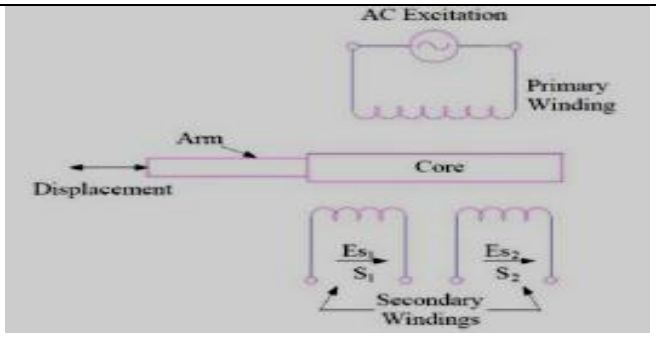
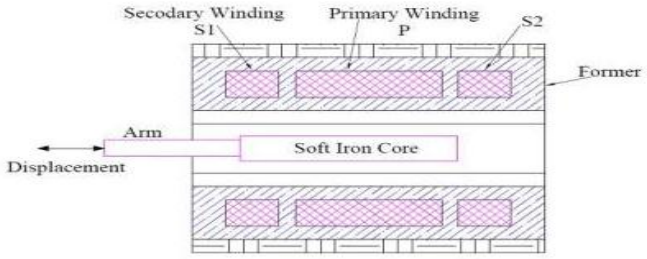
WINTER – 19 EXAMINATIONS

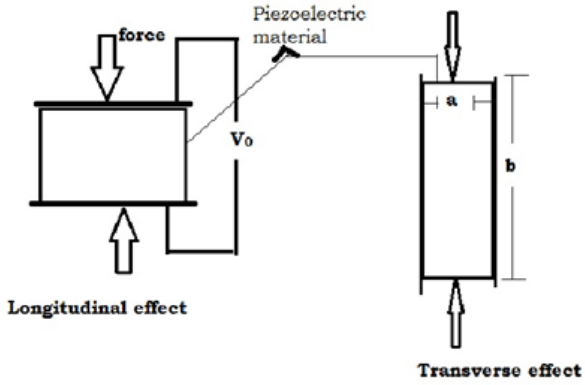
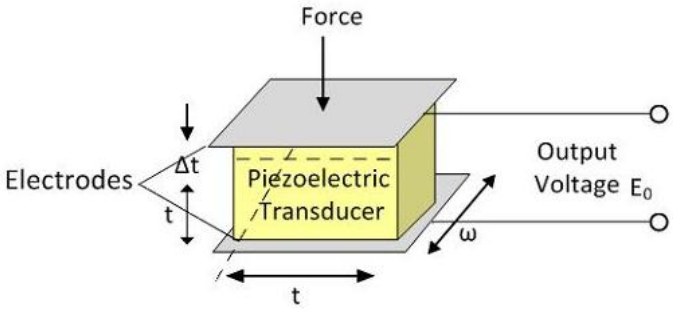
Subject Name: Industrial Transducers **Model Answer** Subject Code: 22432

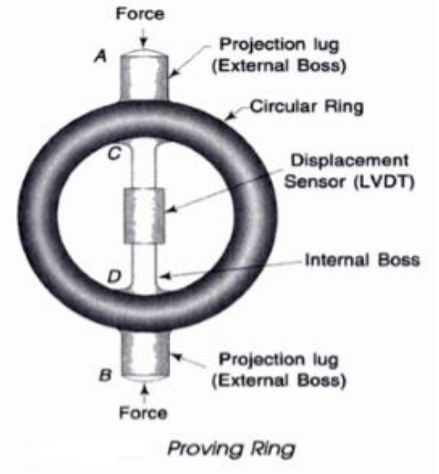
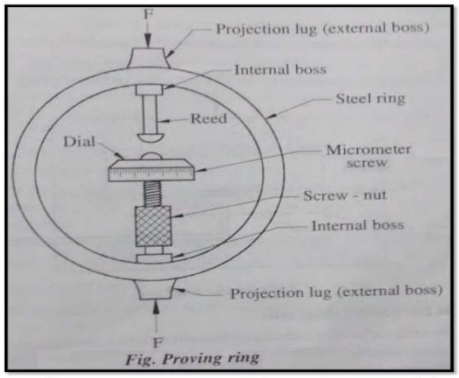
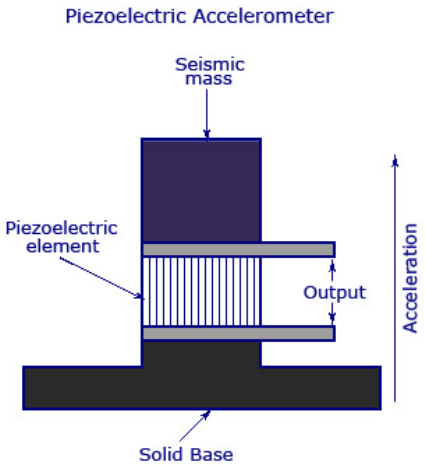
Important Instructions to examiners:

