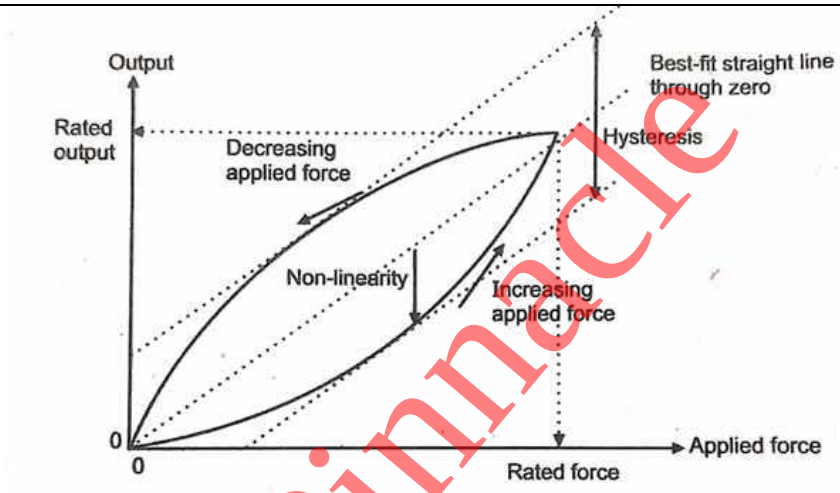
SUMMER – 19 EXAMINATION

Subject Name: Mechanical Engg. Measurement **Model Answer** **Subject Code: 22443**

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.1.		**Attempt any FIVE of the following:**	**10 Marks**
	a)	**State the parameters for selection of displacement transducer.**	
	Sol.	Operating principle Operating range Accuracy Error Transient & Frequency response Loading effect	**(Any four)** **½ mark each**
	b)	**Enlist the applications of load cell.**	
	Sol.	i) Scale Ex. Weighbridge ii) Force gauges: Ex. Torque gauge iii) Measuring instruments: Ex.: Laboratory balance, Industrial scale, Platform scale, Universal testing machine	**(Any Two)** **01 mark each**
	c)	**State the law of intermediate metal.**	
	Sol.	"The introduction of a third metal into the thermocouple circuit will have no effect on the EMF generated, as long as the junctions of the third metal with the thermocouple metals are at the same temperature."	**02 marks**
	d)	**State the materials of tube and float of rotameter.**	
	Sol.	**Material for tube:** Borosilicate Glass, polycarbonate plastic, metallic tube of aluminum, brass etc. **Material for float:** Gun metal, Stainless steel.	**01 mark** **01 mark**

	e)	**Define gauge factor.**	
	Sol.	**Gauge Factor:** It is a ratio of change in resistance to the stain. $$\text{Gauge Factor} = \frac{\text{Change in resistance}}{\text{Strain}}$$ $$G_f = \frac{\frac{\Delta R}{R}}{\frac{dl}{l}}$$	**01 mark** **01 mark**
	f)	**State the principle of working of slipping clutch tachometer.**	
	Sol.	Slipping Clutch tachometer helps by allowing the clutch to partially slip until the rotational speed matches measuring speed.	**02 marks**
	g)	**State the characteristics of force measurement.**	
	Sol.	 **Figure: Output characteristics of force measurement system** Characterising the performance of a force measuring system is commonly based on calculating such a best fit least squares lines and stating the measurement errors with respect to it.	**01 mark** **01 mark**
Q.2.		**Attempt any <u>THREE</u> of the following:**	**12 Marks**
	a)	**a) Define:** **(i) Fidelity** **(ii) Threshold** **(iii) Overshoot** **(iv) Drift**	
	Sol.	**Fidelity: Fidelity** of an instrumentation system is defined as the degree of closeness with which the system indicates or records the signal which is impressed upon it. It refers to the ability of the system to reproduce the output in the same form as the input. If the input is a sine wave then for 100 % fidelity, the output should be a sine wave. **Threshold:** When the input signal to an instrument is gradually increased from zero, there will be some minimum value input before which the instrument will not detect any output change. This minimum value is called threshold of instrument. Threshold defines the minimum value of input	**01 mark**

which necessary to cause detectable change from zero output. **01 mark**

Overshoot: The overshoot is defined as the maximum amounts by which the pointer moves beyond the steady state. **01 mark**

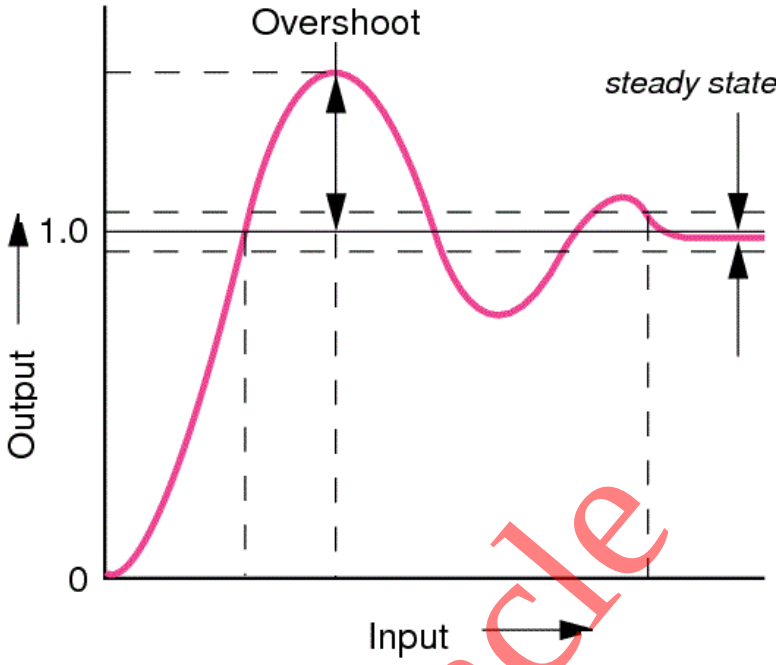


Figure: Overshoot

Drift: It is an undesired gradual departure of an instrument output over a period of a time that is unrelated to changes in input, operating condition or load. An instrument is said to have no drift if it reproduces same reading at different times for same variation in measured variables. **01 mark**

b) Explain with neat sketch working of Eddy current dynamometer.

