# MODULE : II

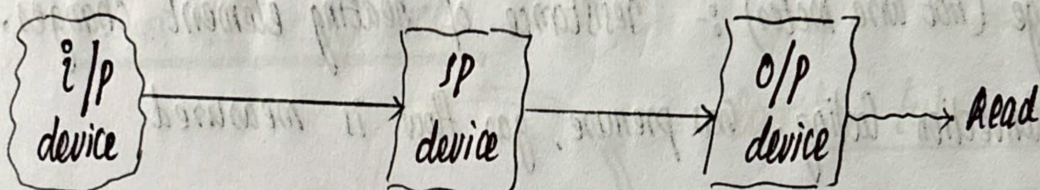
## TRANSDUCER :-

A device which Converts a form of energy to other, when it actuates.

* Electrical transducers :- Physical quantity & non-electrical quant.y ⟶ Electrical qnty.

Advantages of electrical transducers :- Converts physical / non-electrical qnty to electrical qty

→ Why we have electronic Instruments




→ i/p : electrical signal

Pu ↓
* Amplif"
* Attenuat"
* Modulation

} form suitable for o/p device.

Advantages :-
i) easy signal processing
ii) mass inertia is negligible (only mobile part is electrons) - no friction
iii) miniaturisation [using IC chips - Compatability, Portability]
IV) Telemetry :- fast transmission of information
V) very low power level.

## CLASSIFICATION

Main elements :-
- Primery sensing element.
- transduction element.

Auxilary elements

## (1) Based on transduction principle :-

ⓐ Resistance :- • non-electrical qnty is transmitted as resistence / change in resistance

- Potentiometer device : Positioning of a slider by external forces vary resistance. force and displacement is measured using potentiometer.

- Resistance strain gauge :- force/strain applied to the strain gauge points Δ resist. force, torque and displacement is measured

- Pirani gauge (Hot wire meter) :- resistance of heating element changes, by convection cooling. Gas pressure, gas flow is measured

- Resist. thermometer :- for +ve temp. coeff materials (+ve $\alpha$), temperature changes resistance. Temp. measurement.

- Resist. Hydrometer :- resistance changes with moist content. Humidity meas't.

- Photo conductive cell :- incident light changes resistance of P.C material. Application in photosensitive relay.

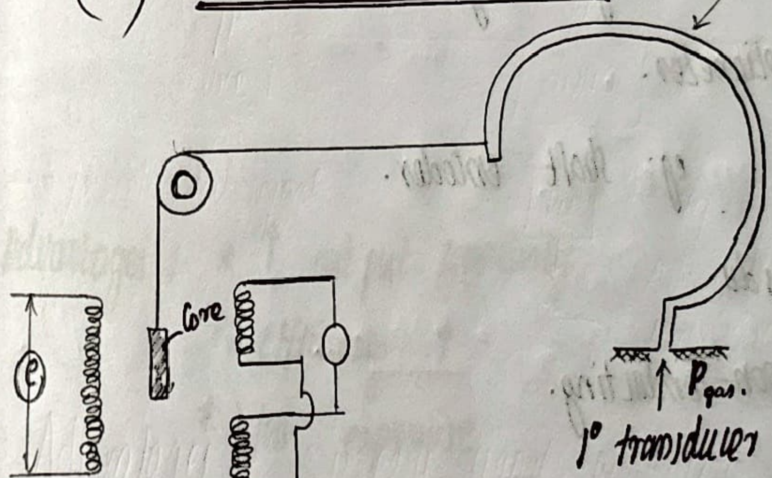
ⓑ Capacitive transductor :- $C = \frac{A \epsilon_0 \epsilon_r}{d}$

| Device | Principle | Application |
|---|---|---|
| Variable capacitance pressure gauge | capacitance of a $\parallel^{el}$ plate capacitor changes | Displacement & pressure. |
| Capacitor microphone | Capacit. of a movable diaphragm changes | Speech / Noise. |
| Dielectric Gauge | Variation of capacitance by dielectric medium | Liquid level, thickness |

## (c) Inductive transduction :-

| Device | Principle | application. |
|---|---|---|
| Magnetic ckt transducer | self or mutual induction changes by changing magnetic flux. | Pressure or displacement. |
| Reluctance pick up | By changing reluctance | Press., displa, vibration |
| Diffrential transformer | change in position of Core | Press., disp, position. |
| Eddy Current gauge | change in eddy Current change the inductan. | force, displacement. |
| Magnetostriction gauge | change in m.f | force, torque |

## (II) 1° or 2° transducer



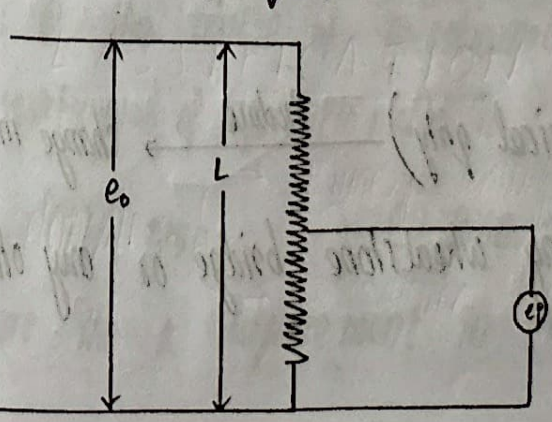
2° transducer.

**Bourdon tube pressure system :-**

* input physical qnty is Converted to a displacement.
* in the Curved part, As pressure increases tube straightens Cause a displacement
* The advanced setups like transformer Converts displacement to electrical signal.

## (III) Passive & active transducer.

- Derive power required for transduction form an ~~ex~~ auxillary power source. these are externally powerd. Eg: potentiometer.

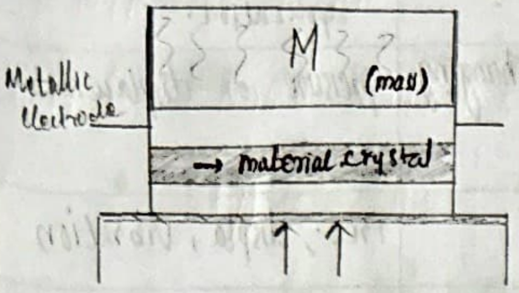



$$e_0 = \frac{x_i}{L} e_i$$

$$x_i = \frac{L e_0}{e_i}$$

A passive transducer.

