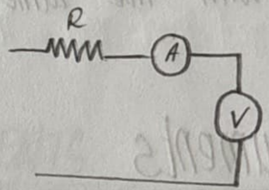
Mesurements & MEASURMENT SYSTEMS. *

* Comparing a quantity with a know quality or known standard, and assigning a neumerical value.

* Measurments ⇒ direct measurment
  indirect measur.

ⓐ direct measurment : Measured directly by some method.
dose not need any conversion

ⓑ indirect measurment :-



$V = IR$

for getting R, we measure "I" using ammeter and Voltage.

* Primery m/s :- Direct measurment (eg: measurment of length)
  High accuracy is not assured
  Depends on sight (ie on brain).

eg: Colour diffrence.

* Secondary measurments :- one coversion of measurment occurs.

eg: during pressure measurments, pressure converted to change in leng

* Tertiary measurment :- Eg: for measuring temperature

temp $\longrightarrow$ Thermo couple $\xrightarrow{\text{Voltage}}$ Voltmeter $\longrightarrow$ Change of Length

Here more than one conversion of measurment occurs.

- Measurment System :-

- Instruments :- Tools for measuring the quantity.
- Repeatability :- Getting the same value for a given measuring quantity while measuring with the same instrum. again & again.

Classification of instruments *

Absolute instruments & 2° instr.

* The unknown is obtained using deflection and physical const.
* Need not be calibrated
* Accurate

eg: tangent galvanometer : $\boxed{i = \frac{2\pi B_H}{\mu_0 n} \cdot \tan\theta}$

* Above gives absolute instrument.

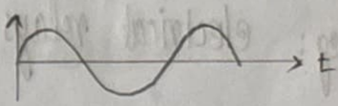
→ Secondary instrument :-

* unknown is obtained as deflection indicating on instrum.
* directly measure the unknown qty.
* Need caliberation [using an absolute or std. instrument]

eg: Ammeter, galvanometer, watmeter.

Analog or digital instruments *

Analog instruments :-

* output obtaind is a analog signal. 

Digital instruments :-

* discrete value   * finite value   * Accurate   * High sensitivity.

eg: Digital ameter, Digital voltmeter.

MANUAL OR AUTOMATIC INSTRUMENTS *

* Man help is required
 traditional weighing scale - ത്രാസ്

SELF OPERATED OR POWER OPERATED *

Self operated :- * No external power supply
 * qnty to be measured will activate the unit.
 * eg: Ammeter.

Power operated :-

Indicating, Recording, Integrating and Controlling unit

⇒ INDICATING : indicate the value to be measured - Ammeter / voltmeter.

⇒ Recording : Record the value of unknown qty - As graph, neumerical value

eg: ECG machine

⇒ Integrating : will get the value as summation of values of unknown qty from a particular time to time of measurment.

eg: Energy meter.

⇒ Controlling instruments :- Controls the measured value using some information

eg: electrical relays.

Mechanical - Electrical - Electronics : Accroding to process

- A mechanical process is there to measure unknown qnty. Not relaiable due to wear and tear and inertia.

- Electrical process :-

  eg: Ammeter, Voltmeter

- Electronics :- Semi Conductor devices

  More accurate and reliable

  eg: Any electronic sensors.

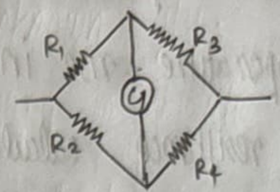
NULL AND DEFLECTION TYPE.

- Deflection of a pointer shows the unknown quantity

  eg: Normal ammeter or voltmeter.

- Null type : instrument is balancing to a null position in order to get unknown qnty.

eg: Wheatstone bridge:



$\frac{R_1}{R_2} = \frac{R_3}{R_4}$

STANDARSD AND CALIBERTION

* Caliberation is the comparison of performance of an instrument against a std instrument.

Need of Caliberation :- * For accuracy and traceability.
* Safety
* Compliance with regulation. (IMO, SOLAS)

Safety of life@

→ Lab caliberation, Online caliberation, Onsite caliberation.

* Standards are refering instruments for caliberation.

→ 1° standard : national or international stds.
→ 2° stds : industry or particular academic system
→ working stds :

ERRORS IN INSTRUMENTS

Deviation from true value.

Error = true value − Indicated value

Systematic error :- * regular or reproducable errors
* instrumental error or imperfection.

eg: Null or zero position error.

Observer imperfection :- May be due to parallax error, stopwatch error.

Environmental fluctuation : eg: Temperature rise in resistance calculation

Theoretical error :- eg: * While resistance calculation, neglecting air resistance
* Neglecting earth mag. field

GROSS ERROR :- Due to observer's issues,

→ Parallax error, incorrect ~~err~~ recording

Random error :- * Random reasons
* Correcting by taking no. of measurments and do statistical analysis

PERFORMANCE CHARACTERISTIC OF INSTRUMENTS

Describe performance of a instrum.

Static performance char.
→ will not change with time
change slowly time

Desirable char.
- Accuracy
- precision
- Sensitivity
- Repeatability.
- Reproducability.

Undesirable char.
- Drift
- Dead zone & dead time
- Threshold
- Hysterisis
- Resolution.

Dynamic perform. charact.
→ will change w.r.t time

- speed of response & time of response, Fidelity comes under desirable ch.
- lag & dynamic error comes under undesirable char.

STATIC PERFORMANCE CHAR :-

i) Accuracy :-

How much measured value is close to true value or measure of closeness of indicated value to true value.

- Accuracy :- True value + Indicated value.

% Accuracy : $\frac{A_i - A_t}{A_t} \times 100$

- we can express accuracy in diffrent ways :-

Not acceptable a) accuracy as the % of full scale reading.

eg: 

$\pm \cdot 1\,\%$ full scale reading

$\Rightarrow \cdot 1\,\%$ of $50 \Rightarrow \cdot 05 \longrightarrow 25\,V \pm \cdot 05$

Acceptable b) Accuracy as % of true value.

in pervious eg: $50V \longrightarrow$ Accuracy is $\cdot 1\,\%$ of $50 \rightarrow 50 \pm \cdot 05$

$25\,V \rightarrow$ Accuracy is $\cdot 1\,\%$ of $25 \Rightarrow 25 \pm \cdot 025$

c) Accuracy as % of scale span :-

$\boxed{25 \longrightarrow 225}$ instrum. $\Rightarrow$ Scale span : $225 - 25 = 200$.