Sol.

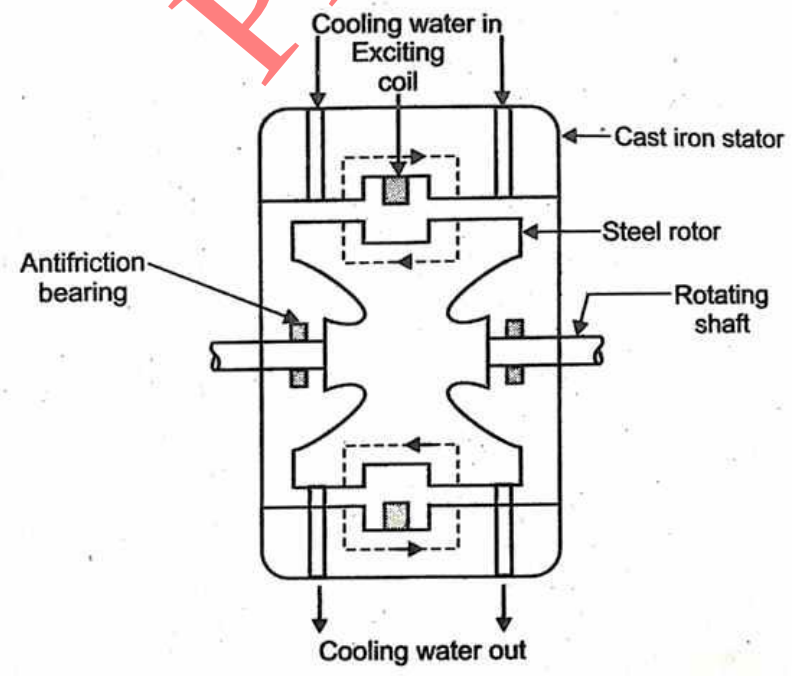


Figure: Eddy current Dynamometer

02 marks for figure

Working:

- ✓ 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 oppose 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.

02 marks

c) Explain with neat sketch Pirani gauge. State advantages also.

Sol.

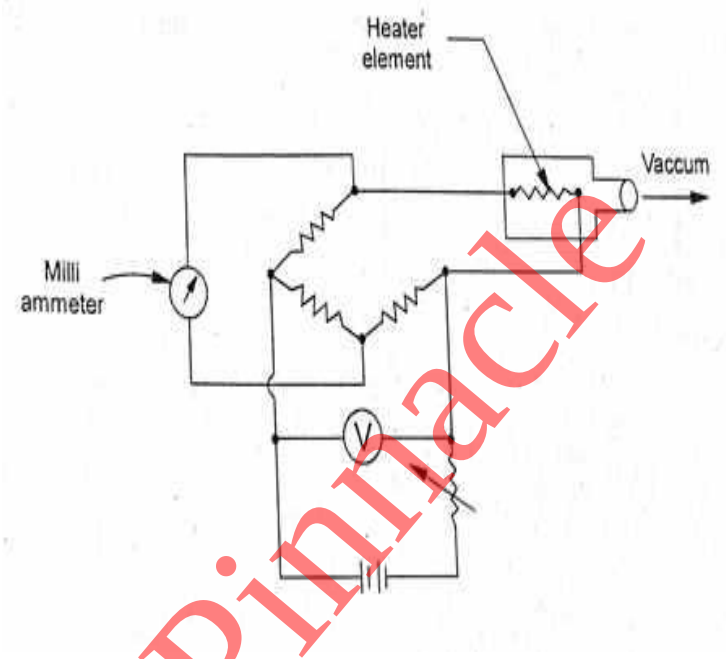


Figure: Pirani gauge

01 mark

Construction:

- ✓ Consists of platinum filament wire enclosed in a chamber connected to unknown pressure source.
- ✓ Filament forms an arm of Wheatstone-bridge.
- ✓ Compensating resistance is placed in opposite arm.

01 mark

Working:

Pirani gauge operates on 3 modes:

