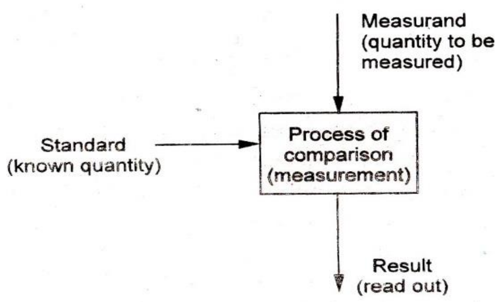
UNIT-1

Measurement:-

The old measurement is used to tell us length, weight and temperature are a change of these physical measurement is the result of an opinion formed by one (or) more observes about the relative size (or) intensity of some physical quantities.

Definition:

The word measurement is used to tell us the length, the weight, the temperature, the colour or a change in one of these physical entities of a material. Measurement provides us with means for describing the various physical and chemical parameters of materials in quantitative terms. For example 10 cm length of and object implies that the object is 10 times as large as 1 cm; the unit employed in expressing length.



Fundamental measuring process

These are two requirements which are to be satisfied to get good result from the measurement.

1. The standard must be accurately known and internationally accepted.
2. The apparatus and experimental procedure adopted for comparison must be provable.

Instrumentation:-

Definition:

The human senses cannot provide exact quantitative information about the knowledge of events occurring in our environments. The stringent requirements of precise and accurate measurements in the technological fields have, therefore, led to the development of mechanical aids called instruments.

Or

Definition: the technology of using instruments to measure and control physical and chemical properties of materials is called instrumentation.

In the measuring and controlling instruments are combined so that measurements provide impulses for remote automatic action, the result is called control system.

Uses:

-> study the function of different components and determine the cause of all functioning of the system, to formulate certain empirical relations.
-> to test a product on materials for quality control.
-> to discover effective components.
-> to develop new theories.
-> monitor a data in the interest of health and safety.

Ex:- fore casting weather it predicting in the earth case.

Methods of measurement:-

1. Direct and indirect measurement.
2. Primary and secondary & tertiary measurement.
3. Contact and non-contact type of measurement.

1. Direct and indirect measurement:

Measurement is a process of comparison of the physical quantity with a standard depending upon requirement and based upon the standard employed, these are the two basic methods of measurement.

Direct measurement:

The value of the physical parameter is determined by comparing it directly with different standards. The physical standards like mass, length and time are measured by direct measurement.

Indirect measurement:

The value of the physical parameter is more generally determined by indirect comparison with the secondary standards through calibration.

The measurement is convert into an analogous signal which subsequently process and fed to the end device at present the result of measurement.

2. Primary and secondary & tertiary measurement:

The complexity of an instrument system depending upon measurement being made and upon the accuracy level to which the measurement is needed. Based upon the complexity of the measurement systems, the measurement are generally grouped into three categories.

i. Primary
ii. Secondary
iii. Tertiary.

In the primary mode, the sought value of physical parameter is determined by comparing it directly with reference standards the required information is obtained to sense of side and touch.

Examples are:

a) Matching of two lengths is determining the length of a object with ruler.
b) Estimation the temperature difference between the components of the container by inserting fingers.
c) Use of bean balance measure masses.
d) Measurement of time by counting a number of strokes of a block.

Secondary and tertiary measurement are the indirect measurements involving one transmission are called secondary measurements and those involving two convergent are called tertiary measurements.

Ex:

The convergent of pressure into displacement by means of be allows and the convergent of force into displacement.

Pressure measurement by manometer and the temperature measurement by mercury in glass tube thermometer.

The measurement of static pressure by boundary tube pressure gauge is a typical example of tertiary measurement.

3. Contact and non-contact type of measurements:

Contact type:
Where the sensing element of measuring device as a contact with medium whose characteristics are being measured.