Accuracy is $\pm 0.1\,\%$ Scale span

$\Rightarrow \frac{\cdot 1}{100} \times (225 - 25) = \frac{\cdot 1 \times 200}{100} = \underline{\underline{\cdot 2}}$

Not acceptable ⓓ Point accuracy :-

Gives accuracy on a particular value.

2) PRECISION :

* Property of repeating the same measurement value for multiple msts.
* Consistency in repeated measurements.
* Conformity :- How much the readed value is near to the true value.
* Significant figures are important in case of precision.

eg: If an instrum. can only show 3 digit (Resistance calculation)

eg when true resist. is ~~12.5F4200~~ Ω, it show 12.5 MΩ as reading and it is less precise to true value.

* Precision = P

$$\boxed{P = 1 - \left| \frac{x_n - \bar{x}_n}{\bar{x}_n} \right|}$$

$\frac{302.21}{6} = \bar{x}_n$

eg: Readings: 51.1°C, 50.01, 50.3, 49.8, 51.5, 49.5

Precision of 3rd reading: $P = 1 - \left| \frac{50.3 - 50.368}{50.368} \right| = 1 - .00135$

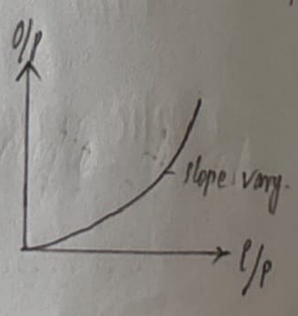
$= \underline{.99865}$

3) SENSITIVITY (δ)

It is ratio of change in output to change in input.

$$\delta = \frac{\Delta A_{out}}{\Delta A_{in}} \times 100\ \%$$

* For a linear curve / linear change, sensitivity is const.
for a non-linear change, sensitivity is varying.



4) Repeatability.

= Repeating the same measurment at same condition by same person.

= It is the variation in measurement taken on the same item under the same Condⁿ.

* Ability to produce the same reading under Identical Condⁿ.

* Measure of precision.

5) REPRODUCABILITY

* It is the ability of a measurment to be duplicated either by the same person or by some one else on slightly changed Condⁿ.

The degree to which repeated measurments taken under ~~same~~ changed Condⁿ (operated time) yields same result.

* It shows reliability & Consistancy of instrument.

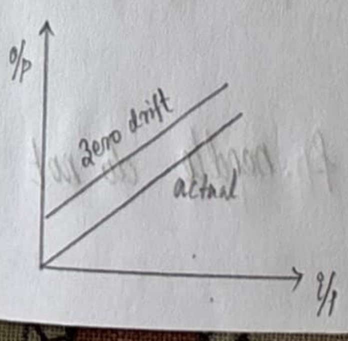
6) DRIFT

* change in output without changing input.

* It may be because of external factors like magnetic field, vibrations and

* The slow change in the output of a instrument over time when input remains Const.

ⓐ Zero drift :-

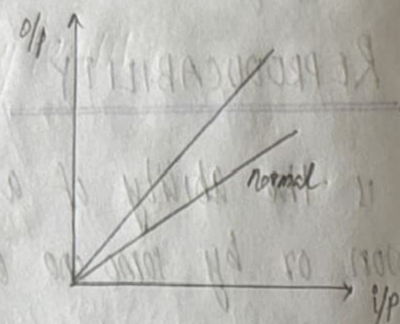


⇒ Due to stray EF / MF, Mechanical vibrations, Temperature Variation, Mechanical stress and wear and tear

Reduction : * Stray EF/MF : Shield protection * Temp. change : proper temp. compensation
* Mech. vibration : Proper Support
* Wear & tear : " maintenance

If the whole caliberation gradually shifts due to various reasons, zero drift happens.

ⓑ ~~Zonet drift~~ (Sensitivity drift)

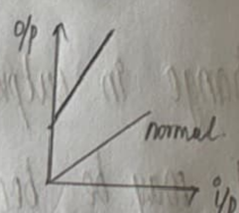


* If there is a proportional change in the indication all along the upward scale known as sensitivity drift.
* It defines the amount by which an instrument's sensitivity of measurment varies as external conditions varies.

ⓒ Zonal drift *

The drift occurs only over a particular range of measurment's of the Instruments.

ⓓ When simultaneously zero drift & sensitivity drift occurs :



7 DEAD TIME & DEAD ZONE

Dead time : Delay b/w change happens in the process and when instrument starts to respond. During this time instrument dose not show any indication that the value has changed.

Eg: in furnace, when temp changes, the sensors shows lags & needle do not deflects

* Significant causes for dead time :-

*1 Sensor delay : Some instrument take time to detect changes

*2 Transmission delay : Signal from the sensor may take time to reach the display unit

*3 Process delay : Some instruments take time to process the sensored value before displaying.

DEAD ZONE :- It is the smallest change in the measured value that do not cause the instrument to respond.

Causes of dead zone : * Friction : moving parts inside instrument may need a bigger force to start moving.

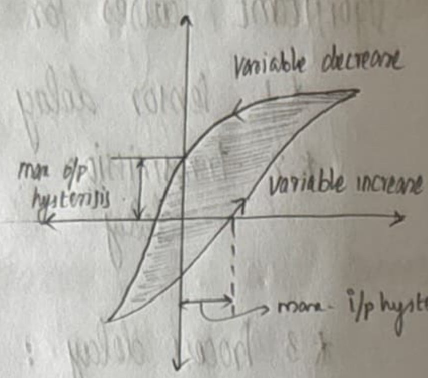
* Back lash :- In mechanical systems, gears and linkage may have gaps, which prevent small changes from being transmitted immediatly

* Noise filtering :- Some instruments ignore small fluctuations to avoid noise.

⑧ THRESHOLD

If the input to an instrument gradually increased from zero, It should reach a minimum value to actuate the measuring process of instrument. This minimum level of instrument is called threshold of the instrument.

9 HYSTERISIS



If the input measured qnty. of the instrument is stredly increase from a -ve value, the output varies in a particular manner and if the input is steadly decreased, the output varies in another manner. This whole coincident b/w loading & unloading curve is referd as hysterisis

10 RESOLUTION

smallest quantity measured which can be

* If a non-zero input qnty. slowly incrse, output reading will not increase until some minimum change in input takes place. This minimum change which cause the instrument to show a detectable output.

11 CREAP

Creap is caused by the time an instrument need to adapt the change in applied input.

1 STATIC ERROR : Neumerical diffrence b/w true value of a qnty. and the value obtained from measurment.

$e_s = A_t - A_i$, in % → $e_s = \frac{A_t - A_i}{A_t} \times 100$.

DYNAMIC CHAR. OF INSTRUMENTS

* SPEED OF RESPONSE : The rapidity at which the instrument or measurment system response to changes it's measured qnty.