Active transducer : Eg: Piezo electric material:




* the property of piezo electric crystal is when a force applied to it produce an output voltage. The mass exert a certain force due to the accl$^n$, due to which the voltage is generated.

The mass being fixed, force $\propto$ accl$^n$ ⇒ output voltage $\propto$ force $\propto$ accl$^n$.

## IV) Analog & Digital Transducer.

Analog: Produce an analog o/p signal. Continuously varing with time.

eg: Potentiometer.

Digital: Produce digital o/p or pulses. eg: shaft encoder.

opaque and transdu

Photo conducting and non-Conducting.

## TRANSDUCER & INVERCE TRANSDUCER

Inverse transducer: electrical ⟶ non-electrical. (Mechanical or.....)

eg: Piezoelectric crystal (voltage ⟶ mech. vibrations).

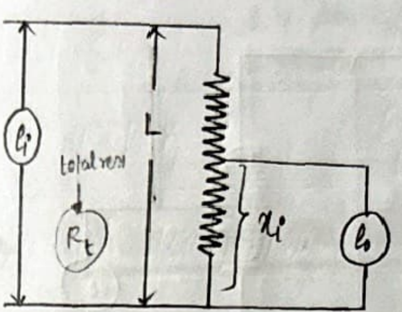
# RESISTIVE TRANSDUCER

* Any environmental change (Application of physical qnty) $\xrightarrow{\text{Produce}}$ change in resistance

This change in resistance is measured using wheatstone bridge or any other analogous method.

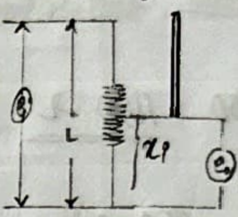
* Resistance of an element :- $R = \rho l / A$.

Eg: Potentiometer :-




$x_i = L \frac{e_o}{e_i}$

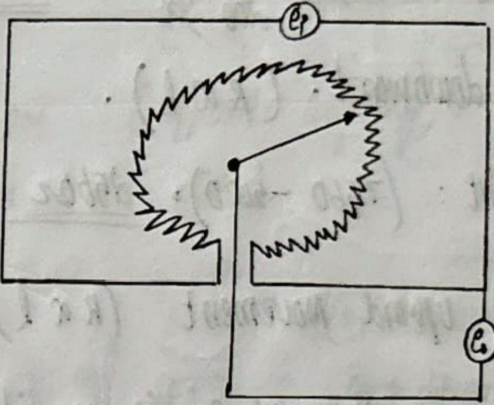
* Measuring translational movement :-




→ Called POT

① Rotational movement measurement :-

($10° \longrightarrow 60°$)




Advantages :- * ↑ output sensitivity
* efficiency ↑
* less expensive
* Variable shapes
* Rugged Construction
* Fast response

disadvantage : * wear & tear.
- less lifespan.

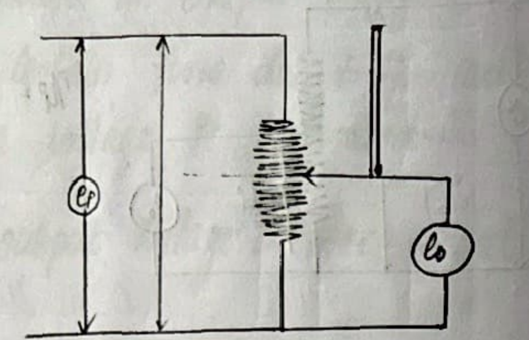
Qn: A linear resistance potentiometer is 50 mm long & is uniformly wound with a wire having resistance of 10000 Ω. At the normal Condition, the slider is @ the Centre of potentiometer. Find the linear displacement when the resistance of potentiometer is measured by a Wheat stone bridge

(i) 3850 Ω (ii) 7560 Ω

are the 2 displacement in the same dir? If it is possible to measure a minimum value of $10\Omega$ resist. with this arrangement. Find resolution of potentiometer in mm.

Ans :- Normal resistance = $5000\,\Omega$ (slider @ centre).

$$R/l = \frac{10000}{50} = 200\,\Omega\,mm^{-1}$$



(i) change in resist. = $5000 - 3850 = 1150\,\Omega$

$$x\ (\text{dist. moved}) = \frac{1150\,\Omega}{200\,\Omega}\,mm = 5.75\,mm$$

movement is downward. ($R \propto l$).

(ii) change in resist : $(7560 - 5000) = 2560\,\Omega$ → $x_{moved} = \left(\frac{2560\,\Omega}{200\,\Omega}\,mm\right) = 12.8\,mm$.

upward movement ($R \propto l$).

ie direction of movement is in opposite dir$^n$.

$\frac{10000}{50} = 200\,\Omega$

$10\,\Omega \rightarrow$

(c) $50\,mm \longrightarrow 10000\,\Omega$ ; $1\,mm \longrightarrow \frac{10000}{50}\,\Omega$ $\Big\}$ Resol$^n$ = $10 \times \frac{1}{200} = .05\,mm$. (for $10\Omega$ resist$^n$).

## INDUCTIVE TRANSDUCER

* Self inductance or mutual inductance changes on applic$^n$ of the physical qnty. Here formation of eddy current occurs.

• Self inductance : $L = \frac{\mu_0 N^2 A}{l} = \mu_0 N^2 G$.

From eq$^n$ : It may be of 3 types (Δ self induct.) → change in permeab. → change → change

$$L = \frac{N^2}{S} = N^2 \frac{\mu_0 A}{l} = N^2 \mu_0 G \quad (G = \text{geometric factor}).$$

* using inductive transducer: we can measure displacement.
* During measurement, Differential o/p inductive transducer

$\left.\begin{matrix} L+\Delta L \\ L-\Delta L \end{matrix}\right\}$ diffrence : $2\Delta L$ ⟶ Accuracy & sensitivity ↑

external MF effect, Variation with temp & Vol. frequency ↓

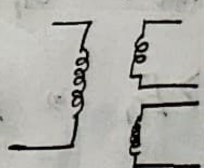
→ <u>Change in mutual inductance.</u> 8

$M = K\sqrt{L_1 L_2}$ · change $\left\langle \begin{matrix} \text{changing "L"} \\ \text{changing "K"} \end{matrix}\right.$

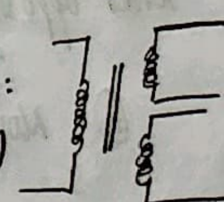
Composite Coupling: $L_1 + L_2 - 2M$ (opposite coupling).

