TUTORIAL SHEET-I

Unit -1

Objective question

1. …………. are integrating instruments?

1. Ammeters
2. Voltmeters
3. Watt-meters
4. Ampere-hour and Watt-hour meters

2.………….. Instruments indicate the instantaneous value of the electrical quantity being measured at the time at which it is being measured?

1. Absolute
2. Indicating
3. Recording
4. Integrating

3. The use of ………….. Instruments is merely confined within laboratories as standardizing instruments.

1. absolute
2. indicating
3. recording
4. integrating
5. none of the above

4. ………….. Instruments measure the total quantity of electricity delivered at a particular time.

1. absolute
2. indicating
3. recording
4. integrating

5. The spring material used in a spring control device should have the following property:

1. should be non-magnetic
2. should have low-temperature co-efficient
3. should have low specific resistance
4. all of the above

6. A …………. device prevents the oscillation of the moving system and enables the latter to reach its final position quickly.

1. deflecting
2. controlling
3. damping
4. all of the above

7. The pointer of an indicating instrument should be ……

1. very light
2. very heavy
3. either 1 or 2
4. neither 1 nor 2

8. **In majority of instruments, damping is provided by ………**

1. fluid friction
2. spring
3. eddy currents
4. all of the above

9. **The switchboard instruments should be mounted in ……….. position.**

1. vertical
2. horizontal
3. either 1 or 2
4. neither 1 nor 2

10. **The multiplier and the meter-coil in a voltmeter are in …….**

1. series
2. parallel
3. series-parallel
4. none of the above

11. **A moving iron instrument can be used for ……..**

1. D.C. only
2. A.C. only
3. both D.C. and A.C.
4. none of the above

12. The resistance in the circuit of the moving coil of a dynamometer should be ……

1. zero
2. low
3. high
4. none of the above

13. In a 3-phase power measurement by two wattmeter method, the reading on one of the wattmeter is zero. The power factor of the load must be ………….

1. unity
2. 0.5
3. 0.3
4. zero

14. In order to achieve high accuracy, the slide wire of a potentiometer should be …………

1. as long as possible
2. as short as possible
3. neither too small nor too large
4. very thick

Long Type

15. Identify basic functional elements of any measurement system of your choice.

Ans:- It is important to have a systematic organization and analysis of measurement systems. An Instrument may be· defined as a device or a system which is designed to maintain a functional relationship between prescribed properties of physical variables and must include ways and means of communication to a human observer. The functional relationships remain valid only as long as the static calibration of system remains constant. On the other hand, the performance of a Measurement system can be described in terms of static and dynamic characteristics. It is possible and desirable to describe the operation of a measuring instrument or a system in a generalized manner without resorting to intricate details of the physical aspects of a specific Instrument or a system. The whole operation can be described in terms of functional elements. Most of the measurement systems contain three main functional elements. They are:

a. Primary Sensing Element
b. Variable Conversion Element
c. Data Presentation Element

Each functional element is made up of a distinct component or groups of components which perform required and definite steps in the measurement. These may be taken as basic elements whose scope is determined by their functioning rather than their construction.

16. Define measurement system and its types

A measurement system consists of a transducing element which converts the quantity to be measured in an analogous form. The analogous signal is then processed by some intermediate means and is then fed to the end devices\which present the results of the measurement.

The methods of measurement may be broadly classified into two categories.

a. **Direct Methods**: In these methods, the unknown quantity (also called the measurand) is directly compared against a standard. The result is expressed as a numerical number and a unit. The standard, in fact, is a physical embodiment of a unit. Direct methods are quite common for the
Measurement of physical quantities like length, mass and time.

b. **Indirect Methods:** Measurement by direct methods are not always possible, feasible and practicable. These methods in most of the cases, are inaccurate because they involve human factors. They are also less sensitive. Hence direct methods are not preferred and are rarely used.

***17.* Define absolute and secondary instruments**

Ans: There are many ways in which instruments can be classified. Broadly, instruments are classified into two categories :

a) Absolute Instruments: These instruments give the. magnitude of .the quantity under measurements in terms of physical constants of the instrument. The examples of this class of instruments are Tangent Galvanometer and Rayleigh's current balance.

b.)Secondary Instruments. These instruments are SO' constructed that the quantity being measured can only be measured by observing the output indicated by the instrument. These instruments are calibrated by comparison with an absolute instrument or another secondary instrument which has already been calibrated against an absolute instrument. Working with absolute instruments for routine work is time consuming since every time a measurement is made, it takes a lot of time to compute the magnitude of the quantity under measurement.

