

TRANSDUCERS

①

Syllabus: Introduction, Passive Electrical transducers, Resistive transducer, Resistance thermometry, Thermistor, Linear Variable Differential Transformer (LVDT) Active Electrical transducers, Piezoelectric transducer, Photoelectric transducers.

* Definition of transducer:

A transducer is a device which converts energy information from one form to another.

②

A transducer is a device which converts a physical quantity @ non electrical quantity (temperature, pressure, displacement, force, sound, light etc) into electrical signal (either voltage @ current)

Note:

① Classification of transducers:

② Based on the role of transducers:

● Input transducer (Instrument transducer)

Output transducer (Power transducer)

→ An input transducer can be used as a measurement device.

→ An output transducer delivers output signals like force, torque, pressure @ displacement when the electrical signal is applied as an input.

③ Based on the operation:

(Externally Powered)

● Active transducer (Self-generating) & Passive transducer

→ Active transducers develop their own Voltage @

current by absorbing the energy needed from the measurement (input)

Ex: Thermo - couple, Piezo electric transducer, Photo - electric cell & photovoltaic cell.

→ Passive transducer accepts energy from an external source to produce output signal (they may absorb some energy from the measurement) (depend on charge in R, L, C)

Ex: Resistance strain gauge, thermistor, Linear Variable differential transformer (LVDT), Hall effect sensor, & photomultiplier tube

① Based on output signal :

● Mechanical transducer & Electrical transducer

→ Mechanical transducer produces mechanical nature signal at its output. (Primary transducer)

→ Electrical transducer produces electrical signal at its output. (Secondary transducer)

② Based on the nature of output :  Analog transducer
Digital transducer

② Sensor & transducer:

→ Sensor (Primary sensing element) is used to detect any quantity and report it in another form of energy (usually electrical signal)

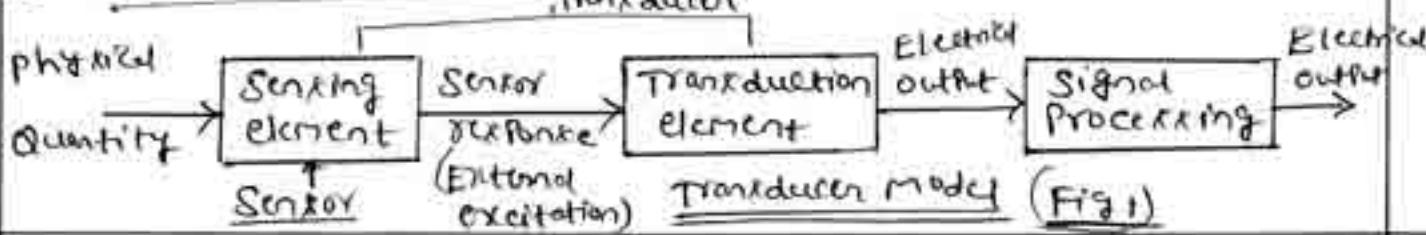
Ex: Intensity & Luminance of a source may be measured

by sensor.

→ Transducer converts a signal from one form to another form of energy (transduction element) (one type to another type)

Ex: Temperature is measured by transducer.

③ Block diagram of transducer Model (Fig 1) (Electrical transducer)



④ Transducer connected in series

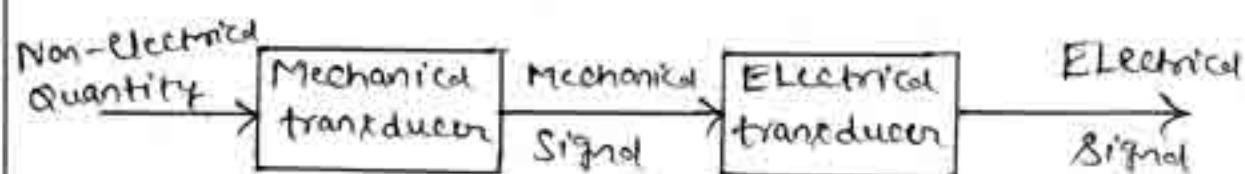


Fig ②: Transducer connected in series

⑤ Measurands: (Quantity to be measured):

Displacement, Position, Velocity, acceleration, Force, Load, strain, Rotation, Encoding, Vibration, Flow, Vacuum, temperature, Pressure, Medical Imaging, Acoustic fields, Magnetic field, Torque, PH and Partial Pressure of O_2 and CO_2 in blood etc

⑥ Advantages & Disadvantages of electrical transducers

→ Advantages

- ① Amplification & attenuation of electrical signal can be easily done.
- ② Can be controlled with a very small level of power.
- ③ Mass-inertia effects are minimized.
- ④ Effect of friction are minimized.
- ⑤ The electrical signal can be easily used, transmitted, and processed for the purpose of measurement.
- ⑥ ~~No~~ No mechanical wear and tear.

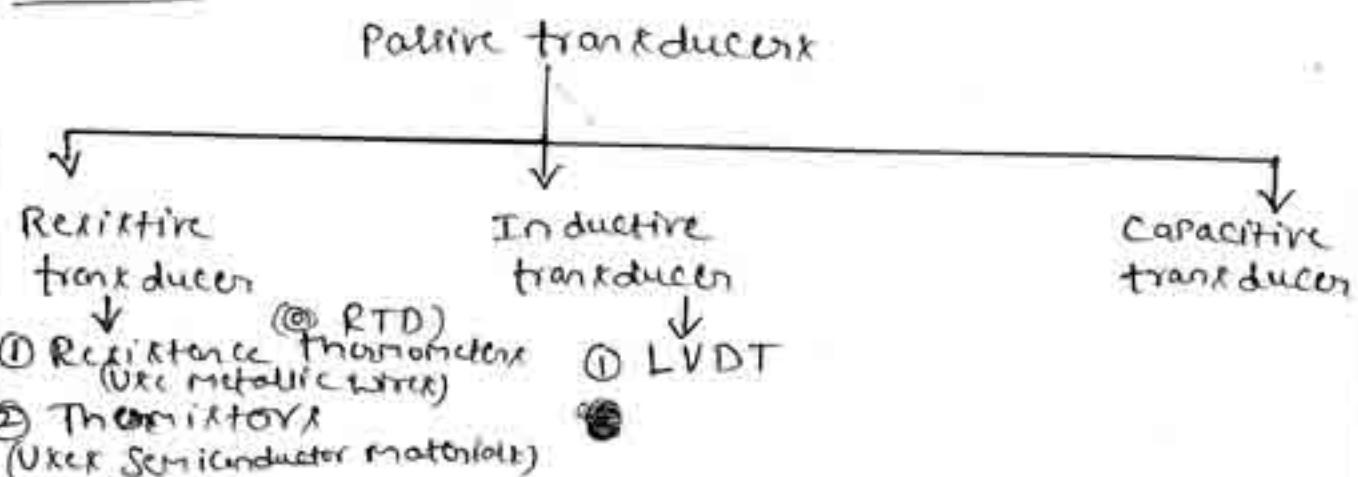
→ Disadvantages

- ① Sensors and signal processing circuit are comparatively expensive.
- ② Less reliable (sometimes) because of ageing & drift of active components.