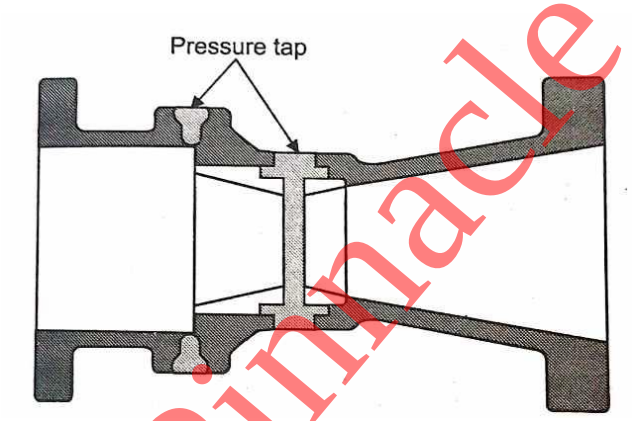
(i) Constant current,

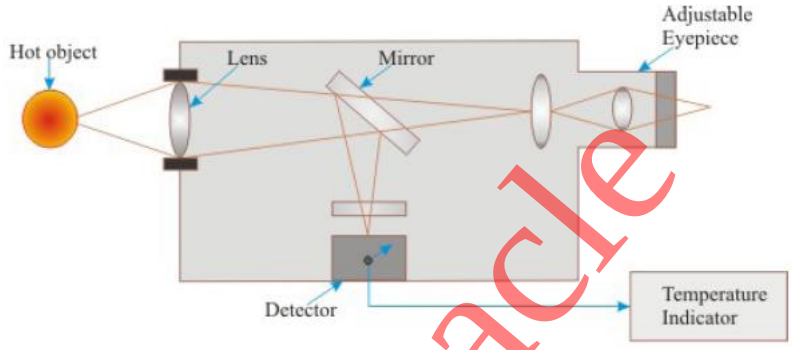
(ii) Constant resistance and

(iii) Constant voltage.

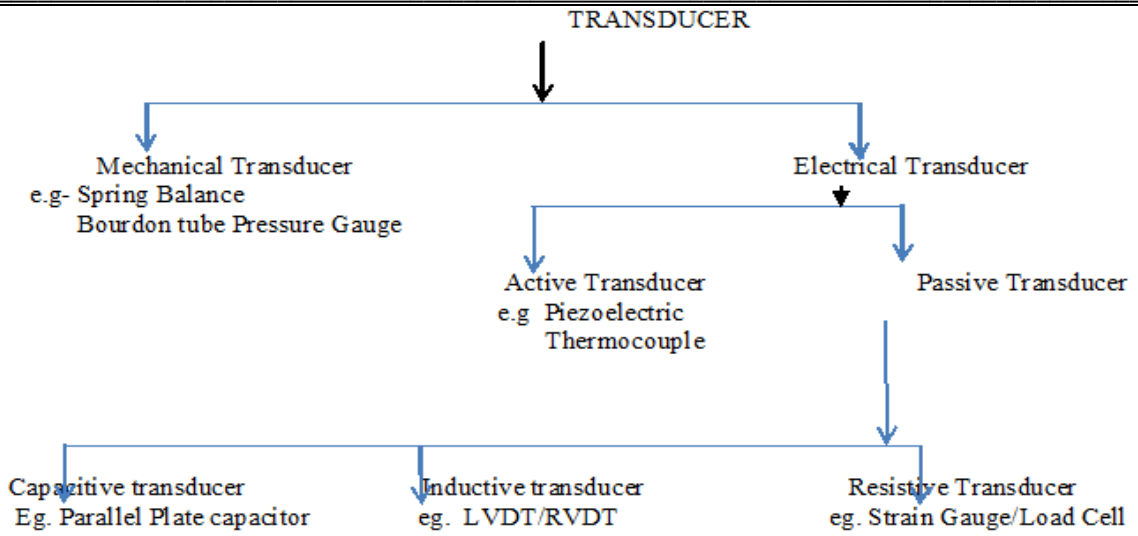
01 mark

- ✓ Due to constant current, filament gets heated .

		✓ At low pressure , thermal conductivity gets reduces. ✓ Temperature variation lead to resistance variation of filament and unbalances the W-bridge. ✓ Change in resistance of wire filament gives value of unknown pressure. **Advantages:** ✓ Simple in design & easy in use . ✓ More accurate than thermocouple gauges. ✓ Remote reading is possible. ✓ Range is between 10^{-5} mm to 1 mm of Hg ✓ Quick and Continuous response to pressure changes.	**01 mark**
	d)	**Describe the working principle of "Dall tube". Also state applications.**	
	Sol.	 **Figure: Dall tube** **Working:** **It** is another restriction type primary element for flow measurement. It is a shortened/modified form of a Venturi meter. The differential pressure of Dall tube is midway of-the orifice and venturi tube. It consists of two sections, with relativity large cone angle. The short straight inlet followed by an abrupt decrease in diameter. A narrow annular slit separates the short inlet and divergent outlet. The throat is formed by a circumstantial slit located between the inlet and outlet cones. The higher pressure is measured at circular slit area, and lower pressure is-measured at upstream. Typically a lithium coating is provided to avoid corrosion of the device by the fluids. The differential pressure produced by Dall tube is much higher, nearly doubled to that of Venturi meter having the same upstream and throat	**1 mark for figure** **02 marks**

		,diameters with the same net head loss. ,It. causes a very low-pressure loss compared to other differential pressure flow elements. Up to '95% Differential pressure can be recovered. **Applications:** i) Applicable to where a significant pressure drop is not tolerated. For example : Gas transmission pipeline ii) Flow measurement in circular tube	**01 mark**
Q.3.		**Attempt any THREE of the following:**	**12 Marks**
	a)	**Explain radiation pyrometer with neat sketch.**	
	Sol.	 **Figure: Radiation pyrometer** **Principle:** It is based on the principle of absorption of total radiation from hot body. **Construction and Working:** ✓ It consists of blackened tube open at one end to receive the radiation from the hot body whose temperature is to be measure. ✓ The other end of the tube has a sighting aperture in which an adjustable eyepiece is fitted. ✓ The thermal radiation from hot body strike on the concave mirror. ✓ Position of the mirror can be adjusted by rack and pinion arrangement for focusing the thermal radiations on the detector disk. ✓ The detector disk is a platinum sheet ✓ The disk is connected to the thermocouple ✓ The leads from the detector disc are used for measuring thermoelectric EMF.	**02 marks** **02 marks**
	b)	**Classify transducers.**	

Sol.