$L_1 + L_2 + 2M$ ( aided

transducer can be : ① Air Cored: (Self inductance do not change unless )



⑪ Iron Cored: ($\mu$ is not const.)

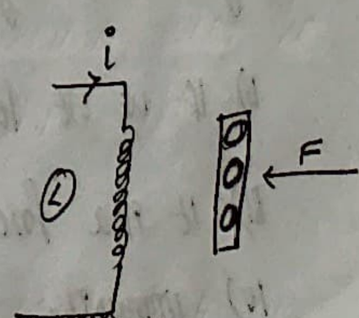


· Air : $\mu_0$ is Const
Not dependent on supply Volt. frequency.
L of the coil const.

Iron : $\mu$ not constant
dependant on supply Volt. freq.
L changes.

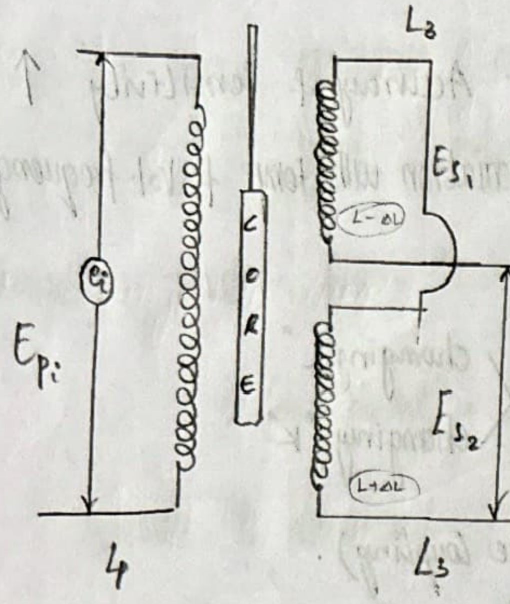
Advantages of Iron cored transducer. Reduce the size
MF Can be Confined in the core
external MF do not affect

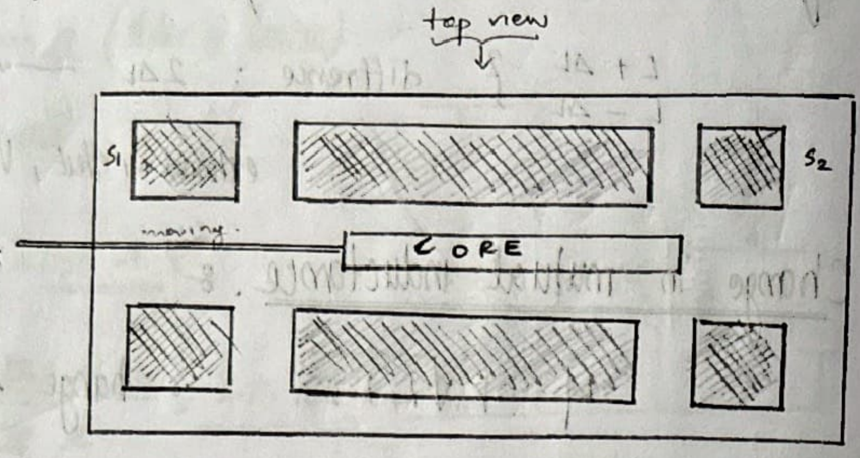
→ <u>Formation of eddy Current:</u>




· Conducting plate is movable. Apply force on that plate, Short ckted secondary M.F by eddy current oppose the MF of the coil. Eddy M.F current. change in L.

# LINEAR VARIABLE DIFFERENTIAL TRANSDUCER (LVDT)



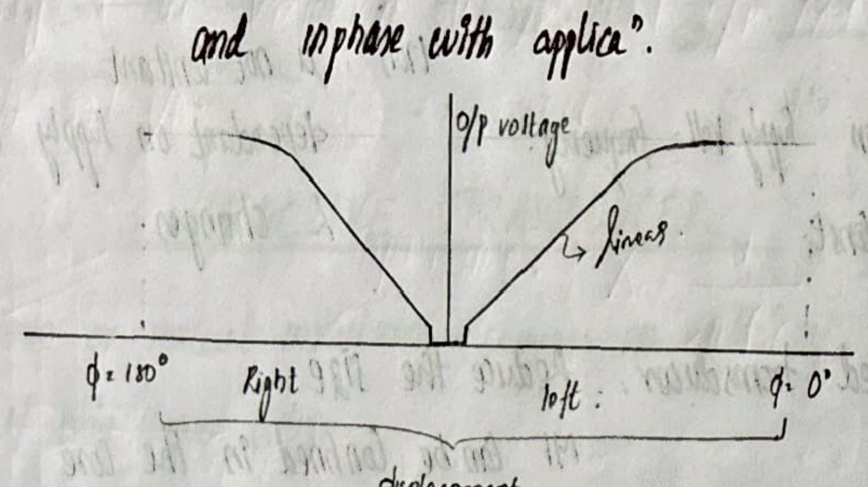

$$E_0 = E_{s_1} - E_{s_2}$$

- Series opposition: (i) Null : $E_{s_1} = E_{s_2} \rightarrow E_0 = 0$

(ii) Moving right : $E_{s_2} > E_{s_1} \Rightarrow E_0 = E_{s_1} - E_{s_2}$ (180° phase diff. with applicaⁿ)

(iii) Moving left : Core towards $S_1$ : $E_{s_1} > E_{s_2}$ $E_0 = E_{s_1} - E_s$

and inphase with applicaⁿ.




diamond hills apartment, Manassery (PO) Mukkom, Kkd

Advantages- i) very high range of measurement of displacement (1·25 mm → 250 mm)

ii) If we use full scale linearity, we can measure up to ·0003 mm

iii) It is a frictionless device with electrical isolation.

iv) immunity from external efforts. (seperation from LVDT, Coils & Core permits the isolation of media such as pressuraised, Corrosive for harmful fluids from the Coil assembly by a know magnetic barrier intercorsed b/w Core & Coil).

v) High o/p ~~ef~~ and high sensitive

vi) low power Consumption

DISADVANTAGES

→ For applicable differentiable output, relatively large output is required.

