SUMMER – 19 EXAMINATION

Subject Name: Mechanical Engineering 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)	**Enlist different types of high pressure gauges.**	
	Sol.	**Different types of high pressure gauges:-** **1** Bourdon pressure gauge **2** Diaphragm pressure gauge **3** Bellows pressure gauge **4** Piezo resistive Strain pressure gauge **5** Capacitive pressure gauge **6** Magnetic pressure gauge **7** Piezoelectric pressure gauge **8** Optical pressure gauge **9** Potentiometric pressure gauge **10** Resonant pressure gauge	**Any four** **½ mark for each**
	b)	**Classify dynamometers.**	
	Sol.	**Classification of dynamometer's** **Absorption type dynamometers:** 1. Prony brake dynamometer, and 2. Rope brake dynamometer. **Transmission type dynamometers** 1. Epicyclic-train dynamometer, 2. Belt transmission dynamometer, and 3. Torsion dynamometer.	**01 mark** **01 mark**
	c)	**List the different applications of potentiometer.**	
	Sol.	**Applications of potentiometer** ○ The potentiometer is used as a voltage divider in the electronic circuit. ○ The potentiometer is used in radio and television (TV) receiver for volume control, tone control and linearity control.	**Any two** **01 mark for each application**

		○ The potentiometer is used in medical equipment. ○ It is used in wood processing machine. ○ It is used in injection mold machines. ○ Potentiometers are widely used as user controls, and may control a very wide variety of equipment functions.	
	d)	**Name material used for diaphragms.**	
	Sol.	**Material used for diaphragm** 1. Stainless steel 5. Teflon 2. Phosphor bronze 6. Rubberized fabric 3. Beryllium copper 7. Neoprene 4. Leather	**Any two** **01 mark for each**
	e)	**Define Reynolds number. State its formula.**	
	Sol.	**Reynolds No.-** Reynolds's number is a dimensionless quantity that is used to determine the type of flow pattern as laminar or turbulent while flowing through a pipe. Reynolds's number is defined by the ratio of inertial forces to that of viscous forces. $Re = \rho VD/\mu$ Where, Re is the Reynolds's number ρ is the density of the fluid V is the velocity of flow D is the pipe diameter μ is the viscosity of the fluid	**01 mark for definition** **01 mark for formula**
	f)	**List the different types of vibration measuring devices.**	
	Sol.	**Vibration Measuring Devices** 1. Stroboscope 5.Velocity pickups 2. Reed Vibrometer 6.Accelerometers 3. Seismic mass transducer 7.Piezoelectric accelerometers 4. Displacement pickups 8. Inductive Pickups 9. Capacitive Pickups	**Any four** **½ mark for each**
	g)	**State the advantages of stroboscope.**	

Sol. **Advantages:** — **Any two**

1. It is contactless method.
2. It does not impose any load on shaft whose speed is to be measured.
3. It does not require any special arrangement with shaft.
4. It is useful where physical contact method cannot be used.

01 mark each advantage

Q.2. **Attempt any THREE of the following:** — **12 Marks**

a) **Explain term-fidelity and overshoot.**

Sol.

Fidelity: — **02 marks**

It is the degree to which an instruments indicates the change in measured variable without dynamic error

It is ability of the system to reproduce the output in the same format as input

Overshoot: — **02 marks**

The overshoot is defined as the maximum amount by which the pointer moves beyond the steady state.

Because of mass and inertia, a moving parts, i.e. the pointer of the instrument does not immediately comes to rest in the final deflection position. The pointer goes beyond the steady state i.e. it overshoots.

b) **Compare infra-red sensor modulation transmitter and frequency**

Sol.

Sr No	Infra-red sensor (IR)	Frequency modulation sensor (FM)
1	Infrared sensors work on the principle of reflected light waves	Frequency modulation sensor work on the principle of reflected sound waves
2	The reflected light is detected and then an estimate of distance is calculated between sensor and object	Distance is estimated by the time interval between sensor and object.
3	Inability to use them in sunlight due to interference	It can be use in sunlight
4	IR sensors are less reliable than FM sensors	FM sensors are more reliable than IR sensors
5	Infrared sensors are used to measure distance or proximity	Frequency modulation sensor are also used to measure distance
6	IR sensors are costly	FM sensors are cheap.

01 mark for each

(Any Four)

c) **Describe the working principle of RTD. Explain with neat sketch.**

Sol.

