SRM INSTITUTE OF SCIENCE AND TECHNOLOGY, RAMAPURAM

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

ANSWER KEY SUBMISSION

Date of Exam & Session	13-10-2022	**Category of Exam**	CLA2
Course Name	SENSORS & TRANSDUCERS	**Course Code**	18ECO133T
Name of the Faculty submitting	Dr.R. Surender	**Date of submission of Answer Key**	13-10-2022
Department to which the faculty belongs to	ECE	**Total Marks**	50

PART A (10x1= 10)

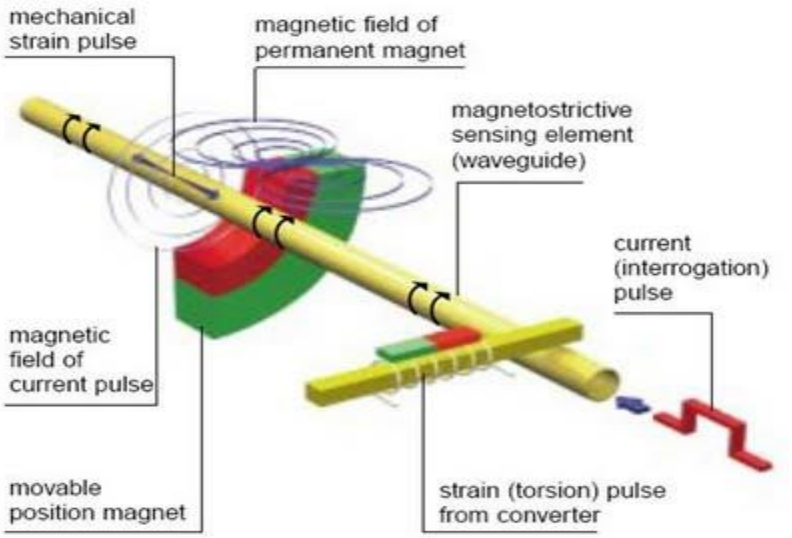
ANSWER ALL THE QUESTIONS

Q. No	Option	Answer
1	a)	Transformer principle
2	d)	All of the above
3	d)	quartz crystal
4	a)	more than audible sound
5	b)	more than 1 dielectric medium
6	c)	Krypton
7	b)	optical pyrometer
8	b)	air
9	a)	active
10	d)	All of the mentioned

PART B (4x4= 16)

ANSWER ANY FOUR OUT OF SIX QUESTIONS

Q.No	Question
11	**Illustrate the concept of magnetostrictive transducer with the help of a diagram.**



- Magnetostrictive position sensors are non-contact linear position sensors
- They use the momentary interaction of two magnetic fields to produce a strain pulse that moves along a waveguide. One field is from a magnet that moves along the outside of the waveguide. The other field is from the waveguide itself.
- Magnetostrictive position sensors a unique signal for each point along the axis of travel.
- The advantage to this type of sensor is that it is non-contact and there is no wear or friction. It is also not affected by vibrations so there is no limit on the number of operating cycles.
- The disadvantage is the dead band on both sides of the sensor which cannot be reduced to zero.

12

Write a short note on Ultrasonic sensors.

- Piezoelectric effect of certain crystalline materials has been successfully utilized in ultrasound production and sensing
- When a electric field is applied to the crystal it changes its shape. This property is utilized in generating acoustic or ultrasound wave
- For transmitting such wave good medium and interfacing should be chosen.
- Barium titanate ($BaTiO_3$) material is chosen, but requires prior polarization
- It consists of randomly oriented tiny piezoelectric crystallites which are properly oriented mostly by DC polling field of several thousand volts per cm and the material is cooled through Curie temperature.
- A strong piezoelectric effect has been observed in compounds such as $PbZrO_3$-$PbTiO_3$ called PZT materials.
- Piezoelectric transducers can generate continuous wave ultrasound or pulsed ultrasound latter being used in SONAR or other similar systems.
- Ultrasonic piezo crystals operate in the range 0f 0.5-10 MHz.
- They are directly attached to the transmitting medium or are separated by a small distance which is filled with coupling materials of suitable acoustic properties.
- Typical couplants at low temperatures are water, grease, and petrojelly and for higher temperatures special polymer couplants may be used.