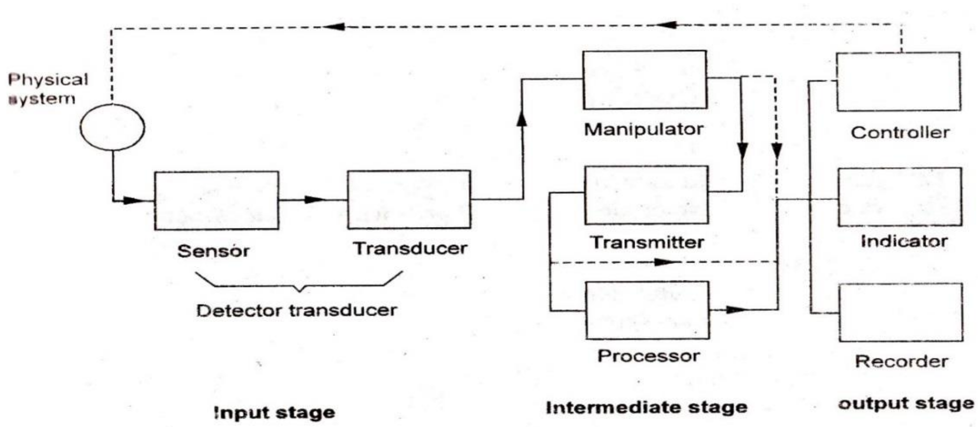
Non-contact type:
Where the sense doesn't communicate physically with the medium.

Ex:
The optical, radioactive and some of the electrical/electronic measurement belong to this category.

Objectives of instrumentation:-

1. The major objective of instrumentation is to measure and control the field parameters to increase safety and efficiency of the process.
2. To achieve good quality.
3. To achieve auto machine and automatic control of process there by reducing human.
4. To maintain the operation of the plan within the design exportations and to achieve good quantity product.

Generalised measurement system and its functional elements:-



Generalised measurement system

1) Primary sensing element.

2) Variable conversion (or) Transducer element.

3) Manipulation of element.

4) Data transmission element.

5) Data processing element.

6) Data presentation element.

The principal functions of an instrument is the acquisition of information by Sensing and perception, the process of that information and its final presentation to a Human observer. For the purpose of analysis and synthesis, the instrument s are considered as systems (or) assembly of inter connected components organised to perform a specified function. The different components are called elements.

1) PIMARY SENSING ELEMENT:

An element that is sensitive to the measured variable .The sensing element sense the condition , state (or) value of the process variable by extracting a small part of energy from the measurement and produces an output which is proportional to the input. Because of the energy expansion, the measured quantity is always disturb. Good instruments are designed to minimise this loading effect.

2) Variable conversion (or) transducer element:

An element that converts the signal from one physical for to Another without changing the information content of the signal.

Example:

- Bourdon tube and bellows which transfer pressure into displacement.
- Proving ring and other elastic members which converts force into displacement.
- Rack and Pinion: It converts rotary to linear and vice versa.
- Thermo couple which converts information about temperature difference to information in the form of E.M.F.

3) MANIPULATION ELEMENT:

It modifies the direct signal by amplification, filtering etc., so that a desired output is produced.

$$[\text{input}] \times \text{constant} = \text{Output}$$

4) DATA TRANSMISSION ELEMENT:

An element that transmits the signal from one location to another without changing the information content. Data may by transmitted over long distances (from one location to another) or short distances (from a test centre to a nearby computer).

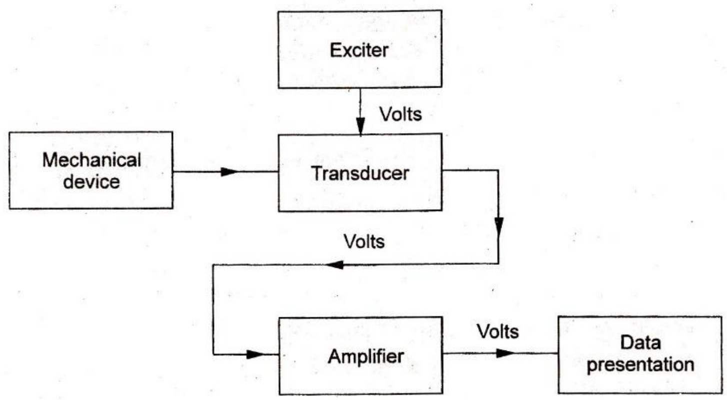
5) DATA PROCESSING ELEMENT:

An element that modifies data before it is displayed or finally recorded. Data processing may be used for such purposes as:

- ✓ Corrections to the measured physical variables to compensate for scaling, non-linearity, zero offset, temperature error etc.

- ✓ Covert the data into useful form, e.g., calculation of engine efficiency from speed, power input and torque developed.
- ✓ Collect information regarding average, statistical and logarithmic values.

6) DATA PRESANTION ELEMENT:



Electro-mechanical measurement system

An element that provides record or indication of the output from the data processing element. Ina measuring system using electrical instrumentation, an exciter and an amplifier are also incorporated into the circuit.