Time req. by an instrument to

* MEASURMENT LAG : The delay in measurment change response of an instrum
It is of 2 types.

  ⓐ Retardation type : in this measurment lag, the response begins immediately after a change in measured qnty. has occured

  ⓑ Time delay : The response begins after the dead zone after the application of the input.

- FIDELITY : Ability of the system to reproduce the output the same form as input or degree to which a measurment system indicate the changes in measured qnty. without any error.

- DYNAMIC ERROR :- Diff. b/w true value & measured value considering the changing with time/ no static error assumed.

ANALYSIS OF ERRORS

* Why : * A systematic analysis is done or a statistical analysis is done because it varies as persons change or the persons may include approximate compromise's.

STATISTICAL ANALYSIS OF ERRORS.

we know Abolute error : $4V \pm .005\,V$

Relative error : $4V \mp .003\,\%$

① UNCERTAINITY ANALYSIS

Let R be a function of $(x_1, x_2, \ldots)$, ie $R = R(x_1, x_2, x_3, \ldots x_n)$

If uncertainity in each measurments are represented as $x_1 \rightarrow W_{R_1}$, $x_2 \rightarrow W_{R_2}$

the
$$\boxed{W_R = \left[\left(\frac{\partial R}{\partial x_1} \cdot W_{R_1}\right)^2 + \left(\frac{\partial R}{\partial x_2} \cdot W_{R_2}\right)^2 + \ldots\ldots\right]^{1/2}}$$

Condition here : errors must have same odd's.

Qn:- The resistance of a certain size wire is given as $R = R_0[1+\alpha(T-20)]$ where $R_0 = 6\,\Omega \pm .3\%$ is the resistance @ $20°C$, and $\alpha = .004\,°C^{-1} \pm 1\%$ (temp. coeff.) and $T = 30 \pm 1°C$. Find the uncertainity in the resistance.

Ans:- We have $R = R_0 + R_0\alpha[T-20]$

ie Nominal resistance : $R = 6[1 + (.004)[30-20]] = 6[1+.04]$

$= 6.24\,\Omega$

uncertainity :- $W_R = \left[\left(\frac{\partial R}{\partial x_1} W_{R_1}\right)^2 + \left(\frac{\partial R}{\partial x_2} \cdot W_{R_2}\right)^2 + \left(\frac{\partial R}{\partial x_3} \cdot W_{R_3}\right)^2\right]^{1/2}$

$= \left[\left(\frac{\partial R}{\partial R_0} \cdot W_{R_0}\right)^2 + \left(\frac{\partial R}{\partial \alpha} W_\alpha\right)^2 + \left(\frac{\partial R}{\partial T} W_T\right)^2\right]^{1/2}$

$.0305 = W_R$ as per teacher

$= \left[(0.1872\times10^{-4})^2 + (24\times10^{-4})^2 + (240\times10^{-4})^2\right]^{1/2} = (58176.035)^{1/2}\times10^{-4}$

$= 241.19\times10^{-4} = .02412\,\Omega$

$\frac{\partial R}{\partial R_0} = 1 + \alpha(T-20) = 1 + .004\,(30-20) = \underline{1.04}$

$\frac{\partial R}{\partial \alpha} = R_0(T-20) = 6[30-20] = 60$

$\frac{\partial R}{\partial T} = R_0\alpha = 6 \times .004 = \underline{.024}$

$\frac{\partial R}{\partial R_0} W_{R_0} = 1.04 \times 6 \times \frac{.3}{100} = 0.01872$

$\frac{\partial R}{\partial R_0} \cdot W_\alpha = 60 \times \cancel{.04}/100 = .6 \times .004 = 24 \times 10^{-4}$

$\frac{\partial R}{\partial T} \cdot W_T = .024 \times 1 = \underline{.024}$

% error $= \frac{.0305}{6.24} \times 100 = \underline{.4887\ \%}$ $(< 1\,\%)$

If ans taken as 0.024 ⇒ % Er = .38%

(II) STATISTICAL ANALYSIS

(a) ARITHMETIC MEAN

* It is more accurate if we have large amount of data (most common meth.)

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n}$$

(b) MEDIAN

Central value when data's are arranged in ascending order. ie If $x_1, x_2, \ldots, x_n$ are the given data,

ie median = Central value of x_n, If n = odd

$= \frac{x_{m_1} + x_{m_2}}{2}$, If n = odd.

(c) ~~MEDIA~~ DEVIATION

If the data is $x_1, x_2, x_3, \ldots x_n$ and mean is x_m $\quad x_m = \frac{x_1 + x_2 + \cdots + x_n}{n}$

$$d_i = x_i - x_m$$

average of all the deviation $= \frac{1}{n}\sum_{i=1}^{n} d_i = \frac{1}{n}\sum_{i=1}^{n}(x_i - x_m)$

Here we take absolute value, $|d_i| = \frac{1}{n}\sum_{i=1}^{n}|d_i|$

(d) STANDARD DEVIATION

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - x_m)^2} \longrightarrow \text{ACCURATE}$$

(e) VARIENCE

Square of SD is called variance, ie $\boxed{\sigma^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - x_m)^2}$

(f) GEOMETRICAL MEAN *

* Generally used in biological (medical field, ...) . ie if data = $x_1, x_2, \cdots x_n$

$$GM = (x_1 \cdot x_2 \cdot x_3 \cdots\cdots x_n)^{1/n}.$$

Qn: The following readings are taken for a certain physical length. Compute

(a) Mean (b) Median (c) SD (d) variance

Readings: 5.30, 5.73, 6.77, 5.26, 4.33, 5.45, 6.09, 5.64, 5.81, 5.75 (cm's)

Ans:- (a) $x_m = \frac{x_1 + x_2 + \cdots + x_n}{n} = \frac{56.13}{10} = \underline{5.613}$ cm

(b) Median :- 4.33, 5.26, 5.30, 5.45, 5.64, 5.73, 5.75, 5.81, 6.09, 6.77

$$\text{Median} = \frac{5.64 + 5.73}{2} = \underline{5.685}$$

(c) For SD : ① $(5.3 - 5.613)^2 \approx .098$ ③ $(6.77 - 5.613)^2 \approx 1.338$ ⑤

② $(5.73 - 5.613) \approx .0137$ ④ $(5.26 - 5.613)^2 \approx .125$

Qns:- A moving coil volt meter has a uniform scale with 100 readings. The full scale deviation is 200 V, and $1/10^{th}$ of a scale deviation can be estimated in a fair degree of certainity. Determine the resolution of the instrument in volt.

