MODEL ANSWER

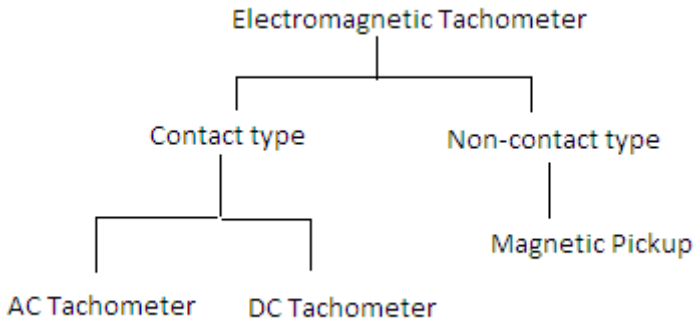
Summer – 19 EXAMINATION

Subject Title: Industrial Transducers

Subject Code:22432

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 anyequivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q.N.	Answer	Marking Scheme
Q1.		**Attempt any FIVE of the following**	10 M
	a)	**State the types of electromagnetic tachometers.**	2 M
	Ans.		2M
	b)	**List down the transducer for force measurement.**	2 M
	Ans.	Measurement of force can be achieved with both mechanical and electrical sensors. 1) Mechanical sensors i) Diaphragm ii) Capsule iii) Bellows iv) Bourdon 2) Electrical sensors: electrical sensors can be further divided into, i) Electromechanical sensor / load cell	2M

	a) Proving rings b) Strain gauge load cell(Cantilever beam & Shear type load cell) c) Piezo electric load cell d) Force balance devices ii) Pressductor (magneto-elastic type) 3) Hydraulic force meter /load cell (can be mechanical /electrical)	
c)	**State the working principle of ultrasonic type thickness measurement.**	**2 M**
Ans.	When ultrasonic vibrations at varying frequencies are passed through the test piece, standing waves are setup on it at certain frequencies. The value of these frequencies depends upon the thickness of test piece as, $$t = \frac{c}{2f}$$ Where, c = velocity of sound in the test piece f = lowest frequency at which standing waves occur.	**2M**
d)	**State the need of vibration measurement.**	**2 M**
Ans.	In general vibration measurements are done for three major reasons. 1) Obtaining the response of a body or structure, such as the response of an aircraft wing to various load condition. 2) Defining the vibratory environment surrounding a vibratory source, eg. Floor vibrations surrounding a high speed compressor or generator. 3) Monitoring and/or controlling of a system, such as in maintaining acceleration at a desired level in electromagnetic exciters or in an inertial navigational system.	**Any two:2M**
e)	**Name the sensing element used in microphones.**	**2 M**
Ans.	Microphones invariably use diaphragm as the sensing element along with different transduction elements like, 1) Metallic diaphragm in condenser arrangement. 2) Metallic diaphragm attached to conducting ribbon. 3) Metallic diaphragm with Piezo - electric crystal.	**2M**
f)	**State the units of vibration.**	**2 M**
Ans.	Vibration has components of amplitude and frequency. Amplitude may be measured in terms of displacement, velocity and acceleration. Hence the units may be, 1) Meter	**2M**

		2) Meter/sec 3) Meter/sec^2 4) hertz	
	g)	**Define force. State its units.**	**2 M**
	Ans.	Force may be defined as a cause that poduces or tends to produce resistance or obstruction to any moving body, or changes the motion of a body. Force is given by, F= Ma M- mass A- acceleration various unit of force are, 1) Dyne 2) Newtons 3) Kilogram – force(Kgf)	**1M** **1M**
Q. 2		**Attempt any THREE of the following**	**12 M**
	a)	**Describe the troubleshooting procedure of piezo-electic load cell.**	**4 M**
	Ans.	One may require the following components for testing a piezo – electric load cell. 1) load cell, with no load applied 2) standard multimeter 3) 9-V battery Trouble shooting of piezo-electric load cell may involve the following steps, to identify and rectify the cause of problem. i) Mechanical inspection: 1) Check for any physical damage. If it is physically deformed, it must be replaced. 2) Look for any distortion or cracks at the end surfaces. 3) Check cables for any short / open circuit ii) Checking for zero balance: 1) With no load applied check the output voltage. 2) If the output is beyond the specified zero tolerance band, the cell is damaged but	**Identifying the steps: 1M** **Brief description of the steps: 3M**

correctable.

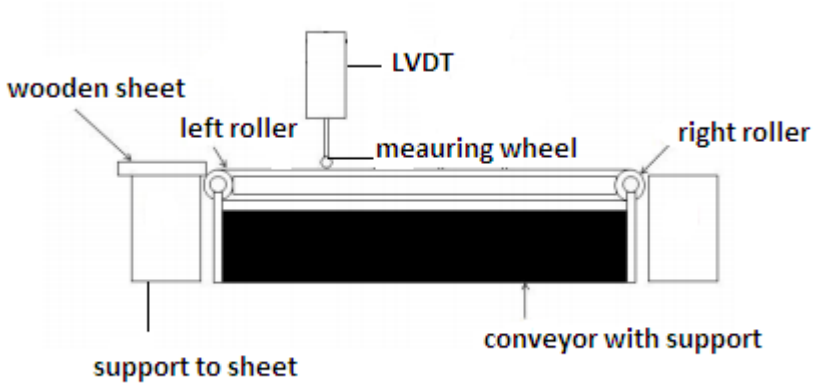
iii) measuring bridge resistance:

1) Measure the resistance across each pair of input and output leads.
2) Compare these with the specifications mentioned.
3) Out of tolerance readings could be due to failure of one or more elements caused due electrical transients or lightning strikes.

iv)measuring resistance to ground:

1) Connect all the input,output and ground leads together and measure the resistance between the body of load cell and leads.
2) It should read atleast 5000 MΩ.
3) If fails, repeat the test without the ground wire.
4) If it still fails, the load cell require repair.
5) If it passes, the problem may be in the cable. It is usually infiltration of moisture causing short circuiting between the electronic circuit and cell body.