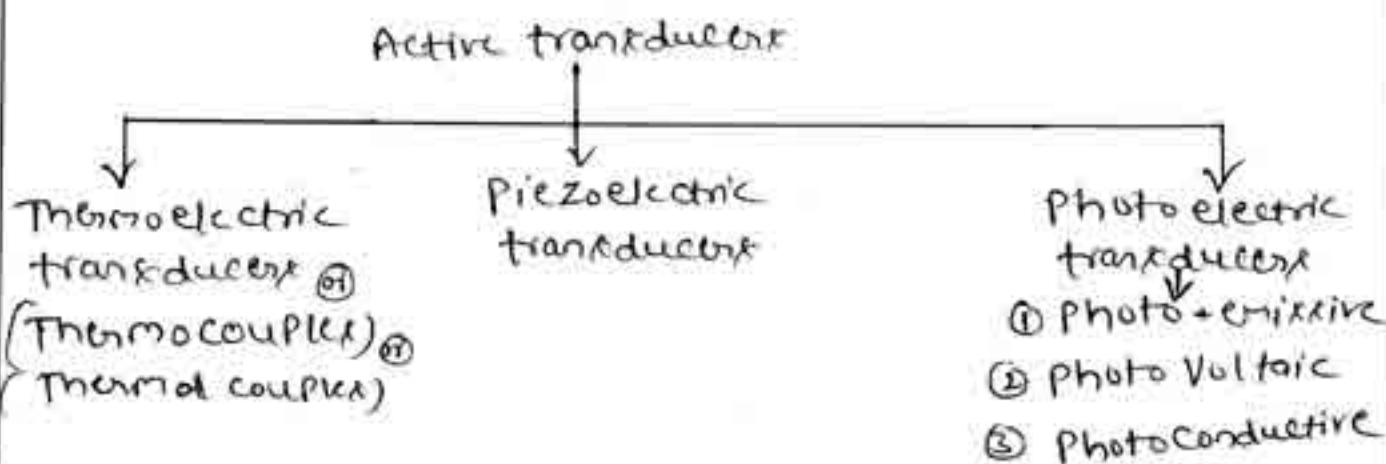
- ⑦ Desirable properties of good transducer ⑦
- Parameter of transducers ⑦ Requirements of transducer
- ① Linearity: The input-output characteristic should be linear.
 - ② Ruggedness: It should be capable of withstanding overload.
 - ③ Dynamic response (Dynamic range): It must operate smoothly (uniformly) over a wide range of frequencies.
 - ④ Repeatability (Precision): It should produce the same output ~~for~~ when the same input is applied repeatedly.
 - ⑤ Accuracy: It should produce high degree of accuracy.
 - ⑥ Stability & reliability: The output should be independent of temperature, vibration & other environmental variations. (Error should be minimal)
 - ⑦ Residual deformation: It must retain its original shape and structure even after long period of usage.
 - ⑧ Physical size: It must have minimal weight & volume.
 - ⑨ Range: It must cover a different range of measurand values.
 - ⑩ Input threshold: It must be possible to detect smallest value of the measurand quantity.
 - ⑪ Resolution: It should detect a small change in the measurand quantity.
 - ⑫ Loading effect: No loading effect should happen.
 - ⑬ Cost: It should be cost-effective.

* Electrical transducer

① Passive electrical transducer: The transducers that are based on the variation of the parameter (Resistance, capacitance & inductance) due to the application of any external stimulus are known as Passive transducers.



② Active electrical transducer: The transducers which produce output ~~independently~~ without external source are known as active transducers.



* Passive electrical transducer:

① Resistive transducer:

→ Resistive transducers are Passive transducers in which the resistance changes due to change in physical quantity sensed (measurand).

→ (DC resistance) Resistance of any metal conductor is given by,

$$R = \frac{\rho L}{A} \quad (\text{J2})$$

Where, $\rho \rightarrow$ Resistivity (Specific resistivity)
 $\rho \rightarrow$ Specific resistance of the conductor ($\Omega\text{-m}$)

$L \rightarrow$ Length of conductor (m)

$A \rightarrow$ Cross-sectional area of conductor (m^2)

→ Change in resistance occurs when the external stimulus (Physical phenomenon) affects either the dimension (L or A) or the resistivity (ρ) of the element.

→ For measurement of displacement, force, pressure, torque etc

When the resistive elements (conductors) are subjected to pressure, force, torque etc, the dimension (L or A) changes thereby resulting in change in resistance Ex: Strain gauges

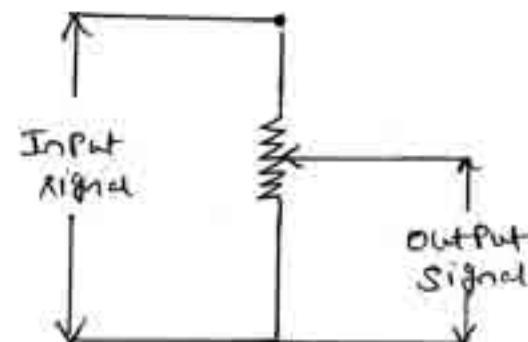
* For measurement of temperature

Variation in temperature causes change in the resistivity of the conductor thereby resulting in the change in resistance. Ex: Resistance thermometers.

→ Thermistor & photoconductive transducers rely (Work) on changing the concentration of charge carriers.

→ Resistive transducer (Resistive potentiometer) consists of a resistive element provided with a sliding contact (wiper).

Motion of sliding contact may be translatory or rotational.