Ans:-

$1/10^{th}$ of scale reading can be measured.

scale reading $= \frac{200}{100} = 2$

Resolution $= 2 \times \frac{1}{10} = .2$ V.

Qn: A digital Voltmeter has read out range from $0 \rightarrow 999$ Counts. Determine the resolution of instrument in volt when full scale reading is $9.999\,V$.

Ans :- Resl^n $= \dfrac{9.999}{1000} = \underline{\underline{.9999}}$ OR 1 mV check ans.

Qn: A wattmeter having a range of 1000 W has an error of $\pm 1\%$, of full scale deflection. If the true power is 100 W, what will be the range of readings.

[Suppose the error is specified as ...

Ans :- 0 – 1000 W & error is 1 % of full. sc. red. $\Rightarrow$ Error $= 1\%$ of $1000 = \underline{\underline{\pm 10W}}$

ie range of reading $= 100 \pm 10 \Rightarrow (90 \longrightarrow 110)\,W$

Qn :- A flowmeter of guaranteed accuracy of $\pm 5\%$ full scale reading of $5\times10^{-6}\,m^3 s^{-1}$. The flow measured by the meter is $.5\times10^{-6}\,m^3 s^{-1}$. Calculate the limiting error in %.

Ans :- $\pm 5\%$ of 5×10^{-6} $\Rightarrow$ $5\times10^{-2} \times 5\times10^{-6} = 25\times10^{-8}$

Limiting error :-

The manufacture specify the accuracy of instrument as the % of full scale reading. And this % indicate the deviation from the specified value of the measurent. This deviation is called limiting error / Guarantee error.

A_a = Acutal value of mesuramt $\Rightarrow \pm \delta E$ = Limiting error.

$$A_a = A_s \pm \delta E$$

Relative error $= \dfrac{\delta A}{A_s} = e$

So we got $\delta A = e \cdot A_s \Rightarrow \delta A = A_s \pm e \cdot A_s = A_s[1 \pm e]$

$$\boxed{\delta A = A_s[1 \pm e]}$$

The relative limiting error is $\left[\frac{A_a - A_s}{A_a}\right] \times 100\ \%$.

Relative error $= \frac{\delta A}{A_s} = \frac{0.25 \times 10^{-6}}{2.5 \times 10^{-6}} = .1$

$\delta A = e A_s \Rightarrow e = \pm .1 \rightarrow \delta A = A_s[1 \pm .1] = 2.5 \times 10^{-6}[1 \pm .1]$

Qn: A pressure gauge having a range of 1000 $kN\,m^{-2}$ has an error of $\pm 1\%$ of full scale deflection. If the true pressure is 100 $kN\,m^{-2}$, what could be the range of reading. And if the error is speified as % of true value, find the range of reading.

Ans:

Qn: Determine the magnitude and limiting error in Ω & % of resistance value for the series combination of following resistors. $R_1 = 27\Omega \pm 5\%$, $R_2 = 75 \pm 5\%$, $R_3 = 50\Omega \pm 5\%$

Ans:- The resistance of a ckt is found by measuring current flowing & power fed in to the ckt. The relative limiting error in the measurment of power and current are $\pm 1.5\%$ & $\pm 1\%$ resp. Find the limiting error in measurment of resistance

$[P = I^2 R]$

LIMITING ERROR : Generator Error.

* Given as % in the end :

 eg: $100 \pm 1\%$ V ⇒ the true value lie in 99 V – 101 V.

* Relative limiting error :- $e_r = \frac{\delta A}{A_s}$ ⇒ $\boxed{A_a = A_s \pm e_r A_s = A_s[1 \pm e_r]}$

 eg: 1 µF ± 1 %

- For a 0-300V Voltmeter, the guarntee error is specified as ± 3 V. Then for a measurment of 100V obtained from instrument, what would be the actual voltage ? And what is relative error in %.

Ans:- Given $A_s = 100V$ $A_a = 100 \pm \delta A$
$= 100 \pm 3$ ⇒ [97 — 103 V] - Actual value range.

Relative error : for 100 V – 3V error ⇒ Relative error = 3/100 %

- If the error is given as ± 1% of full scale reading, then what will be the limiting error in case of measurment of 100V.

Ans: ± 1 % of 300 V ⇒ 3 V

 for 100 V ⇒ 100 V ± 3V ⟶ [97V – 103 V]

For 50 V, relative error : 3/50 .

ie for smaller measurments, relative error is high.

Limiting error in case of composite quantities :-

① Addition

Consider : $y = x_1 + x_2$

$$\Rightarrow \frac{dy}{y} = \frac{dx_1}{y} + \frac{dx_2}{y} = \frac{dx_1}{x_1} \cdot \frac{x_1}{y} + \frac{dx_2}{x_2} \cdot \frac{x_2}{y}.$$

If expected errors are δx_1 & δx_2 $\Rightarrow$ $\boxed{\frac{\delta y}{y} = \pm\left(\frac{\delta x_1}{x_1} \cdot \frac{x_1}{y} + \frac{\delta x_2}{x_2} \cdot \frac{x_2}{y}\right)}$.

② Difference *

Consider $y = x_1 - x_2$

$$\frac{dy}{y} = \frac{dx_1}{y} - \frac{dx_2}{y} = \frac{dx_1}{x_1} \cdot \frac{x_1}{y} - \frac{dx_2}{x_2} \cdot \frac{x_2}{y}$$ — check.

If expected errors are $\pm\delta x_1$ & $\pm\delta x_2$ $\Rightarrow$ $\boxed{\frac{\delta y}{y} = \pm\left(\frac{\delta x_1}{x_1} \cdot \frac{x_1}{y} + \frac{\delta x_2}{x_2} \cdot \frac{x_2}{y}.\right)}$

check the above result (may wrong)

③ Product *

Consider $y = x_1 \cdot x_2$

$\log y = \log x_1 + \log x_2 \rightarrow$ diff $\Rightarrow \frac{1}{y} = \frac{1}{x_1} \cdot \frac{dx_1}{dy} + \frac{1}{x_2} \cdot \frac{dx_2}{dy}$

$$\frac{dy}{y} = \pm\left(\frac{\delta x_1}{x_1} + \frac{\delta x_2}{x_2}\right).$$

④ : If $y = x_1^n x_2^m \Rightarrow$ then also error $\Rightarrow$ $n \cdot$ error on x + $m \cdot$ error on x

Qns:- Resistance of a ckt is found by measuring current flowing and the power fed in to ckt. Find the limiting error in mmt. of result when limiting error's in measurs of P & I are $\pm 1.5\%$ & $\pm 1\%$.