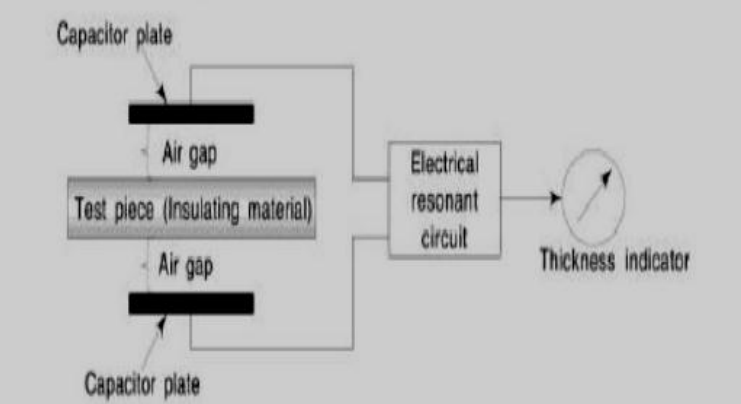
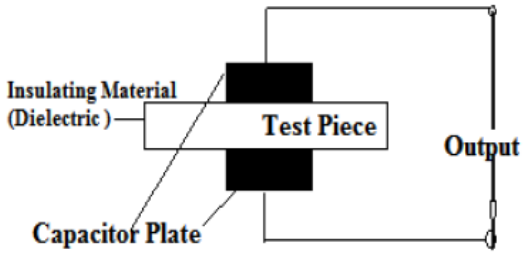
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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 any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q. N.	Answer	Marking Scheme
Q.1		**Attempt any five of the following:**	**10 M**
	a)	**List any one advantage and disadvantage of photo pick-up speed measurement.**	**2M**
	Ans:	**Advantages : (any one)** 1) It is digital instrument so high accuracy. 2) Pulse amplitudes are constant. 3) This simplifies the electronic circuitry. **Disadvantages :** 1) Light source must be replaced time to time. 2) The accuracy depends on the error represented by one pulse.	**1M Each**
	b)	**Define force its unit.**	**2M**
	Ans:	Force may be defined as a cause that produces 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) Newton 3) Kilogram – force (Kgf)	**2M**
	c)	**Define the sketch of LVDT.**	**2M**
	Ans:	 OR	**2M**



d)	**Define vibration and state its unit.**	**2M**
Ans:	Vibration is the periodic motion of particle/elements of a medium. Vibration has components of amplitude and frequency. Amplitude may be measured in terms of displacement, velocity and acceleration. Hence the units may be, (any one) 1) Meter 2) Meter/sec 3) Meter/sec^2 4) hertz	**2M**
e)	**Draw the sketch of piezoelectric crystal.**	**2M**
Ans:	 **OR**  **(Note: consider relevalent diagram of Piezoelectric transducer)**	**2M**

	f)	**Draw the sketch of Proving Ring.**	**2M**
	Ans:	 *Proving Ring* **OR**  *Fig. Proving ring*	**2M**
Q.2		**Attempt any <u>THREE</u> of the following:**	**12M**
	a)	**Describe working with sketches of electromechanical type of vibration measurement transducers.**	**4M**
	Ans:	**Diagram** 	**2M**

		Working **It is Basically Accelerometer used piezoelectric pickup.**It consists of a piezoelectric quartz crystal on which an accelerative force, whose value is to be measured, is applied. Due to the special self-generating property, the crystal produces a voltage that is proportional to the accelerative force. The working and the basic arrangement is shown in the figure above. As the device finds its application as a highly accurate vibration measuring device, it is also called a vibrating sensor. Vibration sensors are used for the measurement of vibration in bearings of heavy equipment and pressure lines.	**2M**
b)	**Explain with sketch the working of the capacitive type of thickness measurement transducers.**		**4M**
Ans:	**Diagram:**	 **Figure : A** **OR**  **Figure : B**	**2M**

Explanation:

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

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

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.