Fig(3): Resistive transducer

→ Merits & Advantages

- ① Easy to operate
- ② Simple in construction
- ③ Efficiency is very high
- ④ Inexpensive
- ⑤ Both AC and DC can be used
- ⑥ Speed of response is high
- ⑦ High resolution
- ⑧ Available in various sizes.

→ Demerits & Drawbacks & Disadvantages

- ① A large force is required to move the sliding contact (when potentiometer is used)
- ② The sliding contact (Wiper) can wear out, become misaligned & generate noise.

D) Resistance Thermometer & Resistance temperature detector (RTD)

→ Construction:

- The wire resistance thermometer usually consists of a coil wound on a mica or ceramic former, as shown in fig (i).
- The coil is wound in bifilar form so as to make it non-inductive. The coils are available in different sizes & with resistance values ranging from 10Ω to 25Ω .
- The resistive element is normally enclosed in a protective tube of Pyrex glass, Porcelain, Quartz or Nickel.
- The glass is brought to
- The tube is evacuated and sealed or filled with air or any other inert gas and kept around atmospheric pressure.

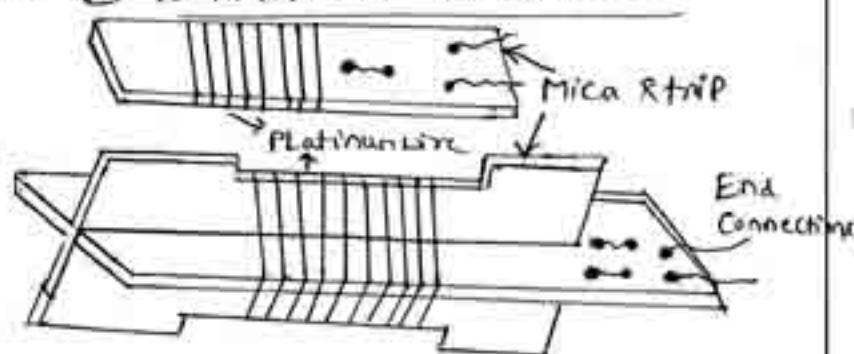


Fig (i): Resistance thermometer

- The element is brought to contact with fluid whose temperature is to be measured.

Principle of operation:

- Resistance thermometer is used to measure the temp by measuring resistance in a wire
- The resistance of conductor changes when its temp changes.
- The resistive element is usually made of a solid material, a metal, metallic alloy @ a semiconductor.
- Most commonly used materials for resistance thermometers are PLATINUM, COPPER and NICKEL.
- PLATINUM ~~is~~ used (^{most stable} metal) predominantly.
- The resistivity of the metal increases with temperature (Positive temperature Coefficient)
- The resistivity of the semiconductor & insulator generally decreases with temperature (Negative temperature coefficient)
- The resistance R_T of a resistance thermometer at any temperature $T^{\circ}\text{C}$ is,

$$R_T = R_0(1 + \alpha T)$$

Where, $R_0 \rightarrow$ Resistance at 0°C (Ω)

$T \rightarrow$ Temperature in $^{\circ}\text{C}$

$\alpha \rightarrow$ Temperature coefficient of resistance ($/^{\circ}\text{C}$)

$$\alpha = \frac{1}{\Delta T} \frac{\Delta R}{R_0}$$

Where, $\Delta T \rightarrow$ Change in temperature in $^{\circ}\text{C}$

$\Delta R/R_0 \rightarrow$ Fractional change in resistance.

$\Delta R \rightarrow$ Change in resistance (Ω)

- The Self-heating coefficient E is.

$$E = \frac{\Delta t}{R_T I^2}$$

Where, $\Delta t =$ (indicated temperature) - (Fluid temperature) $(^{\circ}\text{C})$

$R_T \rightarrow$ Resistance of thermometer (Ω)

$I \rightarrow$ Measurement current (A)

- Fig ⑤ Shows the resistance thermometer with Wheatstone bridge.

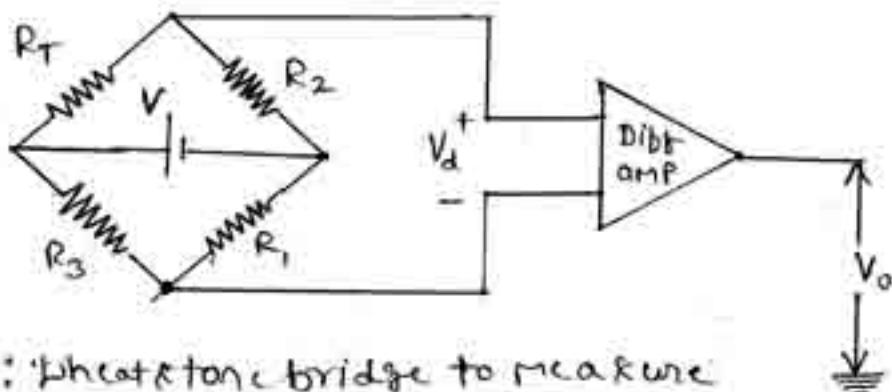


Fig ⑤: Wheatstone bridge to measure
change in R_T

When R_T changes due to change in temperature, the bridge is imbalanced, generating a voltage V_d which is amplified and measured.

- The three main categories of RTD are
 - ① Thin film
 - ② Wire-wound
 - ③ Coiled elements

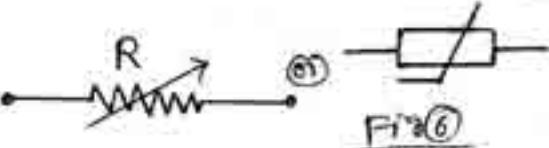
→ Advantages:

- High accuracy
- Excellent stability
- Excellent precision
- Linear temperature-resistance characteristic
- Fast response
- Doesn't require temperature compensation
- Easy install
- Wide operating range
- Low drift

→ Disadvantages:

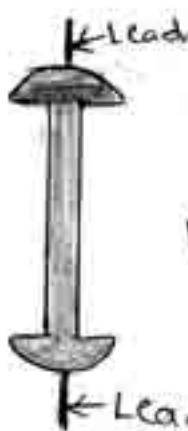
- ① Expensive ② Requires bridge circuit and external power source ③ Possibility of self-heating ④ Large size ⑤ Lower sensitivity ⑥ Tends to drift over time of use

⑤ Thermistor: → Symbol:

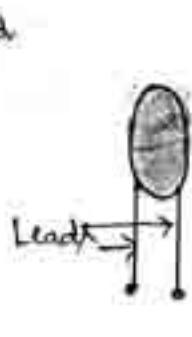


→ Construction:

- Thermistors are made up of oxides of Cobalt, nickel, copper, iron, uranium and manganese.
- Different structures of thermistor are shown in Fig ⑥



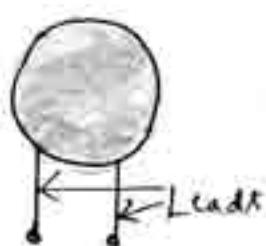
⑥ Rod



⑦ Bead



⑧ Probe



⑨ Disc

Fig ⑥: Different structures of thermistors

- ⑩ Rod: Diameter → 1.25mm - 4.25mm
Length → 12.5mm - 50mm
- ⑪ Bead: Diameter → 0.15mm
- ⑫ probe: Bead with glass coating
- ⑬ Disc: Diameter → 10mm

→ Principle of operation:

→ Thermistor word is derived from THERMALLY SENSITIVE RESISTOR (not metal).

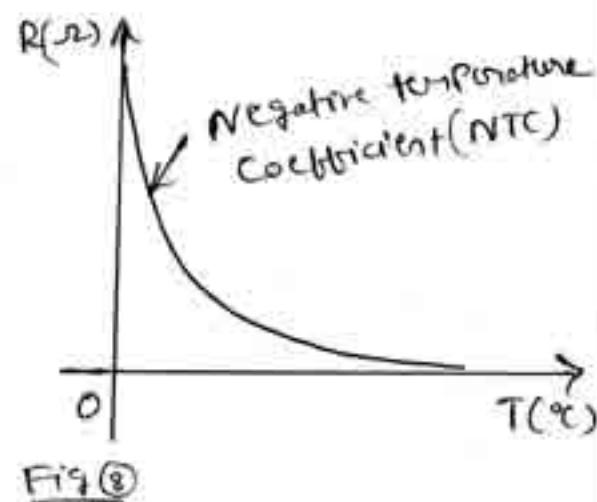
→ Thermistor is a two terminal Semiconductor Slab whose resistance decreases with increase in temperature, unlike a metal. (negative temperature coefficient)

→ Fig(8) Shows the temperature - resistance characteristic of a thermistor.

→ Thermistor has very high NTC (3-5% Per °C)

→ The resistance of the thermistor is (at T(K))

$$R = R_0 e^{\beta \left(\frac{1}{T} - \frac{1}{T_0}\right)} \quad \text{--- (1)}$$



Where, $R_0 \rightarrow$ Resistance at T_0 (K)

$\beta \rightarrow$ Constant to be determined experimentally.

If T is large, then eqn(1) reduces to.

$$R = R_0 e^{\frac{\beta}{T}} \quad \text{--- (2)}$$

→ APPLICATIONS:

- ① Thermistors are used in the measurement of
 - ④ Temperature ⑥ Flow & Pressure ⑤ Liquid level
 - ② Voltage & Power ③ Vacuum ⑦ Thermal conductivity.
- ② It can be used as current Limiting devices for circuit Protection (as replacement for fuses)
- ③ Used as timers
- ④ Used as heater in automotive industry to provide additional heat inside cabin with diesel engine.
- ⑤ Used as temperature compensated Synthesizer Voltage Controlled Oscillators.
- ⑥ Used in consumer appliances (coffee makers, hair dryers etc.)
- ⑦ Military ⑧ Medical electronics etc

→ Advantages

- ① Cost effective (Low cost)
- ② Small size
- ③ Fast response over a narrow temperature range
- ④ Good sensitivity (Sense very small changes in temp.)
- ⑤ Higher accuracy
- ⑥ Rugged
- ⑦ Flexibility in configuration
- ⑧ Chemically stable

→ Disadvantages

- ① Temperature - resistance characteristic is non-linear.
- ② Not suitable for wide temperature range.
- ③ Need of shielded cables due to high resistance.
- ④ Self-heating
- ⑤ Moisture failure (Non-glass only)

Note:

(RTD)

- ① Comparison between Resistance thermometer & thermistor

Parameter	Resistance thermometer	Thermistor
① Principle of operation	Positive temperature of coefficient	Negative temperature of coefficient
② Characteristic	Linear	Non-linear (Exponential)
③ Sensitivity	Medium	High
④ Material	Pure metals (Platinum, copper & Nickel)	Ceramic & Polymer (Copper, iron, manganese etc.)
⑤ Temperature range	Large (-200 to 650°C)	Limited (-100 to 325°C)
⑥ Accuracy	High	Moderate
⑦ Cost	High	Low

⑧ Size	Large	Small
⑨ Response Speed	High	High over a narrow temperature range
⑩ Type	Passive	Passive
⑪ Power required	Constant Voltage @ Current	Constant Voltage @ Current
⑫ Self-heating	No (Possibility Low)	Yes
⑬ Rugged	No	Yes
⑭ Packages	Not Flexible	Flexible

② Important Parameters

- ⑤ Time constant: Time for resistance to fall from final value to 63% of the final value (Range: 1-50s)
- ⑥ Dissipation factor: Power dissipated in Watt / $^{\circ}\text{C}$ temperature (Range : 1-10mW/ $^{\circ}\text{C}$)
- ⑦ Resistance ratio: Ratio of the resistance at 20°C to resistance at 125°C (Range: 3-60)