Ans:- $P = VI = (IR) \cdot I = I^2 R$. $P = I^2 R \Rightarrow R = \frac{P}{I^2}$

ie it is comp. division : error in resist = error in P + 2 [error in curr]

$= \pm 1.5\% + 2 \times [1\%]$

$= \pm 3.5\%$

Qn: The solution for unknown resist. of wheatstone bridge is $R_x = \frac{R_2 R_3}{R_1}$.

$R_1 = 100 \pm 0.5\,\Omega\,\%$, $R_2 = 1000 \pm 0.5\,\%$, $R_3 = 842 \pm 0.5\%\,\Omega$. Determine the magnitude of unknown resist. and limiting error in % and in ohm in %

Ans: $R_x = \frac{1000 \times 842}{100} = \underline{8420\,\Omega}$ error $\frac{\partial R_x}{\partial x} = \pm [.5 + .5 + .5]\% = \underline{1.5\%}$

Relative error $= \frac{1.5}{100} \times 8420 = \underline{126.3\%}$

Qn: 2 resistors R_1 & R_2 are connected in series and then in $\parallel^{el}$. The values of resist. are $R_1 = 100 \pm .1\%\,\Omega$ & $R_2 = 50 \pm .03\,\Omega$. Calculate the uncertainity.

Ans:-

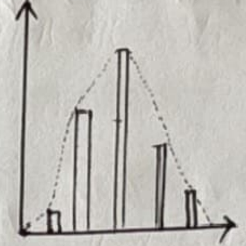
Leonardo-da-vinchi

Probable error :-

Statistical analysis of data :-

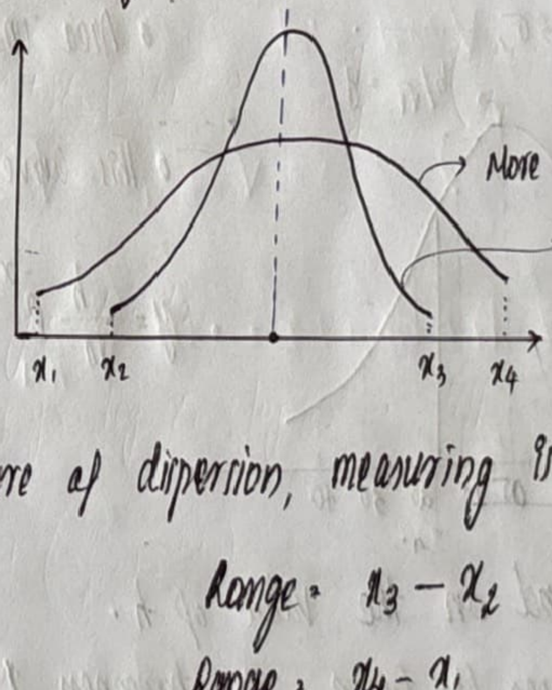
* Multisample data : Diffrent test Cond" such as diff. instruments/test method/observer
* Single sample data : Many samples but same test Cond" (Variable is time).

=> Histogram :-



Bar diagram ⟶ Histogram.

=> Dispersion : in histogram, data is more spreaded around a Central value. ie scattering of data around Central Value is called dispersion.



=> Range :- Measure of dispersion, measuring is done by taking final limit.

$$\text{Range} = x_3 - x_2$$

$$\text{Range} = x_4 - x_1$$

* Normal distribution Curve :-

Gaussian law :- It states that the normal occurrence of deviations from average value of an infinite values of mesurments / observations can be expressed as

$$\boxed{y = \frac{h}{\sqrt{\pi}} e^{-x^2 h^2}}$$

x = deviation (from mean).

y = No. of readings at any deviation x

Here we are taking deviation from mean value : deviation = $x_i - x_n$.

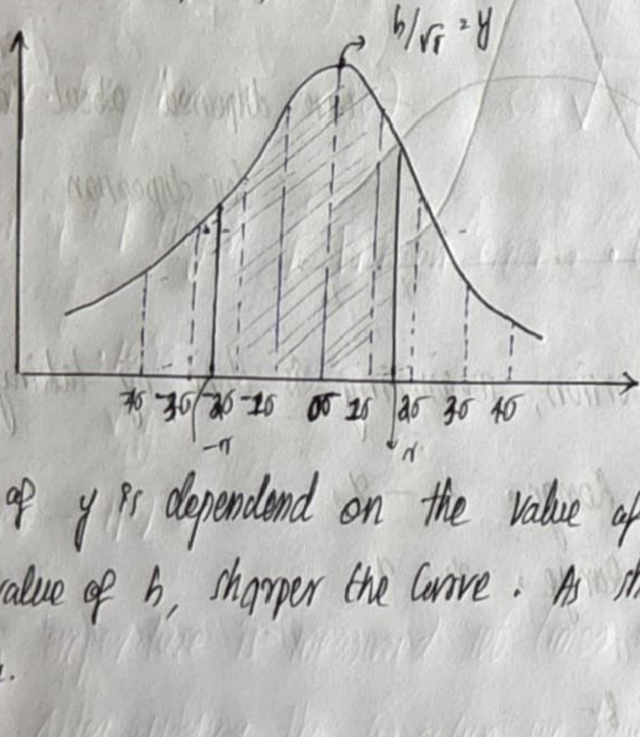
h = A constant called precision index

- If we used standard deviation (σ) insted of deviation from mean, eq^n changes to

$$\boxed{y = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}}}$$

Then the deviations from the mean value are devided in terms of σ units so that the deviations are

$x = \sigma, 2\sigma, 3\sigma, \ldots$



- Area under this curve = 1
- This curve follows 2 eq^{ns}

$$y = \frac{h}{\sqrt{\pi}} e^{-x^2h^2} = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}}$$

#

- Max. value of y is dependend on the value of h.
- Larger the value of h, sharper the curve. As sharpeness ↑, more precision due to less scattering.

Now coming to probable error :-

We have observed that the most probable or best value of a Gaussian distribution is obtained by taking arithematic mean of various values of the varient. And the confidence in the best value is connected with

the sharpness of distribution curve. Let us consider 2 point $-r$ & $+r$.
These points are that the area bounded by the curve, x-axis and the ordinates erected from $-r$ to $+r$, is equal to ½ the area under curve. ie ½ the deviations lies b/w $x = \pm r$ (ie symmetrical). Here a convenient measure of precision is the quantity "r". It is called probable error.