04 marks

c) **Differentiate:**
(i) Range and Span
(ii) Accuracy and Precision

Sol.

i) Compare Range and Span

Sr. No.	Range	Span
1	It is defined as region between lower limit to upper limit of an instrument	It is algebraic difference between upper limit and lower limit of the instrument
2	Eg. If thermometer is used to measure temperature between 0^0C to 100^0C Range:- 0^0C to 100^0C	Eg. If thermometer is used to measure temperature between 0^0C to 100^0C Span:- 100^0C - 0^0C = 100^0C

Any 02 difference

(01 mark each)

ii) Compare Accuracy and Precision

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 g 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 guaranty accuracy.

Any 02 difference

(01 mark each)

Measurements are dependent on the systematic errors	Measurements are dependent on the random errors
Determined by proper calibration	Determined by statistical analysis.

d) Draw a creep curve for force transducer. State significance. — **02 marks**

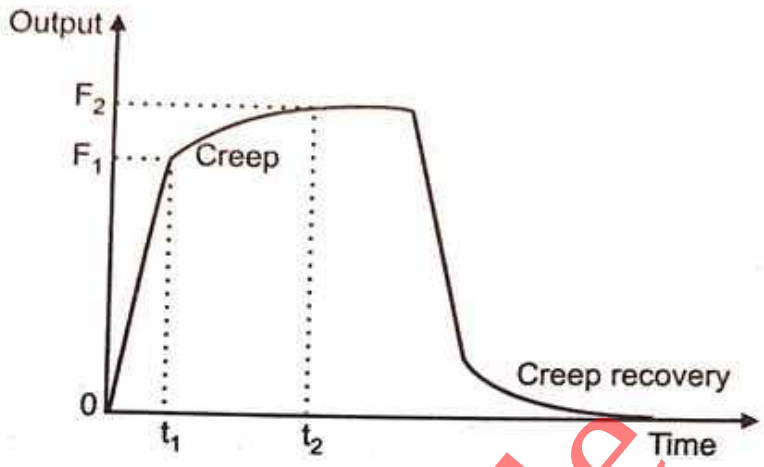


Figure: Creep curve of a typical force transducer

Significance:

A force measurement system will take some time to adjust fully to a change in forced applied, and creep of a force transducer Is usually defined as the change of output with time following a step In ref se In force from one value to another. Most manufacturers specify the creep as the maximum change of output over a specified time after increasing the force from zero to the rated force. Figure follows an example of a creep curve where the transducer exhibits a change in output from F_1 to F_2 over a period of time from t_1 to t_2 after a step change between 0 and t_1• In figure:; this might be, say, 0.03% of rated output over 30 minutes.

Creep recovery is the change of output following a step decrease in the force applied to the force transducer, usually from the rated force to zero. For both creep and creep recovery, the results will depend on how long the force applied has been at zero or the rated value respectively before the change of force Is made.

The frequency response of a force transducer is affected by the nature of the mechanical structure, both within the transducer and of its mounting. A force transducer on a rigid foundation will have a natural frequency of oscillation and large dynamic errors occur when the frequency of the vibration approaches the natural frequency of oscillations of the system.

The effect of temperature changes is felt on both the zero and rated output pf the force measurement system. The temperature coefficient of the output at zero force and the temperature coefficient of the sensitivity are measures of this effect for a given system. A force measurement system may need to be kept at constant temperature, or set-up well in advance, to settle in — **02 marks**

to the ambient conditions if high accuracy measurements are required. In some cases the temperature gradients within the measurement installation create a problem even when the average temperature is stable.

Other influence quantities such as humidity, pressure, electrical power changes or radio- frequency Interference may have analogous effects to those of temperature and may be considered In a similar manner.

Any difference between the indicated value of force and the true value is known as an error of

measurement (although note that strictly a 'true' value can never be perfectly known or indeed defined and the concept of uncertainty takes this into account). Such errors are usually expressed as either a percentage of the force applied at that particular point on the characteristic or as a percentage of the maximum force - see the difference between '% reading' and '% full scale reading..

The rated capacity is the maximum force that a force transducer is designed to measure.

Q.4.		**Attempt any THREE of the following:**	**12 Marks**
	a)	**Explain the working of slip ring sensor with neat sketch.**	
	Sol.	**Slip ring Sensor**	**02 marks for diagram**