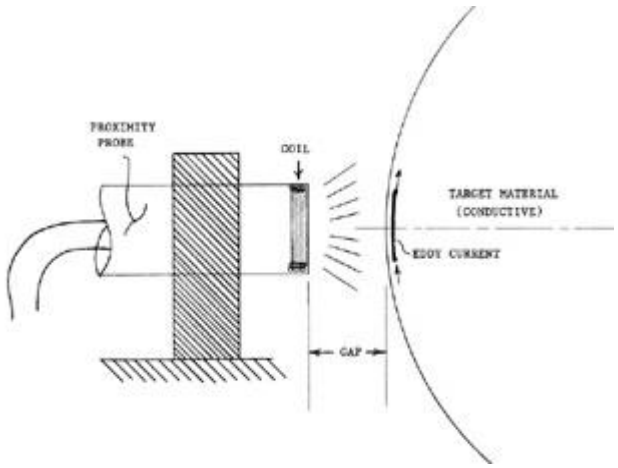
b)	**With suitable sketches explain the working of differenital roller LVDT.**	**4 M**
Ans.	**Construction:**	**2M**

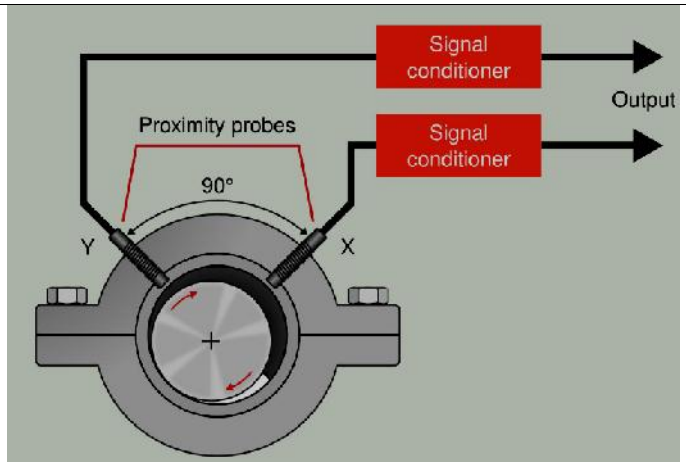


2M

Working:

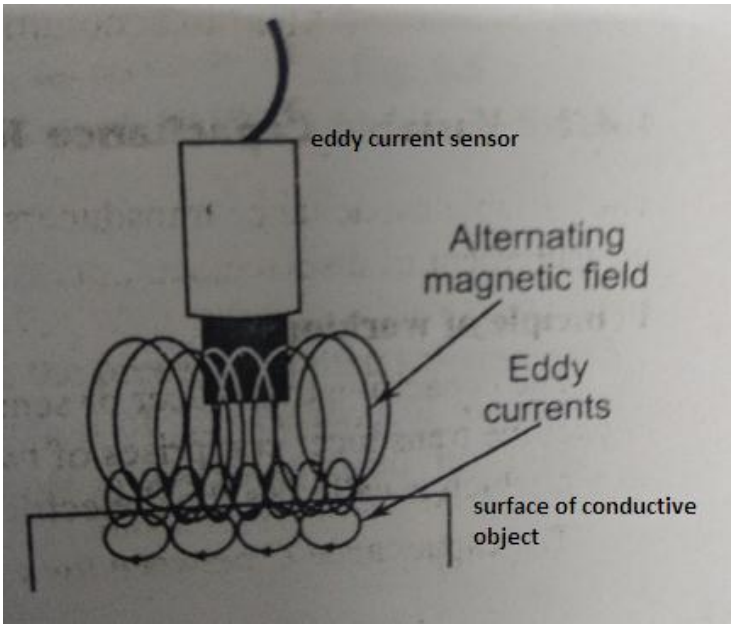
Figure above shows a basic schematic diagram for measurement of thickness using LVDT. The sheet material for which the thickness is to be measured is placed on the conveyor above the left roller at a particular distance from the measuring sensor i.e. LVDT. The conveyor programmed to move the sheet at a particular speed towards LVDT. The LVDT sensor is installed with measuring wheel attached to its core material

		which is freely suspended from rigid support to move on conveyor. As the wooden sheet reaches the LVDT, displacement of measuring wheel takes place due to the thickness of sheet. This displacement of LVDT core will cause change in mutual inductance of the coil which results in change in the output of LVDT. This change in the output is analogous to the thickness of the sheet. The output of LVDT is given to a local controller and for further transmission and Data acquisition. The sheet can be collected at the second roller of the conveyor. **(NOTE: any other relevant setup may be considered.)**	
	c)	**State the quantities involved in the measurement of vibration. Draw the diagram of electromagnetic relative vibration pickup.**	**4 M**
	Ans.	The quantities that are involved in the measurement of vibration are, displacement, velocity and acceleration. **Diagram:** A proximity probe which works on the prnciple of eddy current can measure relative displacement between the end of the probe and the metal surface that is moving**.** The following arrangements are used to measures the relative movement between the sensor tip and the rotating shaft.  **(OR)**	**Naming :1M** **3M**