- If we determine r as the result of n-measurements and then makes an additional measurement, the chances are 50-50% that the new value lie b/w $-r$ & $+r$. ie chances are even that any one reading will have an error not greater than $\pm r$.

$$\Rightarrow \quad 1 = \frac{h}{\sqrt{\pi}} \int_{-\infty}^{\infty} e^{-h^2x^2}\, dx \quad \& \quad \frac{1}{2} = \frac{h}{\sqrt{\pi}} \int_{-r}^{r} e^{-h^2x^2}\, dx \qquad \boxed{r = \frac{0.4769}{h}}$$

- If we take std. deviation, value of r will be $r = 0.6745\,\sigma$

Probable Error Of A Finite No. Of Readings :-

$$r = 0.6745\,\sigma = 0.6745\sqrt{\frac{d_1^2 + d_2^2 + \cdots + d_n^2}{n}} = 0.6745\sqrt{\frac{|d^2|}{n}}$$

For an infinite no. of deviation from normal curve. For finite no. of deviation

$$S = \sqrt{\frac{d_1^2 + d_2^2 + \cdots + d_n^2}{n-1}}$$ (instead of σ, we use S for finite no.).

$\Rightarrow$ If the finite no of readings, the average reading has a probable error of

$r_m = 0.6745\sqrt{\dfrac{\Sigma d_i^2}{n \times (n-1)}}$. If n is very much larger than 1, $(n-1) \approx n$

$$r_m = 0.6745 \cdot \frac{\sigma}{\sqrt{n}}$$

$$\text{SD of mean} = \sigma_m = \frac{\sigma}{\sqrt{n}}$$

$$\text{SD of the SD} = \sigma_\sigma = \frac{\sigma}{\sqrt{2n}} = \frac{\sigma_m}{\sqrt{2}} e^{\left(\frac{-x^2}{2\sigma^2}\right)}.$$

Qn :- Find the mean, SD, Probable error in 1 reading, Probable error of mean and range of the given temperature readings :- 41·7, 42, 41·8, 42, 42·1, 41·9, 42, 41·9, 42·5, 41·8

Ans :- • Mean :- $\frac{\Sigma \text{ temp. readings}}{10} = \frac{419 \cdot 7}{10} = \underline{41 \cdot 97}$ ie mean $= \frac{\Sigma x_i}{n} = 41 \cdot 97$

$$SD = \sqrt{\frac{\Sigma d^2}{n}} = \sqrt{\frac{\cdot 27^2 + \cdot 03^2 + \cdot 17^2 + \cdot 03^2 + \cdot 13^2 + \cdot 07^2 + \cdot 03^2 + \cdot 07^2 + \cdot 53^2 + \cdot 17^2}{10}}$$

$$= \sqrt{\frac{\cdot 441}{10}} = \sqrt{\cdot 0441} = \underline{\cdot 21} \quad \text{(if it was infinite)}$$

• For finite no. less than 20 (<20) $\quad S = \sqrt{\frac{\Sigma d^2}{n-1}} = \sqrt{\frac{\cdot 441}{10-1}} = \sqrt{\cdot 049} = \underline{\cdot 22136}$

• Probable error of 1 rdng :- r_1 = Probable error $= \cdot 6745 \sqrt{\frac{\Sigma d^2}{n-1}} = \cdot 6745 \times \cdot 221 = \underline{\cdot 15^\circ C}$

• $r_m = \frac{r_1}{\sqrt{n-1}} = \frac{\cdot 15^\circ C}{\sqrt{9}} = \underline{\cdot 05^\circ C}$

• Range $= 42 \cdot 5 - 41 \cdot 7 =$

Qn :- In a test, temperature is measured 100 times with variations in apparatus and procedures. After applying the correction, we have

Temp :-	freq :-	Temp :-	freq :-
397	1	403	4
398	3	404	2
399	12	405	2
400	23		
401	37		
402	16		

Calculate (i) A.M (ii) mean deviation (iii) SD (iv) probable error in 1 rdng.

(v) probable error of mean (vi) SD of the SD.

Ans :- (i) $AM = \frac{\sum_i f_i x_i}{\sum f_i} = \frac{10078}{100} = \underline{\underline{100.78\,°c}}$

(ii) Mean deviation = $= \frac{1.98}{}$

Should multip. with freq

(iii) $SD = \sqrt{\frac{\sum d^2}{n-1}} = \sqrt{\frac{14.28 + 7.73 + 3.17 + .60 + .048 + 1.488 + 4.93 + 10.36 + 17.8}{99}}$

$= \sqrt{\frac{60.4144}{99}} \approx \sqrt{.6105} \approx .7819$

(iv) r_1 = Prob. error in 1 rdng $= .6745 \times \sqrt{\frac{\sum d^2}{n-1}} = .6745 \times (.7819) \approx \underline{\underline{.5274\,°c}}$

(v) Probable error of mean $= r_m = \frac{r_1}{\sqrt{99}} = \frac{.5274}{\sqrt{99}}\,°c = \underline{\underline{.053\,°c}}$

(vi) SD. of SD $= \frac{\sigma}{\sqrt{2n}} = \frac{.7819}{\sqrt{2 \times 100}} \approx \underline{\underline{.0553\,°c}}$

PROBABLE ERROR OF COMBINATION OF COMPONENTS :-

- Probable error of Combination of Components → eg : $R = \frac{V}{I}$

Suppose x is the quantity to be measured and is a fn of $(x_1, x_2, x_3 \cdots x_n)$

ie $$X = f(x_1, x_2, \cdots x_n)$$

$$SD = \sqrt{\left(\frac{\partial X}{\partial x_1}\right)^2 \sigma_{x_1}^2 + \left(\frac{\partial X}{\partial x_2}\right)^2 \sigma_{x_2}^2 + \cdots + \left(\frac{\partial X}{\partial x_1}\right)^2 \sigma_{x_n}^2}$$

$$\text{Probable error} = r_x = \sqrt{\left(\frac{\partial X}{\partial x_1}\right)^2 r_{x_1}^2 + \left(\frac{\partial X}{\partial x_2}\right)^2 r_{x_2}^2 + \cdots + \left(\frac{\partial X}{\partial x_n}\right)^2 r_{x_n}^2}$$

Where $r_{x_1}, r_{x_2}, \cdots, r_{x_n}$ are the probable error of components $x_1, x_2, \cdots x_n$.

Qn:- we have a $\parallel^{el}$ ckt having 2 branches. The current in 1 branch I_1 is $100 \pm 2A$. In other branch $I_2 = 200 \pm 5A$. Determine the total curren $I = I_1 + I_2$ by Considering

(i) Errors in I_1 & I_2 as limiting errors.

(ii) Errors as SD.

