passes for a unit is called Peltier effect.

e) Radiation pyrometer (Fig. 2m and explanation 2m)

4m



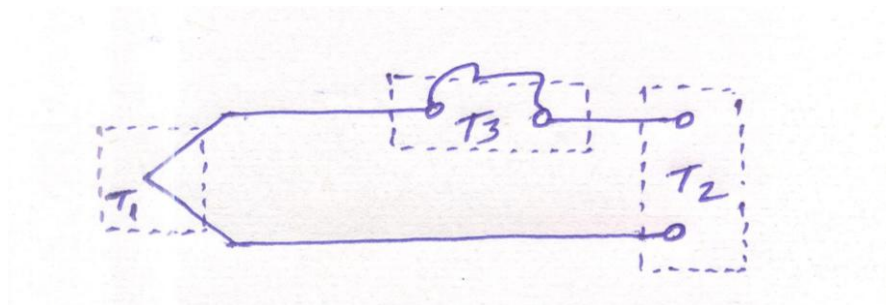
It accepts a controlled sample of total radiation and through determination of heating effect of sample, obtains a measure of temperature. Temperature measuring instruments which respond to all wavelength and therefore operate to Stefan-Boltzmann law are referred to as total radiation pyrometers.

The pyrometer head consists of a metal housing containing a fused silica lens and a thermopile. The lens end is inserted into a small opening in the side of furnace. Radiations from hot body enter the lens and are focused on thermopile. Thermopile develops an emf which deflects a millivoltmeter. It is calibrated in terms of temperature.

Q. 4. A) Attempt any THREE

i) Laws of thermocouples (2m each)

4m



a) Law of intermediate temperature (2m)

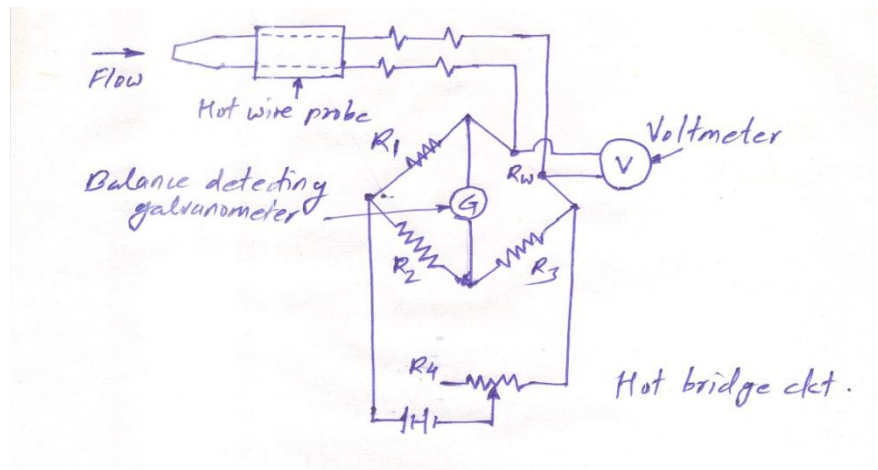
If a simple thermocouple circuit develops an emf  $e_1$ , when its junctions are at temperature  $T_1$  and  $T_2$ , and emf  $e_2$  when its junctions are at temperature  $T_2$  and  $T_3$ , it will develop an emf  $e_1 + e_2$  when its junctions are at temperature  $T_1$  and  $T_3$ .

**b) Law of intermediate metal (2m)**

It states that insertion of an intermediate metal into a thermocouple circuit will not affect the net emf provided the two junctions introduced by the third metal are at same temperature.