The display unit may be required to serve the following functions.

- ✓ transmitting
- ✓ Signalling
- ✓ Registering
- ✓ Indicating
- ✓ recording

The generalised measurement system is classified into 3 stages:

a) Input Stage

b) Intermediate Stage

i. Signal Amplifications

ii. Signal Filtration

iii. Signal Modification

iv. Data Transmission

c) Output Stage

a) Input Stage:

Input stage (Detector-transducer) which is acted upon by the input signal (a variable to be measured) such as length, pressure, temperature, angle etc. and which transforms this signal in some other physical form. When the dimensional units for the input and output signals are same, this functional element/stage is referred to as the transformer.

b) Intermediate Stage:

i. signal amplification to increase the power or amplitude of the signal without affecting its waveform. The output from the detector-transducer element' is generally too small to operate an indicator or a recorder and its amplification is necessary. Depending upon the type of transducer signal, the amplification device may be of mechanical, hydraulic/pneumatic, optical and electrical type.

ii. Signal filtration to extract the desired information from extraneous data. Signal filtration removes the unwanted noise signals that tend to obscure the transducer signal. Depending upon nature of the signal and situation, one may use mechanical, pneumatic or electrical filters.

iii. Signal modification to provide a digital signal from an analog signal or vice versa, or change the form of output from voltage to frequency or from voltage to current.

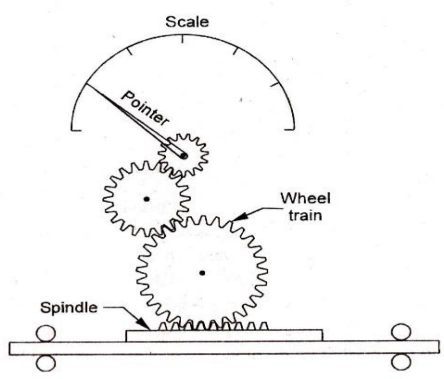
Iv. Data transmission to telemeter the data for remote reading and recording.

c) Output Stage:

which constitutes the data display record or control. The data presentation stage collects the output from the signal-conditioning element and presents the same to be read or seen and noted by the experimenter for analysis. This element may be of:-

- ✓ visual display type such as the height of liquid in a manometer or the position of pointer on a scale
- ✓ numerical readout on an electrical instrument
- ✓ Graphic record on some kind of paper chart or a magnetic tape.

Example: Dial indicator



Dial indicator

CLASSIFICATION OF INSTRUMENTS:-

1) Automatic and Manual instruments:

2) Self generating and power operated

3) Self contact and remote indicating instruments

4) Deflection and null type

5) Analog and digital types

6) Contact and no-contact type

1) Automatic and manual instruments:

The manual instruments require the services of an operator while the automatic types donot. For example, the temperature measurement by mercury-in-glass thermometer is automatic as the instrument indicates the temperature without requiring any manual assistance. However, the measurement of temperature by a resistance thermometer incorporating; Wheatstone brigde in its circuit is manual in operation as it needs an operator for obtaining the null position.

2) Self generating and power operated

Self-generated instruments are the output is supplied entirely by the input signal. The instrument does not require any out side power in performing its function

Example: mercury in glass thermometer, bourdon pressure gauge, pitot tube for measuring velocity

So instruments require same auxillary source of power such as compound air, electricity, hydraulic supply for these operations and hence are called externally powered instruments (or) passive instruments.

Example:

- L.V.D.T(Linear Variable Differential Transducer)
- Strain gauge load cell
- Resistance thermometer and the mister.
- Self contained remote indicator.

3) Self contact and remote indicating instruments:

The different elements of a self-contained instrument are contained in one physical assembly. In a remote indicating instrument, the primary sensing element may be located at a sufficiently long distance from the secondary indicating element. In the modern instrumentation technology, there is a trend to instalremote indicating instruments where the important indications can be displayed in the central control rooms.

4) Deflection and null output instruments:

In null-type instruments, the physical effect caused by the quantity being measured is nullified (deflection maintained at zero) by generating an equivalent opposing effect. The equivalent null causing effect then provides a measure of the unknown quantity. A deflection type instrument is that in which the physical effect generated by the measuring quantity (measurand) is noted and correlated to the measurand.

5) Analog and digital instruments:

The signals of an analog unit vary in a continuous fashion and can take on infinite number of values in a given range. Wrist watch speedometer of an automobile, fuel gauge, ammeters and voltmeters are examples of analog instruments.