Therefore secondary instruments are most commonly used. Absolute instruments are seldom used except in standards institutions while secondary instruments find usage almost in every sphere of measurement. A voltmeter, a glass thermometer and a pressure gauge are typical example’s of secondary instruments.

18. Explain the function of instruments and measurement Systems

There is another way in which instruments or measurement systems may be classified. This classification is based upon the functions they perform. The three main functions are explained below.

a).Indicating Function: Instruments and systems use different kinds of methods for supplying information concerning the variable quantity under measurement. Most of the time this information is obtained as a deflection of a pointer of a measuring instrument. In this way the instrument performs a function which is commonly known as indicating function. For example, the deflection of pointer of a speedometer indicates the speed of the automobile at that moment. . A pressure gauge is used for indicating pressure'. , ·

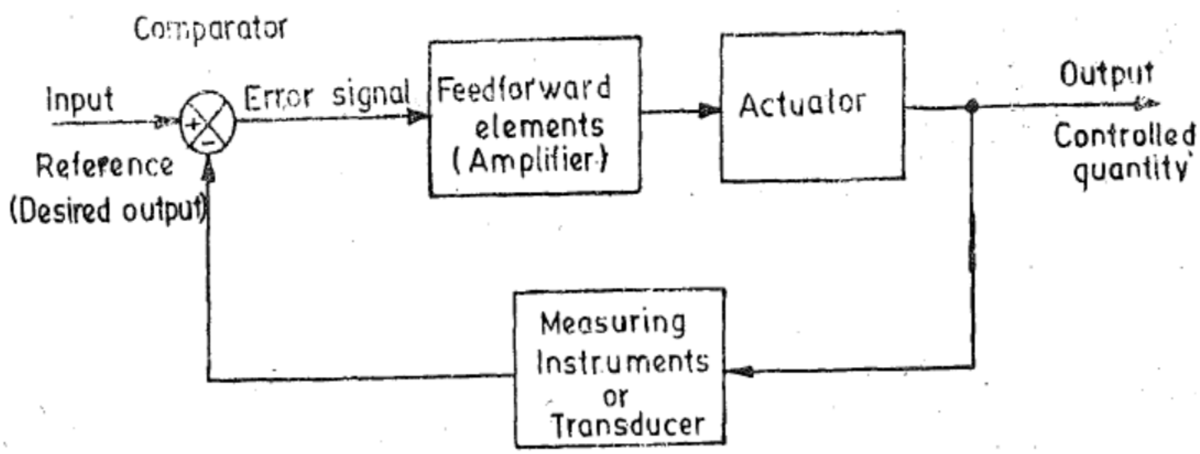
b. Recording Function. In many cases the instrument makes a written record, usually on paper, of the value of the quantity under measurement· against time or against some other variable. Thus the instrument performs a recording function. For example, a potentiometric type of recorder used for monitoring temperature records the instantaneous temperatures on a strip chart recorder.

c. Controlling Function. This is one of the most important functions especially in the field of industrial control processes. In 1his case, the information is used by the instrument or the system to control the original measured quantity.

Thus there are three main groups of instruments. The largest group has the indicating function. Next in line is the group of instruments which have both indicating and or recording functions. The last group falls into a special category and performs all the three functions, *i.e.* indicating, recording and controlling.

19. **Draw the Block diagram of a simple control system and explain**

Ans. Simple Control system: A very useful application of instruments is in automatic control systems. There has been a very strong association between measurement and control. In order that process variables like temperature, pressure, humidity, etc. may be controlled, the prerequisite is that they can be measured at the desired location in the individual plants. Same is true of servo-systems, i.e., systems connected with measurement of position, velocity and acceleration. A block diagram of a. simple control system is shown in Fig.



20. **Explain the Calibration of an Instrument**

Calibration is a comparison between a known measurement (the standard) and the measurement using your instrument. Typically, the accuracy of the standard should be ten times the accuracy of the measuring device being tested. However, accuracy ratio of 3:1 is acceptable by most standards organizations.

Calibration of your measuring instruments has two objectives. It checks the accuracy of the instrument and it determines the traceability of the measurement. In practice, calibration also includes repair of the device if it is out of calibration. A report is provided by the calibration expert, which shows the error in measurements with the measuring device before and after the calibration.

To explain how calibration is performed we can use an external micrometer as an example. Here, accuracy of the scale is the main parameter for calibration. In addition, these instruments are also calibrated for zero error in the fully closed position and flatness and parallelism of the measuring surfaces. For the calibration of the scale, a calibrated slip gauge is used. A calibrated optical flat is used to check the flatness and parallelism.