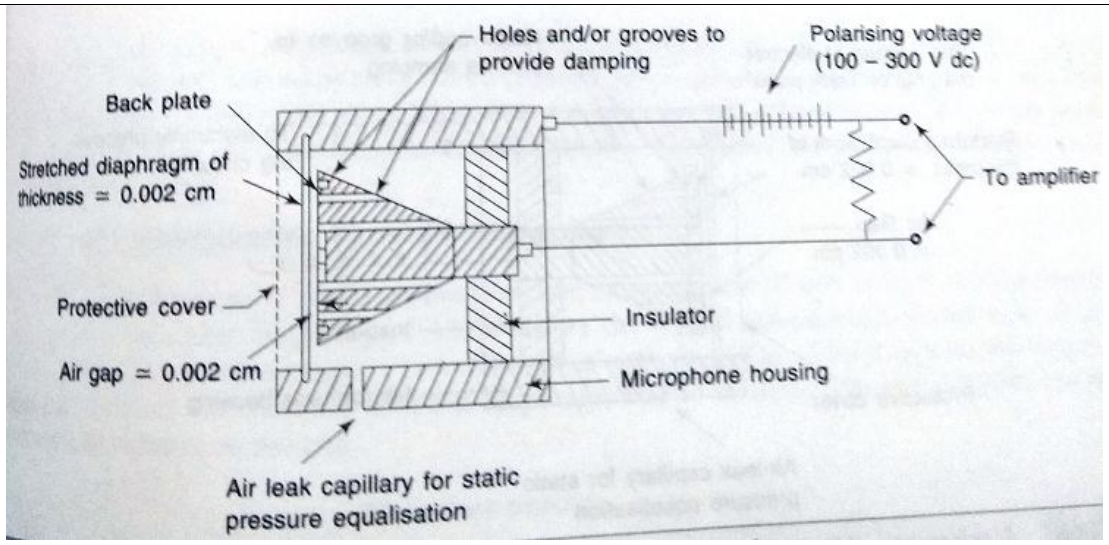
(OR)

Eddy current sensor used to measure position change of a conductive target



(Note: any other relevant diagrams may be considered.)

d)	**Draw and explain measurement of sound level using condenser type microphone.**	**4 M**
Ans.	**Diagram:**	**2M**



Working:

A condenser microphone cartridge consists of a thin metallic diaphragm in close proximity to a stationary backplate as shown in figure. The diaphragm and the backplate form the plates of a capacitor.The movement of the diaphragm caused by the impingement of sound pressure results in an output voltage given by,

E α Qd

Where,

Q = charge provided by the polarising voltage

d = separation between the plates.

As the polarizing voltage is nearly constant , the voltage at the output is proportional to the separation of the plates (which changes according to the sound pressure).

2M

Q. 3		**Attempt any THREE of the following**	**12 M**
	a)	**State the two advantages and disadvantages of control type digital encoder.**	**4 M**
	Ans.	**Advantages of an Encoder** - Highly reliable and accurate - Low-cost feedback - High resolution - Integrated electronics - Fuses optical and digital technology - Can be incorporated into existing applications - Compact size **Disadvantages of an Encoder** - Subject to magnetic or radio interference (Magnetic Encoders) - Direct light source interference (Optical Encoders) - Susceptible to dirt, oil and dust contaminates	**2M** **2M**
	b)	**Compare AC & DC tachometer**	**4 M**

Ans.

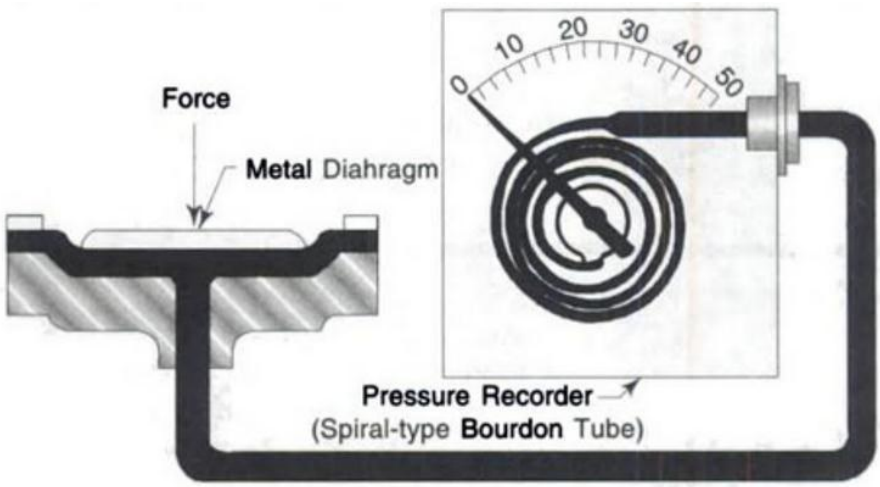
AC Tachometer	DC tachometer
It consist of a stator and a rotor arrangement or a squirrel cage setup.	The construction consist of a horse shoe type permanent magnet
Speed is measured with a moving coil instrument either a permanent magnet or an electromagnet	Speed is measured with a moving coil voltmeter.
Reversal of rotation causes the same action except there is a 180 degree phase shift	Reversal of rotation causes the voltmeter to show negative reading hence the pointer on mid scale
Commutator and brushes are absent in AC tachometer generator.	The commutator and brushes require the periodic maintenance.

1M each

c) Draw and explain hydraulic force meter. State its major specifications. **4 M**

Ans.

2M



Hydraulic Force Meter.

The hydraulic force meter operates on the principle of a force counterbalance. It involves the application of force to a definite area of fluid surface, thus producing hydrostatic pressure in the fluid, which can be measured by a Bourdon tube manometer or any other type of pressure gauge. The transmitting element between force and pressure may be piston, bellow or diaphragm.

