WINTER – 12 EXAMINATION
Subject Code: **12156** **Model Answer**

Q.1 A) ANY THREE **12 marks**

i) (Definition 2m & Classification 2m) **4 marks**

Measurement: -Measurement is the act or the result of a quantitative comparison between a predetermined standard and an unknown magnitude.

Generally there are two basic methods of measurement.

- Direct comparison
- Indirect comparison

There are several methods of classifications of measurement

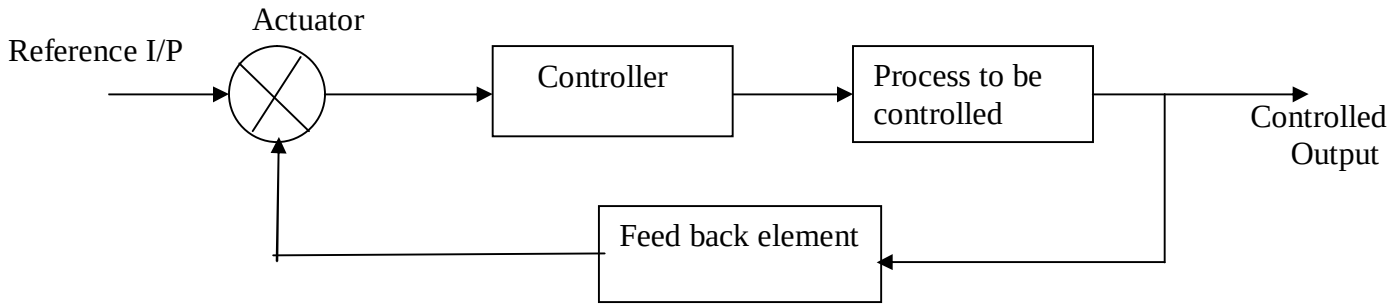
1) Primary measurement: - a primary measurement is one that can be made by direct observation without involving any conversion of the measured quantity.
2) Secondary measurement: - a secondary measurement involves only one conversion to be done on the quantity under measurement.
3) Tertiary measurement: - a tertiary measurement involves two conversions. E.g. temperature measurement by thermocouple.

ii) (Each 1m) **4 marks**

1) **Calibration: -** Every measuring instrument must prove its ability to measure reliably and accurately. The procedure for this is called calibration and essentially involves a comparison with a higher standard which is traceable to national & international standard.
2) **Precision: -** It is the degree of reproducibility among several independent measurements of the same true value under specified conditions. It is usually expressed in terms of the deviation in measurement.
3) **Hysteresis:-**It is the difference between the increasing input value and the decreasing input value which effect the same output value. **Or** The maximum differences in output at any measured value within the specified range when approaching the point first with increasing and then with decreasing input.
4) **Drift: -** It is defined as the variation or change in output for a given input over a period of time. **Or** An instrument is said to have no drift if it reproduces same readings at different times for same variation in measured variable.

iii) Closed loop control system (2m) & Applications 2 m 4 marks

Closed loop control system is the system in which the controlling action is somehow dependent on the output.



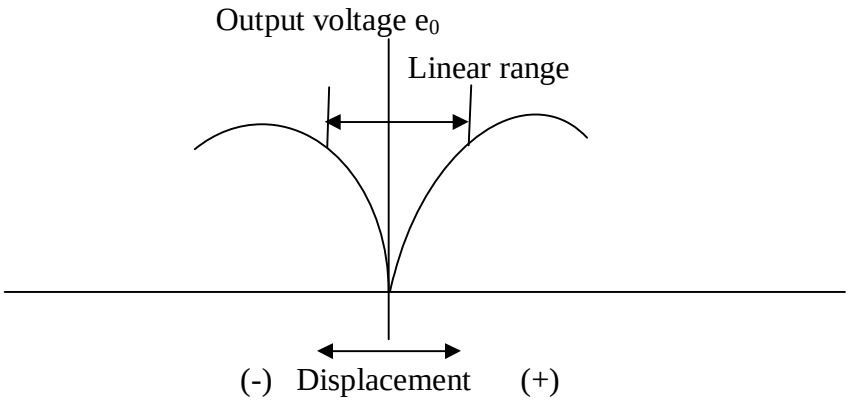
- In the closed loop system the output is feedback to the input and then it is compared with the reference input.
- Feed back is the property of the system which permits the output to be compared with the reference input so that appropriate controlling action can be decided**.**
- Reference input is applied to the system controller. Then the actuating signal transfer towards the process then again the final process signal is verified by the feed back element. This output compare with the input by the feedback signal & again required adjustment done by the actuator.
- In this way control loop system works automatic by installing mechanical/ Electronics device. If human being involves in the open loop system for regular controlling then also it become closed loop system.

Applications of closed loop system:

1. Person driving a car,
2. Guided missile system
3. Temperature control system
4. Position control system
5. Oscillators
6. Radar tracking system etc.

iv) Characteristics of LVDT (any four 4m) 4 marks

i) The output voltage varies linearly with displacement of the core from the null or central position in a central range.



ii) The output voltage at the central or null position of the core may not always be zero due to some magnetic and capacitance effects.

iii) The frequency response of LVDT is limited mainly by the inertia of the core.

iv) The linear range depends upon the length of the secondary coils. In operation there is an 180^0 phase shift from one side of the null position to the other.