→ Magnetic shield is req. to avoid stray mag. field.

→ Performance is affected by vibration

→ operates on AC (Dynamic response is limited mechanically by mass of core).

→ Temperature affects performance of transducer.

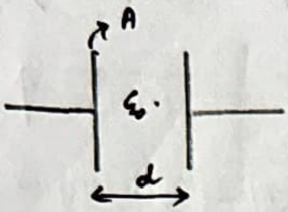
Applications :- * In applications where displacement varies from fraction of mm to few C.m.

* Converts mechanical qnty. to electrical qnty for all process based measts.

* Act as secondary transducer to measure force, wt & pressure etc.

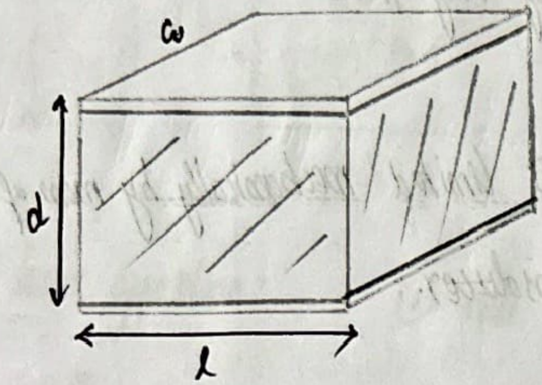
Qn: * The output of an LVDT is connected to a 5V Voltmeter, from an amplifier whose amplifing factor is 250. An o/p of 2 mv, appears accross the terminals of LVDT, when core moves a distance of 0.5 mm. Calculate the sensitivity of LVDT & that of whole sector. The mVolt meter has 100 division and scale can be 1/5 . Calculate the resolution of instrument in mm

# CAPACITIEVE TRANSDUCER :

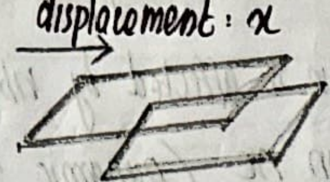



$C = \frac{A\varepsilon_0}{d} \cdot \varepsilon_r$

① **Change in area :-**

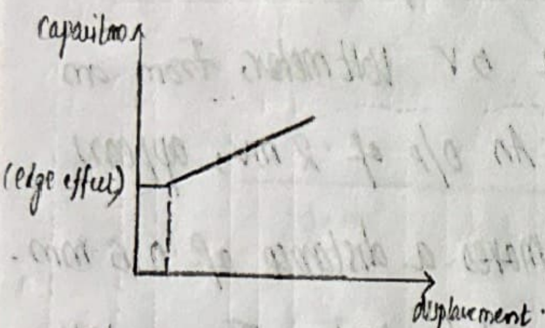



$\Rightarrow$




$C = \frac{A\varepsilon}{d} = \frac{[wx]\varepsilon}{d}$ , Sensityvity Const : $S = \frac{\partial C}{\partial x} = \frac{\varepsilon w}{d}$

- Sensitivity is the variation of o/p w.r.t i/p. And linear relationship b/w o/p and i/p.



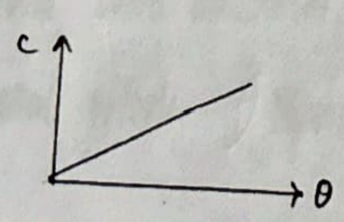

Capacitance : $X_c = \frac{1}{2\pi f C}$

- Angular displacement :

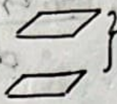
$C = \frac{A\varepsilon}{d} = \frac{A\,\pi r^2}{2d}$ , $C = \frac{\varepsilon\,\theta r^2}{2d}$

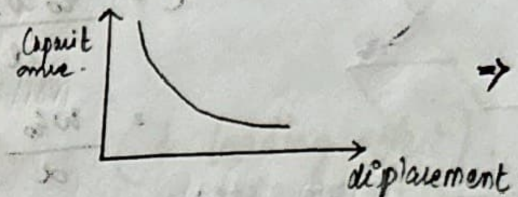
Here also : $S = \frac{\partial C}{\partial x} = \frac{\varepsilon r^2}{2d}$ (d = distance b/w plates).

linear relationship



## ⑪ Change in "d"

- for $\parallel^{el}$ plate capacitor: $C \propto 1/d$ . Here $S = \frac{\partial C}{\partial x} = \frac{-A\varepsilon}{d^2}$
- So if  $\} d$

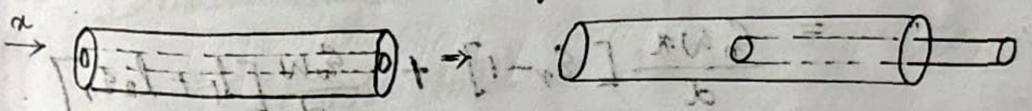



→ Non-linear relationship b/w o/p and i/p.

- since it is non-linear: Suitable for measuring small displacement.

## DIFFERENTIAL CAPACITIVE TRANSDUCER

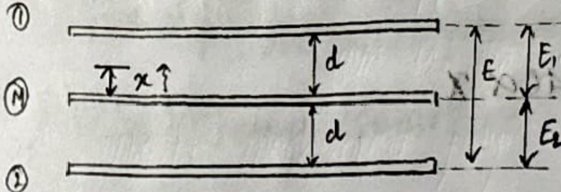
* $D_1$ = inner dia. of outer cylinder, $D_2$ = outer dia. of inner cylinder.




cylindrical capacitor

$$C = \frac{2\pi\varepsilon x}{\log(D_2/D_1)}$$

*




$$C_1 = C_2 = \frac{A\varepsilon}{d}$$

$$E_1 = E_2 = E/2$$

- when we apply a $x$ displacement, $C_1 = \frac{A\varepsilon}{d-x}$ $C_2 = \frac{A\varepsilon}{d+x}$