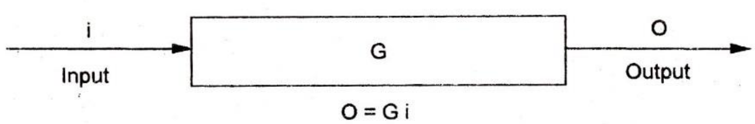
Instruments basically perform two functions:

(i) Collection of data and

(ii) control of plant and process

Accordingly based upon the service rendered, the instruments may also be classified as indicating instruments, recording instruments and controlling instruments.

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 characterised by the operation ‘G’ such that

$$o = G\, i$$

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

i) Desired input:

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

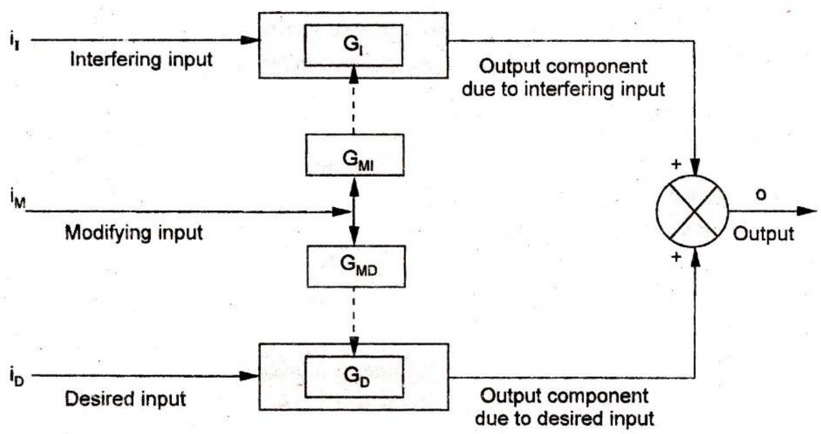
ii) Interfering input:

A quantity to which the instrument is unintentionally sensitive. The interfering input i_l would produce an output component according to input-output relation symbolised by G_l

iii) Modifying input:

A quantity that modifies the input-6utput relationship for both the desired and interfering inputs. The modifying input i_M would cause a change in G_D and/or G_l. The specific manner in which i_M affects G_D and G, is represented by the symbols G_{MD} and G_{Ml}, respectively.

A block diagram of these various aspects has been illustrated in Fig.



Generalised input-output configuration

Example:

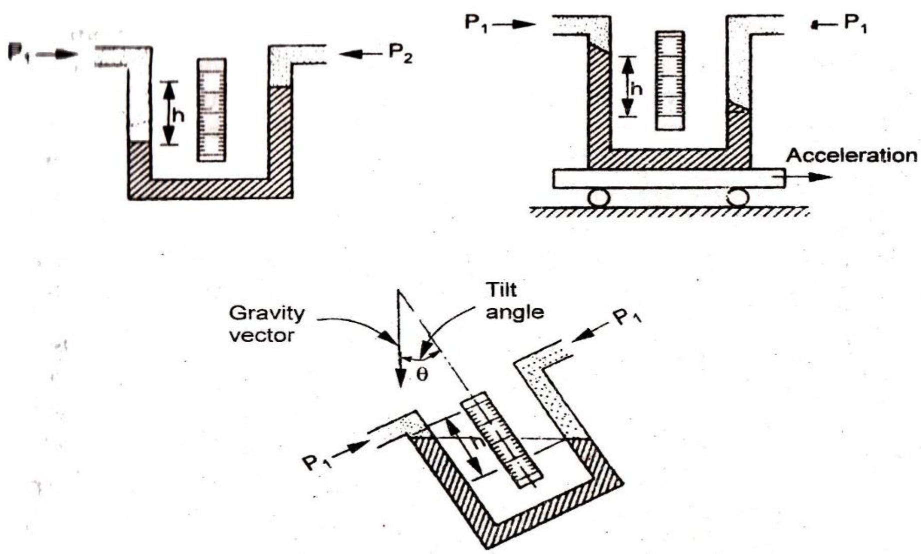
Consider a deferential manometer which consists of an u-tube filled with mercury and with its ends connected to the two points between which the pressure differentia is to be measured .The pressure differential p_1-p_2 is worked out from the hydro static (Equilibrium) equation:

$$(p_1\text{-}p_2)\text{=g h} (\rho_m - \rho_f)$$

ρ_m and ρ_f are the mass densities of mercury and fluid respectively, and h is the scale reading. If the fluid flowing in the pipeline is a gas, then $\rho_f << \rho_m$ accordingly the above identity can be re-written as

$$(p_1\text{-}p_2)\text{=g h } \rho_m$$

Here differential pressure is p_1- p_2 is the desired input; Scale reading 'h' is the output and ρ_m is the parameter which relates the output and the input.