**ii) Hot wire anemometer (Fig. 2m and explanation 2m)**

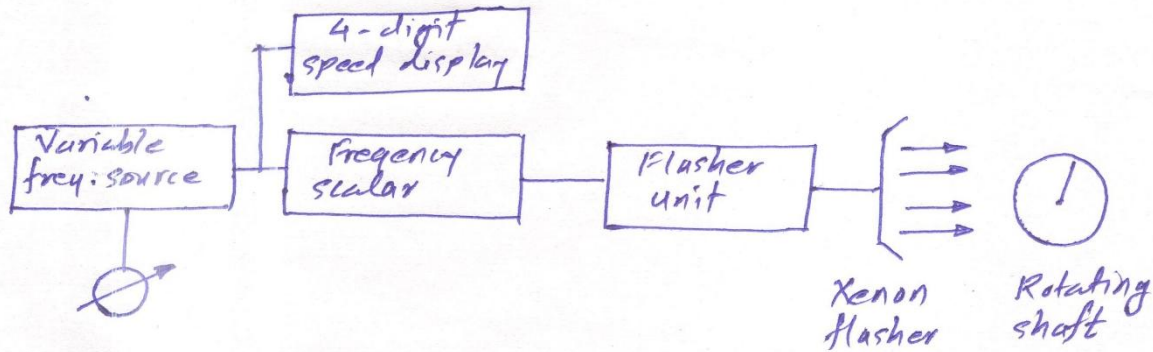
4m



Hot wire anemometer is a commonly used device for measuring the mean and fluctuating velocities in fluid flows. The flow sensing element is a short length of  $5\mu\text{m}$  diameter platinum-tungsten wire welded between two prongs of the probe and heated electrically as a part of Wheatstone bridge as shown in above figure. When the probe is introduced in the fluid stream, it tends to get cooled by the instantaneous velocity and consequently there is a decrease in its resistance. The rate of cooling of the wire depends on the following

- Shape, size and physical properties of the hot wire
- Difference of temperature between the heated hot wire and fluid stream
- Physical properties of flowing and
- Fluid and velocity of fluid

iii) Stroboscope (Fig. 2m and explanation 2m)  
4m

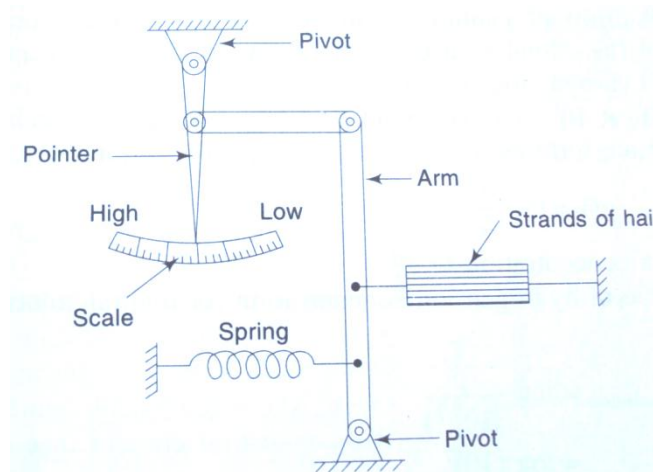


Measurement of the speed of a rotating shaft is a common requirement in many industrial and laboratory applications. Such measurements have usually been carried out in the past with the help of contact type tachometers with friction drive.

In this a high intensity light flash of a variable frequency is directed towards rotating shaft. Any marking on the shaft appears stationary, if the time of one shaft revolution is a multiple of the flash period. Earlier stroboscopes used neon tubes of low intensity which forced their use close to the rotating shaft. A highly stable function generator IC based circuit provides the basic variable frequency timing pulses. These are read on an IC based 4-digit speed display in rpm. The flasher unit generates the high intensity flashes at a suitably scaled rate directed towards the rotating shaft. A 10 turn potentiometer makes the task of speed setting very precise

iv) Hair hygrometer (Fig. 2m and explanation 2m)

4m





Certain materials such as human hair, animal membranes, wood and paper undergo changes in linear dimensions when they absorb moisture from the atmosphere. Human hair becomes longer as the humidity of the surrounding air increases, and shortens when the air becomes drier. This property of hair can be used to operate a pointer or recording pen through a system of mechanical linkage.

