DEPARTMENT OF ELECTRNICS & COMMUNICATION ENGINEERING, KITSW

COURSE: **U14EI 205 - BASIC ELECTRONICS ENGINEERING**	**ECE-I, Semester-II, 2015-16**

ASSIGNMENT-7 HINTS &SOLUTIONS (PART-2- of -3)

5. Define and explain various static characteristics of a measuring instrument.

PERFORMANCE CHARACTERISTICS OF MEASURING INSTRUMENTS

The performance characteristics of an instrument are mainly divided in two categories:

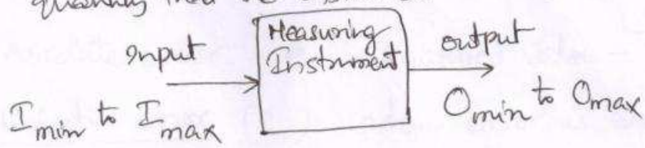
✓ Static characteristics ✓ Dynamic characteristics.

STATIC CHARACTERISTICS:

The various static characteristics are

1. Range
2. Span
3. Sensitivity
4. Accuracy
5. Precision
6. Threshold
7. Resolution
8. Linearity
9. Hysteresis
10. Drift.

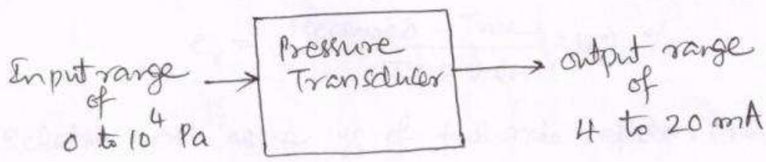
(1) Range: It defines the minimum and maximum values of a quantity that the instrument is designed to measure.

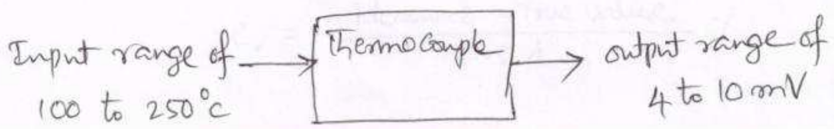


✓ Input range is specified by minimum and max values

✓ output range is specified by minimum and max values

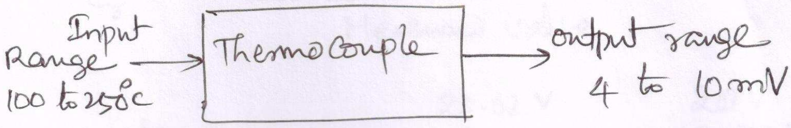
Ex:





(2) Span : Span is the maximum variation in input or o/p

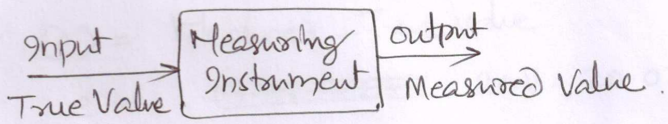
Ex:



The input span of this thermocouple : $I_{max} - I_{min} = 250 - 100 = 150°C$

The output span of this thermocouple = $10mV - 4mV = 6mV$

(3) Error :



→ In general, the measured value does not equal the true value of the measurand.

→ The measurement error (E) = Measured Value − True value.

→ Absolute error **e** = Measured Value − True value.

→ Relative error (e_r) : when error is expressed as a percentage, it becomes a relative error

→ Relative error as a % of true value.

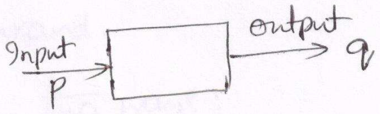
$$e_r = \frac{\text{Measured} - \text{True}}{\text{True Value}} \times 100\ \%$$

→ Relative error as a % of full scale deflection (fsd)

$$e_r = \frac{\text{Measured} - \text{True value}}{\text{f.s.d}} \times 100\ \%$$

→ Relative error as % of measured value } $e_r = \dfrac{\text{Measured} - \text{True Value}}{\text{Measured value}} \times 100\ \%$.