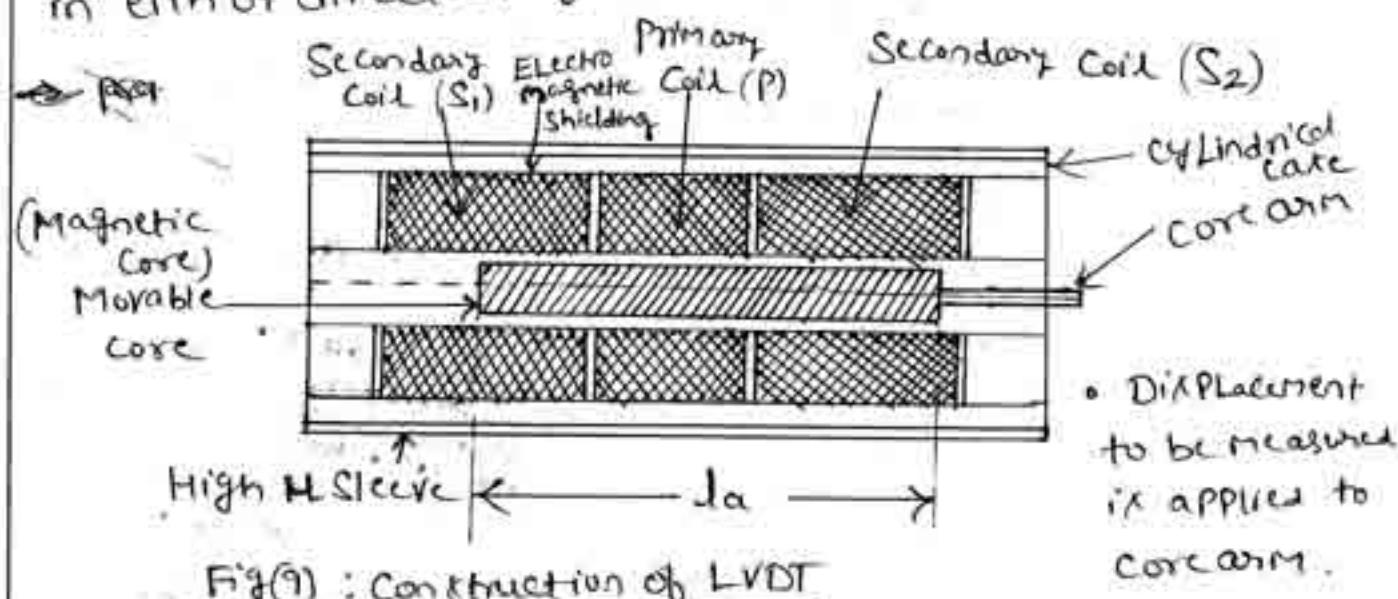
③ Inductive transducer:

LVDT (Linear Variable Differential Transformer):

- LVDT works under the principle of mutual induction
- LVDT is a type of inductive transducer (electrical transformer) used for measuring displacement. (non-electrical energy (displacement) is converted into an electrical energy)
- Here the inductance is varied according to the physical quantity to be measured (measured) @ displacement

Construction: Fig 9)

- LVDT consists of a primary coil (P), uniformly wound over a certain length of the plastic cylindrical former and two identical secondary coils symmetrically wound on either side of the primary coil and away from the centre.
- The secondary coils are connected in series but in phase opposition so that the output voltage will be difference between the individual voltages (V_1 & V_2) induced in the secondary coils (hence the name differential transformer).
- A soft iron core (ferrite rod) is kept inside the plastic former & is free to move inside the former in either direction from the central (null) position.



Fig(9) : Construction of LVDT

Principle of Operation (Working) :

- When an AC Voltage (50 Hz to 20 kHz) is applied to the primary coil, an alternating magnetic field is induced, which in turn induces voltage (emf) in the secondary coils whose value depends on the core position.
- Let us consider three cases:

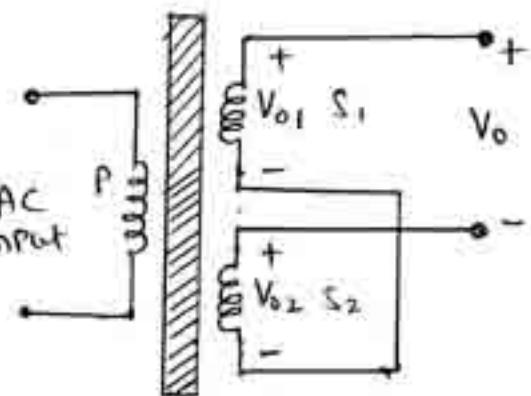
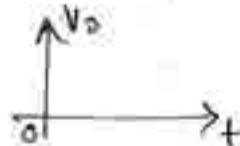
Case 1: (Fig 10)

The induced Voltages (EMF) in Secondary Windings are equal. ($V_{o1} = V_{o2}$)

∴ Output Voltage V_o is,

$$V_o = V_{o1} - V_{o2}$$

$$\boxed{V_o = 0}$$



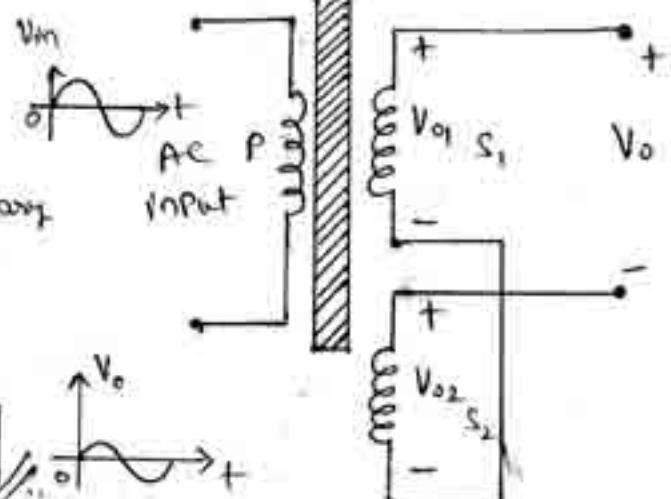
Fig(10): Core in Centre Position

Case 2: (Fig 11)

The Induced voltage (EMF) in Secondary Coil (S₁) is greater than EMF in Secondary Coil (S₂). ($V_{o1} > V_{o2}$)

∴ Output Voltage V_o is,

$$V_o = V_{o1} - V_{o2} \text{ (Positive)}$$



Case 3: (Fig 12)

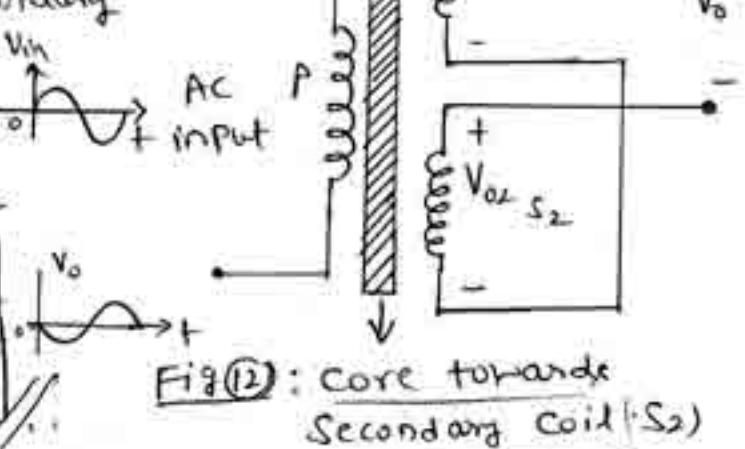
The Induced Voltage (EMF) in Secondary Coil (S₂) is greater than EMF in Secondary Coil (S₁). ($V_{o2} > V_{o1}$)