From voltage divider rule: $\boxed{E_1 = \frac{C_2 \cdot E}{C_1 + C_2}}$ $\boxed{E_2 = \frac{C_1 E}{C_1 + C_2}}$

$$\frac{A\varepsilon\, E(d^2-x^2)}{(d+x)\, A\varepsilon\, 2d} = \frac{E}{2d}(d-x)$$

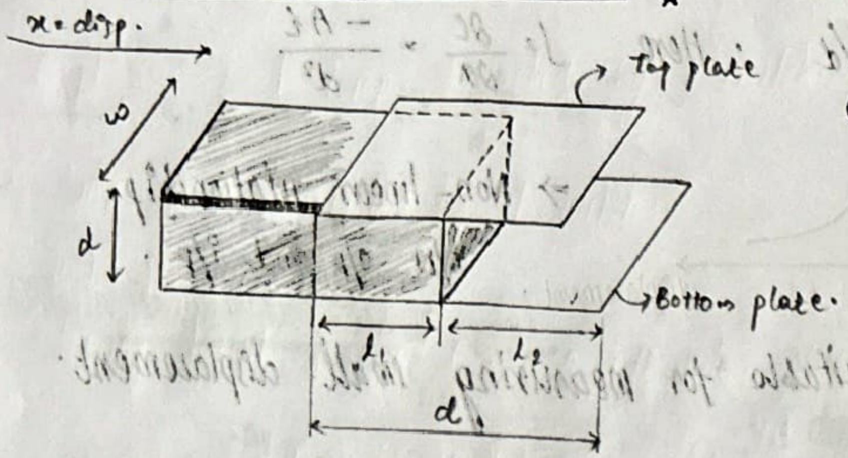
$$E_1 = \frac{E \cdot A\varepsilon/d+x}{A\varepsilon\left[\frac{1}{d-x} + \frac{1}{d+x}\right]} = \frac{E}{2d}[d-x]$$

$$E_2 = \frac{E \cdot A\varepsilon/d-x}{A\varepsilon\left[1/d+x + 1/d-x\right]} = \frac{E}{2d}[d+x]$$

$$\boxed{\Delta E = E_2 - E_1 = \frac{x}{d} \cdot E}$$

$$S = \frac{\Delta E}{x} = \frac{E}{d} \quad \text{(Constant)}$$

## (III) CHANGING DIELECTRIC




$$C = \frac{\varepsilon_0 w l_1}{d} + \frac{\varepsilon_0 \varepsilon_r w l_2}{d}$$

$$= \frac{w\varepsilon_0}{d}\left[l_1 + \varepsilon_r l_2\right]$$

- When applying disp:

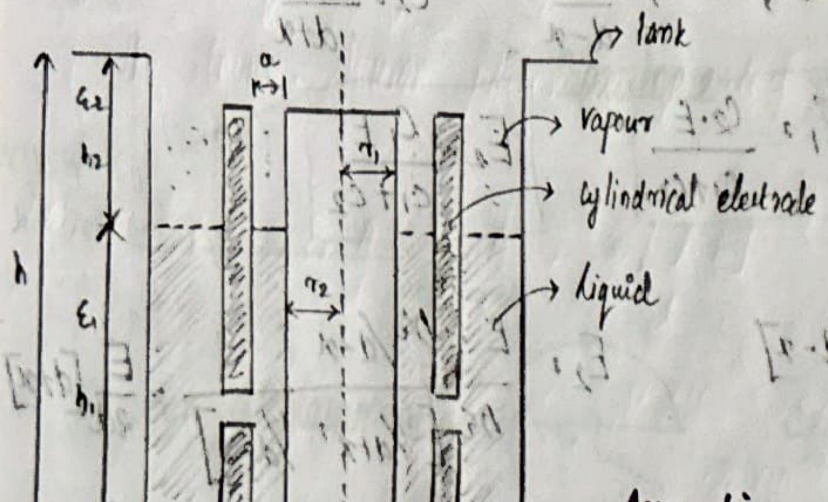
$$C + \Delta C = \frac{\varepsilon_0 w (l_1 - x)}{d} + \frac{\varepsilon_0 \varepsilon_r w (l_2 + x)}{d}$$

$$= \frac{\varepsilon_0 w x}{d}\left[\varepsilon_r - 1\right] + \frac{\varepsilon_0 w}{d}\left[l_1 + l_2 \varepsilon_r\right]$$

$$= \Delta C + C$$

ie $\boxed{\Delta C = \frac{\varepsilon_0 w x}{d}\left[\cancel{\frac{l_1 + \varepsilon_r l_2}{}}\ \varepsilon_r - 1\right]}$ $\Delta C \propto x$

## VARIATION OF DIELECTRIC CONSTANT - LIQUID LEVEL MEASURMENT




$$C = 2\pi\varepsilon_0 \frac{h_1\varepsilon_1 + h_2\varepsilon_2}{\log_e (r_2/r_1)}$$

Assumptions: $h \gg r_2$ & $r_2 \gg r_2 - r_1 \gg a$

$r_2 = r_1 + a$

- Advantages to capacitive transducers :-
  - * very useful for small systems
  - * Highly sensitive
  - * Good freq. responce.
  - * High input impedence (↓ loading effect).
  - * Resolution of order $2.5 \times 10^{-3}$ mm can be obtained.
  - * These can be used for applications where stray mag. fields bar affect, inductive transducers.

→ Disadvantages: * Metallic parts must be insulated from each other.
  - * frames must be earthed to reduce stray capacity.
  - * Shows non-linear relation due to edge effect.
  - * ↑ output impedence cause loading effect.
  - * Temp. sensitive. & Complex ckt systems.

→ * Measurements – force, displacement (angular & linear), humidity & liquid level.

LAB :-

Lab-4th can't operate

Series motor on load cond?

Expt ① : 1 lamp controlled by 1 switch.

Aim: 1 lamp controlled by 1 switch.

Tools & Accessories :

Wiring layout & Cond's on left side. (20 cm

Expt ⑪ : 1 lamp controlled by 2 STDP switch.