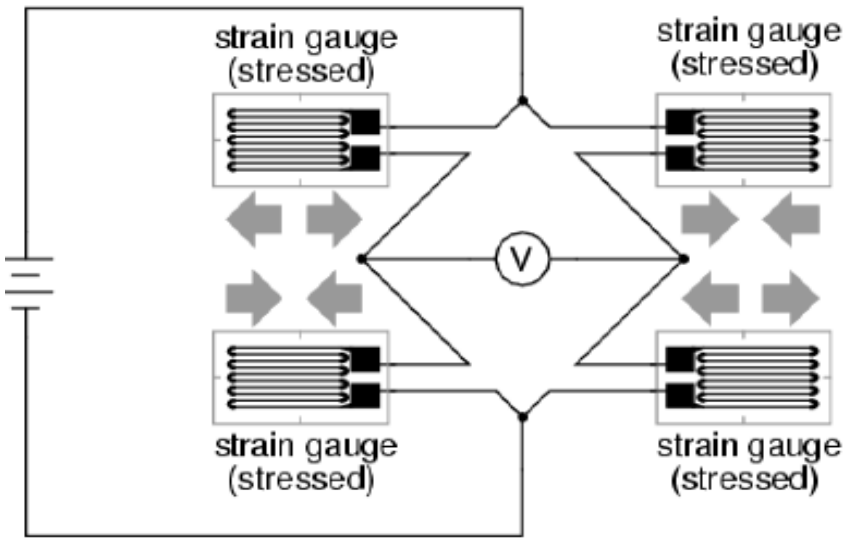
OR

- 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.

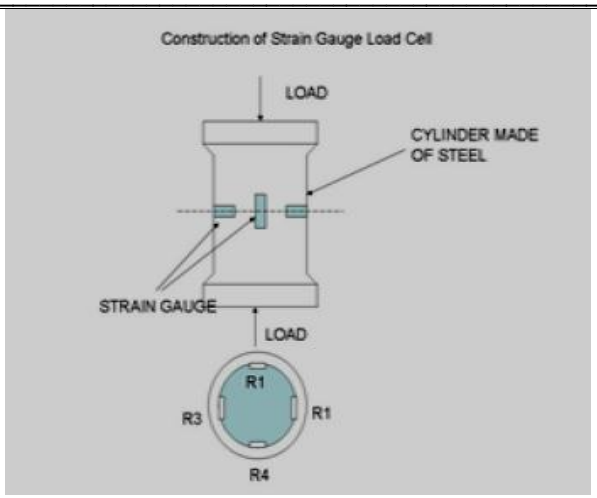
2M

c) Explain with neat sketch working of strain gauge load cell. (2 mark diagram and 2 mark explaination) **4M**

Ans: **Diagram** **2M**



OR

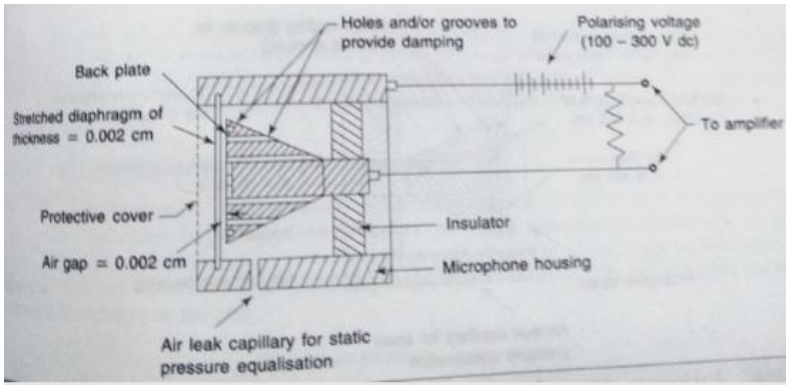


Explanation: (Consider relevant explanation) **2M**

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 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.

d)	**Explain with sketch the working of condenser type of sound measurement transducers.**	**4M**
Ans:	**Diagram:**	**2M**



Working: **2M**

A condenser microphone cartridge consists of a thin metallic diaphragm in close proximity to a stationary back plate 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,