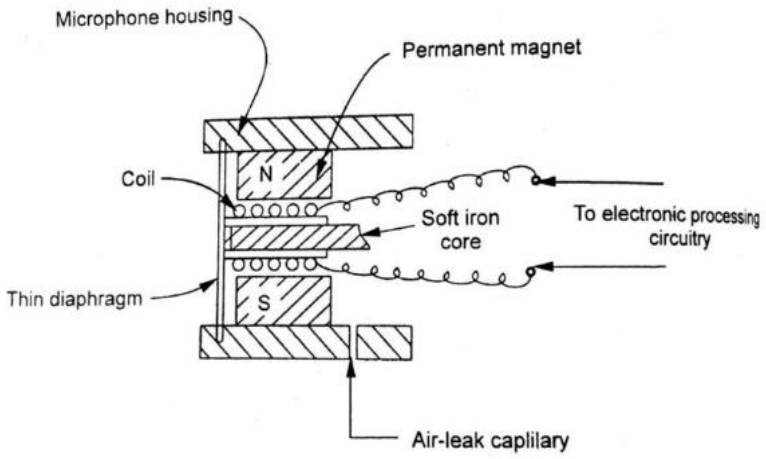
Working:

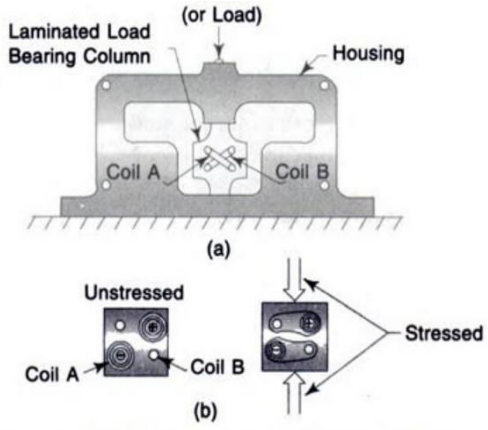
1M

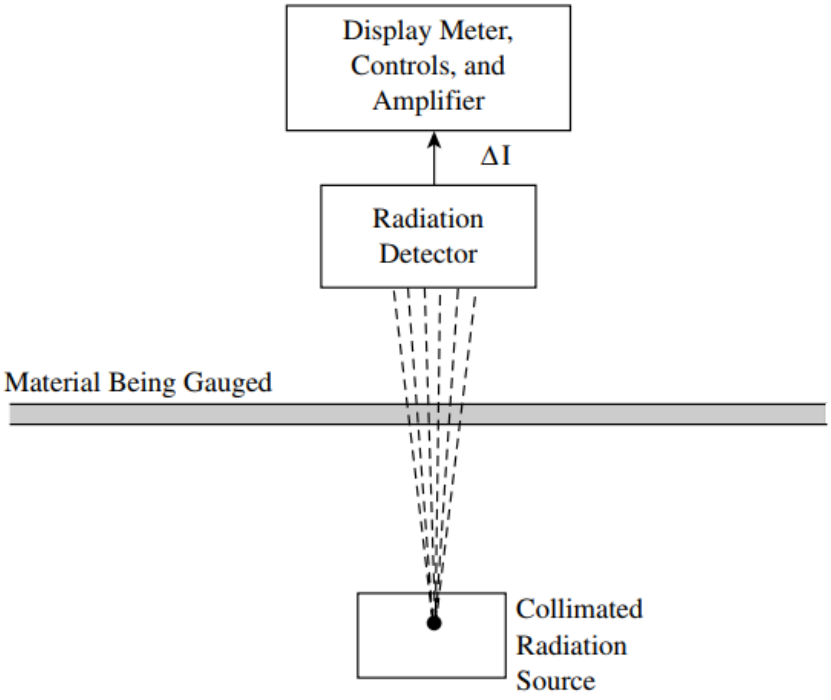
A hydraulic force meter consist of a metal diaphragm on which the force to be measured is applied. The metal diaphragm is attached to a fluid chamber which is connected to a spiral type of bourdon tube pressure gauge through tubing A pointer is attached to the bourdon tube with linkage and gearing, which moves on scale calibrated in units of force. When the force to be measured acts against the diaphragm, it creates a fluid pressure in the chamber which is equal to the force magnitude divided by the effective area of the diaphragm. This pressure is indicated by the pointer of the bourdon tube on the calibrated scale and gives the value of applied force

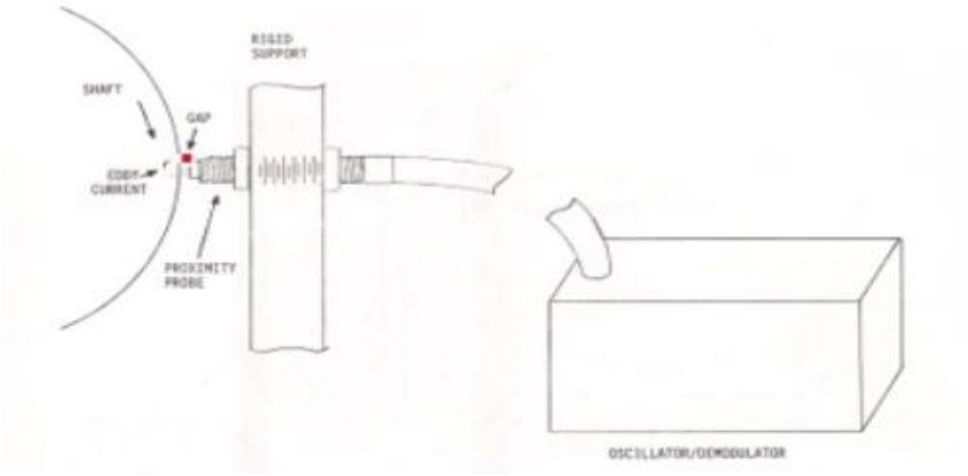
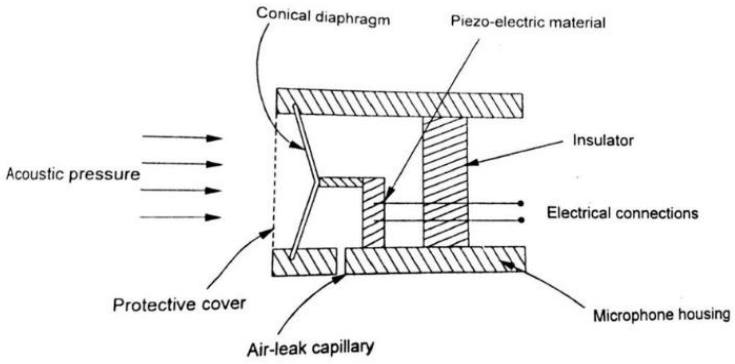
Specifications: **1M**