Qn:


Figure shows a capacitive transducer including 5 plates and dimension of each plates are 25 X 25 mm and the distance b/w the plates are 0.25 mm. This arrangement is to be used for measurement of displacement by observing change in capacitance in distance $x$. Calculate the sensitivity of the device. Assume plates are seperated by air ($\varepsilon_{air} = 8.85 \times 10^{-12}\ Fm^{-1}$)

Ans:-

$$C = \varepsilon_0 \varepsilon_r \frac{A}{d} = \frac{\varepsilon_0 A}{d} = \frac{\varepsilon_0 [l \cdot b]}{d}$$

$l = 25$ mm

$b = .25 \times 4 = 1$ mm

$$= \frac{8.85 \times 10^{-12} \times 25 \times 10^{-3} \times 10^{-3}}{.25 \times 10^{-3}} \approx 8.85 \times 10^{-13}\ Fm^{-1}$$

$$C' = \frac{\varepsilon_0}{d}(l-x)b$$ and total capacitance $= 4C'$ (4 pairs).

$$\text{Sensitivity} = \frac{\partial C}{\partial x} = \frac{\partial}{\partial x}\left(\frac{\varepsilon_0}{d}(l-x)b\right) = -\frac{\varepsilon_0 b}{d} = \frac{-8.85 \times 10^{-12} \times 10^{-3} \times 25}{.25 \times 10^{-3}}$$

$$= 3540000 \times 10^{-12}$$

Qn: A capacitive transducer uses 2 quartz diaphragm of area 750 seperated by a distance of 3.5 mm. A pressure of 900 KN $m^{-2}$ when applied to the top diaphragm produces a deflection of 0.6 mm. The capacitance is 370 pf when no pressure is applied to the diaphragms. Find the value of capacitance after the application of pressure.

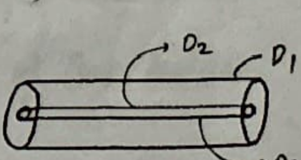
Ans :- $C = \frac{A \epsilon_0}{d}$ ⇒ No pressure ⇒ 370 pf is the capacitance.

$$C' = \frac{A\epsilon_0}{d} = \frac{\epsilon_0}{d'} (A) \cdot 6) \frac{A\epsilon_0}{(d - \cdot 6)}$$

Qn: An capacitive transducer is made up of 2 concentric cylinders. The outer diameter of the inner electrode is 3 mm & dielectric medium is air. The inner diameter or the outer electrode is 3.1 mm. Calculate the dielectric stress when a voltage of 100V is applied across the electrodes. Is it with in some limits. The length of the electrodes is 20 mm. Calculate the change in capacitance if the inner electrode is moved to a distance of 2mm. The break down strength of air is 3kV / mm.

Ans : $D_2 = 3$ mm
$D_1 = 3.1$ mm

length of air gap $= \frac{D_1 - D_2}{2} = 0.05$ mm




⇒ Dielectric stress when application of 100 V $= \frac{100}{0.05} = 2000$ V $mm^{-1}$
$= 2$ kV (Safe limit)

when the cylindrical capacitor moved to a distance $x$, then

$$C' = \frac{2\pi\epsilon_0}{\log(r_2/r_1)} \cdot x = \frac{2\pi \times 8.85\times10^{-12}}{\ln \log(3/3.1)} \times 2\times10^{-3} = \cancel{1809.62\times10^{-15}}$$

$= 4\,pf$ ?

Qn 8- parallel plates of uses plates of $A = 500\ mm^2$, is separated by a distance of 2mm. Calculate the value of capacitance when the dielectric is air.

* calculate the change in capacitance if a linear displacement reduces the distance b/w the plates to 0.18 mm. Also calculate the ratio of per unit change of capacitance to per unit change of displacement.

* Suppose a mica shield of 0.01 mm thick is introduced in the gap calculate the value of original capacitance and change in capacitance for the same displacement.

Ans:-
* $C = \frac{A\epsilon_0}{d} = \frac{500\times10^{-6}\times 8.85\times10^{-12}}{2\times10^{-3}} = 2212.50\times10^{-15} = 22.125\ pf$

* when linear displacement is shown,

$$C = \frac{A\epsilon_0}{d'} = \frac{500\times10^{-6}\times 8.85\times10^{-12}}{.18\times10^{-3}} = 24583.34\times10^{-15}$$

$= 24.584\ pf$

$\Delta C = 24.584 - 22.125 = 2.46\ pf$

ie $\frac{\Delta C/C}{\Delta d/d} = \frac{2.458}{22.125} \Big/ \frac{(0.2 - .18)}{.2} = \underline{\underline{1.111}}$

* when mica sheild introduced,

total : .2 mm
mica : .01 mm
$\varepsilon_{mica} = 8$

$$C'' = \frac{A\varepsilon_0}{\frac{d_1}{\varepsilon_1} + \frac{d_2}{\varepsilon_2}} = \frac{8.85\times10^{-12} \times 500\times10^{-6}}{\left(\frac{.19}{1} + \frac{.01}{8}\right)\times10^{-3}}$$

$$= 23.137 \text{ pf}.$$

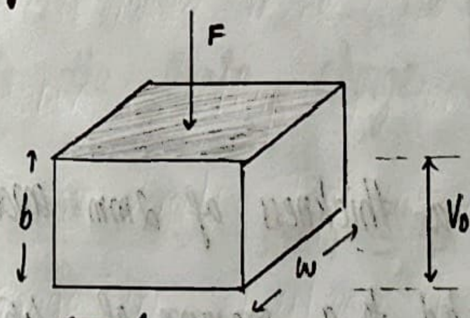
displacement of 0.02 mm ⇒ total : ((0.2 − 0.01) − 0.02) = .17 mm
mica : .01 mm

$$C''' = \frac{8.85\times10^{-12} \times 500\times10^{-6}}{\left(\frac{.17}{1} + \frac{.01}{8}\right)\times10^{-3}} = 25.839 \text{ pf}.$$

Here $\Delta C = 25.839 - 23.137 = \underline{2.702 \text{ pf}}$.

## PIEZOELECTRIC TRANSDUCER.

- Piezoelectric effect is reversible and most common piezo electric material is quarts crystal.




$$V_0 = \frac{Q_0}{C}$$

$Q \propto F$

$Q = j \times F$

where $j$ = charge sensitivity (Property of materi)
= C/N

Also $F = \frac{AY}{t}\Delta t$ where Y = Youngs modulous, $\Delta t$ = change in thickness
t = thickness, A = Area of Cross Section.