Ans:- (i) $I = I_1 + I_2$ and fractional error $= \frac{\delta I}{I} = \pm \left[\frac{I_1}{I} \cdot \frac{\delta I_1}{I_1} + \frac{I_2}{I} \cdot \frac{\delta I_2}{I_2}\right]$

$$\frac{\delta I_1}{I_1} = \frac{2}{100} = .02 \qquad \frac{\delta I_2}{I_2} = \frac{5}{200} = .025$$

$$\frac{\delta I}{I} = \pm\left(\frac{100}{300} \times .02 + \frac{200}{300} \times .025\right) = \pm .0233 \Rightarrow \underline{2.33\%}$$

$$I = 300 \pm 2.33\% \text{ of } 300 = \underline{\underline{300 \pm 6.99\,A}}$$

we also got $\sigma_{I_1} = 2$ $\sigma_{I_2} = 5$

and $\sigma_1 = \sqrt{}$

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 qn

→ 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) miniaturasation [using IC chips - Compatability, Portability]

IV) Telemetry :- fast transmission of information

V) very low power level.

CLASSIFICATION

Main elements :- Primery sensing element. transduction element.

Auxilory 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 α), temperature changes resistance. Temp. measurment.

- Resist. Hydrometer :- resistance changes with moist content. Humidity meas^{r}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

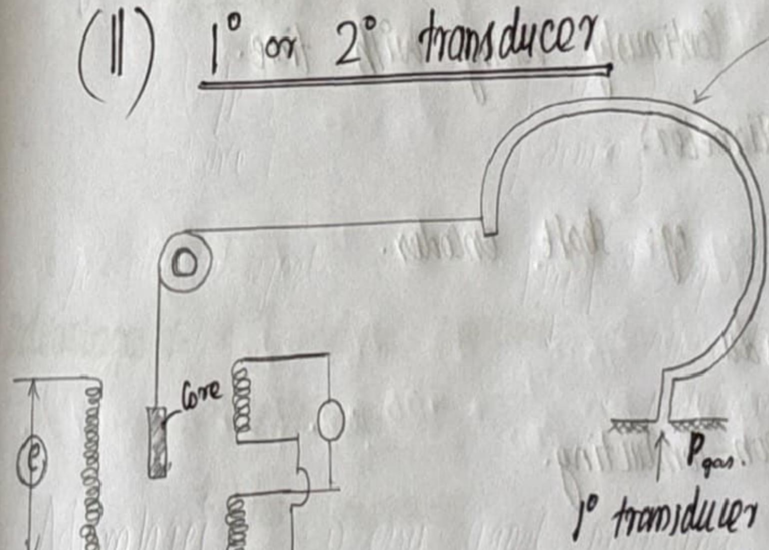
(c) Inductive transduction :-

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

Bourdon tube pressure system :-

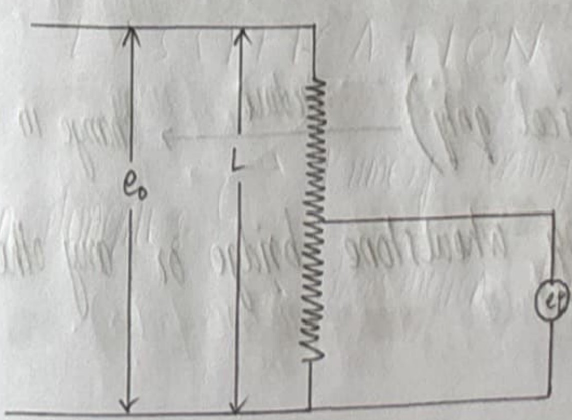
* input physical qnty is converted to a displacement.



2° transducer.

(III) Passive & active transducer.

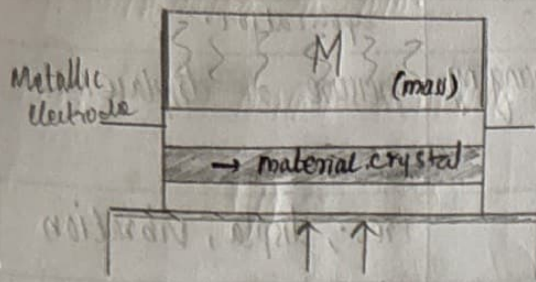
- Derive power required for transduction form an auxillary power source. these are externally powerd. Eg: potentiometer.



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

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 $\Rightarrow$ output voltage $\propto$ force $\propto$ accl^n.

IV) Analog & Digital Transducer.

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

eg: Potentiometer.

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

opaque and trans du

Photo conducting and non-Conducting.

TRANSDUCER & INVERCE TRANSDUCER

inverse transducer : electrical $\longrightarrow$ non-electrical (Mechanical or ....)

eg: Piezoelectric crystal (voltage $\longrightarrow$ mech. vibrations).

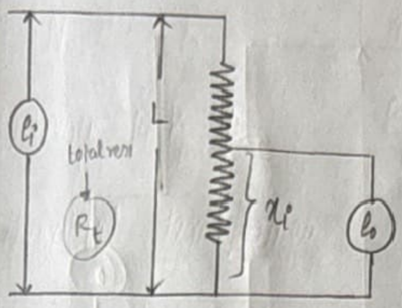
* RESISTIVE TRANSDUCER *

* 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.

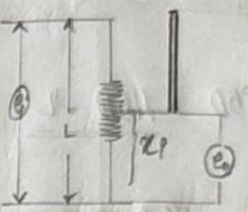
* Resistance of an element :- $R = \rho l / A$.

Eg: <u>Potentiometer</u> :-



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

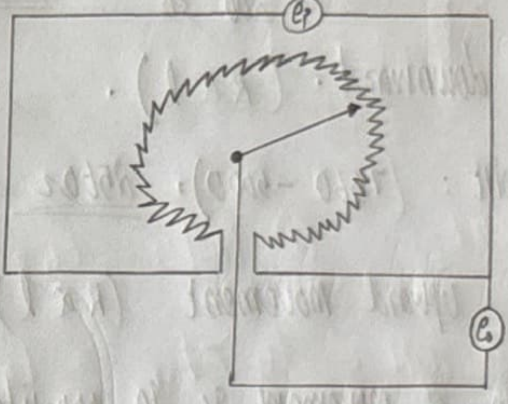
* Measuring translational movement :-



→ 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.