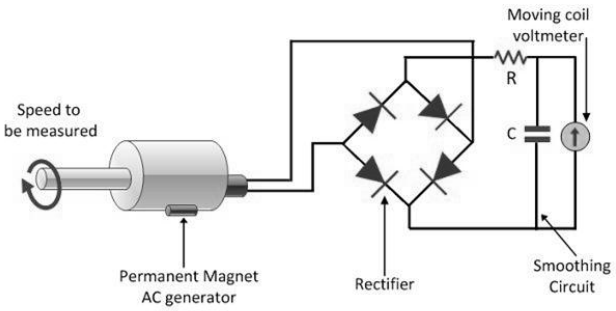
$E \alpha Qd$

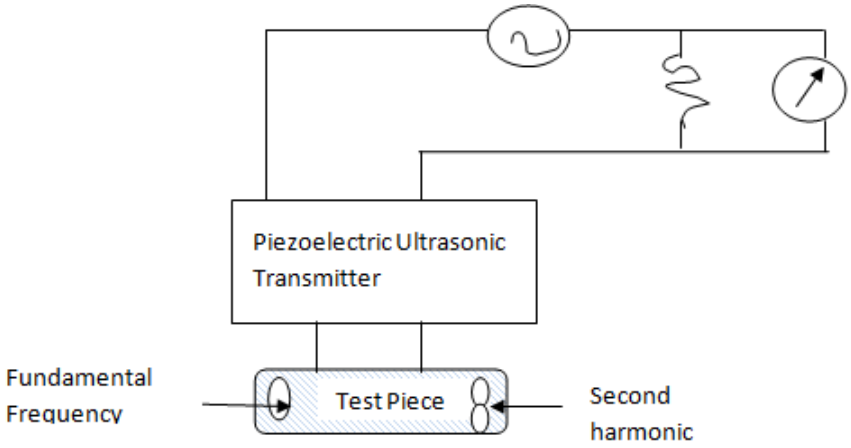
Where,

Q = charge provided by the polarizing voltage

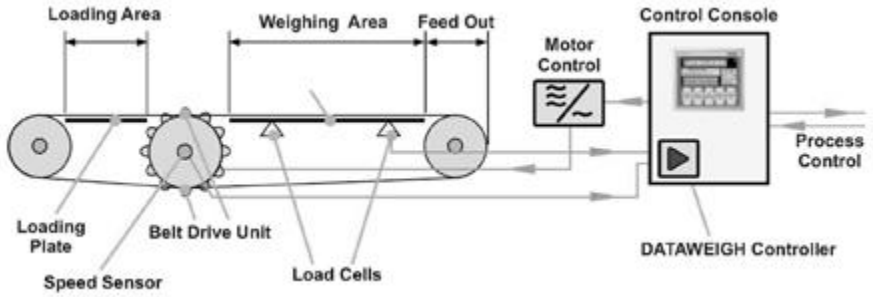
d = separation between the plates.

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).

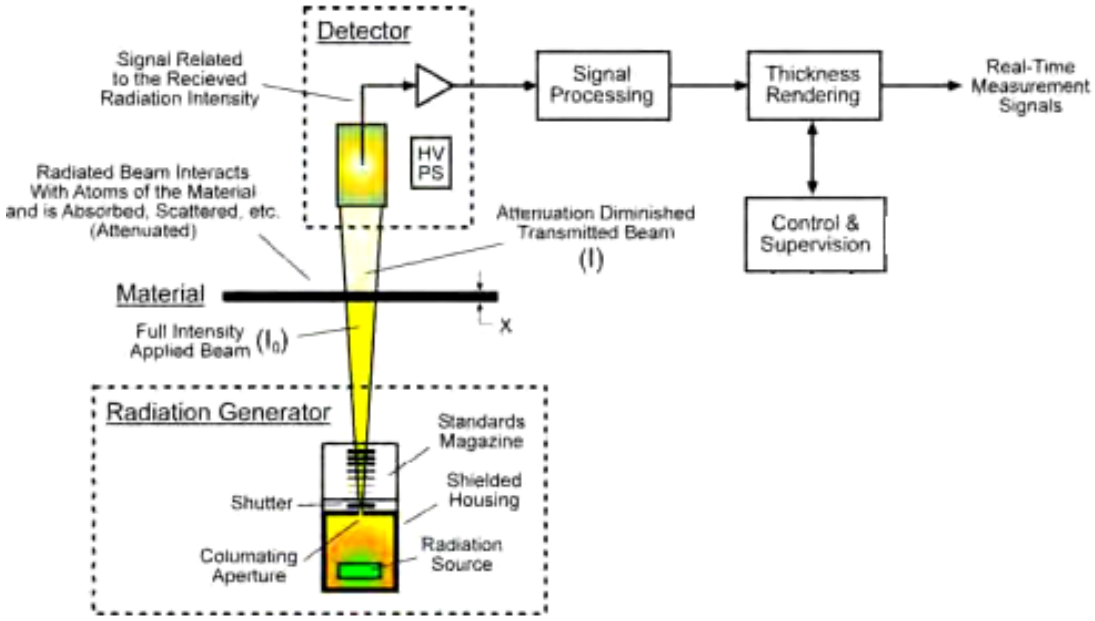
Q.3		Attempt any THREE of the following:	12 Marks
	a)	**Select relevant speed transducer for speech (rpm) of a rotating body with justification.**	4M
	Ans:	Stroboscope can be used to measure speed of rotating body accurately. • As the stroboscope is an instrument that emits a series of brief, intense 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. • Also it is non-contact type speed measurement device so its generated output is without any mechanical losses and can measure high speed within few seconds.	4M
	b)	**Describe the calibration procedure of piezoelectric transducer for sound measuring system.**	4M
	Ans:	A piezoelectric crystal is used for acoustic signal measurement. By application of a principle of reciprocity to the acoustic measurements, the piezoelectric modulus of tourmaline under hydrostatic pressure can be obtained. The piezoelectric modulus d•q-2d• so determined is compared with accepted values for the modulus, and was checked by testing-machine measurements of the modulus d.	4M
	c)	**Explain with diagram AC tachogenerator.**	4M
	Ans:	**Diagram:**  	2M
		Explanation: AC tachogenrator consists of • Permanent magnet • Coil(stator) • Rectifier Bridge • Moving coil(Voltmeter) In AC tachogenerator, the armature is provided with an AC winding either single phase or three phase winding. When the rotor is stationary and primary winding is excited by an AC input voltage, the induced voltage in secondary is zero due to relative position of two winding being placed at 90^0 to each other. As rotor rotates, a voltage is induced in the secondary winding whose magnitude is proportional to the rotor speed.	2M