A measuring device should be calibrated:

1. According to recommendation of the manufacturer.

2. After any mechanical or electrical shock.
3. Periodically (annually, quarterly, monthly)

Unit-2

Objective Question

1. The error of an instrument is normally given as a percentage of
   (a) measured value
   (b) full-scale value
   (c) mean value
   (d) rms value
2. The repeat accuracy of an instrument can be judged from its
   (a) static error
   (b) linearity error
   (c) dynamic error
   (d) standard deviation of error
3. Which of the following meters has a linear scale?
   (a) Thermocouple meter
   (b) Moving iron meter
   (c) Hot wore meter
   (d) Moving coil meter
4. Two voltmeters have the same range 0-400V. The internal impedance are 30,000 Ohms and 20,000 Ohms. If they are connected in series and 600V be applied across them, the readings are
   (a) 360V and 240V
   (b) 300V each
   (c) 400V and 200V
   (d) one of the meters out of the range and other 100V
5. The full-scale deflection current of an ammeter is 1 mA and its internal resistance is 100Ohm. If this meter is to have full deflection at 5A, what is the value of the shunt resistance to be used?
   (a) 49.99 Ohms
   (b) 1/49.99 ohms
   (c) 1 Ohm
   (d) 2 Ohms
6. The full-scale deflection current of an ammeter is 1 mA and its internal resistance is 100Ohm. This is to have full deflection when 100V is measured. What is the value of series resistor to be used?
   (a) 99.99 K ohms
   (b) 100 K ohms
   (c) 99.99 ohms
   (d) 100 ohms

7. The EMF of Weston standard cell is measured using

(a) Moving- iron meter

(b) Moving-coil meter

(c) Digital Volt meter

(d) Potentiometer

8. A 10MHz CRO has

(a) 5MHz sweep

(b) 10MHz vertical oscillator

(c) 10MHz horizontal oscillator

(d) 10MHz supply frequency

9. Which of the following instruments can be used to measure AC current only?
(a) Permanent Magnet Type ammeter
(b) Induction type ammeter
(c) Moving iron voltmeter
(d) Moving iron ammeter
1. D only
2. B only
3. A, B, D
4. B and D only

10. An oscilloscope indicates
(a) Peak to peak value of voltage
(b) DC value of voltage
(c) RMS value
(d) Average value

11. In a ballistic galvanometer, the deflecting torque is proportional to
(a) the current through coil
(b) square of current through coil
(c) square-root of current through coil
(d) sine of measured

12. The error of an instrument is normally given as a percentage of
(a) measured value
(b) full-scale value
(c) mean value
(d) rms value

13. If the instrument is to have a wide range, the instrument should have
(a) Linear scale
(b) Square-law scale
(c) Exponential scale
(d) Logarithmic scale

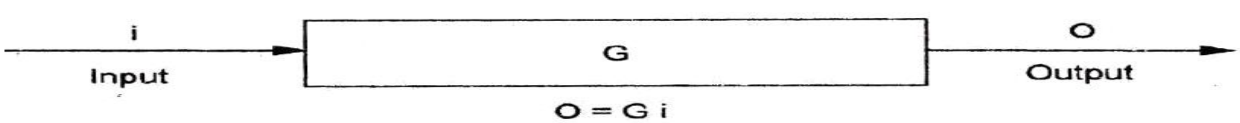
14. The resistance can be measured most accurately by
(a) Voltmeter-ammeter method
(b) bridge method
(c) multi-meter
(d) Megger

15. The repeat accuracy of an instrument can be judged from its
    (a) static error
    (b) linearity error
    (c) dynamic error
    (d) standard deviation of error
16. Which of the following meters has a linear scale?
    (a) Thermocouple meter
    (b) Moving iron meter
    (c) Hot wore meter
    (d) Moving coil meter
17. No eddy current and hysteresis losses occur in
    (a) Electrostatic instruments
    (b) PMMC instruments
    (c) Moving iron instruments
    (d) Electro dynamo meter instruments

LONG TYPE

1. Explain INPUT, OUTPUT CONFIGURATION OF A MEASURING INSTRUMENT:-

Answer : INPUT, OUTPUT CONFIGURATION OF A MEASURING INSTRUMENT:-



Input-output relation of a measurement system

An instrument performs an operation on an input quantity (measurement/designed variable) to provide an output called the measurements. The input is denoted by “i” and the output is denoted by “o”. According to the performance of the instrument can be stated in terms of an operational transfer function(G).The input and output relationship is characterized by the operation ‘G’ such that