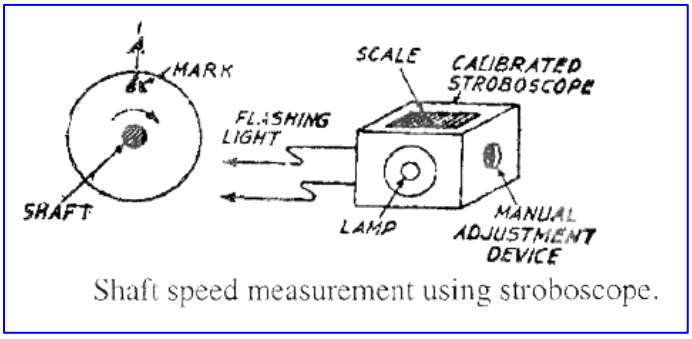
Accuracy ±0.25% of Full Scale

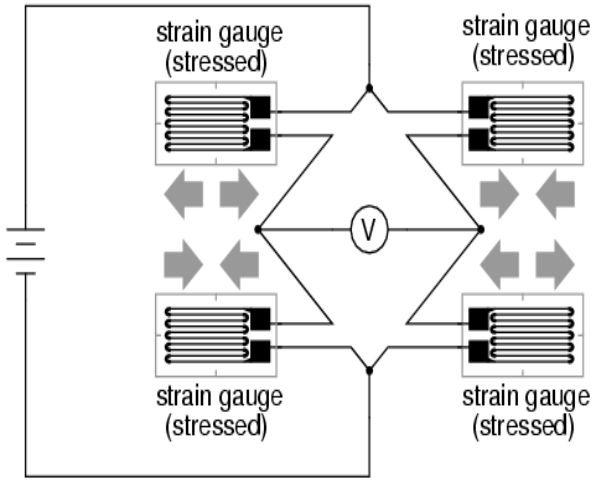
		Max. overload 150% of rated capacity Tare capacity 10% of rated capacity Resolution 1:1000, 1:5000 Data sampling rate 7 KHz Peak capture rate 7 KHz Display update rate 10 Hz Operating temp. 5 to 45°C / 40 to 110°F	
	d)	**With relevant diagram explain sound measurement using electro dynamic type microphone.**	**4 M**
	Ans.	**Diagram:**  Electrodynamic type microphone is based on the principle of generation of emf when a moving conductor is placed in the magnetic field The sensing diaphragm is attached to a coil or ribbons placed within the poles of the permanent magnet The movement of the diaphragm due to acoustic pressure generates the analogous induced voltage in the coil.	**2M** **2M**
Q. 4)		**Attempt any THREE of the following**	**12 M**
	a)	**With necessary diagram explain the calibration procedure of any one type of contactless tachometer.**	**4 M**
	Ans.	**Tachometer calibration procedure :** Observe the following before calibration: Be sure to check first the functionality of the tachometer (power on, good battery, and good physical condition, clean). Stabilize the instruments to a suitable environment condition (monitor temperature and humidity) Warm up the reference standard by powering on for at least 30 minutes before using to ensure stable functionality (good performance) Prepare Measurement Data Sheet (MDS) to record necessary details **Calibration Set up:** Power on, select the source function Press the Frequency/Hz button.	**4M**

		Set the voltage to 3V and Set the Waveform to a sine wave Press done. Connect the LED using the connector provided in the port under source (see pic). (a pair of connecting probes can be used also). Press frequency (Hz) button (same as 2nd step button) Set the required frequency range (an example is 60 Hz) Press enter to simulate the frequency and voltage. At this stage, the LED has lighted, Focus the tachometer on the lighted LED with a distance of 3 to 5 inches. Ensure stable aiming of the light to get the most accurate reading. Wait until the reading has stabilized then record. (perform at least 3 trials) Change the frequency range then repeat steps 6 to 9 until the required set points are reached. End of verification Pointing the Tachometers on the LED, take note that 60Hz is equivalent to 3600 RPM The Principle behind this is that the tachometer has a sensor that senses the fluctuation of light or the switching off/on of a light source or a motor that has a changing color (a reflection of white and dark color) while oscillating or rotating. This fluctuation or oscillation has a corresponding frequency in which converted to speed and displayed as RPM. In this setup, the light in the LED is generated by an oscillating sine wave with the corresponding frequency. Below is a conversion of Frequency (Hz) to Revolutions Per Minute (RPM) 1 Hz = 60 RPM For the 60 Hz above, expect the output to be 3600 RPM (60×60).	
	b)	**Draw and explain pressductor load cell.**	**4 M**
	Ans.	**Diagram:**  *(a) & (b) The Pressductor Load Cell.* **Explanation** : The working of the pressductor load cell also known as magnetostrictive load cell is based on the magnetoelastic principle in which the permeability of the ferromagnetic material is changed due to applied mechanical stresses. It consists of a laminated load bearing column enclosed in the housing. A primary and secondary transformer coil windings are wound on the column through holes in the column. Coil A is excited with AC voltage and coil B provides the output signal voltage. Working: When the load cell is unloaded, the permeability of the material is uniform throughout the structure. Since the coil is oriented at 90^0 with respect to each other, the	**2M** **2M**

