UNIT-01

* Measurement →

Measurement is a comparison of an unknown quantity with a known standard quantity (constant quantity)

* Significance of Measurement →

1) Accuracy and consistency
2) Decision Making
3) Quality control
4) Communication
5) Innovation and development
6) Safety and compliance

* Methods of Measurement

1) Direct Method length, mass, time
2) Indirect Method → not feasible, practical

measurand → unknown quantity

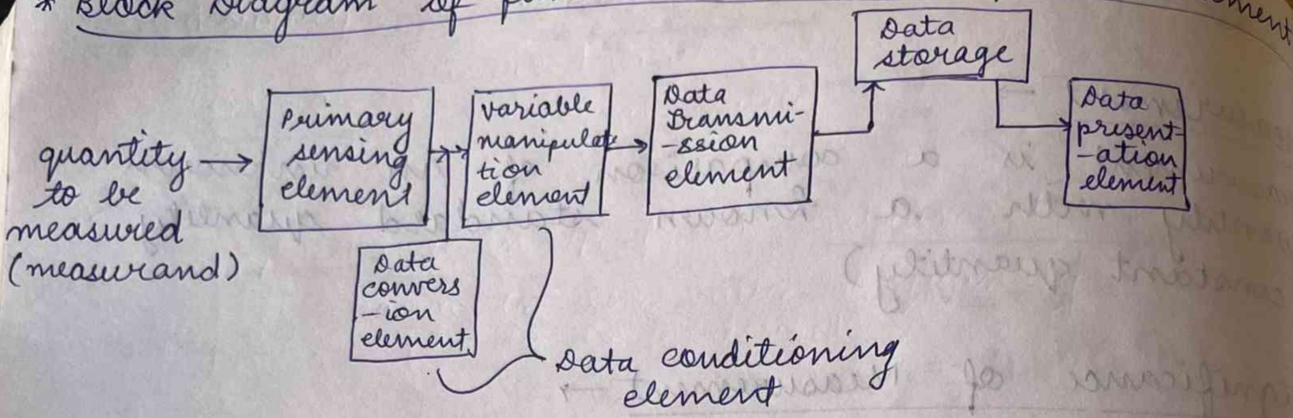
* Elements of Measuring System

1) Primary sensing element
2) Variable conversion element
3) Variable manipulation element

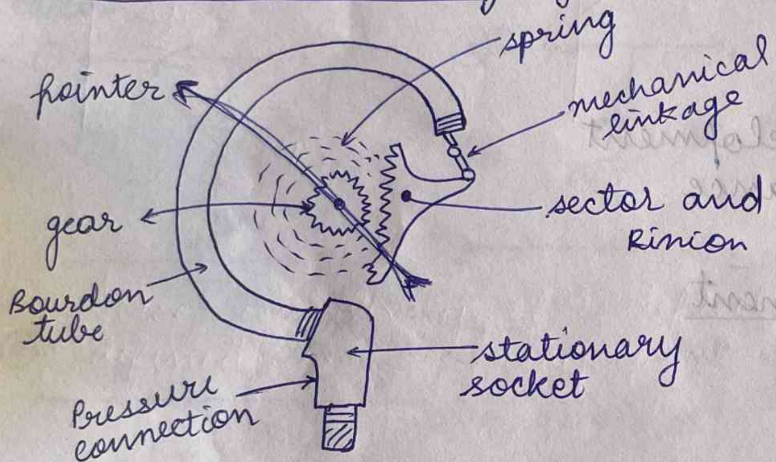
$\left.\right\}$ data conditioning element

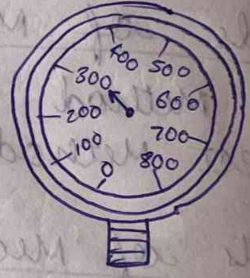
4) Signal conditioning element
5) Data transmission element
6) Data presentation element