		The EMF induced in Quadrature coil is directly proportional to the rotor speed.	
	d)	**Describe the trouble-shooting procedure of pressductor load cell for force measurement transducers.**	**4M**
	Ans:	Pressductor Load cell generate voltage between 1-to-20 VDC with source impedance from 0.5 ohms to 25 ohms. So fault can be • No signal output • Changed zero signal • Incorrect sensitivity • Hysteresis loss So Troubleshooting procedure steps are 1. Check the cable diagram of pressductor transducer. 2. Check the input signal and input impedance. 3. Check the output of when force column are not loaded. 4. Check the voltage when it is maximum loaded. 5. If output of load cell is not zero when it is unloaded then check the winding arrangement which has to be oriented 90^0 from each other. 6. Maintain surrounding temperature to obtain accurate measurement.	**4M**
Q.4		**Attempt any <u>THREE</u> of the following:**	**12-M**
	a)	**Describe with sketches the construction of ultrasonic vibration type of thickness measurement.**	**4M**
	Ans:	**Diagram:**  	**2M**
		Explanation: The transducer is placed on the top of test piece and ultrasonic vibrations are passed through it. The frequency of the oscillator is varied and standing waves are setup at certain frequencies. The values of these frequencies are based on the thickness of test piece. A standard frequency used by an ultrasonic thickness gauge is 5 MHz. Thickness is calculated as $t = 0.5 \frac{v}{f}$, where t= thickness (m, cm, ft) , v= velocity of sound, f=frequency of response.	**2M**
	b)	**Prepare the specification of electro-mechanical vibration pickup vibration measurement transducers.**	**4M**

	Ans:	**Specification :** • Resonant Frequency measurement and detection • Temperature of operation • Sensitivity • Type of output: analog or digital. • Frequency response • Size of sensor based on object under test • Range of vibration • Type of application.	**4M(any four)**
	c)	**State the sound transducer widely used in electronic communication and audio recording device and states its principle.**	**4M**
	Ans:	Condenser microphones which operate on capacitive design are used in electronic communication and audio recording device. • It utilizes basic transduction (the conveyance of energy from a donor to a receptor) principles and will transform the sound pressure to capacitance variations, which are then converted to an electrical voltage. • This is accomplished by taking a small thin diaphragm and stretching it a very small distance away from a stationary metal plate, called a "back plate." • In the presence of oscillating pressure, the diaphragm will move which changes the gap and thus the capacitance between the diaphragm and the back plate. • In order to measure the changing capacitance of the microphone due to the sound field, a voltage is applied to the back plate to form the transducer. • Changes in the acoustic pressure will deflect the diaphragm and produce a voltage from the capacitor proportional to the original pressure oscillation corresponding to the individual microphone's sensitivity. • In order to convert a change in capacitance to a change in voltage, the charge applied to the back plate. • This charge can be generated by two different methods. The first is an externally polarized microphone design where an external power supply is used. The voltage source on this traditional design is 200 volts. • The second, newer design is called a prepolarized microphone design. This modern design utilizes an electret layer placed on the back plate. An electret is a material in which a constant electric charge is placed. This charged material is what supplies the voltage for polarization. Preamplifier can provide great advantages.	**4M**
	d)	**Describe the troubleshooting procedure of DC tachometer for speed measurement transducers.**	**4M**
	Ans:	Troubleshooting procedure of DC tachometer. 1. Identify the fault by visual inspection. 2. Check the supply lines to DC generator. 3. Disconnect the supply line. 4. Check continuity using multimeter. 5. Check commutator and brush assembly status for maintenance. 6. Check output resistance of DC tachometer which should be high enough.	**4M**
	e)	**Describe conveyor belt weigh feeding system with neat sketch.**	**4M**

	Ans:	**Diagram: (Consider relevant diagram)**  **Explanation:** • The above diagram shows Weigh Feeders to feed bulk solids continuously to the process. • In a Weigh Feeder, product is fed as a continuous band onto a conveyor belt, through an inlet slide gate or automatic pre-feeder. • Load cells under the belt continuously measures the weight of the product over a defined length of belt. • The weight is measured directly at the weighing zone sensed by a centrally placed weighing idler which is placed on two numbers of high precision load cells. A digital tachometer detector generates the signal in proportion to the speed of the belt. • The Weigh Feeders are suitable for industrialized environment with light & heavy duty conditions. • The controller continuously compares the actual weight with the set point weight, and automatically adjusts the motor speed to either increase or decrease belt speed, in order to maintain a constant feed rate. • Any variation in the density of the material is reflected as a change in belt loading, which is compensated for by adjusting the belt speed. • They are specifically designed to provide dependable service with minimum maintenance and care. Heavy duty, Long life components are selected to assure a stable and distortion free compact assembly capable of withstanding tough industrial conditions.	**2M** **2M(in brief)**

Q.5		**Attempt any <u>TWO</u> of the following:**	**12M**
	a)	**Describe working of radiation type of thickness measurement with diagram.**	**6M**
	Ans:	**Diagram: (note: any other relevant diagram can be considered)**	**3M**



Working: **3M (in brief)**

Component wise system description and working is as under.