$Q = j \cdot \frac{AY}{t}\Delta t$ and $C = \frac{\varepsilon_0 \varepsilon_r A}{t}$

* lattic of a material is responsible for charge sensitivity.

ie $V_0 = \frac{Q}{C} = \frac{g\frac{AY}{t}\Delta t}{\epsilon_0\epsilon_r A/t} = \frac{gY\Delta t}{\epsilon_0\epsilon_r}$

$$\boxed{V_0 = \frac{gY\Delta t}{\epsilon_0\epsilon_r}}$$

in other way :- $V_0 = \frac{Q}{C} = \frac{g \times F \; t}{\epsilon_0\epsilon_r A} = \frac{g}{\epsilon_0\epsilon_r} \cdot P \cdot t = g \; P t$ $\boxed{g = \frac{j}{\epsilon_0\epsilon_r}}$ = voltage sensi

ie $\boxed{V_0 \propto P \cdot t}$ ($V_0 \propto$ pressure applied).

ie piezo electric transducers are devices that utilize piezoelectric effect to convert a non-electrical quantity to an electrical quantity. They are self generating, ie they dont need external power supply to produce electrical charge when subjected to pysical stress. used for measuring force & pressure.

we have $\boxed{g = \frac{V_0/t}{P} = \frac{E}{P}}$

Qn: A quartz piezoelectric crystal having a thickness of 2mm and voltage sensitivity of $0.055\ VmN^{-1}$. It is subjected to a pressure of $1.5\ MNm^{-2}$. Calculate the voltage output if $\epsilon_{r(quartz)} = 40.6 \times 10^{-12}\ Fm^{-1}$. Also calculate it's charge sensitivity.

Ans:- $g = 0.055\ VmN^{-1}$ $\quad P = 1.5 \times 10^6\ Nm^{-2}$ $\quad \epsilon_r = 40.1 \times 10^{-12}\ Fm^{-1}$ $\quad t = 2 \times 10^{-3}$

$$V_0 = g \times P \times t = 55 \times 10^{-3} \times 1.5 \times 10^6 \times 2 \times 10^{-3} = 165\ V$$

$g = \frac{Q}{F} = g \cdot \varepsilon_0 \varepsilon_r$ ie $J = \cdot 055 \times 40 \cdot 6 \times 10^{-12} = 2 \cdot 293$ pf.

Ans:- A piezo electric crystal having dimension $5 \times 5 \times 1 \cdot 5$ (mm) & $g = 0 \cdot 055$ is used for force measurement. Calculate the force if the voltage developed is 100V.

Ans:- $l \times b \times t = 5 \times 5 \times 1 \cdot 5$

$g = 0 \cdot 055$ $V_0 = 100V$

we know: $g \cdot p \cdot t = V_0 \Rightarrow g \cdot \frac{F}{A} \cdot t = V_0 \Rightarrow F = \frac{V_0 A}{gt}$

$F = \frac{V_0 A}{gt} = \frac{100 \times 2 \times 25 \times 10^{-6}}{0 \cdot 055 \times 3 \times 10^{-3}} = 30303 \cdot 03 \times 10^{-3} = 30 \cdot 3\ N$

Qn: A barium titanate pickup has a dimension of has a 5 mm $\times$ 5 mm $\times$ 1.25 mm The force acting on it 5 N. Charge sensitivity of barium titanate is 150 $pcN^{-1}$ and it's permitivity is $12 \cdot 5 \times 10^{-9}$ $fm^{-1}$. If $Y_{Bar \cdot tit} = 12 \times 10^{6}\ Nm^{-2}$. Calculate the strain, charge and capacitance.

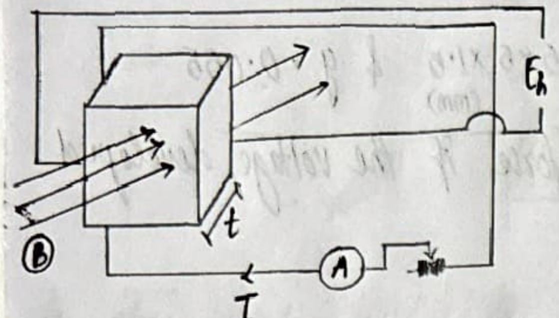
Ans:- $Y = \frac{\text{stresses}}{\text{strain}} \Rightarrow \text{Strain} = \frac{\text{Stress}}{Y} = \frac{F}{AY} = \frac{5}{25 \times 10^{-6} \times 12 \times 10^{6}} = \cdot 01667\ mm$

$C = \frac{\varepsilon_0 \varepsilon_r A}{t} = \frac{25 \times 10^{-9} \times 25 \times 10^{-6} \times 4}{2 \times 5 \times 10^{-3}} = \frac{2500 \times 10^{-15}}{10^{-2}} = 250\ pf$

charge: $V_0 C = gpt \cdot C = \frac{gFtC}{A} = \frac{g}{\varepsilon_0} \cdot \frac{F}{A} \cdot tC = \frac{150 \times 10^{-12}}{8 \cdot 85 \times 10^{-12}} \cdot \frac{5}{30 \times 10^{-6}} \cdot \frac{5 \times 10^{-3}}{4} \times 250 \times 10^{-12}$

$= 8$

# HALL EFFECT TRANSDUCER




A metal strip carrying current placed in a transverse magnetic field produce emf called halle effect emf.

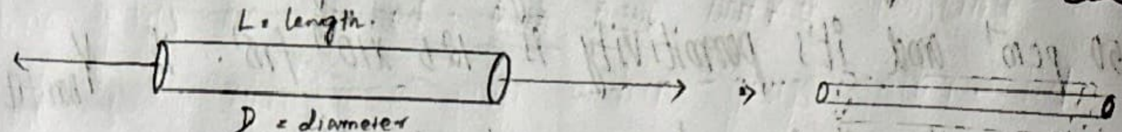
$$E_H \propto \frac{IB}{t} \Rightarrow \boxed{E_H = k_H \cdot \frac{IB}{t}}$$

$k_H$ : Hall effect Const.

Application :
* Magnetic to electric transducer.
* for measuring current.
* Power measurement ( from V & I ).