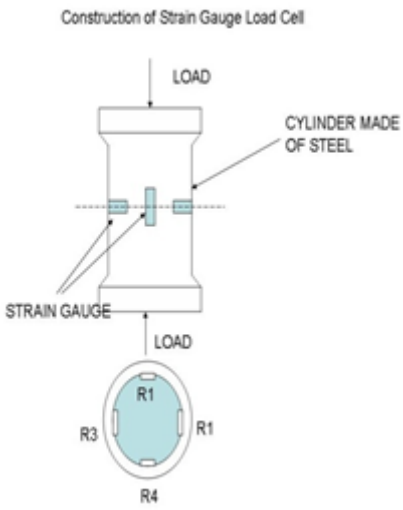
		magnetic flux lines around the winding do not influence each other. Hence no output signal is developed. When the column is loaded, the induced mechanical stressed cause the permeability of the column to be non uniform, resulting in corresponding distortion in the flux pattern within the magnetic material. The magnetic lines of flux of the two coils cut each other, thus a voltage proportional to the applied force is induced in the secondary winding.	
	c)	**Draw and explain non-contact type of thickness measurement.**	**4 M**
	Ans.	**Diagram:**  *Radiation absorption gauge.*	**2M**
		Explanation: **Radiation Type** Thickness Gauges Both beta and x-ray forms of radiation are used in thickness gauging. The beta-radioisotope is used to measure the thickness of sheets or the thickness of coatings on sheets. The measurements are usually calibrated in weight per unit area, such as ounces per square foot, and can be detected within an error of 1%. X-ray thickness gauges are a standard part of computer controlled rolling mills. They can also be used for hot or cold, stationary or moving strips of paper, plastic, glass, rubber, or metal, over a wide range of thickness. When the strip is moving at a high speed, the speed of response of the x-ray gauge will determine the precision at which defects can be isolated. If a mill operates at a speed of 5000 ft/min (1524 m/min), a gauge with a 50 ms response time will allow reaction to a change in thickness after some 4 ft (1.3 m) of material has passed the sensor. The attenuation of radiation from x-rays or radioactive decay by matter is utilized in the radiation absorption gauge to measure the thickness of the material. The equation is **$\Delta I = I_o [1 - \exp(-\mu t)]$** using averaged ionization current for signal, where ΔI = change in ionization current when absorber is inserted	**2M**

		I_o = ionization current without absorber μ = absorption coefficient (cm^2 /µg) t = thickness (µg/cm^2) The display is calibrated to indicate thickness. Radiation gauges are subject to errors from the statistical nature of radioactive decay and from the dependence of the absorption coefficient on the composition of the material being measured	
	d)	**Draw a neat sketch of electromechanical type relative vibration pickup.**	**4 M**
	Ans.	**Diagram:**  	**4M**
	e)	**Draw and explain method of sound measurement using piezo-electric crystal microphone.**	**4 M**
	Ans.	**Diagram:**  **Explanation:** Lead zirconate titanate (PZT) is commonly used in piezoelectric microphones. The force produced by the acoustic pressure on the diaphragm is used to strain the piezoelectric material which in turn produces voltage output in direct proportion to the applied force. A cantilever type of crystal element is mechanically coupled with the sensing diaphragm. There is direct contact between the diaphragm and the crystal element either in bending mode or by direct contact. Piezo electric microphones are very sensitive and can measure accurately sound pressure level below 24 dB.	**2M** **2M**
Q. 5		**Attempt any TWO of the following**	**12M**

	a)	**Draw and explain method of speed measurement using stroboscope. State it's any two applications.**	**6 M**
	Ans.	**Diagram:**  Shaft speed measurement using stroboscope. **Explanation: (Note: Consider relevant explanation)** • A stroboscope is an instrument that emits a series of brief, intense flashing lights at specific intervals. • Stroboscope consists of source of flashing light which is varied and controlled. This Source is called Strobotron. • The variable frequency oscillator controls the flashing frequency. • The speed is measured by adjusting frequency so that moving object appears standstill. • When the flashing light from a stroboscope is directed onto an object rotating at high speed (e.g., a cooling fan inside a PC), the moving object or mark on object appears to stand still due to persistence of human eye. • Under this condition, the speed is equal to the flashing frequency of light. The speed of Stroboscope is calibrated in terms of speed. **Application:** (consider relevant applications, any two) ● It used for measurement of Speed of rotating object. ● It used for observation of high speed object. ● It used with video camera to capture precise images**.**	**2M** **2M** **2M (Any two)**
	b)	**With necessary diagrams explain the working of strain gauge load cell.**	**6 M**
	Ans.	**Diagram:**	**3M**



OR



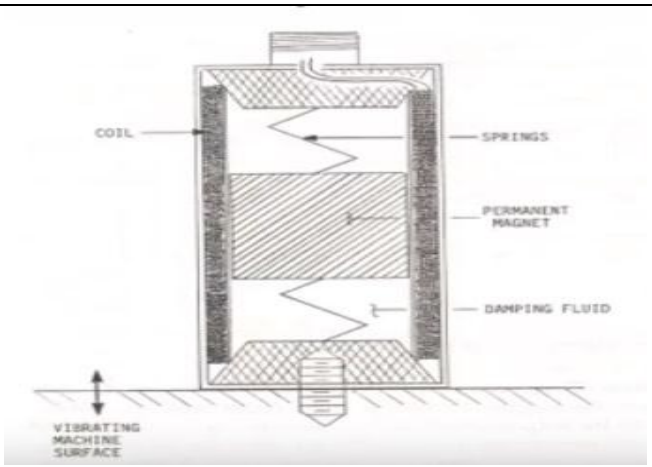
Explanation: (Consider relevant explanation) **3M**

The main parts of the strain gauge load cell are as follows. They are a cylinder made up of steel on which four identical strain gauge are mounted and out of four strain gauges, two of them (R1 and R4) are mounted along the direction of the applied load(vertical gauges). The other two strain gauges (R2 and R3 Horizontal gauges) are mounted circumferentially at right angles to gauges R1 and R4.