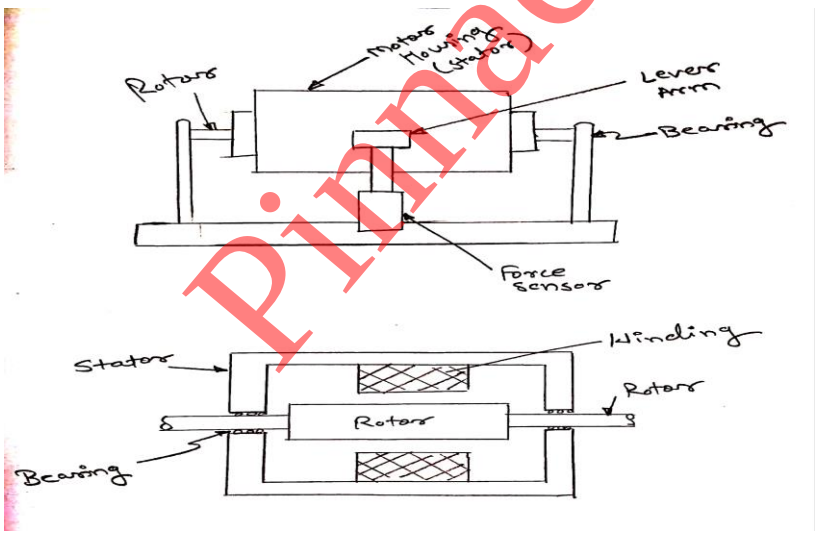
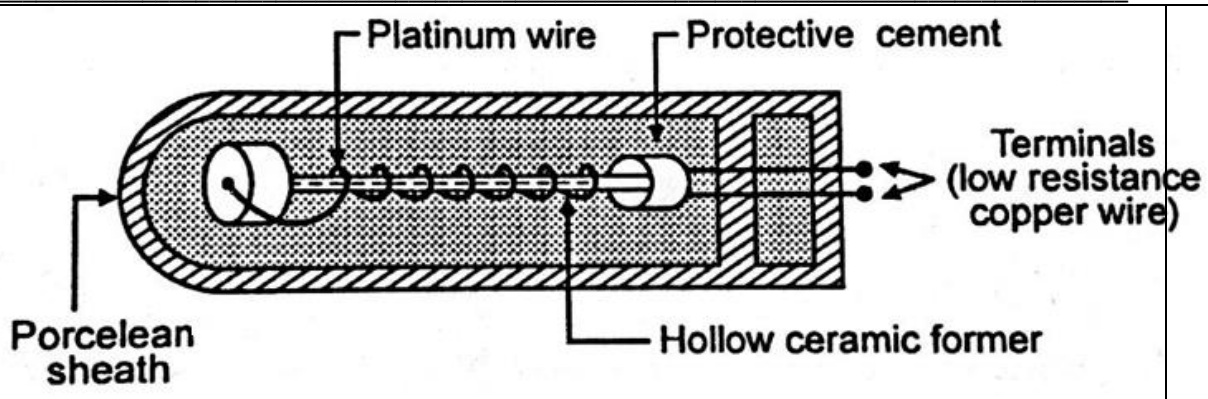
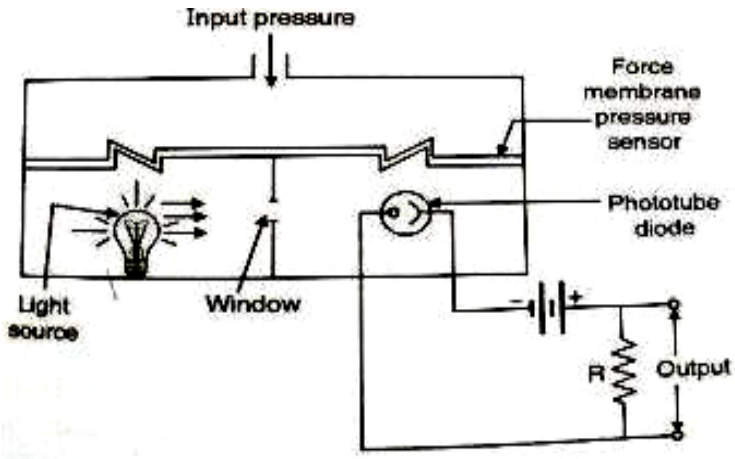


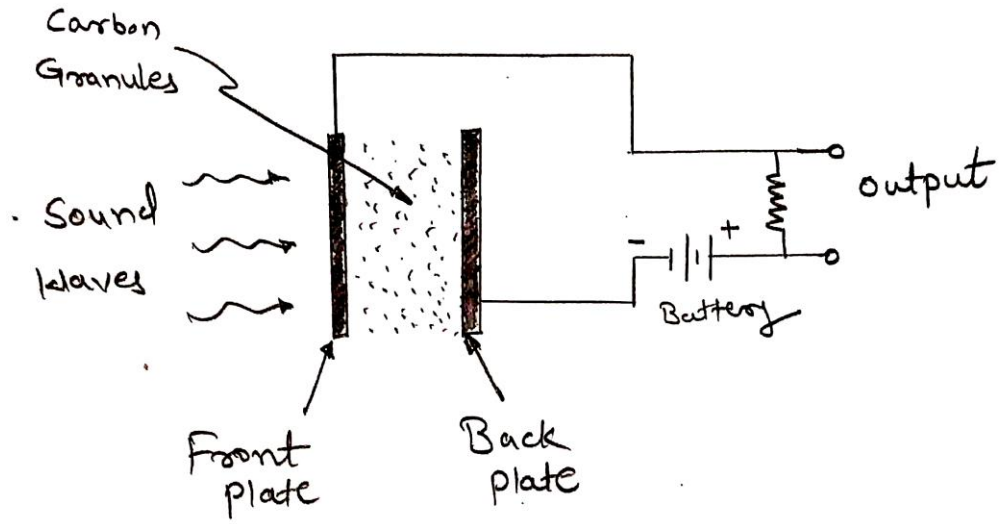
Figure: Slip ring sensor

02 marks for explanation

The principle is based on torsion part of shaft and its torsion. Measurement of torsion of the shaft is possible in several ways. For a torque measurement we must place these strain gauge in this way. For pressure, tension and bending measurement the position of strain gauges are different for the transfer of the signal from moving rotor to stator terminals the slip rings are used in this way the signal is partly interfered. It is also possible to use instead of slip rings the special contacts with mercury or contactless telemetry data transfer