Q. 1. B) ANY ONE 6 marks

i) (Definition 1m, Sources 3 m & measurement 2 m)

Error: - Errors can be defined as the difference between the measured value and the true value. True value is the actual magnitude of an input signal to a measuring instrument.

Error = True value – Measured value

Errors in measurement systems could originate from several sources. Broadly these can be classified under three categories.

1) Gross error: - It occurs due to human mistakes in reading or calculating.
2) Systematic error: - It may occur due to instrument error, environmental errors or observational errors.
3) Random error:- These vary in an unpredictable manner and it is very difficult to list out all the sources of errors but the most common causes are
   a) friction in instrument movement,
   b) Backlash in the movement
   c) Hysteresis in elastic members,
   d) Mechanical vibrations,

e) Parallax errors between pointer and scale.

The measurement of error can done by three categories

Static error: - It is the difference between measured value & True value.

Static error = measured value – true value

Relative error:- Relative error = (measured value – True value) / True value * 100

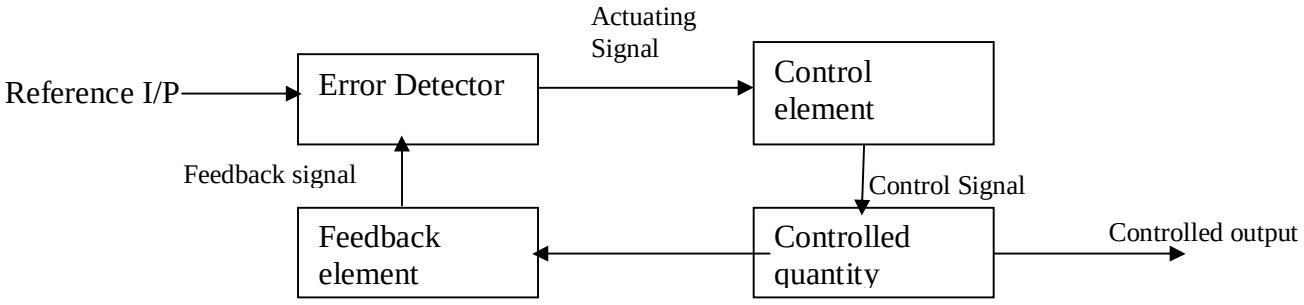
Weighting of errors: - It is calculated when sampling target consist of multiple substrata of different sizes.

ii) (Fig. 2m & Explanation 4 m) 6 marks

Servo motor mechanism:-It is a Control system that converts a small mechanical motion into one requiring much greater power; may include a negative feedback system . Since the operator can't do repetitive and critical functions continuously and correctly due to his limitations then the automatic closed control loop has to be employed in this system which would be doing exactly similar functions continuously and endlessly. The closed loop system is also known as servo mechanism

A servo motor mechanism means simply a system which is used to control the mechanical output of position or time derivative position, Such as velocity or acceleration of input signal. Servo motor mechanism has found number of applications in industry such as in tool position control, missile guidance system, radar tracking system etc.

Actuators are used to operate the valves, heaters etc. actuators are very important elements of servomotor mechanism. The elements of servo motor mechanism are actuators, error detectors, fed back element, amplifiers, controllers (hydraulic/pneumatic/electronic) etc. Servo motor mechanism works very faster in milliseconds. Since this mechanism is costlier but it is convenient because of it's properly controlled fast actions.



Q.2. ANY FOUR **16 marks**

Q. 2 A) Differentiate between closed loop and open loop control system.
(Any 4 points) **4 marks**

Sr. No.	Closed loop control system	Open loop control system
1	Feed back is present	Feedback is absent
2	Not much accurate	Accuracy is good
3	Response is faster	Response is slower
4	Cost is high	Cost is low
5	Construction is difficult	Construction is easy
6	It is less stable	It is more stable
7	Process disturbances control automatically.	Process disturbances are not controllable
8	Applications-boilers, guided missiles etc.	Applications-Toaster in bakery, Traffic signal etc.

Q. 2 B) **(2 m + 2 m)** **4 marks**

i) Span of instrument = 900-450 = 450 ^{o}C

Dead Zone = (0.0150/100)*450 = 0.0675 ^{o}C

The 0.0675 ^{o}C temperature change might occurs before it is detected.

ii) Error (E) = +/- 0.5% of full scale value

= (+/- 0.5 /100)*100

= +/- 0.5^{o}C

Temperature actually indicates in the range 54.5 ^{o}C to 55.5 ^{o}C.

Q. 2. C) **4 marks**

Transducer:- a transducer is a device to convert position displacement, thermal and optical signals into electrical quantities that may be amplified, recorded and processed in the instrumentation system. Transducers are also known as prime sensors.

Transducers can be classified as follows:

Primary/ Secondary Transducers,

Active/ Passive transducers,

Analog/ Digital transducers

Mechanical, Electromechanical, Optical transducers

Primary transducers react directly to the change in the quantity to be measured

Secondary transducers get their input from the output of the primary transducer & change it to another form usually to an electrical output.

Active transducers are self generating type they does not require external power supply.

Passive transducers operation requires energy from external source.

Analog transducer shows variation in output with the variation in input.

Digital transducer shows output in yes or no or in number form.