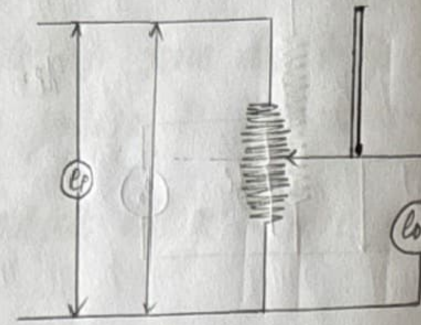
Qn: A linear resistance potentiometer is 50 mm long & is uniformly wound with a wire having resistance of 10000 Ω. At the normal condition, the slider is @ the centre of potentiometer. Find the linear displacement when the resistance of potentiometer is measured by a wheat stone bridge

(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 Ω resist. with this arrangement. Find resolution of potentiometer in mm.

Ans:- Normal resistance = 5000 Ω (slider @ centre).

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



(i) change in resist. = 5000 − 3850 = $\underline{1150\ \Omega}$

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

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

(ii) change in resist: (7560 − 5000) = $\underline{\underline{2560\ \Omega}}$ ⇒ $x_{moved} = \frac{2560\ \Omega}{200\ \Omega}$ mm = $\underline{\underline{12.8\ mm}}$.

upward movement ($R \propto l$).

ie direction of movement is in opposite dirⁿ.

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

$10\ \Omega \rightarrow$

(c) 50 mm ⟶ 10000 Ω
1 mm ⟶ $\frac{10000}{50}$ Ω } Resolⁿ = $10 \times \frac{1}{200} = \underline{\underline{.05\ mm}}$. (for 10 Ω, resolⁿ).

INDUCTIVE TRANSDUCER

* Self inductance or mutual inductance changes on applicⁿ of the physical qnty. Here formation of eddy current occure.

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

From eqⁿ: It may be of 3 types (Δ self induct.) → change in permeab. → change → change

$L = \frac{N^2}{S} = N^2 \frac{\mu_0 A}{l} = N^2 \mu_0 G$ (G = 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 ↓

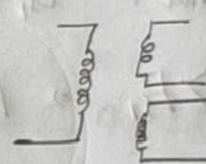
⇒ Change in mutual inductance. &

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

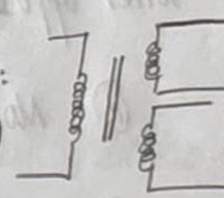
Composite Coupling: $L_1 + L_2 - 2M$ (opposite coupling).

$L_1 + L_2 + 2M$ (aided

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



(II) Iron Cored: (μ is not const.)



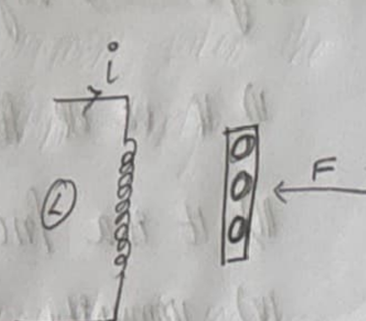
• Air : μ_0 is Const
Not dependent on Supply Volt. frequency.
L of the coil Const.

Iron : μ not Constant
dependant on Supply Volt. freq.
L changes.

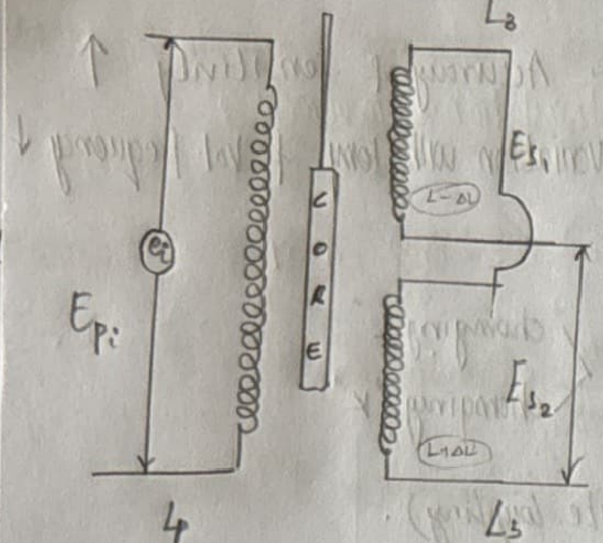
Advantages of Iron Cored transducer: Reduce the size
MF can be Confined in the core
external MF do not affect.

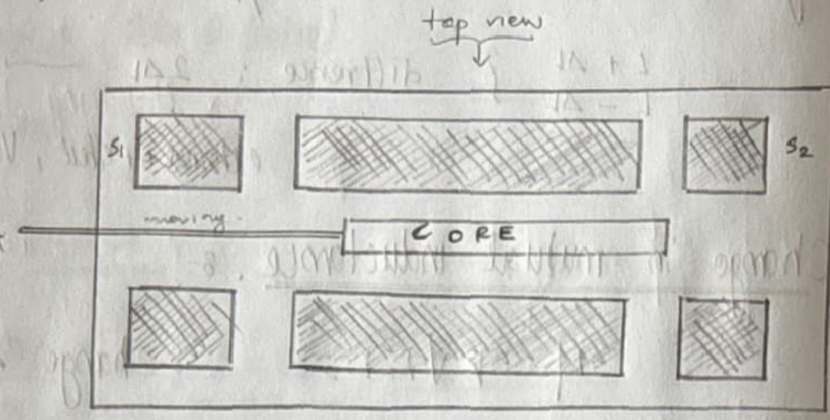
⇒ Formation of eddy Current:

• 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)





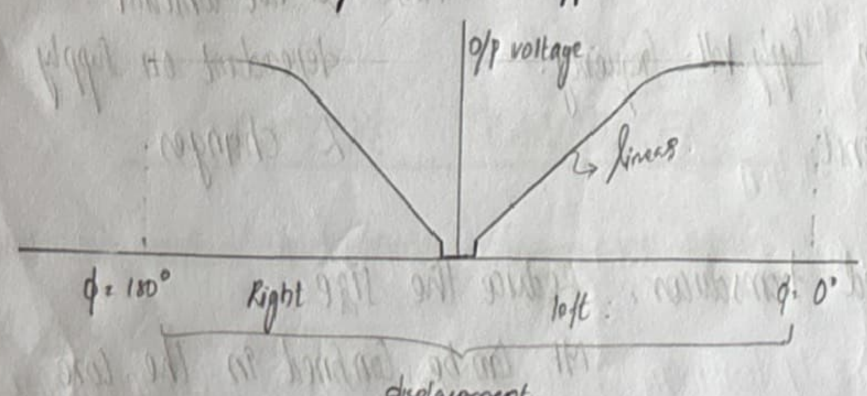
$E_0 = E_{S_1} - E_{S_2}$

- 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
appartment,
Mannanthery (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 ~~of~~ 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 across 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