The indicator scale can be calibrated to give a direct indication of the humidity. Figure shows the schematic diagram of the hair hygrometer. The transducer element consists of strands of hair to give it increased mechanical strength. The hair strands are generally arranged parallel to each other with sufficient space between them for giving free access to the air sample under test.

**Q. 4. b) Attempt any ONE****6m****i) Definition with examples (2m each)**

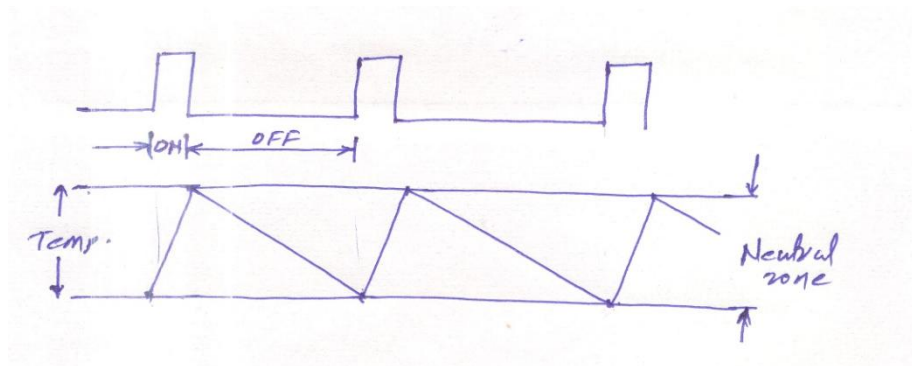
**a) Automatic control system-** An automatic control system is a preset closed-loop control system that requires no operator action. Eg. CNC machine, Washing machine, etc.

**b) Closed loop control system-** A type of control system that automatically changes the output based on the difference between the feedback signals to the input signal. Eg. Servomotors.

**c) Open loop control system-** A type of control system that uses only an input signal to actuate an output. There is no automatic feedback to adjust the process, so adjustments must be made manually by the operator or A control system that does not provide feedback to the controller. Eg. Water pump.

**ii) Different modes of control action (2m)**

- On-off control
- Proportional control
- Proportional plus integral control
- Proportional plus derivative control
- Proportional plus integral plus derivative control

**On-Off Controller (Fig. 2m and explanation 2m)**

This type of controller is used On-off control action which is most simple, cheap and widely used control action. When measured variable is below set point, controller is on and output signal is maximum. When the measured variable is above set point, the controller is off and output is zero.

A room heater is a common example of this type of controller. If temperature drops below set point, heater is turned on. If temperature goes above the set point, heater is turned off. Above figure shows a step by step controller action. It is commonly used in room heaters, refrigerators, level control of water tanks, air conditioners, etc.

**Q5 a Strain Gauge ( Definition 2 marks, types 2 marks, Construction and working 2 marks and figure 2 marks)**

The strain gauge is the electrical wire when undergoes the deformation by the external force (either increase or decrease in length) the resistance of the wire changes. By measuring the change in the resistance one can easily find out the applied external forces.

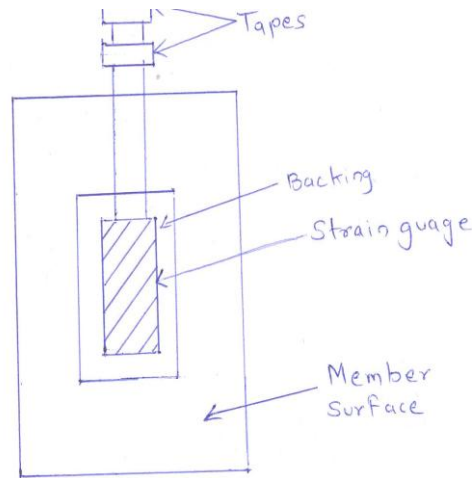
**Types of strain gauges**

- Wire gauge
- Foil Gauge
- Semiconductor Gauge
- Strain gauge rosettes

**Construction and working of bonded strain gauge**

A strain gauge is a device used to measure strain on an object. The bonded strain gauge consists of an insulating flexible backing which supports a metallic foil pattern. The gauge is attached to the object by a suitable adhesive, such as cyanoacrylate. As the object is deformed by the external applied force, the foil

is deformed, causing its electrical resistance of a strain wire to change. This resistance change, usually measured using a Wheatstone bridge, is related to the strain by the quantity known as the gauge factor.