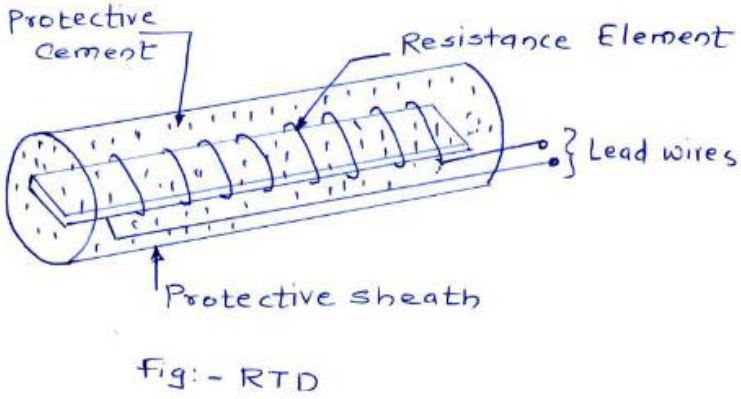


Figure: Constructional details of RTD

02 marks

Working principle:

02 marks

Resistance thermometers or resistance temperature detector works on the principle of positive temperature coefficient of resistance i.e. as temperature increases, resistance offered by thermometer also increases. The resistance element of platinum and iron metal wire is wrapped around an electrically insulating support of glass, ceramic or mic and from the outside, protective sheath of metallic tube can be provided. The lead wires are taken out from the resistance elements which are joined to the circuitry. The resistance thermometers which are alternatively known as RTD works on the principal that " the resistance of a metal varies with a change in temperature" according to the relation as

$$RT = R0[1+\alpha(T-T0)]$$

Where:

RT : Resistance at temperature (T)
R0 : Resistance at temperature (0°C)
α : Temp. coeff.
T: temp(°C)
T0 : Initial temp.

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.

	d)	**Draw the construction and explain working of nutating disc type positive displacement meter.**	

Sol.

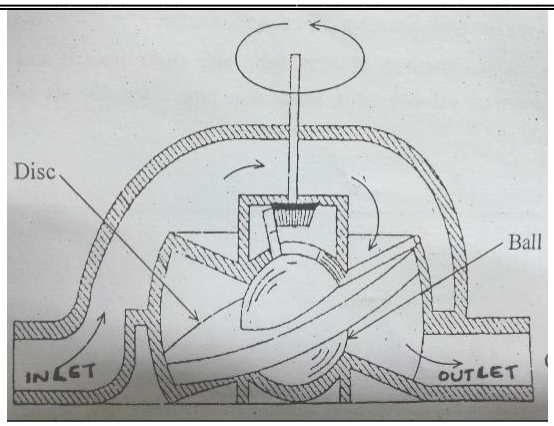


Figure: Nutating Disc

02 Marks for construction diagram

Working:

Nutating disc meters are one of the most common types of positive displacement flow meter. They operate by having a disc mounted to a central ball. When fluid enters the chamber, it causes the disc to wobble (nutate), transferring the displaced volume to the display.

Liquid enters a precision-machined chamber containing a disc which nutates (wobbles). The position of the disc divides the chamber into compartments containing an exact volume. Liquid pressure drives the disc to wobble and a roller cam causes the nutating disc to make a complete cycle. This motion is translated into rotary motion by means of a ball and shaft, which is attached to the disc. The movements of the disc are transmitted by gear train to an indicator/totalizer or pulse transmitter

02 Marks for working

Q.3. Attempt any THREE of the following: 12 Marks

a) Distinguish between Threshold and Resolution.

Sol.

Sr. No.	Threshold	Resolution
1	Threshold defines the minimum value of input which is necessary to cause detectable change from zero output.	Resolution defines the smallest change in the measured value that can be detected with certainty by the instrument.
2	The minimum value of input which is necessary to cause detectable change from zero output.	The minimum value of input which is necessary to cause detectable change from non-zero output.
3	Threshold may be caused by backlash or internal noise.	The resolution is determined by the the ability of the observer to judge the position of a pointer.
4	It may be expressed as an actual value or as a fraction or percentage of full scale value.	It may also be expressed as an actual value or as a fraction or percentage of full scale value.

01 mark each

b) List the different types of errors in measurement system and explain anyone.

	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:** ✓ 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	**02 marks for types** **02 marks for explanation (any one)**

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.

c) Explain construction and working of R.V.D.T.