	b)	**Describe the working of platinum resistance thermometer with neat sketch.**	

	Sol.	 **Figure: Resistance temperature detector (RTD)** **Construction:** ✓ Platinum resistance thermometer consist of pure, well annealed wire. ✓ This wire wound on a hollow insulating ceramic former and covered with protective cement. ✓ Whole assembly placed in Porcelain sheath. ✓ The ends of platinum wire are welded to long leads of low resistance copper wires. ✓ The copper leads that are connected to one of the arm of Wheatstone bridge. ✓ Some times RTD sensor is fabricated by depositing thin films of platinum, nickel, or copper on ceramic substrate. **Working:** ✓ The change in resistance due to temperature change is usually measured by Wheatstone bridge, which may be used either in the null condition or in the deflection condition. ✓ When the RTD is subjected to any change in temp. the bridge get unbalanced and galvanometer shows some deflection. ✓ This galvanometer is calibrated in terms of temperature.	**02 marks diagram** **02 marks for explanation**
	c)	**Explain with neat sketch photoelectric pressure transducer. State advantages.**	
	Sol.	**Photoelectric pressure transducer**  **Figure: Photoelectric pressure transducer** It consist of port for input pressure ,Pressure sensing member like diaphragm ,light source	**01 marks for fig.** **02 marks for explanation**

		,a small window, a photo tube with output circuit. The function of pressure sensing element is to control the aperture of small window. The amount of output is entirely depends upon the amount of incident light falling on phototube. When the pressure to be measured is applied through port to the pressure sensing member, it changes the position of window. As the light source and phototube are separated by a window it changes the amount of light falling on phototube, causing change in the current. This change in current is approximately linear with displacement of window i.e applied pressure. The current in phototube is amplified by a suitable output circuit. A meter connected across output terminal can directly calibrate in terms of pressure measurement. An A.C Modulated light or stable source of light can be used for incident light. **Advantages:** 1. It can measure both static & dynamic pressure. 2. It is highly efficient 3. Easy portability 4. Compact size.	**01 mark**
	d)	**State any four desirable characteristics of bonded type resistance strain gauges.**	
		Desired characteristics of bonded type Resistive strain gauges 1. Small size and very low mass. 2. Fully bonded to basic spring structure. 3. Excellent linearity over wide range of strains. 4. Low and predictable thermal effect 5. Small surface area. 6. Low leakage. 7. High insulation	**Any four (01 mark each)**
	e	**Explain with neat sketch carbon microphone. State disadvantages.**	
		Carbon Microphone  It is also referred as button microphone or a carbon transmitter. Fig. show carbon	01 marks diagram

		microphone. It consists of two metal plates separated by carbon granules. One plate is on the face and acts as a diaphragm. When sound strikes the face plate, a current runs from one plate through the carbon to the other plate. The carbon granules changes the electric resistance between the plate. The resistance causing change in the current and a consequent change in voltage which is the output of the microphone. The principle advantage of carbon microphone is that they have the ability to produce high level audio signals from very low dc voltage. **Disadvantages** 1. Low quality of sound reproduction. 2. Limited frequency response. 3 It required external power source.	02 marks explanation 01 mark for disadvantages
Q.5.		**Attempt any <u>TWO</u> of the following:**	**12 Marks**
	a)	**Classify errors and explain any two of errors.**	
	Sol.	Errors may originate in a variety of ways and the following sources need examination: 1. Instrument errors 2. Environmental errors 3. Translation and signal transmission errors 4. Observation errors 5. Operational errors 6. System interaction errors **1. Instrument error:** There are many factors in the design and construction of instruments that limit the accuracy attainable. Instruments and standards posses inherent inaccuracies and certain additional inaccuracies develop with use and time. Example: a. Improper selection and poor maintenance of instrument. b. Loss of motion due to necessary clearance in gear teeth and bearing. c. Excessive friction at the mating parts etc. **or** **2. Environmental Error:** The instrument location and the environment errors are introduced by using an instrument in conditions different for which it has been designed, assembled and calibrated. The different conditions of use may be Temp., Pressure, humidity and altitude etc. Following are the methods are used to reduce the environmental errors: 1. Use the instrument under the condition for which it was originally assembled and calibrated. 2. Measure the deviation of local condition and apply suitable correction to the instrument. 3. Make the complete new calibration under the local condition. **or** **3. Translation and signal transmission errors:**	**02 marks for classification** **02 marks each for explanation of any two types of error**

		✓ The instrument may not sense or translate the measured effect with complete fidelity. ✓ The error also includes the non capability of the instrument to follow rapid changes in the measured quantity due to inertia and hysteresis effects. ✓ The error may also result from unwanted disturbances such as noise, line pick up, hum, ripple etc. The errors are remedied by calibration and by monitoring the signal at one or more points along its transmission path. **or** **4. Observational Error:** "Instruments are better than the people who use them." 1. Parallax 2. Inaccurate estimate of average reading 3. Incorrect conversion of units in between consecutives readings 4. Personal bias i.e. a tendency to read high or low. **5.** Wrong scale reading and wrong recording data. **or** **5. Operational Error:** "Quite often errors are caused by poor operational techniques." Example: 1. A differential type of flow meter will read inaccurately if it is placed immediately after a valve or bent. 2. A thermometer will not read accurately if the sensitivity portion is insufficiently immersed . 3. Pressure gauge will correctly indicate pressure only when it is exposed only to the pressure which is to be measured.	
	b)	**State the necessity of contactless electrical tachometer and describe with neat sketch photoelectric tachometer.**	
	Sol.	**Necessity of contactless electrical tachometer:-** 1) To measured speed without physical contact. 2) Operated at distance from rotating shaft. 3) Do not transfers load to shaft. 4) For more accuracy. **Photo electric tachometer:-**	**02 marks** **02 marks**