1) Radiation Generator – This device emits a directed beam of high energy ionizing radiation (of known intensity, I0 (in photons/sec), and spectral characteristics) and provides radiation containment.
2) Shielded Housing – This vessel typically consists of a shielded, structural housing containing the associated holders and mounts required to locate and orient the radiation source. The housing may contain dielectric oil immersed components and be supported by an external heat exchanging / cooling system.
3) Radiation Source – This component generates the radiation that will be applied for measurement. The source may be either natural (radioactive isotope) or artificial (X-Ray tube), and may project a radiation pattern that is sensitive to alignment with the housing aperture.
4) Collimating Aperture – Radiation is emitted from the housing chamber through a sealed aperture in the form of a beam having a specific, semi-collimated optical geometry needed to support the form and geometry of the application and detector. The aperture is sealed to reduce the infusion of external contaminants and / or the escape of any (possibly pressurized) internally contained dielectric oil.
5) Shutter - This device provides a means of cutting off the radiation beam, making the radiation generator safe for handling and operations in the proximity.
6) Standards Magazine - This device contains a group of precision (often NIST traceable) samples that can be introduced into the radiation beam (individually or in groups) to provide a means of measuring the emitted beam's intensity and spectral content for calibration and standardization purposes.
7) Material Under Measurement – Material under measurement may be flat rolled, sheet / strip products, composed of various metals (e.g., steel, aluminum, and copper / brass alloys, etc.) The strip may be stationary or moving.

8) Detection System – Transmitted / scattered radiation, I (in photons/sec), that results from the incident radiation, I_0 , penetrating the strip, is collected and measured by this device, which is typically located above the strip and aligned to the optical axis of the radiated beam.
9) Detector – Collected incident radiation is converted to an electrical signal that is functionally related to the radiation intensity.
10) High Voltage Power Supply – Detector sensitivity (gain) is related to the applied potential. A high voltage power supply provides the detector potential with sufficient current capacity to provide the necessary charge recovery.
11) Preamplifier – The feeble detector signal is amplified to usable amplitudes by a high gain, low noise electrometer / trans-conductance amplifier. To reduce signal noise and interference, it is desirable to place the preamplifier as close as possible to the detector and mounted in a shielded, hermetically sealed enclosure.
12) Signal Processing – The amplified detector signal requires wide bandwidth signal processing (in both time and amplitude) to render a calibrated measurement of the intensity of the received radiation (i.e., related to material absorption / attenuation). This processing can be provided by, real-time digital signal processors or Field Programmable Gate Arrays (FPGAs).
13) Thickness Rendering – This subsystem provides the final determination and distribution of the calibrated measurement of strip thickness. Calibration and alloy compensation curves reside in and are supplied by the System Supervisor. The measured thickness is typically transmitted via analog signals or high speed networked numerical data exchanges.
14) System Supervisor – This subsystem oversees and coordinates the gauging system's control, measurement, calibration and operational activities, along with any operational interfacing to the mill / line control systems.

b) **Describe the calibration procedure for magnetic pickup speed transducers.** **6M**

Ans: **Diagram**: **3M**

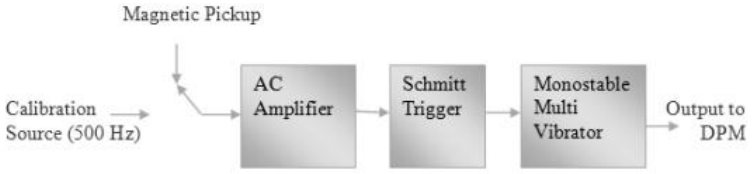


Fig.1

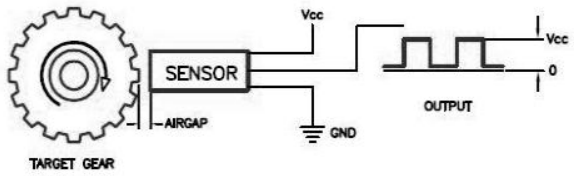


Fig.2

3M

Working:

Fig.1 shows the circuit diagram and fig.2 shows the experimental setup of a magnetic pickup type speed sensor.