$$o=G\ i$$

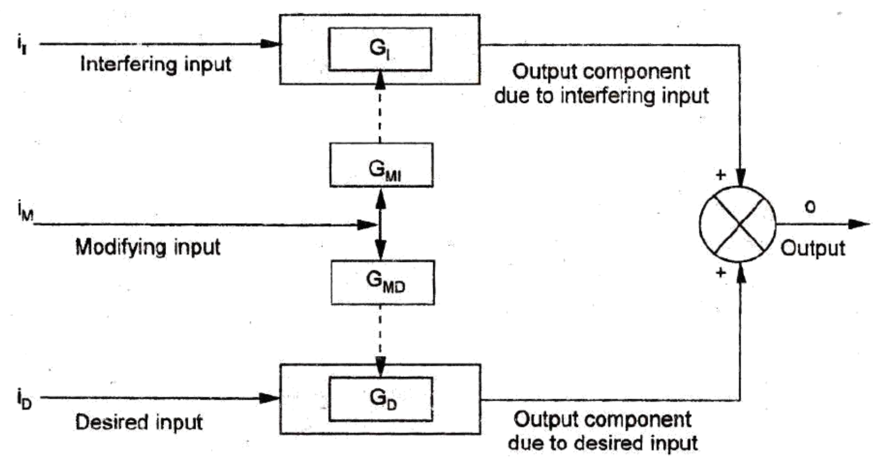
The various inputs to a measurement system can be classified into-three categories:

Desired input: A quantity that the instrument is specifically intended to measure. The desired input produces an output component according to an input-output relation symbolized by ; here represents the mathematical operation necessary to obtain the output from the input.

Interfering input: A quantity to which the instrument is unintentionally sensitive. The interfering input would produce an output component according to input-output relation symbolized by

Modifying input: A quantity that modifies the input-6utput relationship for both the desired and interfering inputs. The modifying input would cause a change in and/or . The specific manner in which affects and G, is represented by the symbols and , respectively. A block diagram of these various aspects has been illustrated in Fig.

i)



Generalised input-output configuration

2.Performance characteristics of a measuring instrument:-

1. Static characteristics
2. Dynamic characteristics

The performance characteristics of an instrument system is conclusion by low accurately the system measures the requires input and how absolutely it reject the undesirable inputs.

Error = measured value (A_m) – true value (A_t)

Static Correction = (true value (A_t) - measured value (A_m).

1. Static characteristics:

a) Range and span, b) Accuracy, error, correction, c) Calibration, d) Repeatability, e) Reproducibility f) Precision, g) Sensitivity, h) Threshold, i) Resolution, j) Drift, k) Hysteresis, dead zone.

3. Define Range and span:

The region between the limits with in which as instrument is designed to operate for measuring, indicating (or) recording a physical quantity is called the range of instrument. The range is expressed by standing the lower and upper values. Span represents the algebraic difference between the upper and lower range values of the instruments.

Ex:

Range - 10 C° to 80 C°	Span=90°c
Range 5 bar to 100 bar	Span=100-5=95 bar
Range 0 v to 75v	Span=75volts

3.Define Accuracy, error, correction and explain Calibration in measurement system

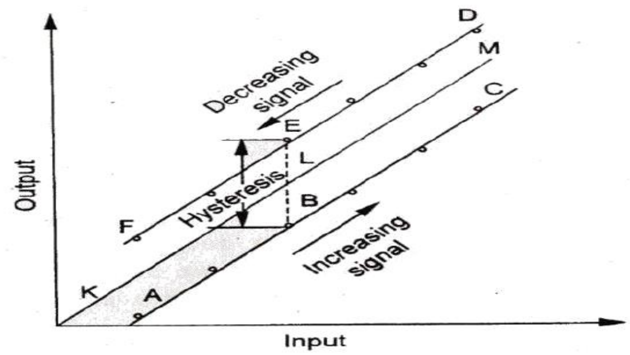
No instrument gives an exact value of what is being measured, there is always some uncertainty in the measured values. This uncertainty express in terms of accuracy and error. **Accuracy** of an indicated value (measured) may be defined as closeness to an accepted standard value (true value). The difference between measured value (A_m) and true value (A_t) of the quantity is

Expressed as **instrument error**. = A_m- A_t

Static correction is defined as - = A_t - A_m

Calibration:

The magnitude of the error and consequently the correction to be applied is determined by making a periodic comparison of the instrument with standards which are known to be constant. The entire procedure laid down for making, adjusting or checking a scale so that readings of an instrument or measurement system conform to an Accepted standard is called the calibration. The graphical Representation of the calibration record is called calibration curve and this curve relates standard values of input or measured to actual values of output throughout the operating range of the instrument. A comparison of the instrument reading may be made with



Calibration curve

(i) a primary standard,
(ii) a secondary standard of accuracy greater than the instrument to be calibrated,
(iii) a known input source.