<u>Sensitivity</u> is defined as the rate of change of output with respect to input.



$$S = \frac{dP}{dq}$$

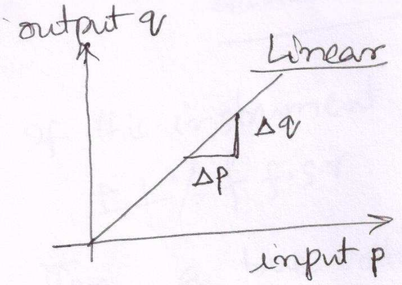
(or) $$S = \frac{\Delta P}{\Delta q}$$

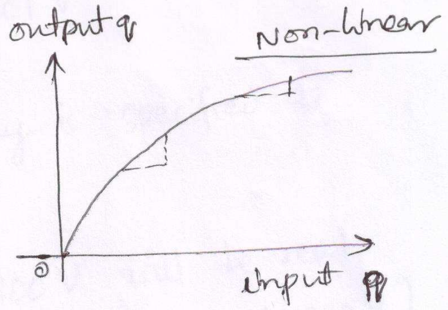
<u>Ex:</u> If in a mercury-in-glass thermometer, the meniscus moves by 1 cm when the temperature changes by 10°C, the sensitivity of the thermometer is

$$S = \frac{\text{change in o/p}}{\text{change in i/p}} = \frac{1\,cm}{10^\circ C} = \frac{10\,mm}{10^\circ C}$$

$$S = 1\ mm/^\circ C$$

✓ The sensitivity of a linear instrument is constant while that of a non-linear one varies from one range to another





✓ Sensitivity of the instrument should be as high as possible

✓ Deflection factor $= \dfrac{1}{\text{sensitivity}}$

Accuracy is the closeness of the instrument reading to the true value of the measurand.

→ Accuracy is often specified in two ways:

(i) Accuracy as "percentage of true value"
(ii) Accuracy as "percentage of full-scale reading".

Ex: A true voltage of 100 V is to be measured using a voltmeter of range 0 – 1000 Volts.
i.e, its full-scale reading is 1000 V.

→ If this instrument's accuracy is specified as ±1% of true value.

→ ∴ A true voltage of 100V will be read as a value between (100 – 1% of 1000) to (100 V + 1% of 100 V)

i.e, 100 V will be read as some value between 99 V to 101 V

→ If this instrument accuracy is specified as ±1% of f.s.r

Then, a true voltage of 100 V will be read as some value between (100V ± 1% of 1000 V)

i.e, 100 V will be read as some value between 90 V to 110 V

∴ Accuracy specification as % of true value is more accurate than the % of full-scale reading.

→ The instrument having high accuracy will result in less errors in measurement //

Precision: Precision is the ability of the instrument to reproduce a group of measurements of same measurand, using same instrument, under same conditions.

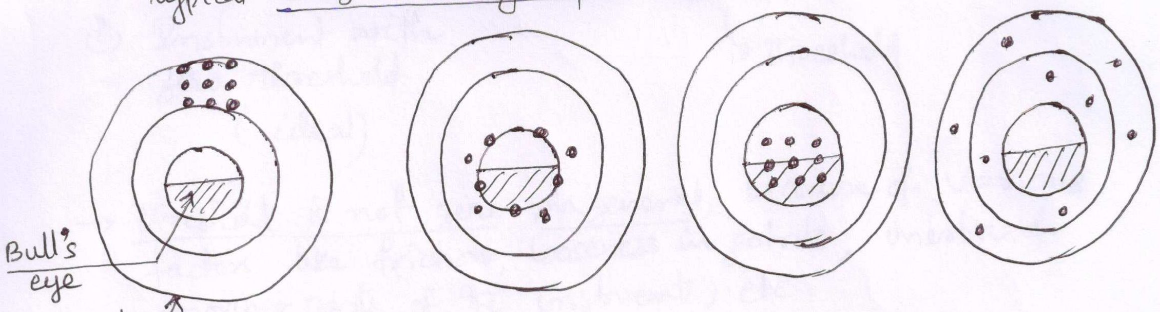
→ Precision of an instrument indicates the degree of repeatability or reproducibility.

Accuracy Vs Precision

→ Accuracy represents the degree of correctness of the measured value w.r.t the true value

→ Precision represents the degree of repeatability of a certain group of measurements.

The accuracy and precision can be illustrated with a typical target shooting experiment.