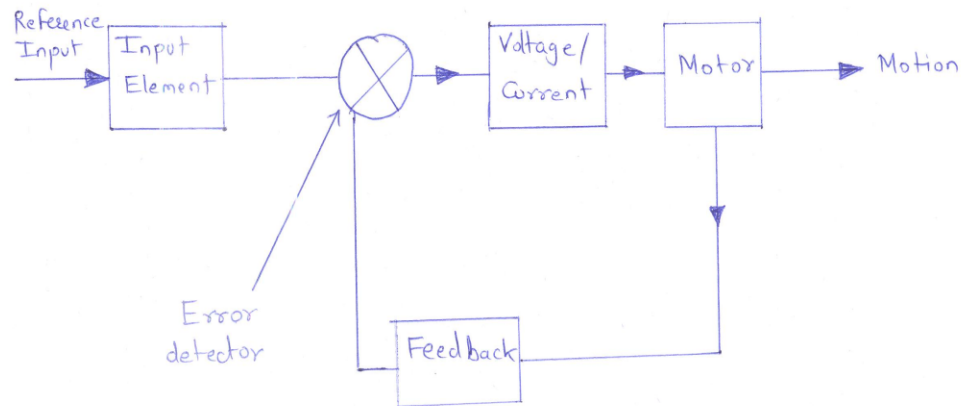
**Q5b (comparison, any four points- 2 marks each)**

Comparison of hydraulic, pneumatic and electronic controller			
<b>Pneumatic controller</b>	<b>Hydraulic controller</b>	<b>Electronic controller</b>	
Low cost	Medium cost	High cost	2 for each for any four points
No fire hazard	Chances of fire hazard	Chances of fire hazard	
Medium speed of response	high speed of response	high speed of response	
Medium power gain	High power gain	High power gain	
High space require	Medium space require	low space require	
Not affected by stray magnetic field	Not affected by stray magnetic field	Affected by stray magnetic field	
Medium power gain	High power gain	low power gain	



**Q5Ci (figure 2 marks and explanation 2 marks)**

The speed controller of a motor consists an error detector, speed controller and a sensor. The speed of the motor is measured by the speed sensor (tachogenerator, encoder or other speed sensor) and the same is compared with a target value. This difference between the actual and desired speed is called the error. The error in the system is fed to the current or voltage controller. According to error signal it will increase or decrease the voltage and accordingly the speed of the motor get change and will obtained the desire speed as per the input value. The desired output is generally entered into the system through a user interface.



**Q5C ii (Explanation 2 marks and importance 2 marks)**

It is employed to provide a position output proportional to input electrical signal. The stator has two distributed windings which is called reference winding and control winding. The main winding (also called the reference or fixed phase) is supplied from a constant voltage source of 110 V and 50 Hz. The other winding (also called the control phase) is supplied with a variable voltage of the same frequency as the reference phase but is phase-displaced by  $90^\circ$  (electrical). The control- phase voltage is controlled by an electronic controller. The speed and torque of the rotor are controlled by the phase difference between the main and control windings. Reversing the phase difference from leading to lagging (or vice-versa) reverses the motor direction. Since the rotor bars have high resistance, the torque-speed characteristics for various armature voltages are almost linear over a wide speed range particularly near the zero speed. The motor operation can be controlled by varying the voltage of the main phase while keeping that of the reference phase constant.