4. **What are the important points and observations that need to consideration while calibrating an instrument?**

The important points and observations that need to consideration while calibrating an instrument

(a) Calibration of the instrument is out with the instrument in the same (upright, horizontal etc.) and subjected same temperature and other environmental conditions under which it is to operate while in service.

(b) The instrument is calibrated with values of the measuring impressed both in the increasing and in the decreasing order. The results are then expressed graphically, typically the output is plotted as the ordinate and the input or measuring as the abscissa.

(c) Output readings for a series of impressed values going up the scale may not agree with the output readings for the same input values when going down.

(d) Lines or curves plotted in the graphs may not close to form a loop.

6) Define Repeatability, Reproductability, Precision, Sensitivity:

Ans: Repeatability describes the closeness of the output readings, when the same input is applied repeatability over a short period of time with the same measurement conditions, same instrument and observer, same location and same conditions of use maintained throughout.

Reproductability: Reproductability describes the closeness of output readings for the same input. When are changes in the method of measurement, observer, measuring instrument, and location, conditions of use and time of measurement.

Precision: The instrument ability to reproduce a certain group of the readings with a given accuracy is known as precision i.e., if a no of measurements are made on the same true value then the degree of closeness of these measurements is called precision. It refers to the ability of an instrument to give its readings again and again in the same manner for constant input signals.

Sensitivity: Sensitivity of an instrument is the ratio of magnitude of response (output signal) to the magnitude of the quantity being measured (input signal) i.e.,

ii) Static sensitivity = $\frac{\text{change of output signal}}{change\ in\ input\ signal}$

7.Define Threshold, Resolution,Drift, Hysteresis, Dead zone:

Threshold defines the minimum value of input which is necessary to cause detectable change from zero output. When the input to an instrument is gradually increased from zero, then the input must reach to a certain minimum value, so that the change in the output can be detected. The minimum value of input refers to threshold.

Resolution: It is defines as the increment in the input of the instrument for which input remains constant i.e., when the input given to the instrument is slowly increased for which the output remains same until the increment exceeds a different value.

Drift: The slow variation of the output signal of a measuring instrument is known as draft. The variation of the output signal is not due to any changes in the input quantity, but to the changes in the working conditions of the components inside the measuring instruments.

Hysteresis, Dead zone: Hysteresis is the maximum difference for the same measuring quantity (input signal) between the up scale and down scale reading during a full range measure in each direction. Dead zone is the largest range through which an input signal can be varied without initiating any response from the indicating instrument it is due to the friction.

Unit-3

Objective Type

1.'Erg' is a unit of measurement for ________

a. ***Energy***
b. Power
c. Voltage
d. Impedance

2.The S.I unit of electric charge is ______.

a. Henry
b. ***Coulomb***
c. Tesla

d. Weber

3.Which one of the following statement is NOT TRUE about the MI type instruments?

a. MI type Instruments are suitable for both AC and DC circuits.
b. Frictional error in MI type instruments is very less.
c. The torque weight ratio of MI type instruments is high.
d. ***The instrument cost is much higher as compared to PMMC type instruments.***

4.Which one of the following statement is NOT TRUE about multimeter

a. Multimeter can be used for the measurement of voltage.
e. ***Multimeter can be used for the measurement of power***
f. Multimeter can be used for the measurement of resistance.
g. Multimeter can be used for the measurement of current.

5.Which one of the following is the main cause of magnetic decay in PMMC type instrument?

a. Variation in the resistance of the moving coil

b. Quality of spring

c. Aging of the spring

d. ***Aging of the magnets***

6. Which of the following materials when used as the viewing surface of a CRO gives a bluish glow?

a. Zinc Sulfide with copper as impurity

b. ***Zinc Sulfide with silver as impurity***

c. Yttrium Oxide

d. Pure Zinc Sulfide

7. What is the percentage voltage error of a potential transformer with system voltage of 11,000 V and having turns ratio of 100, if the measured secondary side voltage is 105 V?

a. 2.75

b. 3.55

c. ***4.54***

d. 9.09

8. Which of the following is the cause of a speed error in induction type energy meter?

a. ***Incorrect position of brake magnets***

b. Incorrect adjustment of the position of shading bands.

c. Slow but continuous rotation of aluminium disc.

d. Temperature variations

9. A circuit having power factor of 0.8 consumes 20 W. What is the value of reactive power (in VAR) of the circuit?

a. 10

b. ***15***

c. 20

d. 25

10. Which instrument is used to measure the high resistance?

a. Kelvin's double bridge

b. Wheatstone bridge

c. Carey-foster bridged.