13

Write short notes on electrostatic transducer.

Similar to the electromagnetic transducer discussed in Section 2.4.5, capacitive type transducer can also be developed with bilateral characteristics, where it is used with dc polarization. Such a transducer is also referred to as an *electrostatic transducer*. A typical scheme of such a system is shown in Fig. 2.43. A capacitor is formed with a 'flexible' diaphragm which can move due to application of force and a rigid plate p_1. There is bias voltage V_s which is sufficiently large. When the system acts as a transducer, the gap x between the plates changes as by some pressure in case of an 'electrostatic microphone'. This pressure may be considered sinusoidal in nature for analysis purpose. A circuit consisting of a resistance R and capacitance C 'varying sinusoidally' allows V_s to send a sinusoidal current i to flow in it and hence, a sinusoidal output V_o across resistance R is obtained.

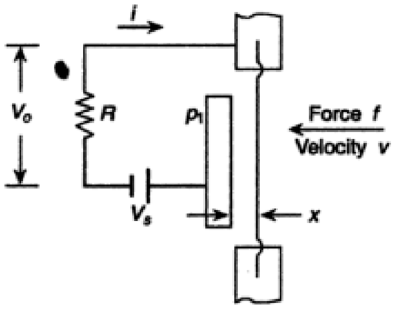


Fig. 2.43 Electrostatic transducer.

Analyzing as in the case of electromagnetic transducer, V_o corresponding to a force f can be obtained in terms of the parameters V_s, x, R, C, ω, mass m, stiffness k, and damping (ζ) of the system. In fact, the dynamic transfer function is given by

$$\frac{V_o(s)}{f(s)} = \frac{s x_o R C_o V_s}{s^3 x_o^2 m R C_o + s^2(m x_o^2 + x_o^2 R C_o \zeta) + s(x_o^2 \zeta + x_o^2 R C_o k) + (x_o^2 k + V_s^2 C_o)} \qquad (2.111)$$

where, C_o and x_o are the initial values of x and C, and s may be replaced by $j\omega$ where ω is the input circular frequency.

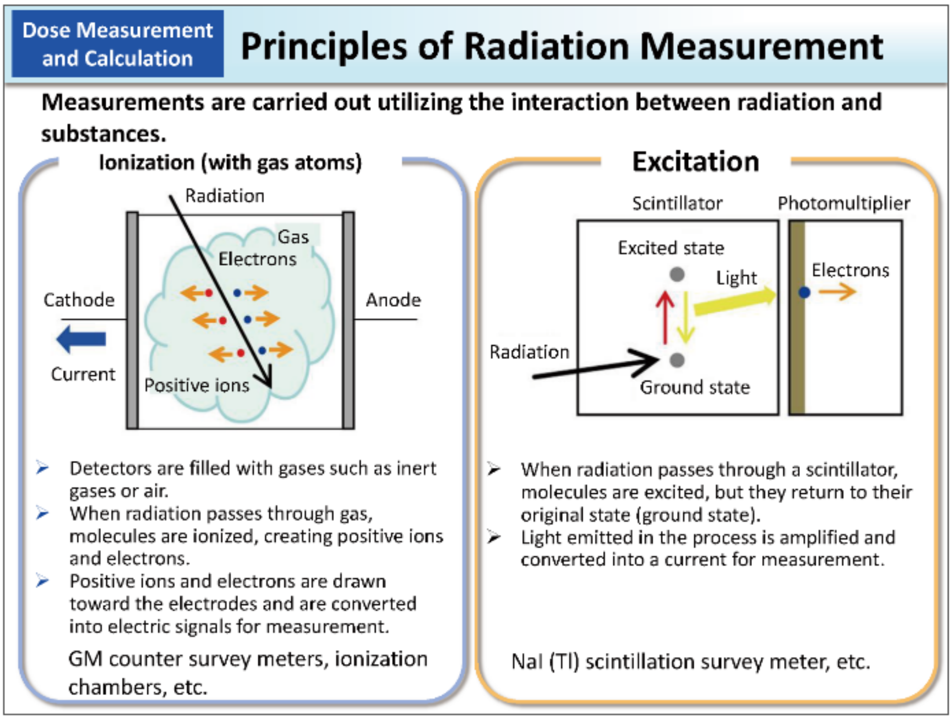
14

List the important factors that themoemf sensors materials depends on.