(i) High precision with poor accuracy shoot

(ii) Good Average Accuracy with poor precision

(iii) High Accuracy with High precision

(iv) Poor Accuracy with poor precision

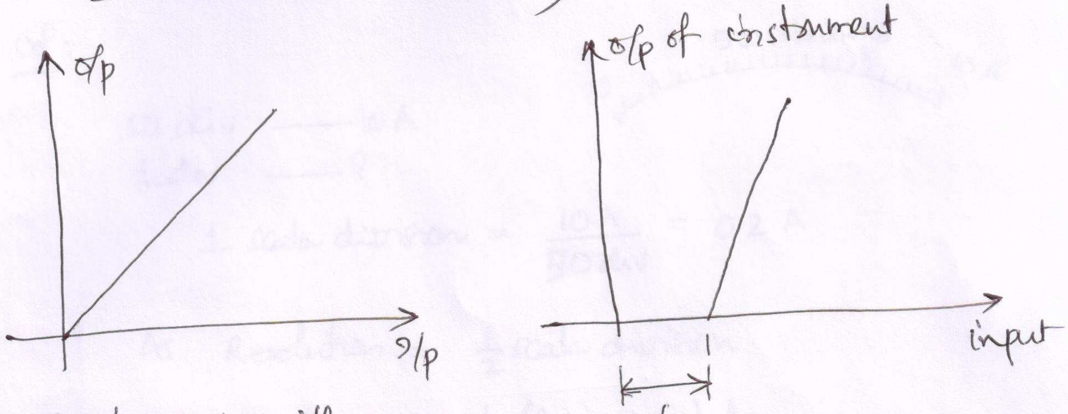
⇒ ∴ A Precise instrument may not necessarily be accurate (case-i) and vice versa

Threshold

Threshold is the minimum input which is necessary to activate an instrument to produce an output.

(→ suppose an instrument is in its zero position i.e, there is no input to it.

→ If the input quantity is gradually increased, the instrument output does not change until some minimum value of input is exceeded. This minimum value of input below which no output can be detected is termed its threshold.)



(i) Instrument with zero threshold (ideal)

→ Threshold is not zero, in general, because of various factors like friction, looseness in joints, inertia of moving parts of the instrument, etc.

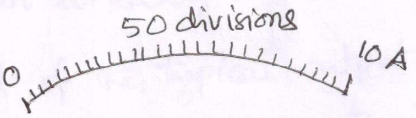
Resolution :

→ An instrument needs a minimum increment in the input to produce a detectable (perceptible) output.

→ The smallest measurable change in the input is called the resolution of the instrument.

Ex : An analog ammeter has a linear scale of 50 divisions. Its full-scale reading is 10 A and half a scale division can be read. What is the resolution of the instrument.

Sol :



50 div —— 10 A
1 div —— ?

$$1 \text{ scale division} = \frac{10\,A}{50\,div} = 0.2\,A$$

$$\text{As Resolution} = \frac{1}{2} \text{ scale division}$$
$$= \frac{1}{2}(0.2) = 0.1\,A$$

The resolution of instrument = 0.1A.

i.e, this ammeter can detect a minimum of 0.1A change in the current.

It will not detect a current change of < 0.1A

Ex : for 5.05 A —It→ will indicate 5.00A

for 5.1 A —It→ will respond to 0.1 A change and indicate 5.1A

→ Thus, Resolution is the smallest measurable input change while, Threshold is the smallest measurable input.

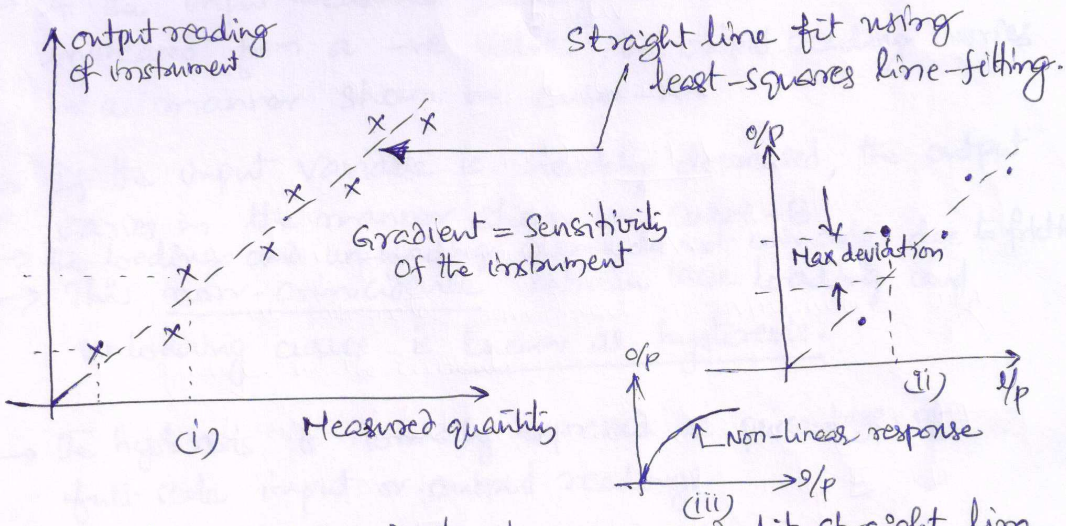
Linearity: Linearity is the most desirable feature of any instrument.