Transducers also classified on the basis of nature of operation.

a) Resistance transducer

b) Capacitance transducer

c) Inductive transducer

d) photovoltaic transducer

e) Piezoelectric transducer etc.

Q. 2. D) Difference between hydraulic and pneumatic controllers
(Any eight points) 4 marks

Sr. No.	Hydraulic controller	Pneumatic controller
1	Works on the principal of Oil	Works on the principal of Air
2	Used incompressible fluid	Used compressible air
3	Heavy applications	Not heavy applications as hydraulics
4	More difficult to operate	Easier to operate
5	Hydraulic Cylinder/Container	Air compressor
6	1000-5000 psi pressure is used	80-100 psi pressure is used
7	Difficult operating	Easy operating
8	Costly	Less costly

Q. 2. E) Specification of RVDT (Any four 4 m) 4 marks

1) RVDT is a continuous rotational device (360^o).

2) The range of most linear operations for a typical RVDT is only about +/- 40^o.

3) Operating range is better than 0.5%of full range.

4) RVDT is used to measure a small angle of displacement i.e. +/- 5^o

5) The practical upper limit of angular measurement with an RVDT is about +/-60^o.

6) The resolution of the RVDT is theoretically infinite.

Q. 2. F) Advantages and Disadvantages of Potentiometer (2m + 2m) 4 marks

Advantages:- **(Any 2)**

1) Potentiometer useful for measurement of displacement, force, pressure etc.

2) Its operation principle is simple & convenient.

3) The cost of potentiometer is low.

Disadvantages**:- (Any 2)**

1) Resolution is poor.
2) The wiper contact may get wear out; become misalign because of long time use.
3) Friction causes poor dynamic response.

Q. 3. A) (Definition 2 m & Classifications 2m) 4 marks

Transducer:-Transducer is a sensing device that converts physical phenomenon and chemical composition into electrical, pneumatic or hydraulic output signals.

Classification of Transducers:-

A) Input / Output
B) Analog / Digital
C) Active / Passive :- Thermoelectric, Photoelectric, Piezoelectric & Electromagnetic
D) Primary / Secondary
   I) Resistive :- Strain gauge, RTD, Thermister
   II) Capacitive
   III) Inductive:-RVDT,LVDT

Q. 3. B) Define (Each 1 m) 4 marks

1. **Overshoot -** The overshoot is defined as the maximum amount by which the pointer moves beyond the Steady state.

2. **Dynamic error**-The difference between the indicated quantity and the true value of the time varying quantity is the dynamic error.

3. **Fidelity**- Fidelity of an instrumentation system is defined as the degree of closeness with which the system indicates or records the signal which impressed upon it.

4. **Speed of response**- The rapidity with which an instrument responds to a change in value of the quantity being measured.

Q. 3. C) Electronic Control System 4 marks

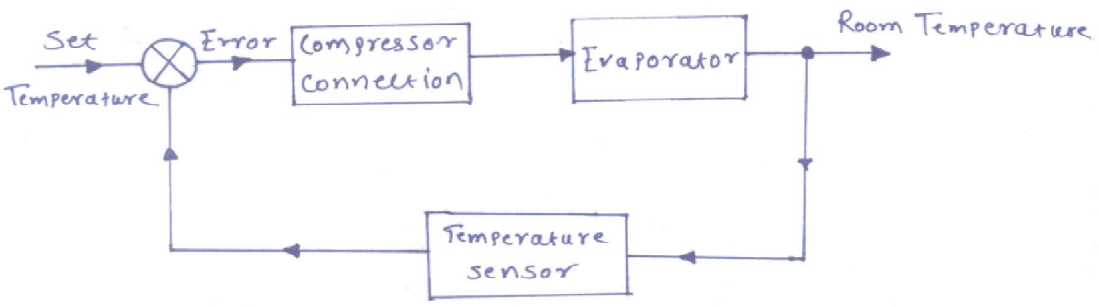
Electronic control system is an assemblage of devices and components connected or related so as to command, direct or regulate itself, or another system. Control system must have inputs, outputs and an arrangement to achieve this input-output combination.

Electronic control system is different from pneumatic control system because of complex design, slow speed of response, high initial cost, maintenance required to overcome the electrical noise. When installed in hazardous areas required proper explosion proof

housing takes long start-up period and electronic signal is less compatible with the control valves and requires additional hardware.

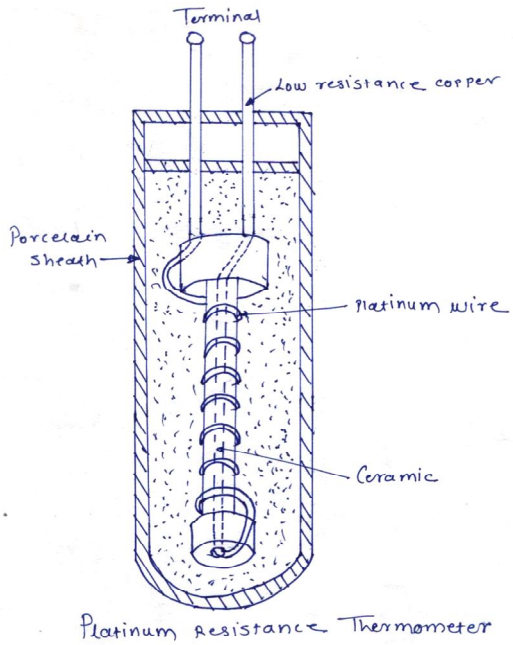
Q. 3. D) Feedback Control System (Fig. 2 m & Explanation 2 m) 4 marks

Feedback control system for air conditioner maintains the room temperature at some predetermined (set) value. When room temperature is more than set value it switch ON compressor to start cooling of room. On reaching the set value of temperature in room it disconnects compressor connections.