- The Type E thermocouple can be used successfully in subzero applications due to high corrosion resistance to high moisture environments. Out of all of the different types of thermocouples, Type E has the highest EMF output per degree.
- If the thermocouple is being used over 540°C (1000°F) an 8 gauge wire should be used due to rapid oxidation of the iron (+) wire. **Type J thermocouples** should not be used in sulfurous applications above 540°C (1000°F).
- The **Type N thermocouple** is the newest addition to the ISA family. lt was developed to be used under the same conditions as a Type K. Type N should be used in oxidizing or inert atmospheres with a service temperature range between -200°C and 1260°C (-330°F to 2300°F).
- The Type R thermocouple is composed of a platinum-13% rhodium (+) wire versus a platinum (-) wire. This type of thermocouple can be used in oxidizing or inert atmospheres with a service temperature range between 0°C and 1480°C (32°F1o 2700°F).
- They should never be used in reducing atmospheres. As with all **platinum type thermocouples**, they should always be protected with a ceramic protection tube. Alumina insulators and protection tubes are preferred to prevent silica contamination from Mullite ceramics

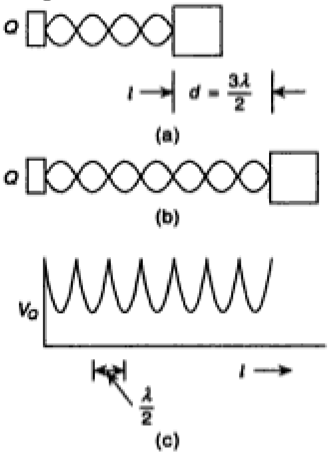
15

Mention only the basic characteristics of radiation sensors.



16	**Explain about acoustic temperature sensor.**

- The realization of this technique is made in acoustic helium interferometer whose working is explained through Fig. 3.6.



- A quartz crystal excited to its resonance frequency is used to transmit this wave through a gas (He) column to be faced by a piston. The wave is reflected at the piston surface to form a pattern as shown
- When the path length l has a multiple number of half-wavelengths and correspondingly the gas column is set to resonate at each such half-wavelength gap, with the piston moving away from the crystal at each resonant peak, the crystal gives out maximum energy and hence the voltage VQ across the crystal defines peaks as shown in Fig. 3.6(c).
- If the piston moves by a distance d to give n such peaks, d = nλ/2 from which C, is determined and thence temperature T. The piston movement must be accurately monitored to within, say 1 μm.

PART C (2x12= 24)

ANSWER THE FOLLOWING QUESTIONS

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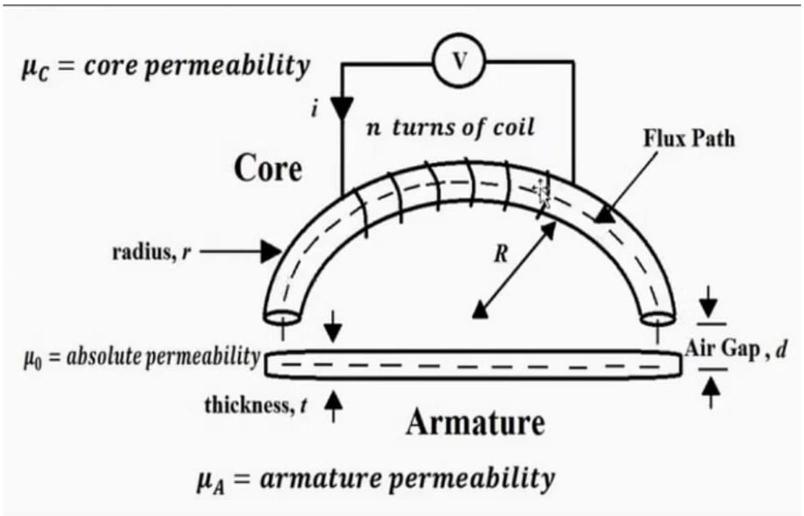
<tr><td>17</td><td>
a) With necessary equations and diagram discuss in detail about the inductive sensors.