→ It is normally desirable that the output reading of an instrument is linearly proportional to the quantity being measured (measurand).

→ The manufacturers of instruments always atempt to design their instruments so that the output is a linear function of the input.

→ A perfect linearity is never completely achieved. Almost all the so-called linear instruments show some deviation from linearity

→ The figure shows the plot of the typical output readings (x marks) when a sequence of inputs is applied.



→ Normal procedure is to draw a good-fit straight line through the crosses (points) using least-squares line fitting.

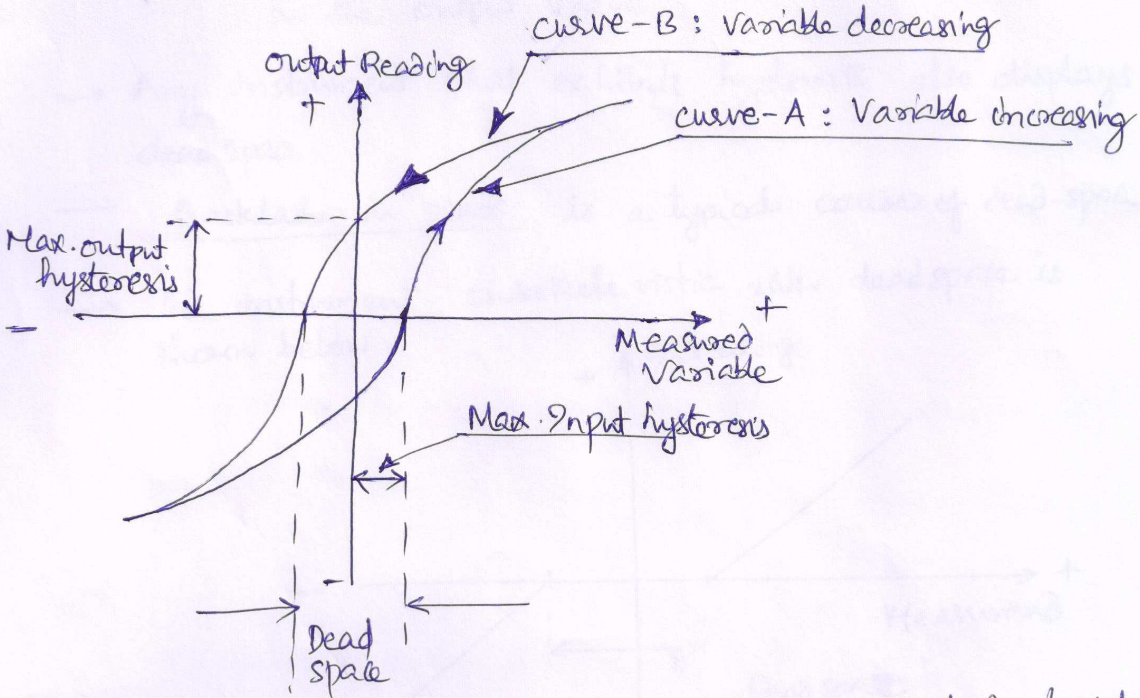
→ Linearity is a measure of how close is the o/p of instrument to the straight line.

→ The non-linearity is then defined as the maximum deviation of any output reading from this straight line.

→ Non-linearity is usually expressed as % of full-scale reading

$$\% \text{ Linearity} = \frac{\text{Max. deviation of output from idealized straight line}}{\text{Full-scale reading}} \times 100\%$$

Hysteresis: The output characteristics of an instrument which exhibits hysteresis is shown below.



→ If the input measured quantity to the instrument is steadily increased from a -ve value, the output reading varies in a manner shown in curve-A.

→ If the input variable is steadily decreased, the output varies in the manner shown in curve-B.

→ The loading and un-loading curves do not coincide due to friction.

→ This non-coincidence between these loading and unloading curves is known as hysteresis.