Representation of Control system for air conditioner

Q. 3. E) Platinum resistance thermometer (Fig. 2 m & Explanation 2 m) 4 marks



Platinum Resistance Thermometer

RTD measures temperature using platinum, nickel, copper wire whose resistance changes with change in temperature. Resistance thermometer works on the principal of positive

temperature coefficient of resistance i.e. as temperature increases, resistance offered by thermometer also increases. The resistance of wire at t^0 C is given by

$Rt = R_0 (1+\alpha_0 t)$ Where Rt = Resistance at t^0C.

R_0 = Resistance at 0^0C.

α_0 = Resistance temperature coefficient

t = Change in temperature

Figure shows the modern platinum resistance thermometer. It consists of pure, well annealed platinum wire wound on thin strip of mica or ceramic and placed in porcelain sheath. Free ends of platinum wire are attached to long lead of low resistance copper wire.

To measure the change in Resistance Bridge network is used. The resistance thermometer is connected to one of the arm of Wheatstone bridge circuit. When resistance thermometer is subjected to temperature variation, the Wheatstone bridge gets unbalanced. The galvanometer deflection can be directly calibrated to give temperature.

The unknown temperature T is given as

$$T = \frac{Rt - R_0}{R_{100}-R_0}$$

Where Rt = Resistance of wire at temperature t.

R_0 = Resistance of wire at O^0C.

R_{100}=Resistance of wire at 100^0C.

Platinum is especially suited for RTD as it withstand high temperature while maintaining excellent stability. Tungsten has a relatively high sensitivity, but it is used for high temperature applications as it is extremely brittle and difficult to work. Copper is occasionally as economical alternative up to temperature 120^0C.

Q. 4. A) ANY THREE **12 marks**

i) **4 marks**

Laws of Thermocouples (3 m)

1. Law of Intermediate Temperature: The e.m.f generated in a thermocouple with junctions at temperatures T1 andT2 is equal to the sum of e.m.f's generated by similar thermocouples. One acting between temperatures T1 and T2 and the other acting between T2 andT3, where T2 lies between T1 and T2.

2. Law of Intermediate Metals: The introduction of a third metal into the thermocouple circuit will have no effect on the e.m.f generated as long as the junctions of the third metal with the thermocouple metals are at the same temperature.

Thermocouple Material (1m)

Copper and Constantan, Iron and Constantan, Chromel and Alumel, Chromel and Constantan and Platinum (90%) +rhodium (10%) and Platinum.

ii) Sound characteristics (1 m each) 4 marks

1. Frequency of Sound Waves: - Is the number of vibrations produced per second. The greater is the frequency of a musical notes the higher is the pitch and vice versa. Two factors determine the frequency range required for satisfactory transmission of speech such as intelligibility and energy
2. Intensity: - The intensity (I) of a sound wave is defined as the energy flowing per second per unit area held normally at a point to the direction of the propagation of sound wave. It is expressed in W/m^2 or $J/sec.m^2$ It is purely a measurable quantity.

The intensity of the sound wave is given by,

$$I=Q/(tA)$$

Where Q is sound energy

T is time

A is area of sound source.

We know that

Power (P)=Q/t

Therefore I=P/A

3. Loudness: - It is the degree of sensation produced in ours ears. The loudness of a sound wave varies from one listener to another. Loudness of a sound wave is directly related to intensity and is proportional to log I

$L \alpha \text{ Log } I$

Greater the intensity of a sound wave, greater is its loudness.

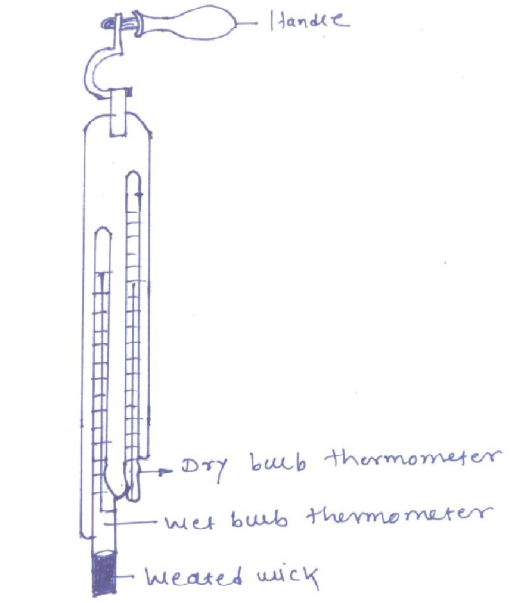
4. Power: - Sound power is the total sound energy radiated by a sound per unit time. The power in the sound emitted from a source can have an extremely large range. Because of this wide range of power, the sound power level is conveniently defined in decibels.

iii) **4 marks**

Humidity (1 m)

Humidity: It is the moisture content in air. It may be expressed as the specific humidity in Kg/kg of dry air, absolute humidity in gm/m^3 or relative humidity in %.