d. ***Megger***

11. Determine the apparent power (in W) of a circuit, if the circuit have a power factor of 0.8 and the reactive power of the circuit is 60 W.

a. 80

b. ***75***

c. 60

d. 55

12. A building has 3 floors and each floor has 4 fans of 50 W that operates for 12 hours a day and one air conditioner of 3000 W that operates for 2 hours per day in the month of the June. Determine the energy consumption (in kWh) of the building in June.

a. 512

b. 252

c. ***756***

d. 504

14. Determine the reading (in kW) of both the wattmeter's used to measure the power of a three-phase three-wire system having input of 6 kW and power factor of 1.

a. 4, 2

b. 5, 1

c. ***3, 3***

d. 6, 0

16. What will be the secondary voltage (in V) of a potential transformer, if the value of system voltage is 11,000 V, the turn's ratio of the potential transformer is 108 and the percentage voltage error of the transformer is 5%

a. 86.8

b. 93.6

c. 84.6

d. ***96.8***

1.What are the Dynamic characteristics in a measurement system?

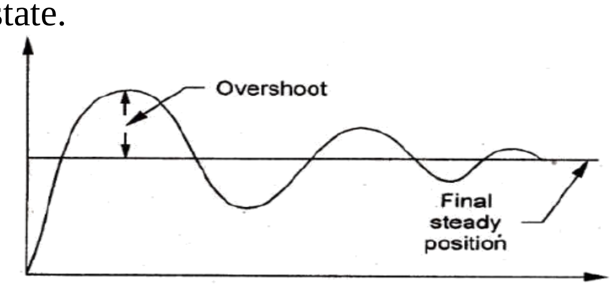
Ans: Dynamic characteristics in a measurement system are following

a) Speed of response and measuring lag, b) Fidelity and dynamic error, c) Over shoot, d) Dead time and dead zone, e) Frequency response.

a) Speed of response and measuring lag:
In a measuring instrument the speed of response (or) responsiveness is defined as the rapidity with which an instrument responds to a change in the value of the quantity being measured. Measuring lag refers to delay in the responds of an instrument to a change in the input signal. The lag is caused by conditions such as inertia, or resistance.

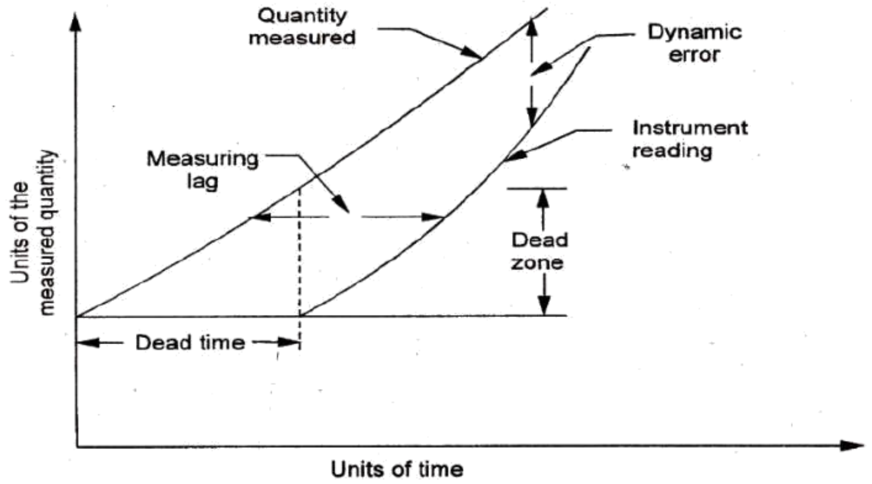
b. Fidelity and dynamic errors: Fidelity of an instrumentation system is defined as the degree of closeness with which the system indicates (or) records the signal which is upon its. It refers to the ability of the system to reproduce the output in the same form as the input. If the input is a sine wave then for 100% fidelity the output should also be a sine wave. The difference between the indicated quantity and the true value of the time quantity is the dynamic error. Here the static error of instrument is assumed to be zero.

c. Over shoot: Because of maximum and inertia. A moving part i.e., the pointer of the instrument does not immediately came to reset in the find deflected position. The pointer goes find deflected position. The pointer goes beyond the steady state i.e., it over shoots. The over shoot is defined as the maximum amount by which the pointer moves beyond the steady state.



Overshoot

d)Dead time and dead zone:
Dead time is defined as the time required for an instrument to begin to respond to a change in the measured quantity it represent the time before the instrument begins to respond after the measured quantity has been altered. Dead zone define the largest change of the measured to which the instrument does not respond. Dead zone is the result as friction backlash in the instrument.