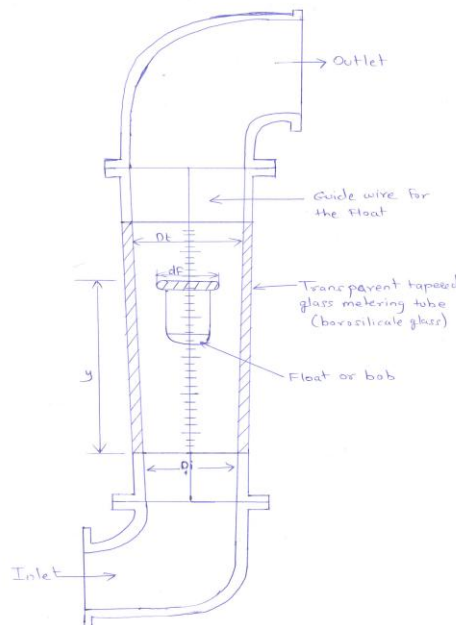
**Importance of servo mechanism in control system**

- A servomotor is a rotary actuator that allows for precise control of angular position , velocity and acceleration
- They are small in size but pack a big punch and are very energy efficient

**Q6 a (Explanation 2 marks and figure 2 marks)**

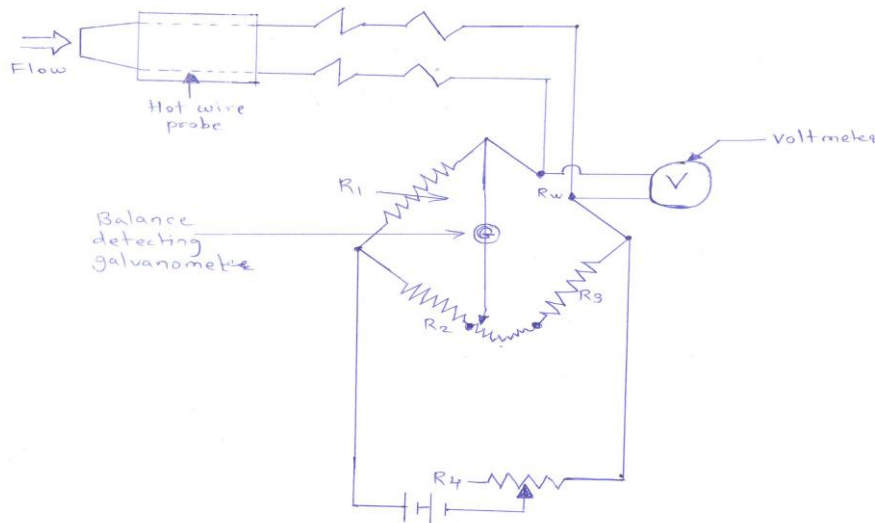
The rotameter consists of three basic elements: A uniformly tapered flow tube, a float, and a measurement scale. A control valve may be added if flow control is also desired. In operation, the rotameter is positioned vertically in the fluid system with the smallest diameter end of the tapered flow tube at the bottom. This is the fluid inlet. The float, typically spherical, is located inside the flow tube, and is engineered so that its diameter is nearly identical to the flow tube's inlet diameter.

When fluid like gas or liquid is introduced into the tube, the float is lifted from its initial position at the inlet, allowing the fluid to pass between it and the tube wall. As the float rises, more and more fluid flows by the float because the tapered tube's diameter is increasing. Ultimately, a point is reached where the drag force exerted by the fluid is balance by weight of float and gravitational force. The float is now stationary at that level within the tube as its weight is being supported by the fluid forces which caused it to rise. This position corresponds to a point on the tube's measurement scale and provides an indication of the fluid's flow rate.