When a force to be measured is applied to supporting column, the column is compressed and length is decreases and area of cross section increases. These changes resistance of strain gauges which are attached to Wheatstone bridge. Output is directly proportional to the force applied.

Strain gauge load cell are made for compression, tension.

c)	**Draw and explain electromagnetic relative vibration pickup. Compare it with electro- mechanical relative vibration pick-up**	**6 M**
Ans.	**Diagram**:	**2M**



- Velocity transducer is also called seismic pickup. It is electromagnetic pick –up as the relative motion between the permanent magnet and the coil generates a voltage that is proportional to the velocity of the motion. **2M**
- The velocity transducer has an internal natural frequency of about 8 Hz.
- The velocity transducer is rather large. On small devices this added mass can significantly affect the vibration output.
- The coil in the velocity pickup is sensitive to external electromagnetic fields.

(NOTE: Comparison(consider Diagram if Drawn, and other relevant points))

Electromagnetic Pickup	Electromechanical Pickup
It is basically Velocity type vibration pickup	It is Basically Accelerometer used piezoelectric pickup.
The electromagnetic seismic harvester is formed by a cylindrical magnetic element with an inner gap where a coil is housed. The two components are connected via soft springs and the coil is fixed to the case of the harvester	The piezoelectric seismic harvester is formed by a cantilever beam with a small block mass at its tip. The beam is fixed to the harvester case and is equipped with piezoelectric patches, which are bonded on its top and bottom surfaces

2M

Q. 6		**Attempt any TWO of the following**	**12M**
	a)	**With relevant diagram explain thickness measurement using capacitive type transducer. State its advantage and disadvantages. (one point each)**	**6 M**
	Ans.	**Diagram:**	**2M**

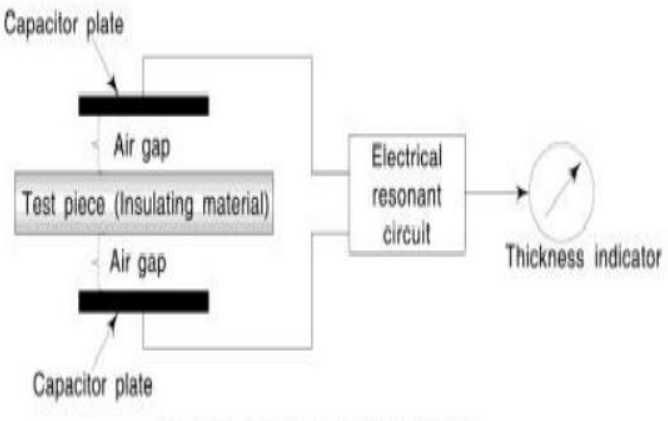


Figure : A

OR

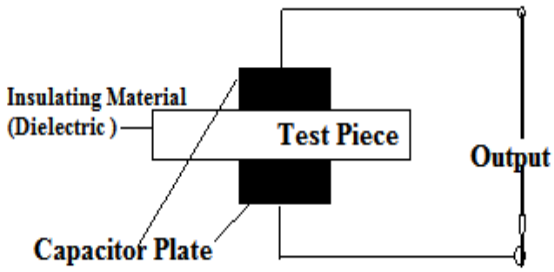


Figure : B

Explanation:

- Capacitance gauge is used for thickness measurement of insulating films. **2M**

$$C = \frac{\varepsilon A}{d}$$

Where,

C = Capacitance in Farads

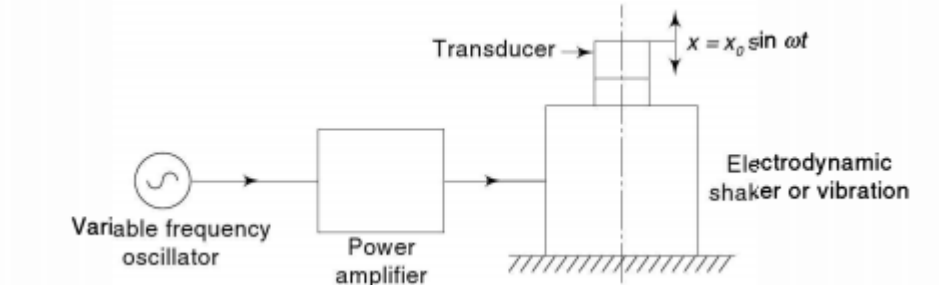
ε = Permittivity of dielectric (absolute, not relative)

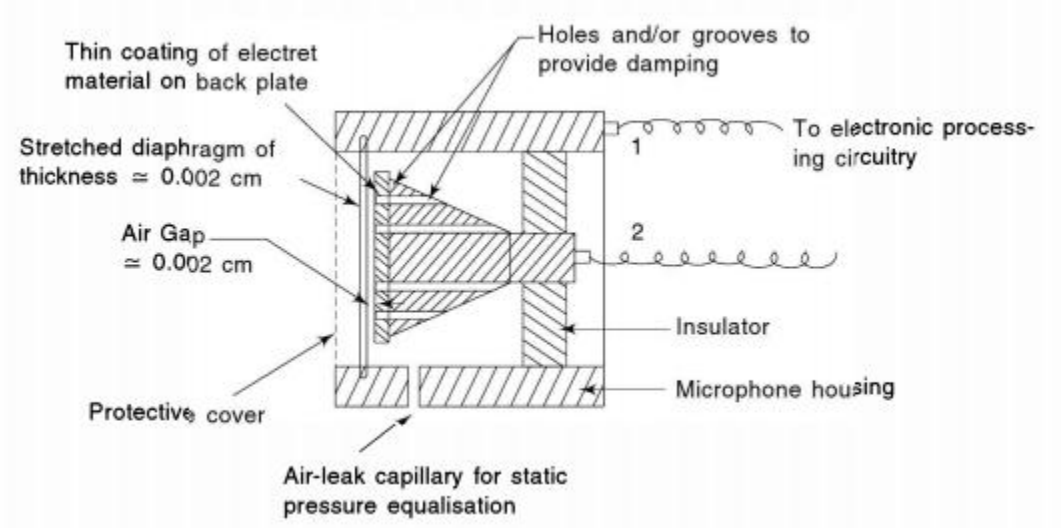
A = Area of plate overlap in square meters