Spurious inputs for a manometer

A) The manometer is placed on a wheel which is subjected to acceleration and scale indicates a reading even through the pressures p_1& p_2 at the two ends are equal.

The acceleration that constitutes the interference input. The manometer has an angular tilt i.e., is not properly align with the direction of the gravitational force.

An output will result even when there is no pressure difference. Here the angular tilt acts as the interfering input.

Here scale factor establishes the input - output relation and this gets modified due to

i) Temperature variation which change the value of density of mercury.

ii) Change in gravitational force due to change in location of a manometer.

So, these 2 are modifying quantities.

1) Signal filtering

2) Compensation by opposing inputs.

3) Output correction.

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 (V_m) – true value ((V_t)

Correction = (V_t-V_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.

a) 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^o to 80 C^o Span=90^oc

Range 5 bar to 100 bar Span=100-5=95 bar

Range 0 v to 75v Span=75volts

b) Accuracy, error, correction:

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 (V_m) and true value (V_t) of the quantity is expressed as instrument error.

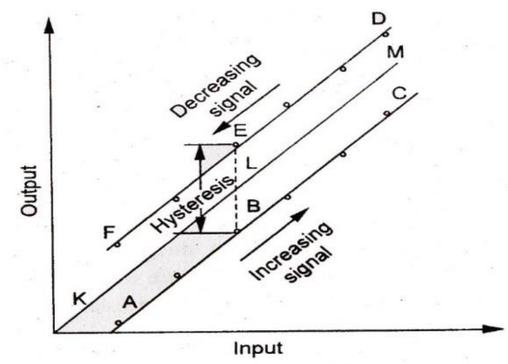
E_s =V_m- V_t

Static correction is defined as V_t-V_m

C_s=V_t-V_m

c) 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 measurand 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.

The following points and observations need 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.

d) Repeatability:

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.

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

f) 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.

g) 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.,

Static sensitivity $= \frac{\text{change of output signal}}{\text{change of input signal}} = \frac{\Delta\theta 0}{\Delta\theta 1}$

h) Threshold:

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.

i) 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.

j) 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.

k) 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.

2. Dynamic characteristics:

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:

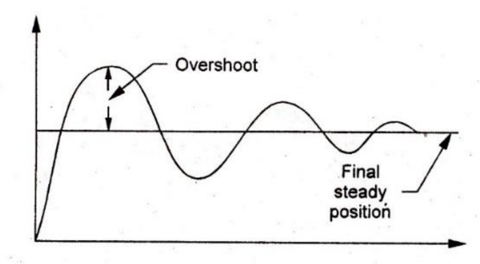
Fidelity of an instrumentation system is defined as the degree of closeness with which the system indicates (or) records the signal which is upon its. It refers to the ability of the system to reproduce the output in the same form as the input. If the input is a sine wave then for 100% fidelity the output 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.