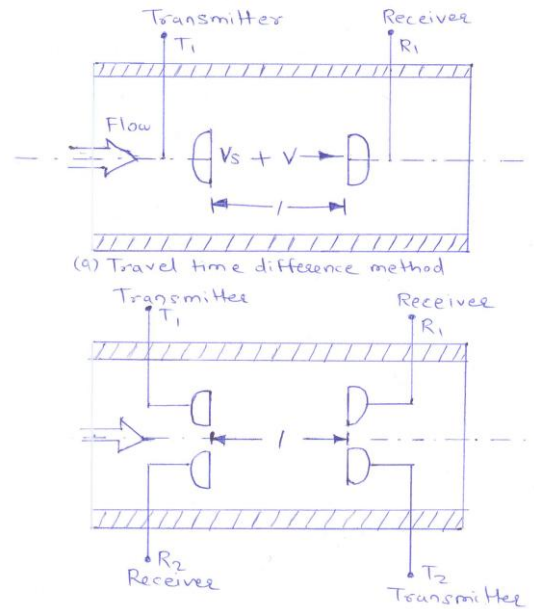


**Q6 b (Explanation 2 marks and figure 2 marks)**

Hot wire anemometers are the commonly used device for measuring the mean and the fluctuating velocities in the fluid flow. It uses a very fine wire (5 micrometres) electrically heated up to some temperature above the ambient temperature. Air flowing past the wire has a cooling effect on the wire. As the electrical resistance of most metals is dependent upon the temperature of the metal (RTD). As the temperature of the wire changes with the velocity of the flowing fluid its resistance get changes. By measuring the change in the resistance with the help of Wheatstone bridge circuit, one can easily find out the velocity of flowing fluid.

**Q6 c (Explanation 2 marks and figure 2 marks)**

An ultrasonic flow meter is a type of flow meter that measures the velocity of a fluid with ultrasound to calculate volume flow. Using ultrasonic transducers, the flow meter can measure the average velocity along the path of an emitted beam of ultrasound, by averaging the difference in measured transit time between the pulses of ultrasound propagating into and against the direction of the flow. It is very expensive device but is often inexpensive to use and maintain because they do not have moving parts, unlike mechanical flow meters.



**Q6 d (Explanation 2 marks and figure 2 marks)**

It consists of two electrode plates which are separated by the dielectric fluid. The change in the fluid level causes the variation in dielectric constant between the two electrodes (capacitive plates) which in turn causes a corresponding change in value of capacitance. By measuring the capacitance between the two plates, one can easily find out the liquid level inside the tank

The capacitance between two plate is given by

$$C = E \cdot KA/d$$

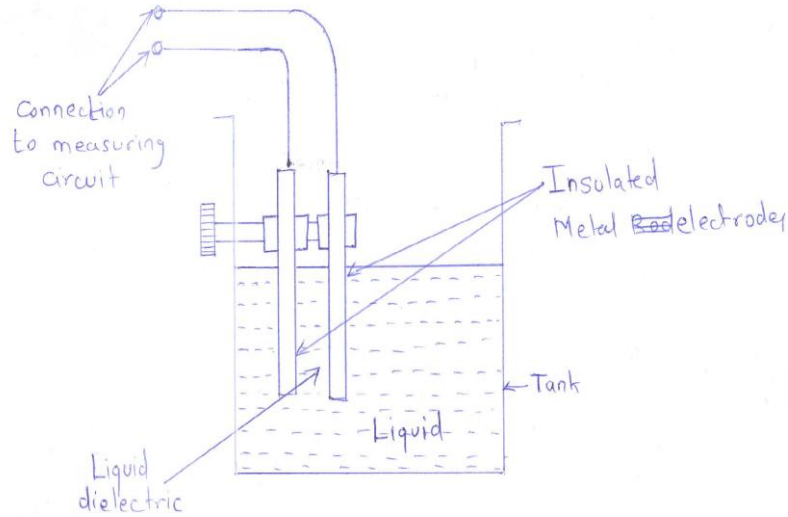
C = capacitance in picofarads (pF)

E = a constant known as the absolute permittivity of free space

K = relative dielectric constant of the insulating material

A = area of capacitive plate

d = distance between the conductors



**Q6 e (Explanation 2 marks and figure 2 marks)**

A tachometer is an instrument which is used to measure the revolution speed of any rotating object such as a shaft or motor. It consists of driving shaft and indicating shaft and these two shafts are connected with the help of slipping clutch. When the driving shaft is connected to any device whose speed is to be measure then the same motion is transmitted to the indicating shaft trough clutch. When the spring force is more than the shaft force then the clutch get slip and the indicator stop at certain position on the indicating scale.