Dynamic terms

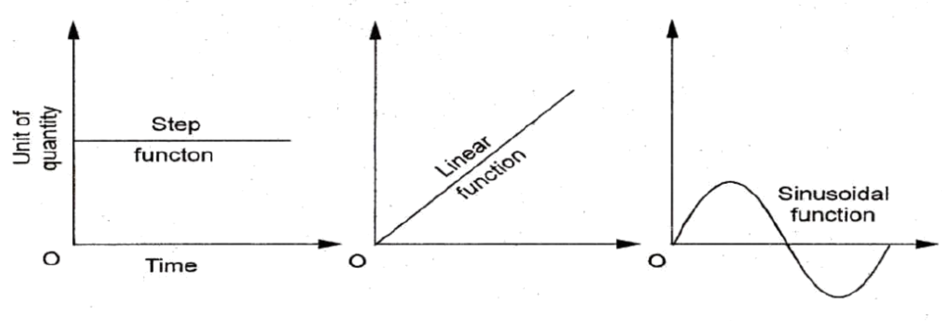
e) Frequency response: The dynamic performance of both measuring and control system is determine by applying some known and predetermined input signal to its primary sensing element and them) Maximum frequency of the measured variable that an instrument is capable of following with error. The usual requirement is that the frequencies of the measured should not exceed 60% of the natural frequency measuring instrument.

2. Define Standard test inputs:

The dynamic performance of both measuring and control system is determined by applying some known and predetermined input signal to its primary sensing element and then studying the behavior of the output signals.

The most common standard inputs used for dynamic analysis

i. Step functions
ii. Linear (or) ramp functions
iii. Sinusoidal (or) sine wave functions



Standard input functions

3. **Explain Zero Order System**

Ans: A zero order instrument is one where the highest order of the derivative describing the system behaviour is zero. Therefore from Eqn. 24.23, a zero order instrument is described by,

$$a_0\, c(t) = b_0\, r(t) \qquad ...(24\cdot27)$$

where $c(t)$=output, $r(t)$=input and a_0 and b_0 are constants.

Examining Eqn. 24·27, it is observed that it is a simple algebraic equation.

Any instrument or system that closely obeys Eqn. 24·27 over its entire operating range is defined as a **zero order instrument**.

We can rewrite Eqn. 24·27 as : output $c(t) = \frac{b_0}{a_0}\, r(t) \doteq S\, r(t)$ ...(24·28)

where S=static sensitivity (steady state gain)$= \frac{b_0}{a_0}$ ...(24·29)

Now Eqn. 24·28 is a simple algebraic equation and therefore no matter how the input $r(t)$ varies with time, the output follows it perfectly and faithfully. This means that neither there is a distortion nor any time lag. A linear potentiometer shown in Fig. 24·7 (*a*) may be considered as a zero order instrument.

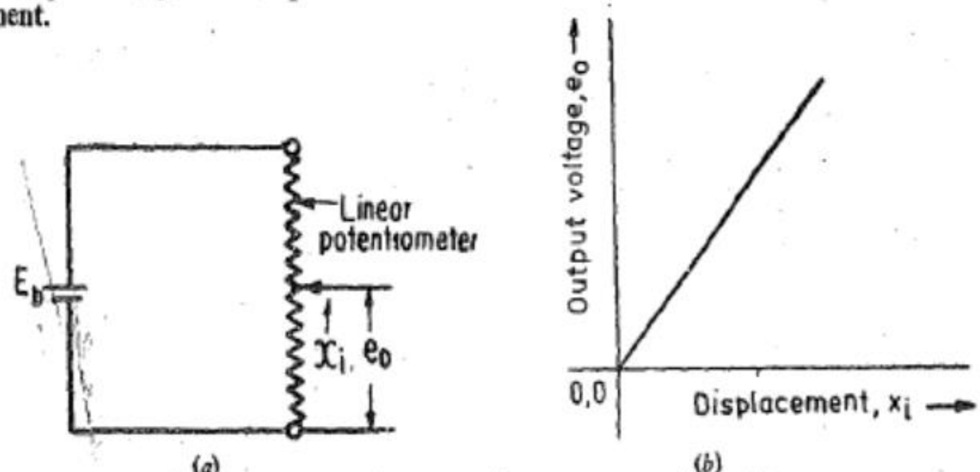


Fig. 24·7. Linear potentiometer and its input-output relationship.

Suppose E_b=supply voltage to potentiometer ; V,
L=length of potentiometer ; m,
$x_i(t)$=displacement of sliding contact at any time t ; m,
and $e_0(t)$=output voltage at any time t ; V.

Since the resistance of potentiometer is linearly distributed along its length, the voltage per unit length=E_b/L.