Sling psychrometer (Fig. 1 m & Explanation 2 m)

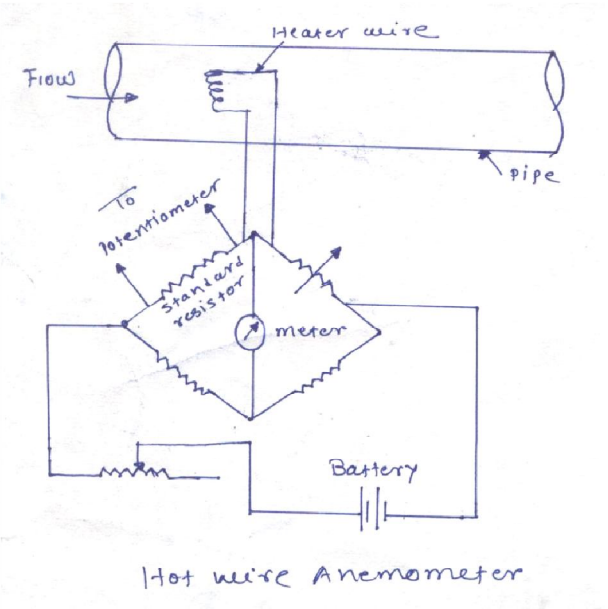


Sling psychrometer

The equipment used to measure dry bulb and wet bulb temperature simultaneously is known as Psychrometer. The sling psychrometer consists of two mercury thermometers mounted on frame, which has handle provided for rotation of psychrometer. Thus air movement is obtained by whirling the thermometer in air. One bulb among the two is covered with the wet wick to read wet bulb temperature. The velocity recommended for rotation is 5 to 8m/min.

iv) Working of hot wire anemometer (Fig. 2 m & Explanation 2 m) **4 marks**

In hot wire anemometer, heat is supplied electrically to a fine wire placed in the flow stream. The temperature of wire is determined by measuring its resistance with a Wheatstone bridge. One of the method is adjusting the current through the wire so that temperature remains constant and measures the heat current. In this way bridge is always balanced. The voltage drop across standard resistor is found by a potentiometer.



Hot wire Anemometer

Heat loss from heated wire is = $a (v\rho + b)^{1/2}$ J/s

Where v = Velocity of heat flow

ρ =Density of fluid

a,b = constants

Constants a and b depends on dimensions and physical properties of wire and fluid. The values of these constants are found by calibrating the instrument against a static pitot tube.

Suppose, a current I flows through the wire having a resistance R.

Therefore, under equilibrium conditions,

Heat generated = heat loss or I^2R

$= a (v\rho + b)^{1/2}$

$$v = \frac{(I^4R^2/a^2 - b)}{\rho}$$

Thus if resistance and the temperature, of wire are kept constant, the fluid flow rate is measured by measuring current I through heater wire.

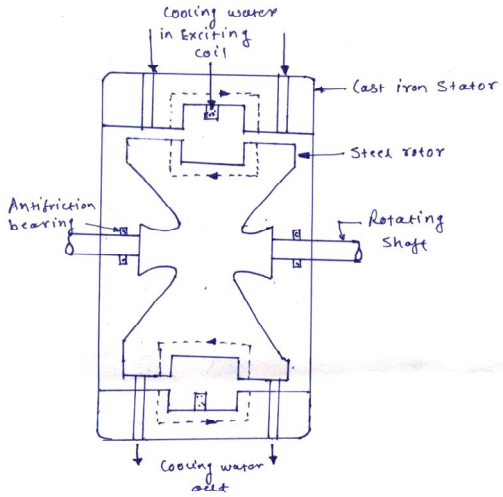
Q. 4. B) ANY ONE **6 marks**

i) Difference between Resistance thermometer & Thermistor

(Any 6 points) **6 marks**

Resistance Thermometer	**Thermistor**
Made of metals which are good conductors of electricity such as copper, platinum, nickel	Made of metallic sintered oxides such as cobalt, manganese, nickel iron and uranium
It has positive temperature coefficient of resistance	It has both negative and positive temperature
Works in temperature range of -100^{0}C to 650^{0}C.	Works in temperature range of -50^{0}C to 300^{0}C.
Resistance change is small, positive and linear	Resistance change is large and non-linear
They have better reproducibility and low hysteresis	They have less reproducibility and more hysteresis
Relatively bigger in size	Quite small in size