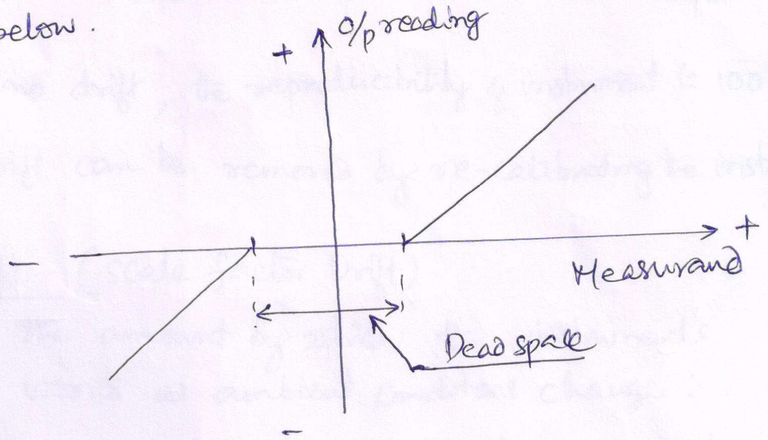
→ The hysteresis is normally expressed as percentage of full-scale input or output readings.

Dead Space Dead space is defined as the range of different input values over which there is no change in the output value.

→ Any instrument that exhibits hysteresis also displays dead space.

→ Backlash in gears is a typical cause of dead-space.

→ The instrument characteristic with deadspace is shown below.



Drift or Zero Drift (Bias).

→ All calibrations and specifications of an instrument are valid only under controlled conditions of temperature, pressure and other ambient conditions.

→ The environmental changes affect instrument in two main ways:

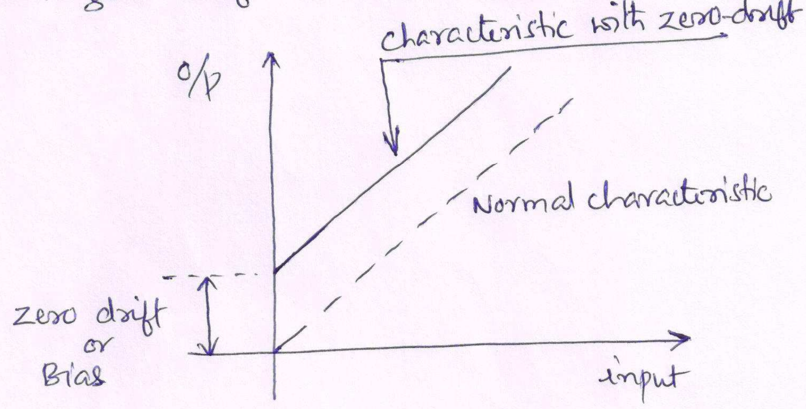
(i) Zero drift

(ii) sensitivity drift.

Zero Drift: when input = 0, the output of instrument should be zero.

→ But the zero reading of the instrument will be modified by a change in ambient conditions.

An instrument with zero drift is shown below



→ If there is no drift, the reproducibility of instrument is 100%.

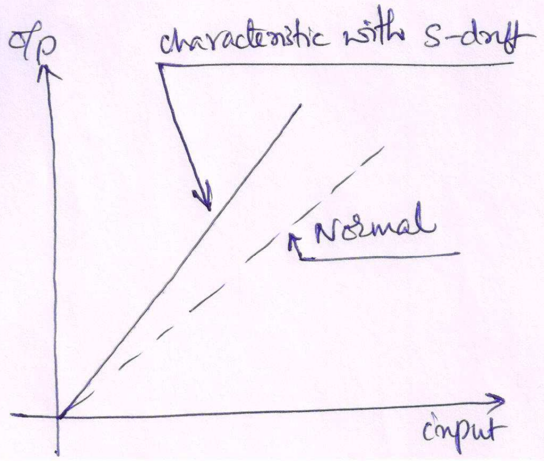
→ The zero drift can be removed by re-calibrating the instrument

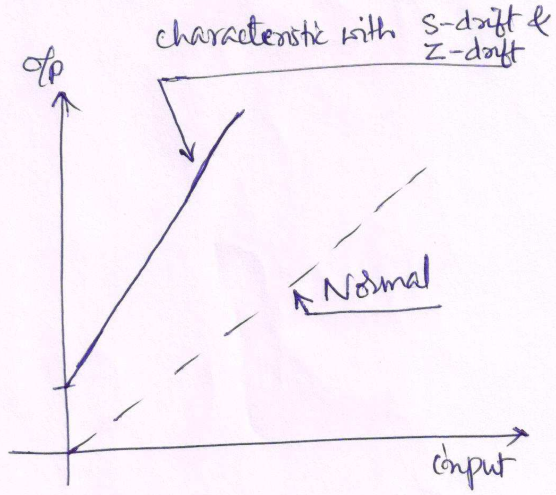
Sensitivity Drift (scale factor Drift)

→ It defines the amount by which the instrument's sensitivity varies as ambient conditions change.

→ An instrument which suffers sensitivity drift is shown below

→ An instrument which suffers both zero drift and sensitivity drift is shown below.





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