uses the principle of electromagnetic induction to detect or measure objects
An inductor develops a magnetic field when a current flows through it; alternatively, a current will flow through a circuit containing an inductor when the magnetic field through it changes. This effect can be used to detect metallic objects that interact with a magnetic field.
Non-metallic substances such as liquids or some kinds of dirt do not interact with the magnetic field, so an inductive sensor can operate in wet or dirty conditions.
One form of inductive sensor drives a coil with an oscillator.
A metallic object approaching the coil will alter the inductance of the coil, producing a change in frequency or a change in the current in the coil.
These changes can be detected, amplified, compared to a threshold and use to switch an external circuit.
The coil may have a ferromagnetic core to make the magnetic field more intense and to increase the sensitivity of the device.
A coil with no ferromagnetic core ("air core") can also be used, especially if the oscillator coil must cover a large area.
Another form of inductive sensor uses one coil to produce a changing magnetic field, and a second coil (or other device) to sense the changes in the magnetic field produced by an object, for example, due to eddy currents induced in a metal object

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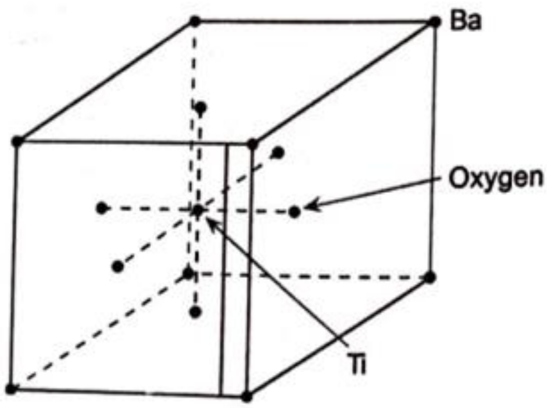
b) With the help of neat diagram, discuss in detail about the piezoelectric elements.



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- Materials are divided into 2 groups:

(i) Occur naturally such as Quartz, Rochelle salt $NaKC_4H_4O_6$, $4H_2O$, tourmaline

(ii) those produced synthetically such as lithium sulphate (LS), $NH_4H_2PO_4$ or ammonium dihydrogen Phosphate (ADP), $BaTiO_3$ or barium titanate (BT).

- Barium titanate is actually a ferroelectric ceramic and requires to be polarized before use.

Besides, there are certain polymer films which also exhibit the piezoelectric property

- The material properties that are relevant to the piezoelectric sensors are

(i) dielectric constant,
(ii) d-coefficients (xx, say),
(iii) resistivity (specifically, volume resistivity is considered),
(iv) Young's modulus,
(v) humidity range (since above or below this range large absorption of moisture occurs changing volume resistivity and performance characteristics),
(vi) temperature range, and
(vii) density.

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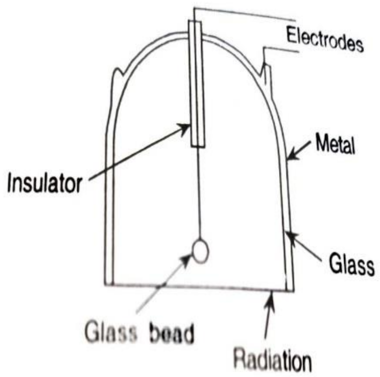
<tr><td>18</td><td>

With the help of a neat sketch explain in detail about the Geiger counter.



- It detects ionizing radiation such as alpha particles, beta particles, and gamma rays using the ionization effect produced in a Geiger–Müller tube, which gives its name to the instrument. In wide and prominent use as a hand-held radiation survey instrument, it is perhaps one of the world's best-known radiation detection instruments.
- It can be made to have longer operating life time by particularly using Halogen gas filling.
- In the end window type, a metal coated glass tube of cylindrical form has a thin tungsten wire of 0.002-0.01 cm diameter passing through the centre acting as the collector electrode with the body as the other.
- The end window s usually made of mica sheet of a thickness less than 1 mg/cm^2.
- To avoid spark over the central electrode, it terminates into a glass bead .
- Radiation is received by the end window.
- In the cylindrical GM counters,radiation is received by the side walls.
- In the Needle type GM counter, where insertion in a narrow channel s required.