ii) Eddy Current Dynamometer (Fig. 2 m & Explanation 4 m) **6 marks**

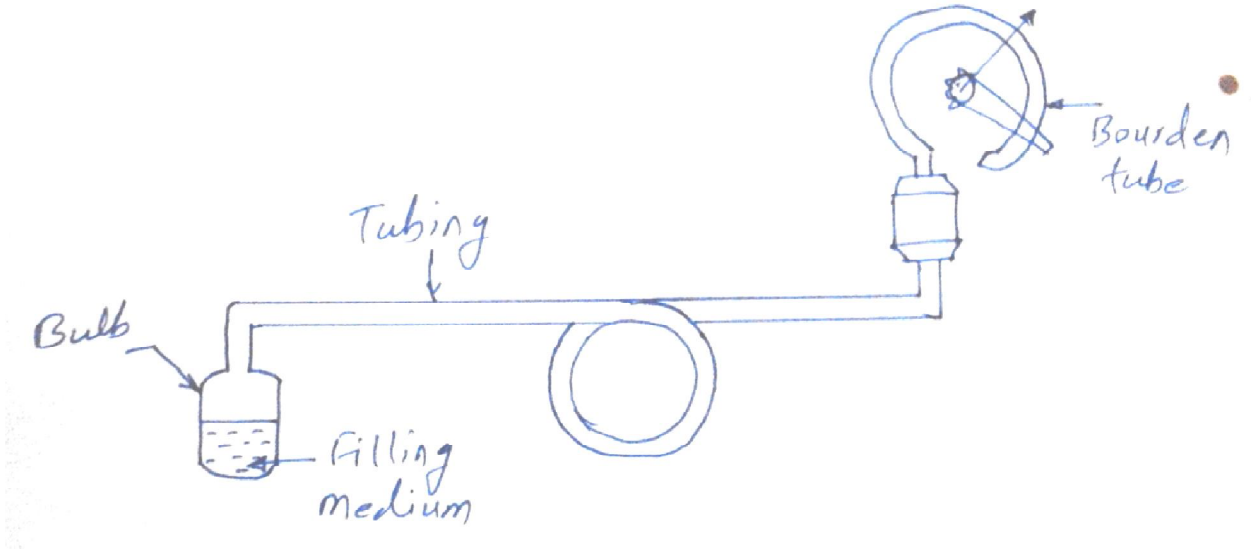


Eddy current Dynamometer

When the dynamometer is under operation, the rotor turns and it causes a constant change in the flux density at all parts of the stator. Consequently eddy currents are induced in the stator which opposes the rotation of rotor. The movement of resistance is measured by the brake arm and so the torque and shaft can be estimated. Mechanical power supplied to

the dynamometer shaft is converted into heat which is then carried by air circulation induced by the rotor tooth acting as blower vanes and partly by water circulation through cooling channels formed in the stator.

Q. 5. A) Constant pressure thermometer (Fig. 2 m & Explanation 2 m) 4 marks

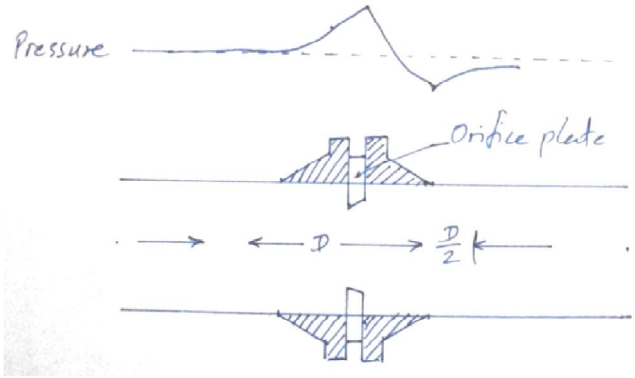


They provide remote indication. Sufficient force output is produced that permits direct driving of recording and controlling devices. Basically there are four parts as metal bulb, capillary tube pressure sensing device and filling medium. According to filling medium pressure thermometers are classified as i) liquid thermometers ii) gas filled thermometers iii) liquid and its vapour filled thermometers.

The metal bulb either contains liquid or gas or liquid and its vapour. Bulb can be made of stainless steel, brass, monel, nickel, choice of bulb material depends on corrosion, wear, strength required etc. Mercury tends to amalgamate with copper. Therefore, with mercury as filling medium, steel bulb is used.

Errors are produced in this type of thermometer and they are improper location of bulb, incorrect immersion of bulb, change in ambient temperature and pressure, radiation effect.

Q. 5. B) Orifice plate (Fig. 2 m & Explanation 2 m) 4 marks



It is a thin plate of metal circular in shape. It is thick enough to withstand buckling forces caused by potential difference. The material used is steel, monel, phosphor bronze. It should withstand corrosive effect of fluid.

A figure show that occurs when orifice plate is inserted in a fluid stream in a pipe. Vena contracta occurs at one half pipe diameter length. At points tap is taken at one diameter distance from orifice plate and downstream tap is located at ½ pipe diameter distance. Downstream static pressure never recovers its upstream value. Nearly 30% pressure head is lost in orifice meters.

Q. 5. C) Direct & Indirect Liquid level measurement devices

(2m + 2m) 4 marks

Direct liquid level measurement devices:

1. Bob and tape method 2. Sight glass method 3. Floats 4. Displacer

Indirect liquid level measurement devices:

1. Pressure gauges 2. A diaphragm method 3. Bellows

Q. 5. D) Electrical tachometer (Explanation 4 m) 4 marks

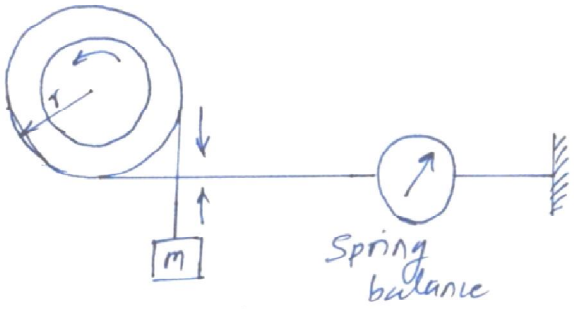
The electrical tachometer system is based upon the principle of sensing rotational or peripheral speed by means of any pulse producing transducer, eg. A magnetic perception head, phototransistor, alternator or proximity switch. Primarily designed to operate with magnetic perception heads, ferrous objects passing in close proximity of the perception head pole piece, varies the reluctance of the self-contained magnetic circuit and generate a train of pulses, proportional to the to the rotational speed.