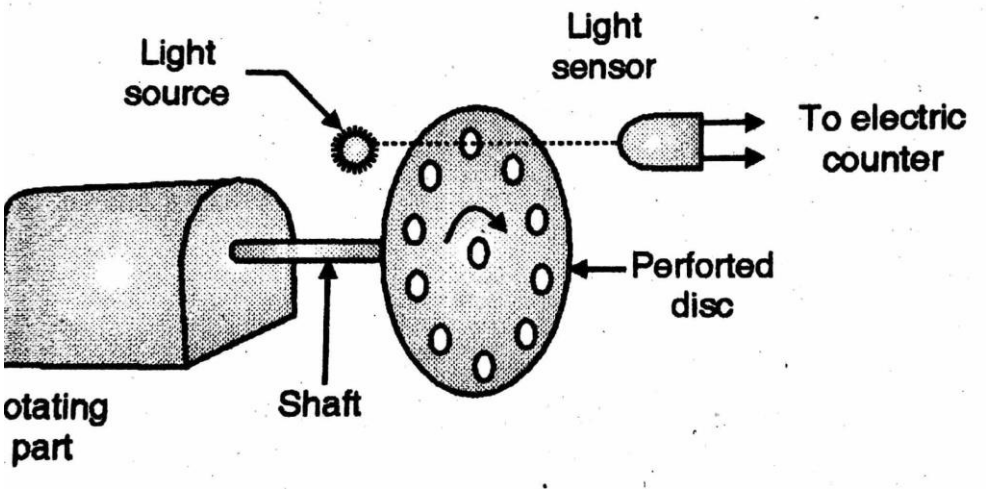


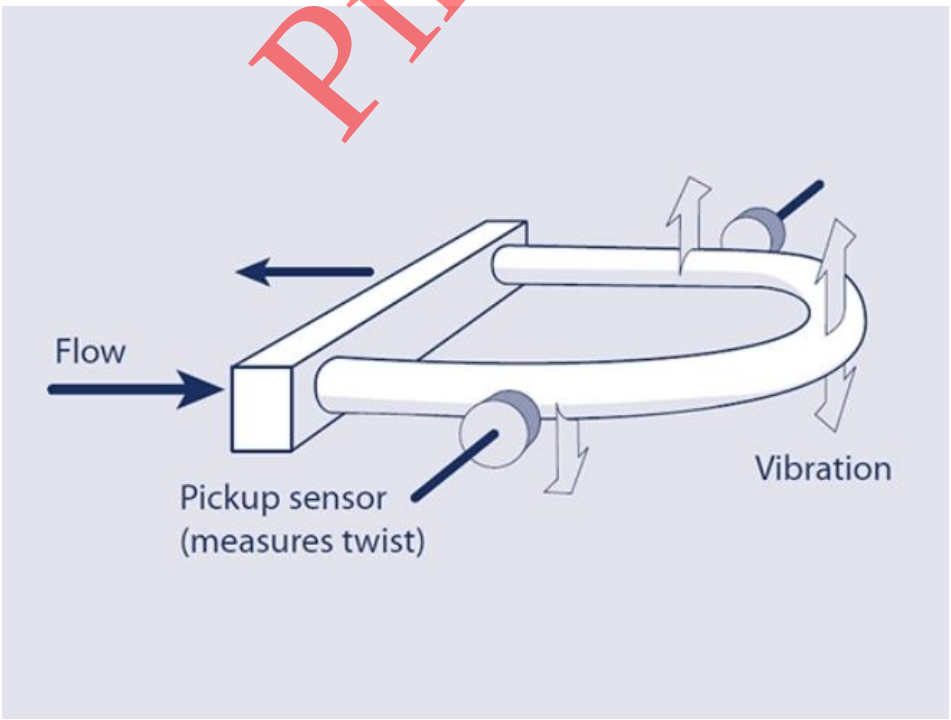
Figure: Photo electric tachometer

This method of measuring speed of rotation 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 and at the other side of the disc and in line with light source, a light sensor such as phototube is placed. When the opaque portion of the disc is between the light source and the light sensor, the latter is un-illuminated and produces no output. But when a hole appears between the two, the light falling upon the sensor produces an output pulse. The frequency at which these are produced depends upon the number of holes in the disc and its speed of rotation.

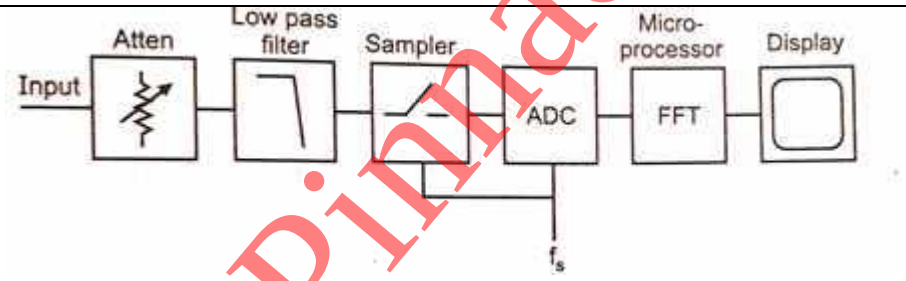
02 marks

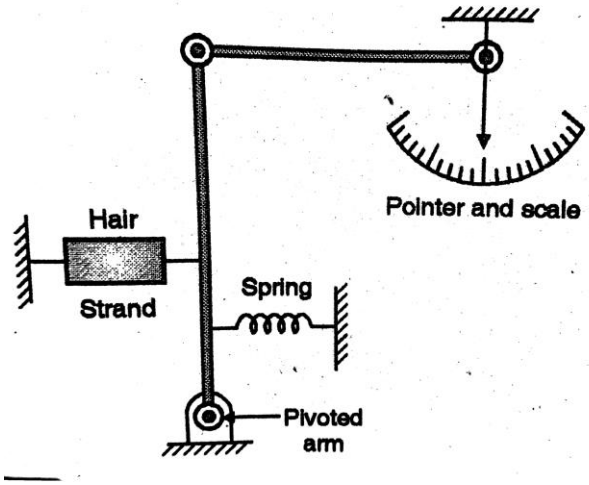
c) Explain with neat sketch Coriolis flowmeter. State advantages and applications.