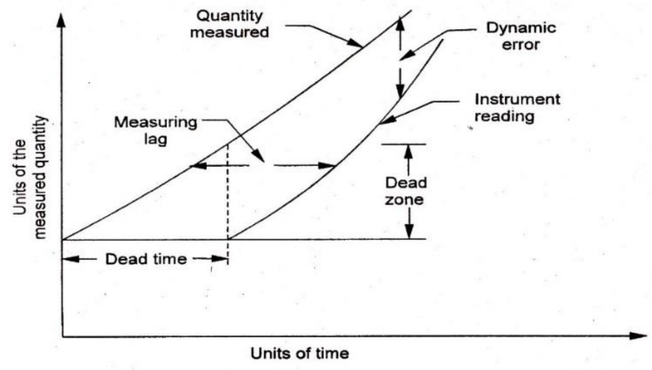


Overshoot

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

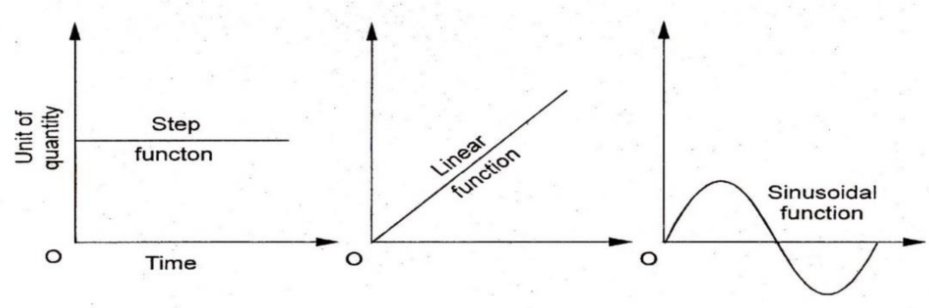
e) Frequency response:

(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.

<u>Standard test inputs:</u>

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 behaviour of the output signals.



Standard input functions

The most common standard inputs used for dynamic analysis

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

i. Step function:

Which is a sudden change from one steady value to another the step input is mathematically represented by

$$\theta_i = 0 \text{ at } t < 0$$
$$\theta_i = \theta_0 \text{ at } t \geq 0$$

Where θ_0 *is a constant value of the input single* θ_i.

ii. Ramp (or) linear function:

The input varies linearly with time. The ramp input is mathematical represented as

$$\theta_i = 0 \; at \; t < 0$$

$$\theta_i = \Omega \, t \; at \; \geq 0$$

Where Ω slope of the input versus time relationship.

iii. Sinusoidal (or) sine wave function:

Here the input has a cycle variation, the input varies sinusoidal with a constant amplitude mathematically it may be represented as

$$\theta_i = A \sin \omega t$$

where A is the amplitude and ω is the frequency in rad/s.

The frequency or harmonic response is a measure of the capability of the system to respond to inputs of cyclic nature.

A general measurement system can be mathematically described by the following differential equation

$$\left(A_n D^n + A_{n-1} D^{n-1} + \dots\dots\dots A_1 D + A_0\right) \theta_0$$

$$\left(B_m D^m + B_{m-1} D^{m-1} + \dots\dots B_1 D + B_0\right) \theta_i$$

where the A's and B's are constants depending upon the physical parameter of the syst

D^k is the operative derivative of the order k,

θ_0 is the information out of the measurement system, and

θ_i is the input information

The time factor in the input or driving function may correspond to step input, ramp input, sinusoidal input or any combination of these.

The order of the measurement system is generally classified by the value of the power of n

- *Zero order system* : $n = 0$ and $A_1, A_2 \dots\dots\dots\dots A_n = 0$
- *First order system* : $n = 1$ and $A_2, A_3 \dots\dots\dots\dots A_n = 0$
- *Second order system* : $n = 2$ and $A_3, A_4 \dots\dots\dots\dots A_n = 0$

Zero, first and second order systems:-

Zero order system **:** Consider an ideal measuring system, *i.e.*, a system whose output is directly proportional to input ; no matter how the input varies. The output is a faithful reproduction of input without any distortion or time lag. The mathematical equation relating output to input is of the form

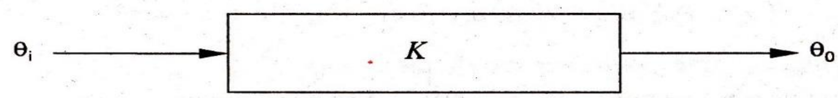
$$\theta_o = K\theta_i$$

where K is the sensitivity of the system. This equation of the zero order system is obtained when the power of n is set equal to zero in the general equation for a measurement system.

That gives : $A_0\,\theta_0 = B_0\,\theta_i$

or $$\theta_0 = \frac{B_0}{A_0}\theta_i = K\,\theta_i$$

The static sensitivity is the only parameter which characterises a zero order system and its value can be obtained through the process of static calibration. A block diagram representing zero-order systems has been shown in Fig. 2.12(*a*)



Block diagram for a zero system

Some examples of zero-order system are :

* mechanical levers,
* amplifiers, and
* potentiometer which gives an output voltage proportional to the displacement of the wiper.