* Block Diagram of functional element of measurement



* Bourdon Pressure gauge





Instrument
- Mechanical
- Electrical
  - Absoulute indirect
  - Secondary Direct
    - Analog
      - Deflecting type
      - Integrating type
      - Recording type
    - Digital
- Electronic

algebric sum of deviations $= d_1 + d_2 + d_3 + \dots d_n$

$= (x_1 - \bar{x}) + (x_2 - \bar{x}) - \dots - (x_n - \bar{x})$

$(x_1 + x_2 + x_3 + \dots x_n) = n\bar{x}_n$

* average deviation $= \frac{\Sigma|d|}{n}$

* standard deviation : $S = \sqrt{\frac{d_1^2 + d_2^2 + d_3^2 + \dots d_n^2}{n}}$

$S.D. = S = \sqrt{\frac{\Sigma d_n^2}{n}}$ (more than 20 values)

$S = \sqrt{\frac{\Sigma d^2}{n-1}}$ (less than 20 value)

* variance $= (S.D.)^2 = (\sigma)^2 = \frac{\Sigma d^2}{n}$

when the no. of observations is less than 20

variance $= (S.D.)^2 = (\sigma)^2 = \frac{\Sigma d^2}{n-1}$

$\boxed{A_a = A_s \pm \delta A}$ —— ①

$A_a \rightarrow$ actual value
$A_s \rightarrow$ nominal value
$\delta A \rightarrow$ limiting error

e.g., $A_a = 100 \pm 10V$
$= (100+10)$ or $(100-10)$

Relative limiting error $\varepsilon_r = \frac{\delta A}{A_s} = \frac{\varepsilon_0}{A_s}$ —— ②

$\varepsilon_r = \frac{\varepsilon_0}{A_s}$ $\{\varepsilon_0 = \delta A\}$

$\boxed{\varepsilon_0 = \varepsilon_r A_s}$

So, from eqⁿ ① & ②, limiting values are

$A_a = A_s \pm \delta A$

$\boxed{A_a = A_s \pm \varepsilon_r A_s}$

Percentage limiting error
$\% \varepsilon_0 = \varepsilon_r \times 100$

$\boxed{\varepsilon_r = \frac{A_a - A_s}{A_s}}$

Ques) A 0-150 voltmeter has a guarented accuracy of 1% of full scale reading. The voltage measured by this inst. is 75V. Calculate the limiting error in %

★ Arithmetic mean $\bar{x} = \frac{x_1 + x_2 + x_3 \dots x_n}{n}$

$\boxed{\bar{X} = \frac{\sum x_n}{n}}$

Derivation: $d_1 = x_1 - \bar{x}$
$d_2 = x_2 - \bar{x}$
⋮
$\bar{x} = \sum(x_n - d_n)$

STATIC ERROR

$$\boxed{\delta A = A_M - A_t} \text{ ——— } ①$$ (FOM)

δA = error

A_m = measured value of quantity

A_t = true value of quantity

static error, also called absolute error

$$\boxed{\delta A = \varepsilon_0} \text{ ——— } ②$$

ε_0 = absolute static error of quantity A

relative static error $\varepsilon_r = \frac{\delta A}{A_t}$

$$\varepsilon_r = \frac{\text{absolute error}}{\text{true error}}$$

$$\boxed{\varepsilon_r = \frac{\varepsilon_0}{A_t}} \text{ ——— } ③ \quad [\delta A = \varepsilon_0]$$