d = Distance between plates in meters

- As shown in above equation, Capacitance varies directly with the thickness of dielectric material between two plates and inversely proportional to the distance between the plates.
- As shown figure a, test piece whose thickness is to be measured, works as dielectric material.
- The Capacitor Plates and test piece form part of an electrical resonance circuit. Its output is calibrated to indicate Thickness.

		OR • In Figure b , Two metal electrodes are placed on the two sides of insulating material being tested. • This arrangement forms a parallel plate capacitor , the two electrodes acting as the two plates with insulating material acting as the dielectric. • The capacitance depends upon the thickness of the insulating material under test. Thus by measuring capacitance of the system, the thickness of the insulating material can be determined. **Advantages:** (any one) • Capacitive transducers require very little force to operate them. • They are extremely sensitive. • They have good frequency response. **Disadvantages:** (any one) • The performance is affected by dirt and other contaminations. • They are sensitive to temperature variations and signal get distorted. • Moisture content and air gap are the main sources of error.	**1M** **1M**
	b)	**State the common causes of vibration. Explain calibration procedure of any one vibration sensor with appropriate sketches.**	**6M**
	Ans.	**Causes** : **(NOTE: consider relevant causes explanations)** Vibration can result from a number of conditions, acting alone or in combination. Vibration problems might be caused by auxiliary equipment or by the primary equipment. Imbalance - A "heavy spot" in a rotating component will cause vibration when the unbalanced weight rotates around the machine's axis, creating a centrifugal force. Imbalance could be caused by manufacturing defects (machining errors, casting flaws) or maintenance issues (deformed or dirty fan blades, missing balance weights). As machine speed increases the effects of imbalance become greater. Imbalance can severely reduce bearing life as well as cause undue machine vibration. Misalignment/shaft runout - Vibration can result when machine shafts are out of line. Angular misalignment occurs when the axes of (for example) a motor and pump are not parallel. When the axes are parallel but not exactly aligned, the condition is known as parallel misalignment. Misalignment can be caused during assembly or develop over time, due to thermal expansion, components shifting or improper reassembly after maintenance. The resulting vibration can be radial or axial (in line with the axis of the machine) or both. Wear - As components such as ball or roller bearings, drive belts or gears become worn, they might cause vibration. When a roller bearing race becomes pitted, for instance, the bearing rollers will cause a vibration each time they travel over the damaged area. A gear tooth that is heavily chipped or worn, or a drive belt that is breaking down, can also produce vibration.	**3M**

		Looseness : Vibration causes due to loose bearings or is loosely attached to its mounts. Such vibrations cause damage, such as further bearing wear, wear and fatigue in equipment mounts and other components. **Calibration of vibration sensors: (NOTE: consider any relevant method or procedure)** For Dynamic calibration of displacement, velocity or acceleration measuring devices, an electrodynamic shaker is used. The shaker is driven by variable frequency oscillator and a power amplifier. The transducer to be calibrated is mounted on the shaker table and moved at circular frequency ω which can be changed by oscillator setting. The amplitude of harmonics can be changed by power amplifier. Thus amplitude, velocity and acceleration can be read with help of optical device. So as vibration transducer easily calibrated. 	**3M**
	c)	**(i) define the following terms related to sound measurement:** **(a) sound** **(b) sound power** **(c) intensity level** **(ii) Explain the working principle of electorate type microphone.**	**6 M**
	Ans.	**(i)Define**: (consider if right formula is written) (a) **Sound**: Any audible vibration which transmitted through solid, liquid , gases. (b**) Sound Power level**: A logarithmic measure of ratio of the power of a sound relative to a reference value. Sound power level = $10 \log_{10}\left(\frac{P}{P_0}\right)$ dB or $\text{PWL} = 10 \log_{10} \frac{W}{W_{\text{ref}}}$ dB Where P,W= Acoustic Power of Source P_0 ,W_0 = reference Acoustic Power= 10^{-12} Watts (c) **Intensity level**: A logarithmic measure of the rate of energy flow (sound power) across a unit area. Sound intensity level = $10 \log_{10}\left(\frac{I}{I_0}\right)$ **ii) Electorate type Microphone:**	**1M each definitio n**



1.5 M

An Electret microphone is a type of condenser microphone which is with a permanent charge built into it.

All microphones need a pair of charged plates (positive and negative plates) in order to function and record sound. Electret microphones, however, come with a permanent built-in charge.

1.5M

An electret microphone is a variation of the condenser microphone. Instead of requiring an external voltage source to charge the diaphragm, an electret microphone uses a permanently charged plastic element (electret) placed in parallel with a conductive metal back plate.

It consists of two plates, one fixed (called the back plate) and the other moveable (called Diaphragm) with a small gap between them. An electric potential charges the plate. When sound strikes the diaphragm it starts moving, thereby changing the capacitance between the plates which in turn results in a variable electric current to flow.