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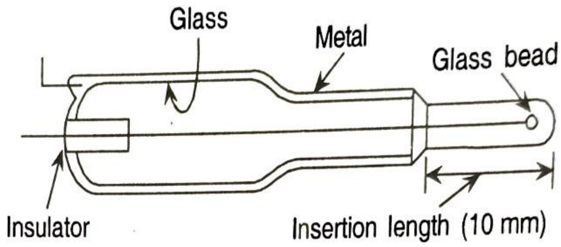
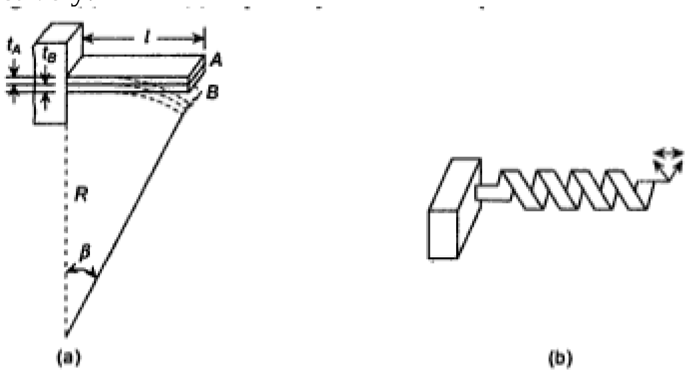


Fig. 5.50 Needle type design of a GM counter.

- The GM counter chamber uses a gas at a low pressure of about 0.1-0.15 kg/cm² that consists of 90% insert gas such as Ar & Ne and 10% ethyl alcohol or other organic vapours like methane.
- This mixture ensures charge transit through electrons only.
- One important thing in gas filled counters is the discharges mechanism.
- In the GM counter, the Townsend discharge occurs and with the bulk of electrons in the discharge being collected by the anode, a positive ion sheath or cloud is left to reduce the field and stop the discharge. This is known as Quenching of the discharge.

a) Discuss in detail about the thermal expansion type thermometric sensors.

- Thermal expansion is the phenomenon observed in solids, liquids, and gases. In this process, an object or body expands on the application of heat (temperature). Thermal expansion defines the tendency of an object to change its dimension either in length, density, area, or volume due to heat. When the substance is heated it increases its kinetic energy. Thermal expansion is of three types:
  - Linear expansion
  - Area expansion
  - Volume expansion
- The thermal expansion types thermometric sensors are, perhaps. the oldest varieties still used commercially to a certain extent.
- Earliest of this kind is the solid expansion type bimetallic sensor which uses the difference in thermal expansion coefficients of different metals.
- Two metal strips A and *B* of thickness t_A and t_B and thermal expansion coefficients α_A and α_B **are** firmly bonded together at a temperature, usually the lowest or the reference temperature, to form a cantilever or a helix with one end fixed as shown in Figs 3.4(a) and 3.4(b) respectively.



- When the temperature of the cantilever or the helix is raised by heating or lowered by cooling. one strip expands or contracts more and free end of either of the two moves as shown.
- The cantilever, in fact, bends into a circular arc with radius of curvature *R* given by the relation

$$R = \frac{(t_A + t_B)\left[3\left(1 + \frac{t_B}{t_A}\right)^2 + \left(1 + \left(\frac{t_B}{t_A}\right)\left(\frac{Y_B}{Y_A}\right)\right)\left\{\left(\frac{t_B}{t_A}\right)^2 + \frac{t_A Y_A}{t_B Y_B}\right\}\right]}{6(\alpha_A - \alpha_B)(T_h - T_b)\left(1 + \frac{t_B}{t_A}\right)^2} \tag{3.8}$$

where Y is the Young's modulus,
T_h is the raised temperature, and
T_b is the bonding temperature.

Equation (3.8) is simplified using $t_A = t_B = t$ and $Y_A \approx Y_B$. This gives

$$R = \frac{4t}{3(\alpha_A - \alpha_B)(T_h - T_b)} \tag{3.9}$$

The angular deflection, β, per unit temperature change, that is, sensitivity (for small β) is given by

$$S_T^\beta = \frac{\beta}{(T_h - T_b)} = 3l\,\frac{\alpha_A - \alpha_B}{4t} \tag{3.10}$$

where l is the length of the cantilever.