First Order Systems:

The behaviour of a first order system is represented by a first order differential equation of the form.

$$A_1\frac{d\theta_0}{dt} + A_0\,\theta_0 = B_0\,\theta_i$$

(obtained by substituting $n = 1$ in general equation)

This may be manipulated to rewrite in the following standard form :

$$\frac{A_1}{A_0}\frac{d\theta_0}{dt} + \theta_0 = \frac{B_0}{A_0}\theta_i$$

$$\tau\frac{d\theta_0}{dt} + \theta_0 = K\theta_i$$

where τ is the time constant ($\tau = A_1/A_0$) and K is the static sensitivity ($K = B_0/A_0$)

In terms of D-operator where

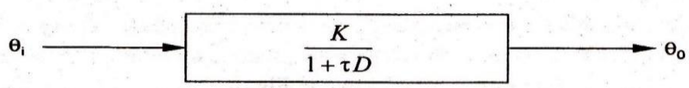
$$D = \frac{d}{dt} \text{ and } D^2 = \frac{d^2}{dt^2}$$

we have :

$$\tau\,D\theta_0 + \theta_0 = K\,\theta_i \quad ; \quad (\tau\,D + 1)\,\theta_0 = K\,\theta_i$$

$$\frac{\theta_0}{\theta_i} = \frac{K}{(\tau\,D + 1)} \qquad \text{———— 2.10}$$

Equation 2.20 represents the standard form of transfer operator for the first-order system ; its block diagram has been indicated in Fig 2.12(*b*).



Block diagram for a first order system

Some examples of the first-order system are :

- temperature measurement by mercury-in-glass thermometers, thermocouples and thermistors
- build-up of air pressure in bellows
- network of resistance-capacitance
- velocity of a free falling mass

Second-order systems **: The input/output relationship of a second order system is described by a differential equation of the form**

$$A_2 \frac{d^2\theta_0}{dt^2} + A_1 \frac{d\theta_0}{dt} + A_0\theta_0 = B_0\theta_i$$

(obtained by substituting $n=2$ in the general equation)

Dividing both sides by A_0 and letting

$$\omega_n = \sqrt{\frac{A_0}{A_2}} = \text{undamped natural frequency, rad/s}$$

$$\zeta = \frac{A_1}{2\sqrt{A_0 A_2}} = \text{damping ratio, dimensionless}$$

$$K = \frac{B_0}{A_0} = \text{static sensitvity or steady state gain}$$

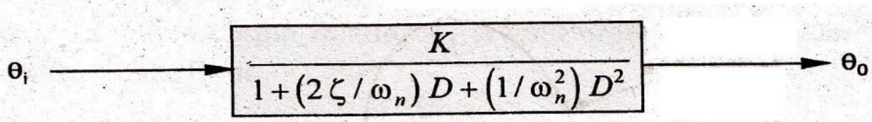
we obtain :

$$\frac{1}{\omega_n^2}\frac{d^2\theta_0}{dt^2} + \frac{2\zeta}{\omega_n}\frac{d\theta_0}{dt} + \theta_0 = K\theta_i$$

In terms of *D*-operator

$$\left(\frac{D^2}{\omega_n^2} + \frac{2\zeta}{\omega_n}D + 1\right)\theta_0 = K\theta_i$$

or $$\frac{\theta_0}{\theta_i} = \frac{K}{\frac{1}{\omega_n^2}D^2 + \frac{2\zeta}{\omega_n}D + 1} \longrightarrow 2.23$$



Block diagram for a second order system

Equation 2.23 represents the standard form of transfer operator of the second-order system; its block diagram has been indicated in Fig. 2.12(*c*).

Some examples of second-order instruments are :

* spring-mass system employed for acceleration and force measurements,
* piezo electric pick ups,
* U.V. galvanometer, and
* pen control system on X-Y plotters

Most of the mechanical instruments invariably consist of a spring and a moving mass, and their combination provides a system which will oscillate naturally at a given frequency. The amplitude of the oscillation is affected by damping which is a means of dissipating energy in the system.

Sources of error:

1. Calibration of Instrument
2. Instrument reproducibility
3. Measuring arrangement
4. Work piece
5. Environmental condition
6. Observes skill

1. Calibration of Instrument:

For any instrument calibration` is necessary before starting the process of measurement. When the instrument is load frequently for long time, the calibration of instrument is used frequently for long time, the calibration of instrument may get disturbed. The instrument which is gone out of b ration cannot give actual value of the measured. Therefore the output produced by such an instrument have error. The error due to improper calibration of instrument is known as systematic instrumental error, and it occurs regularly.

Therefore this error can be eliminated by, properly calibrating the instrument at frequent intervals.