∴ Output Voltage V_o is,

$$V_o = V_{o2} - V_{o1} \text{ (Positive)}$$

(*)

$$V_o = V_{o1} - V_{o2} \text{ (negative)}$$



Fig(12): Core towards Secondary Coil (S₂)

- The transfer characteristic of LVDT is shown in fig(13)

→ Applications :

- ① Used to measure force.
- ② Used to measure height.
- ③ Used to measure pressure.
- ④ Used to measure Velocity, acceleration.
- ⑤ Sensing vibrations.
- ⑥ Used in all applications where displacement ranging from fraction millimeter to centimeter.

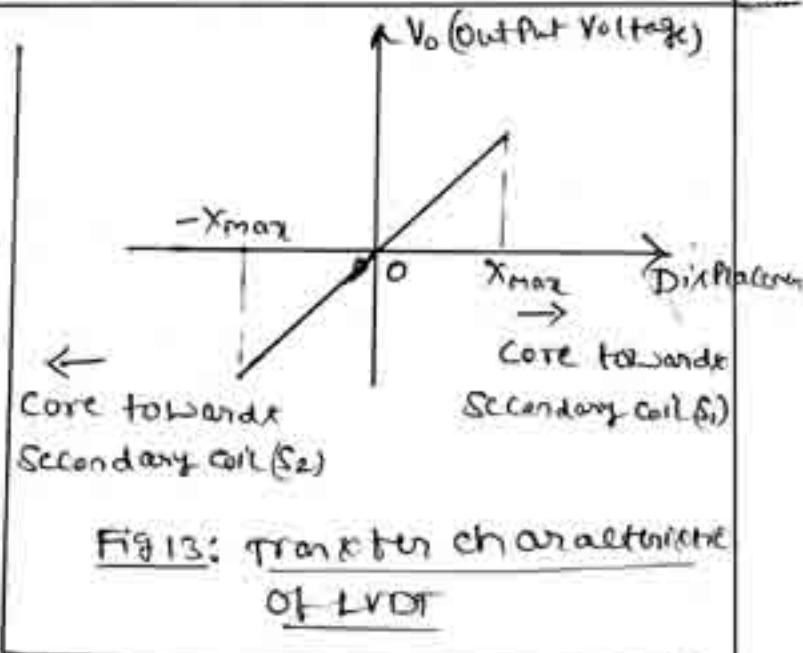


Fig 13: Transfer characteristic of LVDT

→ Advantages :

- ① Infinite resolution
- ② Linear
- ③ High output
- ④ High sensitivity
- ⑤ Ruggedness
- ⑥ Less friction (less wear & tear)
- ⑦ Low power consumption
- ⑧ Low hysteresis
- ⑨ Good dynamic range
- ⑩ Relatively low cost
- ⑪ Robust
- ⑫ Short response time
- ⑬ No permanent damage (Exceed the designed range)

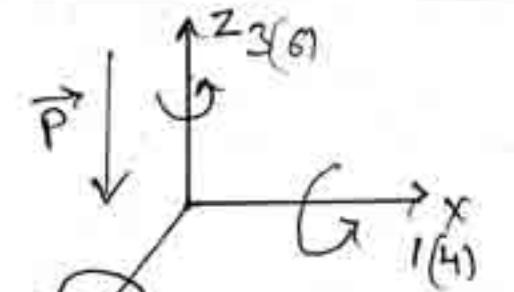
→ Disadvantages :

- ① Very high displacement is required for generating high voltages.
- ② Sensitive to magnetic field (shielding is required).
- ③ Performance is affected by vibrations.
- ④ Erroneously affected by temperature changes.
- ⑤ It can only run at speeds up to ≈ 10 % of the excitation frequency (input).

* Active Electrical transducer :

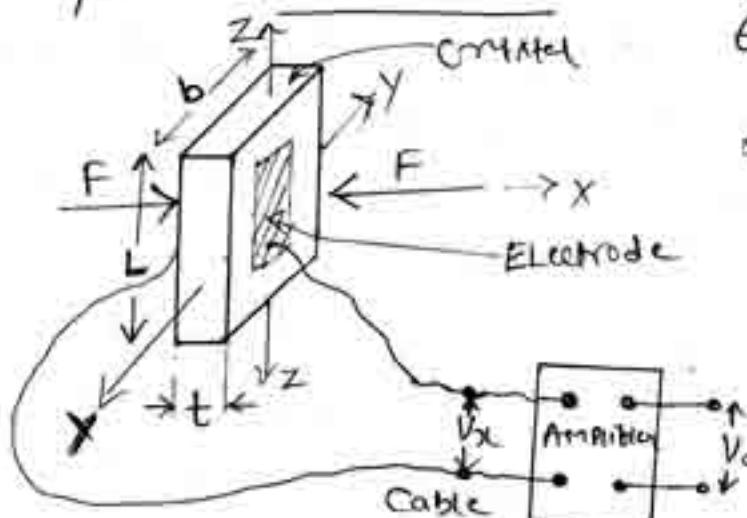
- ① Piezoelectric transducer : → Construction & Operation

* The ability of certain materials (Cry & Etal & certain Ceramics)



#	Axis
1	X
2	Y
3	Z
4	Shear around X
5	Shear around Y
6	Shear around Z

* ELECTRIC POLARIZATION \vec{P}
 $\vec{P} = P_{xx}\hat{x} + P_{yy}\hat{y} + P_{zz}\hat{z}$



* The output voltage V_o is

$$V_o = \frac{g + F}{A} \text{ (Volts)}$$

$$\text{Where } g = \frac{K}{t} \quad [g = \frac{C}{t}]$$

$g \rightarrow$ Voltage sensitivity (Vm/N)

$F \rightarrow$ Force (N)

$P \rightarrow$ Pressure (F/A) (Nm⁻²)

$A \rightarrow$ Area of crystal (m²)

$t \rightarrow$ Thickness of the crystal (m)

$K \rightarrow$ Piezoelectric constant

(1) High frequency response

(2) Small size

(3) High output

(4) Light weight

(5) Simple signal conditioning

(6) Negligible phase shift

(7) High mechanical rigidity (Rugged)

(8) Linearity

(9) Low leakage

(10) High sensitivity

(11) Wide measuring range

(12) Ultra noise

(13) Reliable & robust

(14) Unaffected by

exterior EM fields

(15) Polarity sensitive

→ Disadvantages:

(1) Cannot measure static conditions

(2) Output affected by temp. changes.