1) Connect the A.C amplifier of the circuit to a precise signal generator of variable

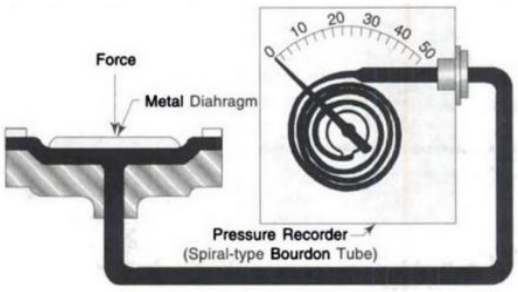
frequency, by putting the selector switch to calibration source.

2) Set the frequency of signal generator to say, 500Hz which corresponds to the maximum speed (range) of the sensor (here the motor whose speed is to be measured is fitted with a toothed wheel of 20 teeth. When the motor runs at 1500 rpm (i.e. 25 revolutions/sec), the frequency of the pulse = 25 x 20 = 500 per second).
3) Set the amplifier gain so that the DPM reads 1500 RPM.
4) Now apply reduced frequency supply in steps corresponding to different speeds below 1500 RPM.
5) Each time measure the outputs of DPM.
6) Tabulate/compare theoretical and practical (DPM) values.

Sr no.	Theoretical value (N_{TH})	DPM output (N_{PR})	% error=$\frac{N_{TH}-N_{PR}}{N_{TH}} * 100$

(c) Explain with sketch the working of hydraulic force meter. **6M**

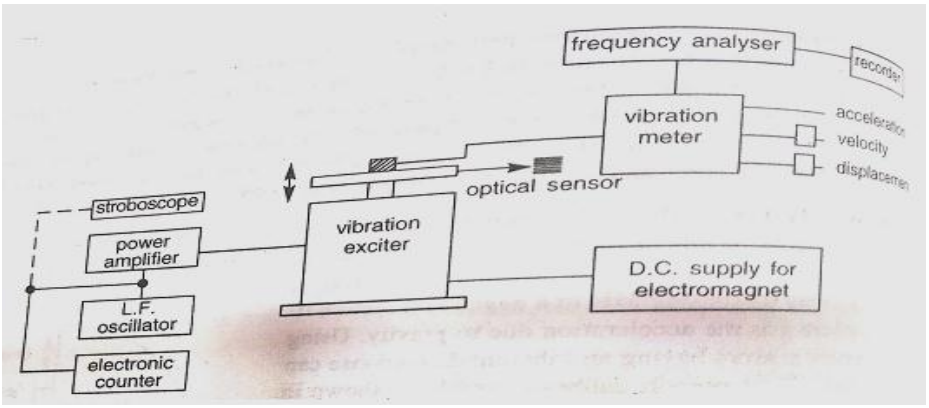
Ans: **Diagram:** **3M**

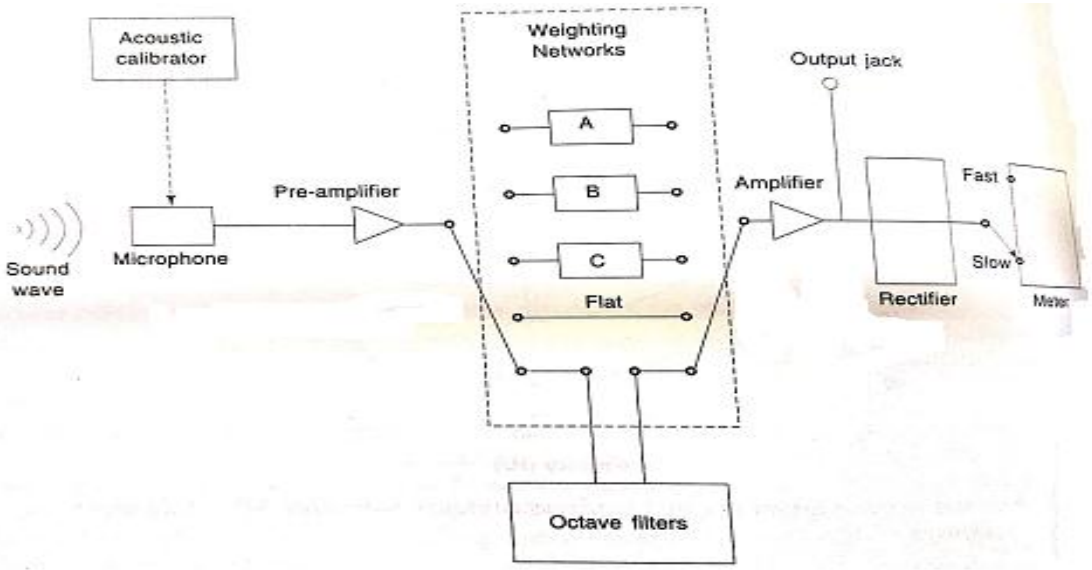


Working: **3M**

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.

Fig. shows 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.