The signal from the perception head is transmitted by standard twin screened cable to the indicator. The indicators are energized by either A.C. or D.C. supply, can be connected in parallel to give multiple indication for a single perception head, or one indicator can be

used to display the output from a series of perception heads selected via a suitable low resistance switch

The moving coil assembly used in electrical tachometers is mounted on a robust, jewelled suspension capable of withstanding shock of up to 30 g. The full range of tachometers is temperature compensated, stabilised during manufacture and is capable of operating over an ambient temperature range of – 20 to + 70 degrees Celsius. Typical system accuracies of +/- 2% of full-scale deflection are achieved in industrial applications.

Q. 5. E) Mechanical type dynamometer (Fig. 2 m & Explanation 2 m) 4 marks



In mechanical type dynamometers, the friction of rope, band or block brake absorbs the energy. Heat is dissipated by cooling the brake with water. Figure shows a rope brake, one end of rope which is connected to mass while the other end is connected to spring balance. Due to rotation, frictional force is generated, inducing tensions at the two ends of the rope. In the former, a band brake with friction lining material, passes over a pulley while in the Prony type of block brake, the curved blocks are clamped on the pulley rim.

Q. 5. F) Problem 4 marks

Given,

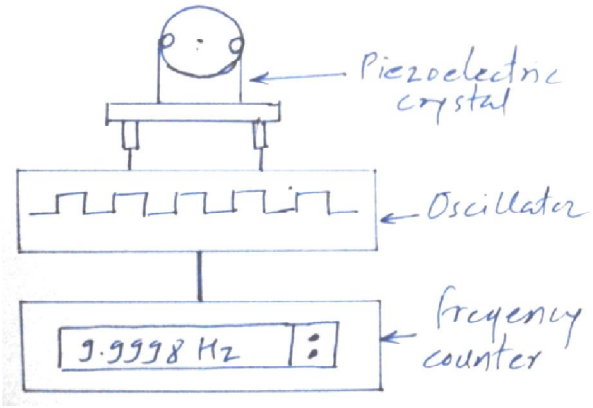
Dead load (W) = 200 N, Spring load (S) = 30 N, Dia. Of wheel (D) = 600 mm,

Dia. Of rope (d) = 26 mm, Speed of engine (N) = 450 rpm

Power (P) = $\frac{(W-S)\ \pi\ N\ (D+d)}{60\ X\ 1000}$ Kw

= $\frac{(200\ -30\ )\ \pi\ X\ 450\ (600+26)}{60\ X\ 1000}$ Kw **P = 2507.46 Kw**

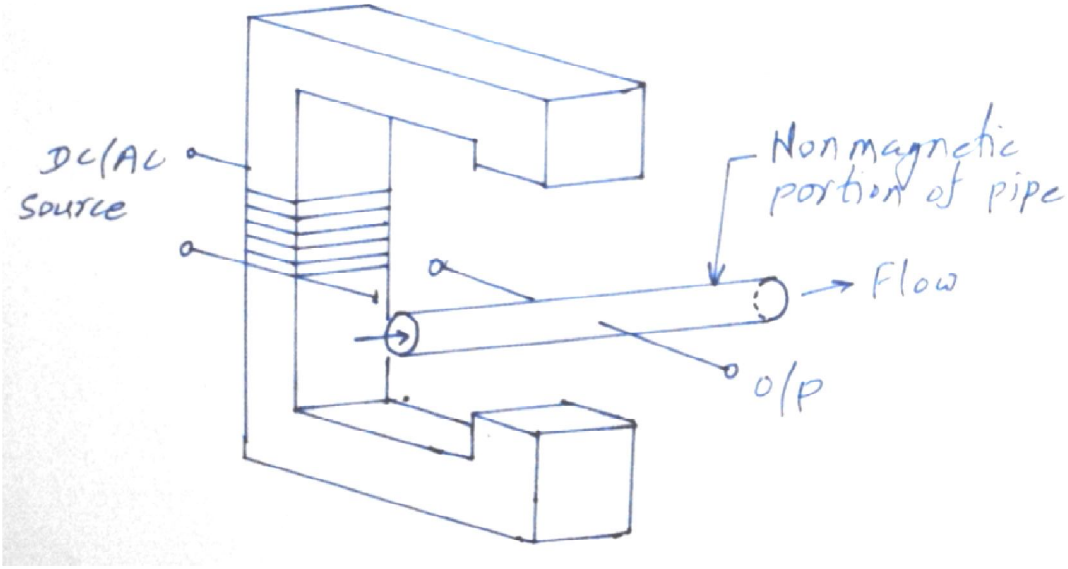
Q. 6. A) Quartz thermometer (Fig. 2 m & Explanation 2 m) 4 marks



A piezo electric crystal provides a highly accurate and sensitive method of temperature measurement based on the change in its resonant frequency which is directly proportional to the temperature change. Here in the crystal cut in the form of shear type LC cut, in which the change in which the change in resonant frequency is highly linear as well as repeatable. The associated electronic circuitry of this thermometer is shown in figure which consists of piezoelectric crystal, oscillator and frequency counter with measurement display.