Sol.

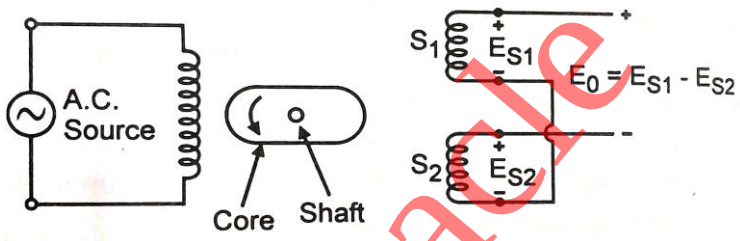


Figure: R.V.D.T.

02 marks for figure

01 mark for construction

Constructiion of RVDT:

- ✓ It is used to sense angular displacement. The setup for measurement of angular displacement is shown in figure.
- ✓ RVDT consist of one primary winding (P) and two secondary winding (S_1) and (S_2) wound symetrically on a coil form (stator).
- ✓ The primary winding is excited by A.C. supply.
- ✓ Two secondary winding S_1 & S_2 are connected in series opposition.
- ✓ A cam shaped soft iron core is placed between primary winding and two secondary windings.
- ✓ The core is coupled with shaft whose angular displacement is measured.

01 mark for working

Working of RVDT:

- ✓ Primary winding excited by A.C. Current flows through the coil and magnetic filed is produce.
- ✓ This magnetic field interact with two secondary coil an emf produce in. secondary coil Output voltage of secondary S_1 is ES_1 and secondary S_2 is ES_2.
- ✓ To covert the outputs from S_1 & S_2 are connected in series opposition.
- ✓ When the cam shaped core is rotate in clockwise direction, more flux link with secondary S_2 and hence more voltage generated in secondary winding S_2.

$$E_0 = ES_2 - ES_1$$

- ✓ When the cam shaped core is rotate in anti clockwise direction, more flux link with secondary S_1 and hence more voltage generated in secondary winding S_1.

$E_0=ES_2-ES_1$ where $ES_1>ES_2$

The output of secondary windings is proportional to the angular displacement of the cam shaped core and hence quantity being measured.

d) Explain radiation pyrometer with neat sketch.

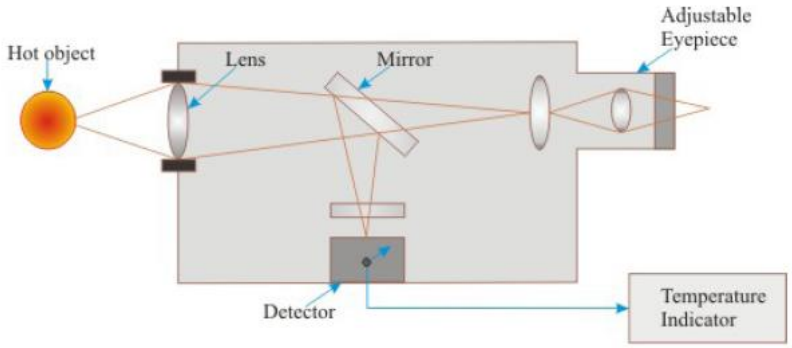


Figure: Radiation pyrometer

02 marks for figure

02 marks for explanation

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.

Q.4. Attempt any THREE of the following: 12 Marks

a) Draw creep curve for force transducer. State its significance.

Sol.