$$\varepsilon_r = \frac{\delta A}{A_t}$$

Percentage static error

$$\% \varepsilon_r = \varepsilon_r \times 100 \text{ ——— } ④$$

∵ we have

$$A_t = A_m - \delta A$$

$$\boxed{\delta C = -\delta A}$$

$$A_t = A_m - \varepsilon_0$$

$$A_t = A_m - \varepsilon_r A_t$$

$$A_t + \varepsilon_r A_t = A_m$$

$$A_t = \frac{A_m}{1 + \varepsilon_r} \text{ ——— } ⑤$$

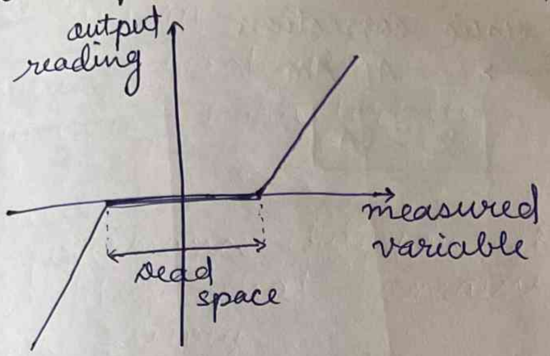
Ques) A thermometer reads $\underset{A_m}{95.45\,°C}$ & the static correction given is $\underset{\delta C}{-0.08\,°C}$. Determine true value of

Ques) A voltage has true value of $\overset{A_t}{1.50\,V}$ and analog indicating instrument with scale range of 0–2.50 shows a voltage of $1.46\,V^{A_m}$. What are the value of absolute error and correction. Express the error as a fraction of true value and full scale deflection.

$\delta A = ?$ $\varepsilon_r = ?$

$\delta C = ?$

* Dead space of zone → the range of diff. I/p values over which there is no O/p value



[II] DYNAMIC CHARACTERISTICS

→ speed of response
→ measuring lag → retardation type
→ time delay lag
→ fidelity
→ dynamic error

* ERROR

→ gross error
→ systematic error → instrumental error
→ observational error
→ environmental error
→ Random error

* Static error = Measured value − True value

absolute error $\boxed{SA = A_m - A_t}$

$\boxed{\varepsilon_0 = SA}$

ε_0 → absolute static error of quantity A (under measurement)

* Relative ~~absolute~~ static error = $\frac{\text{absolute error}}{\text{true value}}$

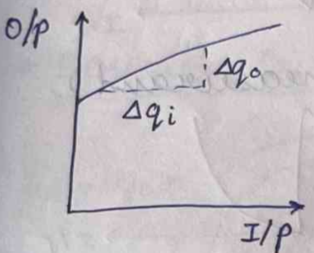
$$\varepsilon_r = \frac{SA}{A_t} = \frac{\varepsilon_0}{A_t}$$

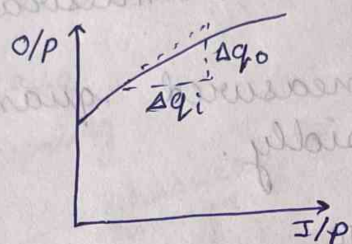
% static error = $\%\varepsilon_r = \varepsilon_r \times 100$

Accuracy = 100% − error rate

$$\text{Error rate} = \frac{\text{observed value} - \text{actual value}}{\text{actual value}} \times 100\%$$

$$\text{SENSITIVITY} = \frac{\text{change in o/p of an instrument}}{\text{change in the value of quantity to be measured}}$$





→ Inverse sensitivity or deflection factor is defined as reciprocal of sensitivity.

$$\text{Inverse sensitivity / Deflection factor} = \frac{1}{\text{sensitivity}} = \frac{\Delta q_i}{\Delta q_o}$$