Q. 6. B) Electromagnetic flow meter

(Fig. 2 m & Explanation 2 m) 4 marks

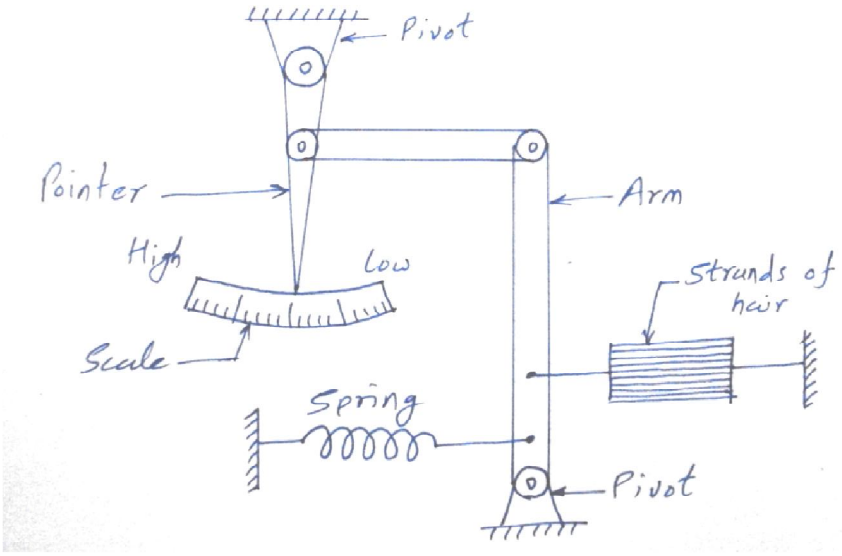


It consists of a pipe, short section of which is subjected to a transverse magnetic field. The conductive fluid is passed through this pipe. As fluid passes, its motion relative to field produces an emf proportional to velocity according to Faraday's law.

This output emf is collected by the electrodes (kept at points of maximum potential difference) and is given to external circuitry.

In practice, the pipe must be non-magnetic to allow the field to penetrate the fluid and usually is nonconductive (plastic/glass) so that it does not provide a short circuit path between positive and negative induced potentials at fluid surface.

Q. 6. C) Hair Hygrometer (Fig. 2 m & Explanation 2 m) 4 marks



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 illustrates the schematic diagram of the hair hygrometer. The transducer element consist of strands of hair to give it increased mechanical strength. The hair strands are generally arranged parallel to each other with sufficient apace between them for giving free access to the air sample under test. Further, for proper functioning, the element is maintained under light tension by a spring.

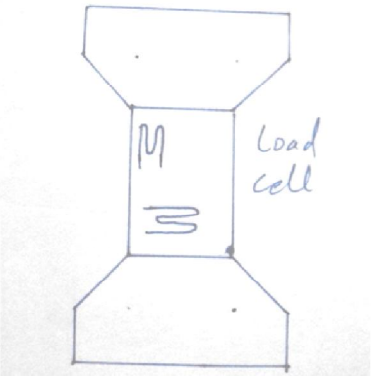
Q. 6. D) Types of Strain Gauges (1 X 4) 4 marks

Various means like mechanical, optical, acoustical, pneumatic or electrical can be used to measure deformation (strain) of an object. Following are the various types of Strain gauges.

1. **Semiconductor strain gauges:** semiconductor strain gages are based upon the piezo resistive effects of silicon or germanium and measure the change in resistance with stress as opposed to strain

2. **Thin film strain gauges:** Thin-film strain gage is more advanced form of strain gauge as it doesn't necessitate adhesive bonding. A thin film strain gauge is constructed by first depositing an electrical insulation, usually a ceramic onto the stressed metal surface, and then depositing the strain gage onto this insulation layer.
3. **Diffused semiconductor strain gauges:** Diffused semiconductor strain gages since they purge the need for bonding agents. By eliminating bonding agents, errors due to creep and hysteresis also are eliminated. The diffused semiconductor strain gage employs photolithography masking techniques and solid-state diffusion of boron to molecularly bond the resistance elements.
4. **Bonded resistance gauges:** These strain gauges are only moderately affected by temperature changes. They are extremely sensitive and have low mass. Bonded resistance strain gages can be employed to measure both static and dynamic strain.

Q. 6. E) Load Cell **(Fig. 1 m & Explanation 3 m)** **4 marks**



It is one of the simplest configurations of bonded strain gauge transducers. Important application of strain gauges is for the measurement of force or weight. Load cells measure deformation by force or weight.

Load cell consist of a cylindrical or rectangular load column. On its slides strain gauges are mounted. As load is applied the calibrated steel column deflects and bonded strain gauges measure the strain produced. Desired ranges of 20 kg to 20000 kg are obtained by variations in mass and design of load column.

Load cells are used to measure such variables as weight, force, thrust, compression, tension, etc. Generally these devices are calibrated so that force is directly related to resistance change.

---THE END ---