(3) Output affected by Long use

or high temperatures

- to produce electric charges (which in turn produces potential @ voltage) when mechanical stress is applied across them it called Piezo electric effect \oplus
- Piezoelectricity i.e. such crystals (material) are called Piezoelectric crystals (Piezo electric transducers) (Converts mechanical energy into electrical energy)
- * The Piezoelectric effect is reversible, i.e. conversely, if a varying potential is applied to crystal, it will change the dimensions of the crystal.
 - * Voltage depends on the magnitude & direction of force applied to crystal.
 - * Materials exhibiting the Piezoelectric Phenomenon are Quartz, Rochelle salt, tourmaline, Ammonium Dihydrogen Phosphate (ADP), Lithium Sulphate (LS) & Di Potassium Tartrate (DKT) etc
 - * The word Piezo- is derived from the Greek word 'Piezen', which means to Squeeze \oplus Press.
 - * Types of Piezoelectric material \leftarrow tourmaline
 - ① Natural crystals (Ex: Quartz, rochelle salt)
 - ② Synthetic Crystals (Ex: Lithium Phosphate)
 - ③ Ferroelectric Ceramics (Ex: Barium titanate)
 - * Based on the direction of force applied, there are three modes of operation.
 - ① Thickness Expander mode
 - ② Length Expander mode
 - ③ Volume Expander mode
 - * Fig(14) shows Piezoelectric transducer.

→ Applications

- ① It is used to measure force, pressure, acceleration, torque, strain & amplitude of vibration.
- ② Used in ③ Aircraft flight test ④ Generation of ultrasonic frequencies ⑤ Gas lighters ⑥ Electronic cigarette lighters ⑦ Aero-space ⑧ Medicine ⑨ Industry ⑩ Microphones (ii) Actuator

② Photo electric transducer:

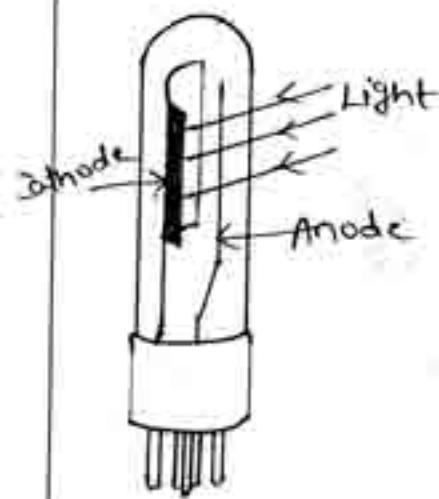
→ Construction & Working

* If light is incident on a metal surface, the entire quantum energy is converted into kinetic energy of the electron & helps the electron to move & contribute current in the metal. This is called Photoelectric effect.

* According to operating principle, Photoelectric transducers may be grouped as follows.

- ① Photoemissive ② Photo Voltaic ③ Photo conductive (resistive)

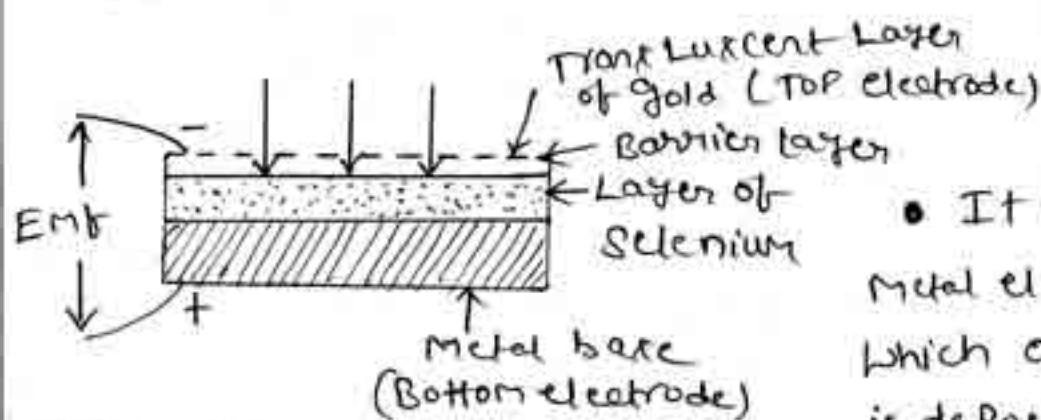
* Photoemissive cell (Photoemissive transducer) (Photo tube)



Fig(15): Photoemissive cell

- It consists of semi-cylindrical ② V-shaped electrode (cathode) coated with a photo emissive material and an anode (thin wire), both enclosed in an evacuated glass bulb (Fig 15).
- When the light falls on the cathode, electrons are emitted and are attracted by the anode & hence current flows.
- Current depends on (i) Intensity of incident radiation & (ii) Anode - Cathode Voltage.

* Photo Voltaic cell (Solar cell)



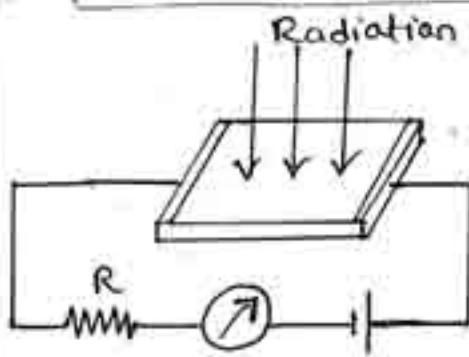
Fig(6): Photo Voltaic (Selenium) transducer

- It consists of a metal electrode (bottom) on which a layer of Selenium is deposited, on the top of this a barrier layer is formed which is coated with a very thin layer of gold. (Fig 16)

- When light falls on Semiconductor (Selenium), a potential (Voltage) is generated.