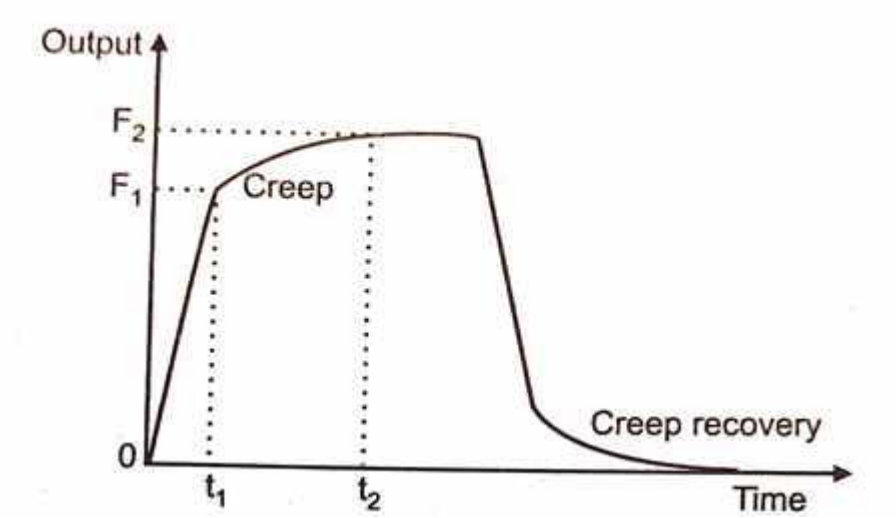
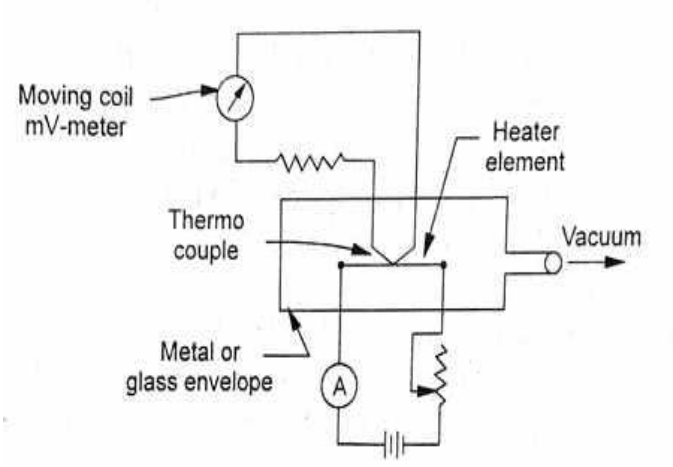
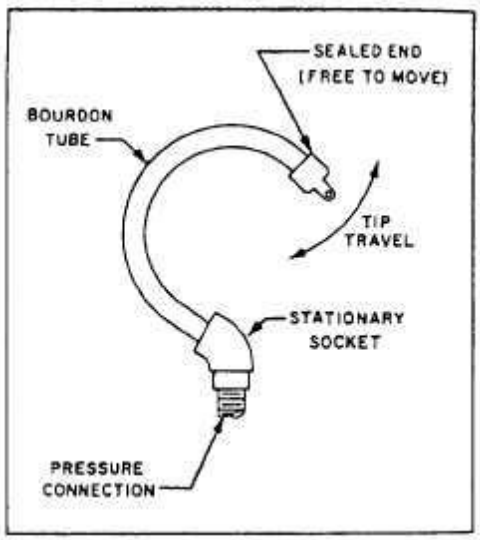


Figure: Creep curve of a typical force transducer

02 marks for diagram

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. Fig. 2.1.0 follows an example of a creep curve where the transducer exhibits a change in output from Fl to F2 over a period of time from tl to t2 after a step change between 0 and t_1• In figure:; thls 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 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.	**02 marks for significance**
	b)	**Explain the construction and working of thermocouple vacuum gauge.**	

	Sol.	 **Figure: Thermocouple vacuum gauge** **Principle:** "Lower the gas pressure, the lower the thermal conductivity and consequently the higher the filament temp. for a given electric energy input". **Construction and Working:** ✓ It consists a heater element 0.025 mm tungsten wire. ✓ This wire heated by a current 10-100 mA to a temp between 75^0C-400^0C. ✓ A thermocouple welded to it to heater enclosed in a glass tube. ✓ Other end of glass tube is connected to vacuum system whose pressure is to be measured. ✓ Constant current is supplied to heater element. ✓ "Lower the gas pressure, the lower the thermal conductivity and consequently the higher the filament temp. for a given electric energy input" ✓ Temp. of heater element is function of pressure and is measured by thermocouple. ✓ The output voltage of thermocouple is measured gives pressure. ✓ Range: 10^{-4} to 1 mm of Hg.	**01 mark diagram** **01 mark Principle** **01 mark construction** **01 mark working**
	c)	**Describe working principle of C-type Bourdon tube. List material used in it.**	
	Sol.	**Materials for Tube:** Brass, Bronze, SS, Monel, Beryllium copper, Inconel X, Ni-Span C  **Figure: C-type boudon tube**	**02 marks for principle** **02 marks for material**

Working principle:

When the prssure is applied the inside of the tube,its coss section tends to become circular.this makes the tube straighten itself out with a increase in radius of curvature. This cause the free end of the tube to move. This displacement of tube creats the angular movement in rack and pinion through mechanical linkage.

d) Explain FFT analyzer with block diagram of the FFT spectrum analyzer.