$\therefore$ Output voltage $e_0(t) = (E_b/L)x_i(t) = S\, x_i(t)$ ...(24·30)

where sensitivity $S = \frac{E_b}{L}$ V/m. ...(24·31)

4. Define transfer Function, its poles and zeros

It is defined as the ratio of output and input provided all the initial condition are zeros

Poles of a Transfer Function: The poles of transfer function are the value of Laplace Transform variable(s) that cause the transfer function becomes infinite.

The denominator of a transfer function is actually the poles of function.

Zeros of a Transfer Function: The zeros of transfer function are the values of Laplace Transform variable(s) that cause the transfer function becomes zero. The nominator of a transfer function is actually the zeros of function

5. **Explain the first order system of transfer function**

First order Non- Electrical System:-

1. Thermal System:- A thermal system is described by a first order differential eq^n as-

$$RC\frac{d\theta(t)}{dt} + \theta(t) = h_i(t)R, \quad \text{—(B)}$$

where R is Thermal resistance; $°c/JS^{-1}$

c is " capacitance; $J/°c$

eq^n(B) can be written as—

$$\tau\frac{d\theta(t)}{dt} + \theta(t) = h_i(t)R$$; τ is thermal time constant.

Taking Laplace Transform,

$$\tau S\theta(S) + \theta(S) = H_i(S)R.$$

$$\Rightarrow \theta(S)(1+\tau S) = H_i(S)\cdot R$$

Now, input $r(t) = h_i(t) \Rightarrow R(S) = H_i(S)$ and o/p is

$$c(t) = \theta(t) \Rightarrow C(S) = \theta(S).$$

$$\therefore \text{ Transfer function } G(S) = \frac{C(S)}{R(S)} = \frac{\theta(S)}{H_i(S)} = \frac{R}{1+\tau S}$$

Now, when input $r(t)$ is a step function.

i.e. $r(t) = h_i u(t)$

$R(S) = \frac{1}{S}H_i(S)$

$G(S) = \frac{\theta(S)}{R(S)}$

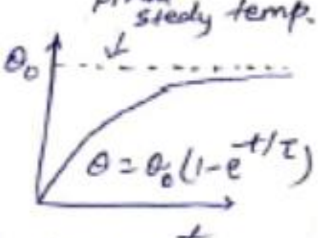
$$\therefore \theta(S) = G(S)\cdot R_i(S)$$

$$= \frac{R}{1+\tau S}\cdot\frac{1}{S}\cdot H_i(S) = R\,H_i(S)\cdot\left[\frac{1}{S} - \frac{\tau}{1+\tau S}\right]$$

Taking Laplace inverse,

$$L^{-1}\left[\theta(s) = RH_i(s)\left[\frac{1}{s} - \frac{\tau}{1+\tau s}\right]\right]$$

$$\Rightarrow \theta(t) = R h_i(t)\left[1 - e^{-t/\tau}\right] \quad \text{—— (C)}$$



Step response of 1st order thermal system.

From eqn-(C), when $t \to \infty$.

$\theta_0 = R h_i \to$ steady state temperature.

∴ eqn-(C) can be -

$$\boxed{\theta(t) = \theta_0\left(1 - e^{-t/\tau}\right)}$$

6. Derive the transfer function of a first order system when the input is step signal

First order system response when an i/p unit step is applied.

Let unit step u(t) to be applied to 1st order system.

$r(t) = u(t)$ or,

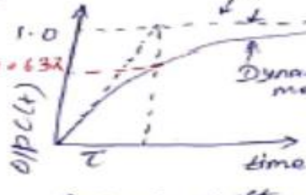
$R(s) = 1/s$

T.F. of 1st order system is.

$$G(s) = \frac{1}{1+\tau s} = \frac{C(s)}{R(s)}$$

$$\therefore C(s) = G(s)\cdot R(s) = \frac{1}{s(1+\tau s)} = \frac{1}{s} - \frac{\tau}{1+\tau s}$$

Taking Inverse Laplace Transform, $\boxed{c(t) = 1 - e^{-t/\tau}}$ —— (A)



Response of 1st order sys. when i/p is unit step

From eqn-(A) differentiating both side-

$$\left.\frac{dc}{dt}\right|_{t=0} = \frac{1}{\tau}\cdot e^{-t/\tau}\Big|_{t=0} = \frac{1}{\tau}$$

Thus, if the initial rate of change is maintained, the system will reach its final value in time (t) is τ, which is called Time constant of system.

∴ o/p at $t=\tau$;

$$c(t) = 1 - e^{-\tau/\tau} = 1 - e^{-1} = 0.632$$