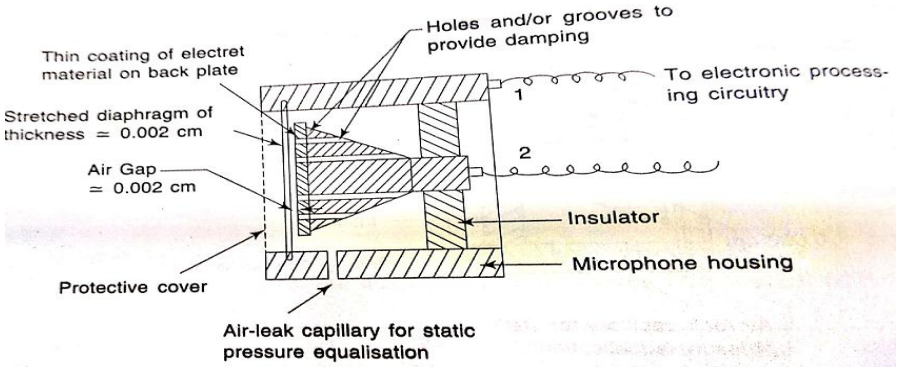
Q.6		Attempt any TWO of the following:	12Total Marks
	(a)	**Describe the calibration procedure for the relative displacement vibration pickup type of vibration measurement transducers.**	6M
	Ans:	**Diagram** 	3M
		Procedure: 1) Mount the sensor on the platform table of a standard electro dynamic shaker (vibration exciter)as shown in figure. The armature and table should be fixed as rigid as practicable. 2) Switch on the vibration exciter. The motion obtained will be sinusoidal when the armature is excited with a sine wave signal. The magnitude of displacement is proportional to the power input fed to the armature coil. 3) Measure the peak to peak displacement with the help of a synchronized stroboscope and a graticule scale of a telescope. 4) Measure the sensor output. 5) Repeat for various frequencies of input supply. 6) Calculate the dynamic velocity and acceleration levels. 7) Calculate the sensor sensitivity which is the ratio of sensor output and input motion, at various frequencies and displacement levels. **8)** Assess the frequency response and sensitivity characteristics.	3M

	(b)	**Describe working of sound level meter with diagram.**	**6M**
	Ans:	**Diagram:**  **Working:** Sound level meters convert acoustic pressure into a voltage. Figure shows the block diagram of a typical sound level meter. The system contains a microphone, an electric amplifier with frequency weighting network and a recorder/meter calibrated in decibels. Microphone converts sound pressure variations into analogous electrical signals. It uses a thin diaphragm to convert pressure into motion. Motion is then converted into a suitable electrical output using a secondary transducer like, capacitor type, piezo - electric type, electro dynamic type and carbon granules type. Signal is amplified and applied to a frequency weighing network. The frequency weighting network provides a response similar to that of a human ear. Three standard weighing networks, A, B and C are used to approximate the equal loudness curve. These give different amount of amplification for each frequency.ie, it provide greater amplification for frequencies between 500 and 5000Hz. A rectifier circuit included produces a signal proportional to the root mean square value. Finally the electrical signal is given to a recorder or meter.	**3M** **3M**
	c)	**Select relevant sound measurement transducer for sound measurement near crushing mills.**	**6M**
	Ans.	**Selection description:** Near a crushing mill the sound level would be very high which is around 90db -120 db and require a low sensitivity microphone. The specifications of sound level meters are given in IEC 60651 for four types 0, 1, 2, 3 differing by the measurement precision. The measurement precision is reduced as the type number increases, affecting manufacturing costs significantly. The type 0 sound level meters is intended as a laboratory reference standard. Type 1 is intended especially for laboratory use and for field use where the acoustical environment has to be closely specified and controlled. The type 2 sound level meter is suitable for general field applications. Type 3 is intended primarily for field noise survey applications. Type 2 and type 3 sound level meters usually include only the A-weighting network and the FAST and SLOW response. For type 2 &3, models with AC outlets should be chosen as they make it possible to record the noise on a magnetic tape recorder for further analysis. They are usually	**3M**

equipped with a diffuse field piezoelectric or electret microphone.

The electrical signal from the microphone is fed to the pre-amplifier of the sound level meter and a weighted filter. Further amplification prepares the signal either for output to other instruments such as a tape recorder or for rectification and direct reading on the meter.

Diagram: **3M**



Construction & working:

A variation on the condenser microphone which is currently very popular is the electret type. In this case the potential difference is provided by a permanent electrostatic charge on the condenser plates. This is done with the help of a thin coat of electret material at the back plate. Hence it doesn't require an external polarizing voltage. The diaphragm and the back plate 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,

$E \propto Qd.$

Q = charge on the plate

d= distance between the plates.

This type of microphone is less sensitive to dirt and moisture than the condenser microphone with a polarization voltage. They have excellent frequency response and are relatively free from noise in humid environments.