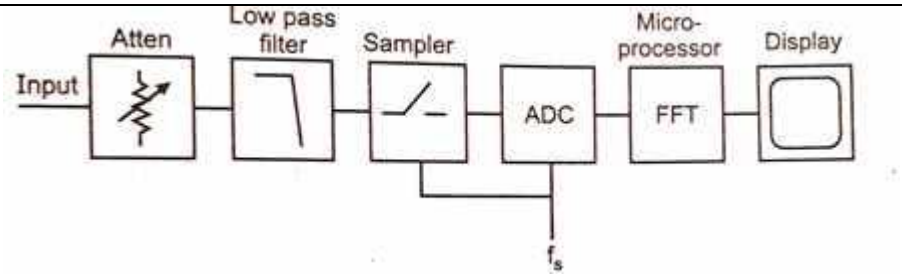


Figure: Block diagram of FFT spectrum analyzer

02 marks for diagram

The Fast Fourier transform can be used to determine the frequency domain representation (spectrum) of a time domain signal. The signal must be digitized in the time domain; then the FFT algorithm is executed to find the spectrum. Figure shows the FFT spectrum analyzer. The input signal is first passed through a variable attenuator to provide various measurement ranges. Then the signal is low-pass filtered to remove undesirable high frequency content which is beyond the frequency range of the sampler circuit and the analog to digital converter. The microprocessor receives the sampled waveform, computes the spectrum of the waveform using FFT, and writes the results on the display.

The FFT analyzer accomplishes the same thing that the bank of filters analyzer does, but without the need for many bandpass filters. instead , the FFT analyzer uses digital signal processing to implement the equivalent of many individual filters. thus, when considering the operation of the FFT analyzer, it is appropriate to think in terms of a bank of parallel filters, each filtering a portion of the frequency spectrum.

02 marks for explanation

e) Explain how sound is measured by carbon-microphone.

Carbon-microphone:

01 mark for Figure

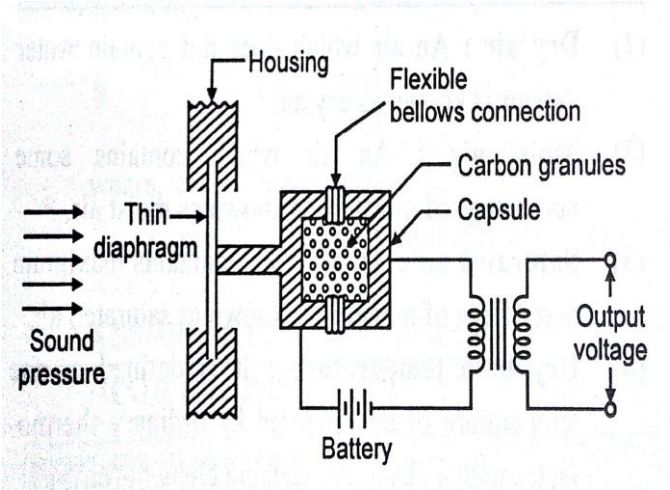
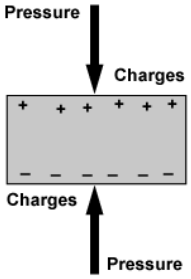


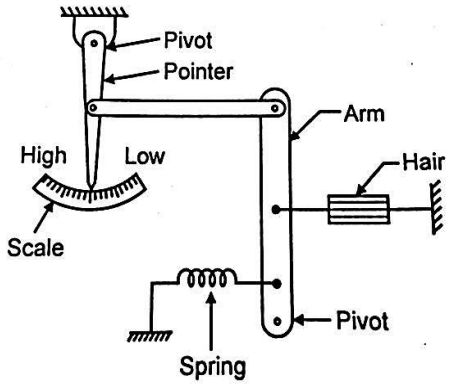
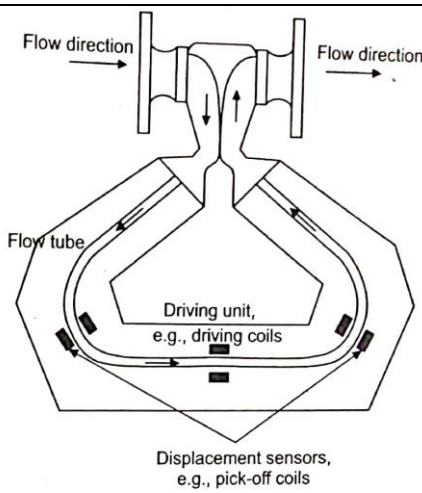
Figure: Carbon microphone

Principle:

Resistance varies with change in pressure sensed by diaphragm of a microphone.