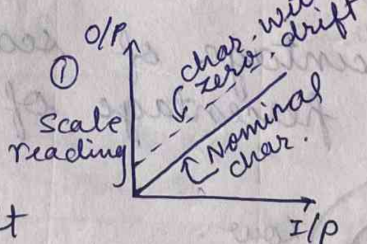
* Linearity

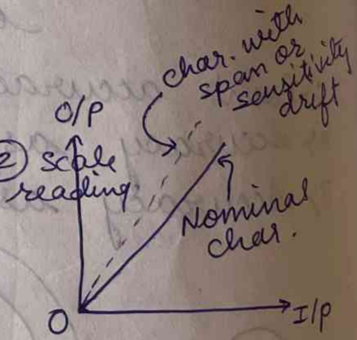
* Drift

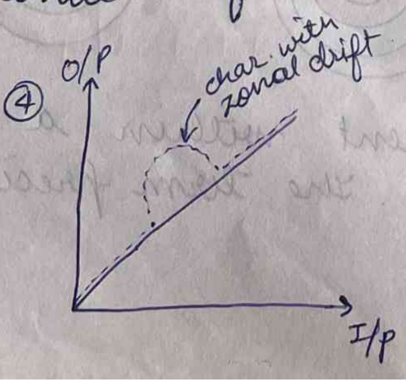
① zero drift

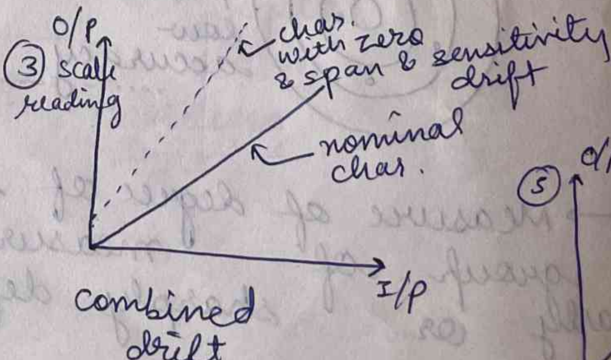
② span or sensitivity drift

③ zonal drift

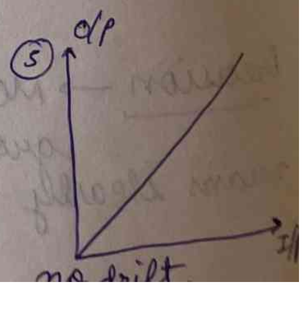








combined drift



no drift

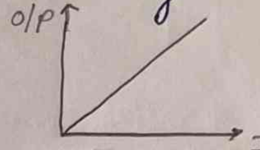
Performance Characteristic of a measurement System

1) static characteristic
2) Dynamic Characteristic

STATIC

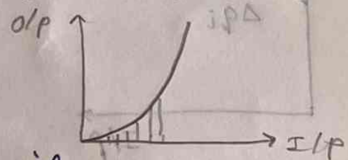
→ The performance criterion for the measurement of quantities that remains constant or vary only quite slowly.

It is divided into → desirable → undesirable



DYNAMIC

→ Input & ouptup measured quantity (measurand) is varing rapidly.

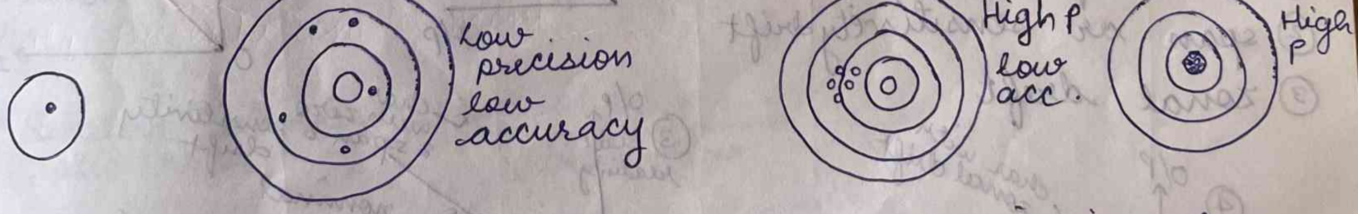


[I] STATIC CHARACTERISTC

→ Accuracy → Precision → sensitivity → linearity.
→ Reproducability → Repeatability → resolution.
→ Threshold → Drift (undesirable) → stability
→ Tolerance (und.) → Range or span → Dead zone
→ static error (und.)

Accuracy → Degree of closeness with which the reading approaches the true value of the quantity to be measured.

1) Point accuracy
2) Accuracy as percentage of scale span
3) Accuracy as a percentage of true value.



Precision → Measure of degree of agreement within a group of measurement. The term precise means clearly or sharply defined.