2. Instrument reproducibility:

Though an instrument is calibrated perfectly under group of conditions, the output produced by that instrument contains error. This occurs if the instrument is used under those set of conditions which are not identical to the conditions existing during calibration. i.e., the instrument should be used under those set of conditions at which -.the instrument is calibrated. This type of error may occur systematically or accidentally.

3. Measuring arrangement:

The process of measurement itself acts as a source of error if the arrangement of different components of a measuring instrument is not proper.

Example:

While measuring length, the comparator law of Abbe should be followed. According to this, actual value of length is obtained when measuring instrument and scale axes are collinear, and any misalignment of these will give error value. Hence this type of error can be eliminated by having proper arrangement of measuring instrument.

4. Work piece:

The physical nature of object (work piece) i.e., roughness, softness and hardness of the object acts as a source of error. Many optomechanical and mechanical type of instruments contact the. Object under certain fixed pressure conditions. Since the response of soft and hard objects under these fixed conditions is different the output of measurement will be in error.

5. Environmental condition:

Changes in the environmental conditions is also a major source of error. The environmental conditions such as temperature, humidity, pressure, magnetic or electrostatic field surrounding the instrument may affect the instrumental characteristics. Due to this the result produced by the measurement may contain error.

There errors are undesirable and can be reduced by the following ways,

(a) Arrangement must be made to keep the conditions approximately constant.

(b) Employing hermetically sealing to certain components in the instrument, which eliminate the effects of the humidity, dust, etc.

(c) Magnetic and electrostatic shields must be provided.

6. Observes skill:

It is a well-known fact that the output of measurement of a physical quantity is different from operator to operator and sometimes even for the same operator the result may vary with sentimental and physical states. One of the examples of error produced by the operator is parallax error in reading a meter scale. To minimize parallax errors modern electrical instruments have digital display of output.

Classification of errors and elimination of errors:

No measurement can be made with perfect accuracy but it is important to find out what accuracy is and how different errors have entered into the measurement. A steady of errors is a first step in finding ways to reduce them. Errors may arise from different sources and are usually classified as under.

1. Gross errors
2. Systematic (or) instrumental errors
3. Random (or) environmental errors

1. gross errors:

This cause of errors mainly covers human mistakes in reading instruments and recording and calculating measurement result. The responsibility of the mistake normally lies with the experimental.

Ex: The temperature is 31.5^0c, but it will write as 21.5^0c its an error how ever they can be avoided by adopting two means

1. Great care should be taken in reading and recording the data.
2. Two, three (or) even more readings should be taken for quantity under measurement

2. systematic errors:

These type of errors are divided into three categories.

a. Instrumental errors
b. Environmental errors
c. Observational errors

a. Instrumentation errors:

These errors occurs due to three main reasons.

a. Due to inherent short comings of the instrument
b. Due to misuse of instruments
c. Due to loading effects of instruments.

b. Environmental errors:

These errors are caused due to changes in the environmental conditions in the area surrounding the instrument, that may affect the instrument characteristics, such as the affects of changes in temperature, humidity, barometric pressure or if magnetic field or electrostatic field.

These undesirable errors can be reduced by the following ways.

(i) Arrangement must be made to keep the conditions approximately constant.

(ii) Employing hermetically sealing to certain components in the instrument, which eliminate the effects of the humidity dust, etc.

(iii) Magnetic or electrostatic shields must be provided.

c. Observational errors:

These errors are produced by the experiment. Enter. The most frequent error is the parallax error introduced in reading a meter scale.

These errors are caused by the habits of individual observers To minimize parallax errors modern electrical instruments have digital display of output.

3. Random (or) accidental errors:

The causes of such errors is unknown (or) not determinable in the ordinary process making measurements. Such errors are normally small and follow the law of chance. Random errors they may be treated mathematically according to the law of probability.

a. Certain human errors
b. Errors caused due to the disturbances to the equipment's
c. Errors caused by fluctuating experimental conditions.

a. Certain human errors:

These errors occur due to inconsistency in estimating successive readings from the instrument by an experimenter. To reduce these errors it is necessary to exercise extreme care with mature and considered judgement in recording the observations.

b. Errors caused due to the disturbances to the equipment:

Precision errors in the instrument may arise from the outside disturbances to the measuring system. These disturbances may be variations or mechanical vibrations. Poorly controlled processes also lead to random errors.

c. Errors caused by fluctuating experimental conditions:

These errors are caused due to some uncontrolled, disturbances which influence the instrument output. Line voltage fluctuations, vibrations of the instrument supports, etc., are common examples of this type.

/* The End */