01 mark for principle

		Construction: Consist of a thin diaphragm which is connected to a capsule having flexible bellow. ✓ A capsule containing carbon granules. ✓ Electrical circuit to for signal conditioning and indication of output. ✓ These elements are joined together as shown in figure. **Working:** ✓ Sound waves strikes on thin diaphragm ✓ Diaphragm displaces the bellows. (expansion or compression) ✓ Diaphragm compresses the carbon granules in flexible capsule. ✓ Compression of flexible capsule causes change in resistance and current. ✓ The output voltage change is calibrated in terms of sound pressure.	**01 mark for construction** **01 mark for working**
Q.5.		**Attempt any TWO of the following:**	**12 Marks**
	a)	**State the working principle of piezo-electric transducer and its applications.**	
	Sol.	**Working Principle:** • When a piezoelectric material is subjected to a force, it generates an electrical potential or voltage proportional to the applied magnitude of force and vice-versa. • Force may be due sound wave, shock or pressure. • Force applied is direction sensitive. • Applied force opposite electric charges collect on the ends of the crystal.  **Applications:** • High sensitive microphones • As generators and detectors of ultrasound. • In non-destructive testing, in the generation of high voltages. • As an actuators for the exact adjustment of fine optical instruments, lasers, and atomic force microscopes.	**02 mark for principle** **01 mark for diagram** **3 marks for any three correct applications**
	b)	**State the applications of orifice meter Venturi tube and Pitot tube.**	
	Sol.	**i. Orifice meter:** • It is used to measure the flow rate of fluids in their single state (i.e. gaseous state or liquid state). • It can also be used to measure the flow rate of fluids in a mixed state (both gaseous and liquid states) such as, wet steam, or natural gas with water. • Also used where robust construction of device is required. **ii. Venturi meter:** • Used where the permanent pressure loss is main problem and where the maximum accuracy is desired in the measurement of high viscous fluids. • Used to handle slurries and dirty liquids. **iii. Pitot tube:** • It is a device used for measuring the velocity of flow at any point in a pipe or a channel. • Used to determine flow in very large pipes or ducts. • Used in aircrafts and missiles.	**02 marks** **02 marks** **02 marks**

		• Used in gas flow measurement.	
	c)	**Draw the constructional details of hair hygrometer? State its applications.**	
	Sol.	 **Figure:** Constructional details of Hair Hygrometer **Construction:** • Human hair is used as a humidity sensor. The hair is arranged on a parallel beam and separated from each other to expose them to the surrounding air / atmosphere. Numbers of hairs are placed in parallel to increase the mechanical strength. • This hair arrangement is placed under a small tension by the use of a tension spring to ensure proper functioning. • The hair arrangement is connected to an arm and a link arrangement and the link is attached to a pointer rotated at one end. • The pointer sweeps over a calibrated scale of humidity **Applications:** • Used where high precision is not required. • These hydrometers are used in the temperature range of 0'C to 75'C. • These hydrometers are used in the range of relative humidity (relative humidity) from 30 to 95%.	**02 marks diagram** **02 marks for construction** **02 marks for any two applications**
Q.6.		**Attempt any <u>TWO</u> of the following:**	**12 Marks**
	a)	**Draw and explain the working of Coriolis flowmeter.**	
	Sol.	 **Figure:** Corolis Flowmeter	**02 marks for diagram**

Working:

- Based on the Coriolis force (causes the deflection of an object from its linear path when it moves in a rotating plane).
- Measures mass flow directly.
- Measure the force resulting from the acceleration caused by the mass moving toward (or away from) a center of rotation.
- The "swinging" is generated by vibrating the tube(s) in which the fluid flows.
- The amount of twist is proportional to the mass flow rate of fluid passing through the tube(s).
- Flow is guided into U-shaped tube.
- When the oscillating excitation force is applied to the tube causing it to vibrate, the fluid flowing through the tube will induce a rotation or twist to the tube because of the Coriolis acceleration acting in opposite directions on either side of the applied force.
- For example when tube is moving upward during the first half of a cycle, the fluid flowing into the meter resists being forced up by pushing down on the tube. On the opposite side, the liquid flowing out of the meter resists having its vertical motion decreased by pushing up on the tube. This action causes the tube to twist. When the tube is moving downward during the second half of the vibration cycle, it twists in the opposite direction. This twist results in the phase difference (time lag) between the inlet side and outlet side and this phase difference is directly affected by the mass flowing through the tube.