Sol. **Coriolis flowmeter:**



02 marks for fig.

		Figure: Coriolis flowmeter The operation principle of a coriolis flow meter is basic but very effective. A coriolis flow meter contains a tube which is energized by a fixed vibration. When a fluid (gas or liquid) passes through this tube the mass flow momentum will cause a change in the tube vibration, the tube will twist resulting in a phase shift. This phase shift can be measured and a linear output derived proportional to flow. **Advantages:-** 1) It can direct take measurement of mass flow with high accuracy. 2) It has wide range of measurable fluids, including high viscosity fluids, liquid – solid two phase fluids. 3) The change in fluid viscosity has no significant effect on the measured value. 4) Bidirectional flow measurement. **Application:-** 1) In chemical process where fluids can be corrosive. 2) It is used where the physical properties of the fluid are not well know.	**02 marks for explanation** **01 marks for any two points** **01 marks for any two points**
Q.6.		**Attempt any TWO of the following:**	**12 Marks**
	a)	**Draw a labelled block diagram of FFT analyser. State the advantages and applications.**	
	Sol.	 **Figure: Block diagram of FFT spectrum analyzer** **Advantages of FFT Analyzer:-** 1) It is measure all frequency components at the same time. 2) The magnitude is a real quantity and represents the total signal amplitude in each frequency bin, independent of phase. **Application of FFT Analyzer:-** 1) To measure the transfer function of a mechanical system. 2) In forensics, laboratory for measuring the wavelength of light at which a material will absorb in the infrared rays.	**02 marks for fig.** **02 marks** **02 marks**
	b)	**Describe with the neat sketch working of Hair Hygrometer. Enlist disadvantages.**	
	Sol.	**Hair hygrometer:-**	**02 marks for fig.**



Hair hygrometer is the simplest and oldest type of hygrometer. It is made using hair. Human hair lengthens by 3 percent when the humidity changes from 0 to 100 percent, this property of hair can be used to operate a pointer or recording pen through a system of mechanical linkage. The transducer element consists of strands of hair which are generally arranged parallel to each other. It is not a precision instrument and not recommended where high degree of accuracy is requires. The change in length can be used to control a pointer for visual readings or a transducer such as linear variable differential transformers (LVDT) for an electrical output.

Disadvantages:-

1) Rapid changes in humidity magnify the error recorded by the hair hygrometer.
2) The hair sample can become damaged due to continuous tension.
3) Increase sensitivity to rapid changes in humidity limits.

03 marks for explain

01 marks for any two point

c) Define ultrasonic flow measurement. Describe working principle of doppler flow meter with two advantages.

Sol.

Ultrasonic Flow Measurement:-

It is a type of flow meter that measures the velocity of a fluid with ultrasound to calculate volume flow.

01 mark for define

Doppler flow meter:-

It is operates on the principle of the Doppler effect. The frequencies of the sound waves received by an observes are dependent upon the motion of the sound. A Doppler flow meter uses a transducer to emit an ultrasonic beam in to the stream flowing through the pipe. For the flow meter to operate there must be solid particles or air bubbles in the stream to reflect the ultrasonic beam. The motion of particles shifts the frequency of the beam which is received by a second transducer. The Doppler flow meter relies on particles flowing in the liquid to operate, consideration must be given to the lower limits for concentration and sizes of solids or bubbles. In addition the liquid must flow at a rate high enough to keep the solids suspended. The Doppler flow meter must have particles or bubbles to reflect the ultrasonic signals.

02 marks for explain

02 marks for fig.

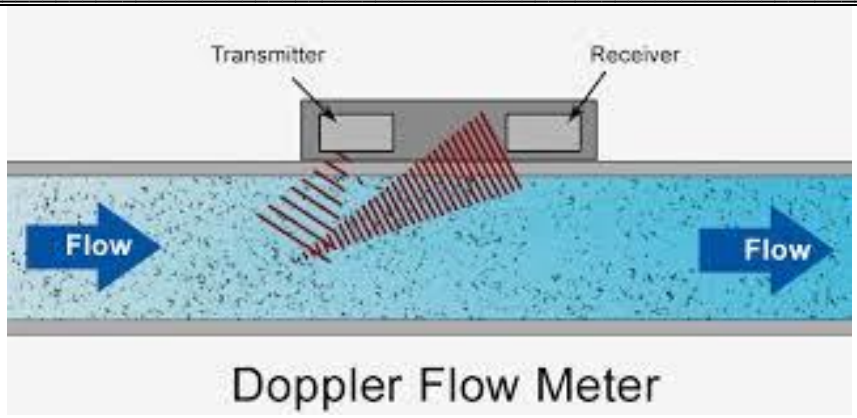


Figure: Doppler flow meter

Advantages:-

1) Easy installation and removal.
2) No process downtime during installation.
3) No moving part to wear out.

No process contamination

01 marks for any two point.