* Photo Conductive cell @ Photo resistive cell : ②

Light Dependent Resistor (LDR)



Fig(7): Photo Conductive transducer

- It consists of Semiconductor Material (Like Selenium, Cadmium Sulphide, Lead Sulphide and Thallium Sulphide) with two electrodes.

- When the light is illuminated on Semiconductor Material, its resistance decreases so current through the circuit increases.

→ Advantages

- ① Low cost
- ② Fast response
- ③ Sensitivity
- ④ Energy conversion efficient

→ Disadvantages

- ① Incident light must have enough energy to impart to electron

→ APPLICATIONS

① Photo-emissive cell

- ④ Photometry & Colorimetry
- ⑤ Sound reproduction from a motion-picture film
- ⑥ On & off circuits
- ⑦ Automatic opening of door
- ⑧ Sorting of objects on a conveyor belt.

② Photo-Voltaic cell

- ① Automatic control systems
- ② Television circuits
- ③ Sound motion picture and reproducing equipment.
- ④ Solar vehicles, solar lamps
- ⑤ Space crafts.

③ Photo-conductive cell

- ① Detection of ships & aircrafts
- ② Telephony by modulated infrared lights
- ③ Optical communication systems
- ④ Object counting in industry.

④ Thermoelectric transducer

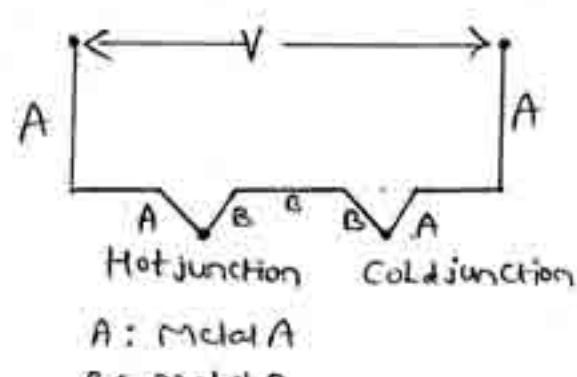
⑤ Thermo Coupler

→ It converts thermal energy into electrical energy or vice versa.

→ It consists of two wires of different metals joined together to form two junctions as shown in fig①.

→ One of the two junctions is called the hot junction & the other is cold junction (reference junction)

→ There are four physical effects that contribute to the output voltage of the thermo couple.



Fig①: Thermo couple

- (a) Seebeck effect
 (b) Peltier effect
 (c) Thomson effect
 (d) Joule heating → Irreversible thermo-electric effect
- } Thermodynamically reversible effects

(a) Seebeck effect:

→ It is the conversion of heat directly into electricity at the junction of different types of wire (at different temperatures)

→ In 1821, the German physicist Thomas Johann Seebeck discovered that a compass needle would be deflected by a closed loop formed by two different metals joined in two places, with a temperature difference between the joints (because of magnetic field)

→ Emf is given by, $E_{\text{ent}} = -S \nabla T$

Where, $S \rightarrow$ Seebeck effect @ Thermo power (-100 $\mu\text{V/K}$ to 1,000 $\mu\text{V/K}$)
 $\nabla T \rightarrow$ Gradient in temperature

(b) Peltier effect:

→ It is the reverse phenomenon of Seebeck effect

→ It is the conversion of electricity into heat (or cool)

→ The amount of heat liberated @ absorbed is proportional to the quantity of current that crosses the junction.

→ The amount of heat liberated @ absorbed when one ampere passes for a second is called the Peltier coefficient

→ Peltier heat generated at the junction per unit time is

$$\dot{Q} = (\Pi_A - \Pi_B) I$$

Where $\Pi_A (\Pi_B) \rightarrow$ Peltier Coefficient of conductor A (B)
 $I \rightarrow$ Electric current (from A to B)

② Thomson effect :

- It is also the reverse phenomenon of Seebeck effect.
- It is the conversion of electricity into heat
- Ex: When a current flows through a copper conductor, having thermal gradient (temperature difference) along its length, heat is liberated at any point where the current is in the same direction as the heat flow, while heat is absorbed at any point when the current flows in the direction opposite to the flow of heat.
- Heat Production rate per unit Volume.

$$\dot{Q} = -K J \cdot \nabla T$$

$K \rightarrow$ Thomson coefficient

$\nabla T \rightarrow$ Temperature gradient

$J \rightarrow$ Current density.

- First Thomson relation is,

$$K = \frac{d\pi}{dT} - S$$

APPLICATIONS OF THERMOCOUPLE

Steel industry, gas-bed heating,

Thermoelectric refrigerator

Generator, Measurement of
temperature and radiation.

③ Tower heating:

- It is irreversible thermoelectric effect.
- Heat is generated whenever a current is passed through a resistive material.
- The electric current I is transformed into heat P according to,

$$P = R I^2$$

where, $P \rightarrow$ Power (W)

$R \rightarrow$ Electrical resistance of the conductor (Ω)

$I \rightarrow$ Electric current (A).

Problem

- ① In a linear Voltage differential transformer (LVDT) the output voltage is 1.8V at maximum displacement. At a certain load the deviation from linearity is maximum and is $\pm 0.0045V$ from a straight line through the origin. Find the linearity at the given load.

Sol: Given $V_o = 1.8V$, $\Delta V = \pm 0.0045V$

$$\therefore \text{Linearity} = \frac{\Delta V}{V_o} = \frac{\pm 0.0045}{1.8} = \pm 0.0025 = \underline{\underline{\pm 0.25\%}}$$

- ② A piezoelectric crystal measuring $6\text{mm} \times 6\text{mm} \times 1.8\text{mm}$ is used to measure force. Its voltage sensitivity is 0.055V/mm/N . Calculate the force if voltage developed is 120V.

Sol: Given $A = 6\text{mm} \times 6\text{mm}$, $t = 1.8\text{mm}$,

$$g = 0.055\text{V/mm/N}$$
, $V_o = 120\text{V}$

$$\text{Plot } V_o = gtP$$

$$\Rightarrow P = \frac{V_o}{gt} = \frac{120}{0.055 \times 1.8 \times 10^{-3}} = \underline{\underline{1.212 \text{ MN/m}^2}}$$

$$\therefore \text{Force, } F = PA = 1.212 \times 10^6 \times 8 \times 10^{-3} \times 6 \times 10^{-3}$$

$$F = \underline{\underline{43.63\text{N}}}$$