04 marks for explanation of working

b) Explain the working and application of bonded strain gauge.

Sol.

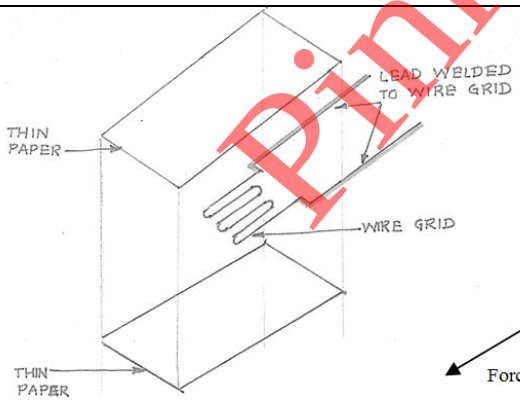


Figure 1 (a) Construction of strain gauge

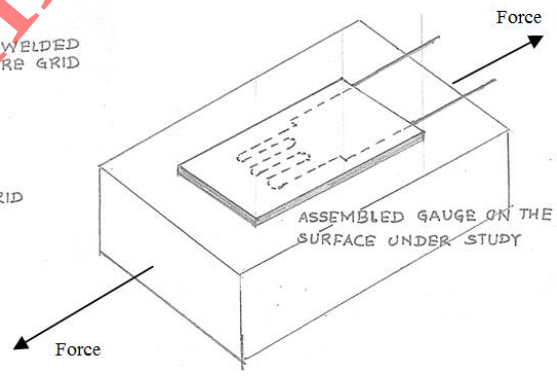


Figure (b) Assembled Strain Gauge bonded on Surface

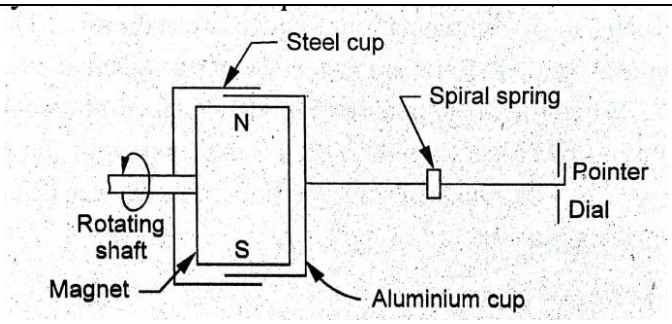
02 marks diagram

Working

- With the help of an adhesive material, the strain gauge is pasted/ bonded on the structure under study.
- The structure is subjected to a force (tensile or compressive). Due to the force, the structure will change the dimension.
- As the strain gauge is bonded to the structure, the stain gauge will also undergo change in both in length and cross-section (that is, it strained).
- This strain (change in dimension) changes the resistance of the strain gauge which can be measured using a wheat stone bridge.
- This change in resistance of the strain gauge becomes a measure of the extent to which the structure is strained and a measure of the applied force when calibrated.

02 marks explanation of working principle.

02 marks

		Application: • Measurement of force or thrust • Measurement of pressure • Measurement of torque.	**any two Applications**
	c)	**Explain with neat sketch working principle of eddy current generation type tachometer.**	
	Sol.	 **Figure : Eddy Current Tachometer** • It is electrical type tachometer, which works on eddy current. • The shaft whose speed is to be measured is connected to permanent magnet at its end. • A nonmagnetic cup generally made of aluminum is provided very close to magnet, which is connected to pointer through spring. • Due to rotation of magnet, induced voltage in to cup which thereby produce circulating eddy current in cup material. • This eddy current interacts with the magnetic fields to produce a torque on the cup in proportion to the relative velocity of magnet and cup. • This causes cup to turn through small angle. • Low torque measuring transducer is used to measure torque. It can be calibrated to find the speed of shaft.	**02 marks diagram** **04 marks explanation of working principle.**