## STRAIN GAUGE (Resistance).

* Explanation can be based on elastic property of material. $\boxed{R = \frac{\rho l}{A}}$




* used in shaft of ship, furnen to measure pressure, force and more ...
* Due to the application of stress, resistance changes in cylindrical shaft since $\rho, l, A$ are changing.

ie $$\frac{dR}{ds} = \frac{\rho}{A}\frac{\partial L}{\partial s} - \frac{\rho L}{A^2}\frac{\partial A}{\partial s} + \frac{L}{A}\frac{\partial \rho}{\partial s} \longrightarrow ①$$ (change in resist. due to change in $\rho, l$ & $A$).

$$①/R = \frac{1}{R}\,dR/ds = \frac{1}{L}\frac{\partial L}{\partial s} - \frac{1}{A}\frac{\partial A}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s}$$

since it is cylindrical : $A = \pi r^2 = \frac{\pi D^2}{4} \Rightarrow \frac{\partial A}{\partial s} = \frac{\pi D}{2}\frac{\partial D}{\partial s}$

ie $$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial s} - \frac{\pi}{A2}D\frac{\partial D}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s}$$

$$= \frac{1}{L}\,\frac{\partial L}{\partial s} - 2\cdot\frac{1}{D}\frac{\partial D}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s}$$

⇒ Gauge factor:- $\frac{\text{per unit change in lateral dimention}}{\text{p.u change in longitudinal dimension}} = \nu$ = poison ration

ie $\nu$ = Poissons ratio = $\frac{-\partial D/D}{\partial L/L} = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$.

Now Gauge factor :-

$$GF = \frac{\text{P.U change in } R}{\text{P.U change in } L} = \frac{\Delta R/R}{\Delta L/L}$$

for small variations :- $$\frac{1}{R}\frac{\Delta R}{R} = \frac{1}{L}\frac{\Delta L}{\Delta S} - 2\cdot\frac{1}{D}\frac{\Delta D}{\Delta S} + \frac{1}{\rho}\frac{\Delta \rho}{\Delta S}$$

⇒ NRONG eq?

$$\Delta R/R = \frac{\Delta L}{L} - 2\frac{\Delta D}{D} + \Delta\rho/\rho$$

Gauge factor

$$\boxed{\frac{\Delta R/R}{\Delta L/L} = 1 - 2\frac{-\Delta D/D}{\Delta L/L} + \frac{\Delta\rho/\rho}{\Delta L/L} = 1 + 2\nu + \frac{\Delta\rho/\rho}{\varepsilon}}$$

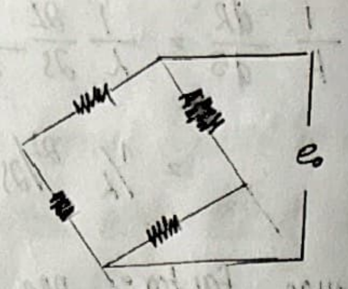
$\varepsilon$ = strain

change in length — change in diameter — Resist. change due to piezoelectric effect.

Qn :- The resistance wire strain gauge uses a wire of small diameter. The gauge factor is + 4.2. Neglecting the piezo effective, Calculate the Poissons ratio

Am : GF = 1 + 2ν ⇒ 4.2 = 1 + 2ν ⇒ $\nu = \frac{4.2-1}{2} = 1.6$ //

# UNBONDED STRAIN GAUGE

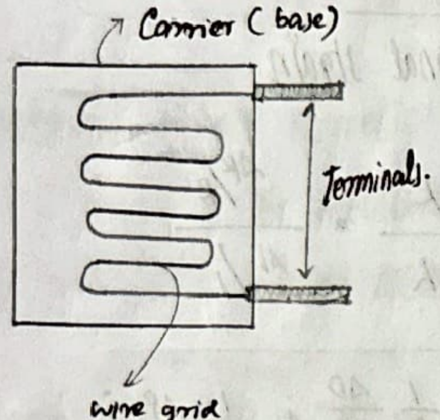



Parts :-

* Diaphragm
* Force rod
* Strain gauge winding
* Mounting
* Sapphire post
* spring element

(1,2) (3,4)

# BONDED STRAIN GAUGE




* Consist of grid of small or fine resistance wire
* fine wire cemented on base which may be bakalite.

Qn :- A Compressive strain of 5 microne is applied to a structural member. 2 strain gauges are attached. Both have nominal resistance 120 Ω. 1 gauge is an equal wire gauge with in gauge factor - 12.1 and other is a nichrome wire gauge with a gauge factor 2.1. Calculate the resistance of each gauge after strain.

② A resistance wire strain gauge with nominal resistance 350 Ω is subjected to a strain of 500 μ strain. Neglect piezo ~~resist~~ effective effect and find the change in resistance

→ 0.35 Ω

③ A Tensile force of 1000 N is applied to a 10 m long aluminium bar, having cross sectional area $4 \times 10^{-3}\ m^2$. The $e_{alumin} = 69$ giga $N/m^2$.

Find the resulting strain

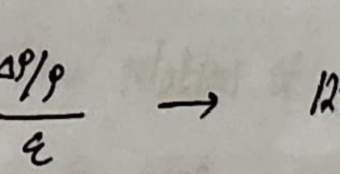
④ A ~~strain of~~ metallic strain gauge has a gauge factor 1.2 and resistance 120 Ω. It is installed on an aluminium structure with yield point stress 0.2 giga and youngs modulous 68 KN $m^{-2}$. Determine the change in resistance of gauge when material loaded to it's yield point.

⑤ A semicond. gauge with resist. 1000 Ω and gauge fact. .133 is subjected to a compressive strain of 500 μ strain. Calculate the new resistance

Ans: Compressive strain ⇒ −ve sign.

② Gauge factor = $1 + 2\nu$ ⇒

① Strain = $-5 \times 10^{-6}$




• $GF_W = 12.1$  $GF_N = 2.1$  $R_W = 120$  $R_N = 120$

$$GF = \frac{\Delta R/R}{\Delta L/L} = 1 + 2\nu + \frac{\Delta \rho/\rho}{\varepsilon} \rightarrow 12.1 = \frac{\Delta R/120}{5 \times 10^{-6}/1} \Rightarrow$$

$$12.1 \times 5 \times 10^{-6} \times 120 = \Delta R = 7260 \times 10^{-6} = \underline{.72 \times 10^{-2}\ \Omega}$$