ATME College of Engineering

Department of EEE
Emitting Elite Energy

BEE306B:Electrical Measurements and Instrumentation

Course Objective :

- To understand the significance and method of measurement, elements of generalized measurement system and errors in measurements.
- To measure resistance, inductance, capacitance by use of different bridges.
- To study the construction, working and characteristics of various instrument transformers.
- To have the working knowledge of electronic instruments and display devices.

Module-1

Measurements and Measurement systems: Introduction, significance and methods of Measurements, Instruments and measurement systems, Mechanical, electrical and electronic instruments. Classification of instruments. Functions and applications of Measurement systems. Types of Instrumentation systems, information and signal processing. Elements of generalized measurement system. Input-output configurations of measuring instruments and measurement systems. Methods of correction for interfering and modifying inputs, errors in measurements, Accuracy and precision.

Module-2

Measurement of Resistance: Wheatstone's bridge, sensitivity, limitations. Kelvin's double bridge. Earth resistance measurement by fall of potential method and by using Megger.

Measurement of Inductance and Capacitance: Sources and detectors, Maxwell's inductance and capacitance bridge, Hay's bridge, Anderson's bridge, Desauty's bridge, Schering bridge. Shielding of bridges. (Derivations and Numerical as applicable).

Module-3

Instrument Transformers: Introduction, Use of Instrument transformers. Burden on Instrument transformer.

Current transformer (CT): Relationships in CT, Errors in CT, characteristics of CT, causes and reduction of errors in CT, Construction and theory of CT.

Potential transformer (PT): Difference between CT and PT, Relationships in PT, Errors in PT, characteristics of PT, reduction of errors in PT.

Magnetic measurements: Introduction, measurement of flux/ flux density, magnetizing force and leakage factor.

Module-4

Electronic and Digital Instruments:

Introduction. Essentials of electronic instruments, Advantages of electronic instruments. True RMS reading voltmeter. Electronic multimeters. Digital voltmeters (DVM) - Ramp type DVM, Integrating type DVM and Successive - approximation DVM. Q meter. Principle of working of electronic energy meter (with block diagram), extra features offered by present day meters and
their significance in billing.

Module-5

Display Devices: Introduction, character formats, segment displays, Dot matrix displays, Bar graph displays. Cathode ray tubes, Light emitting diodes, Liquid crystal displays, Nixes, Incandescent, Fluorescent, Liquid vapor and Visual displays.

Recording Devices: Introduction, Strip chart recorders, Galvanometer recorders, Null balance recorders, Potentiometer type recorders, Bridge type recorders, LVDT type recorders, Circular chart and XY recorders. Digital tape recording, Ultraviolet recorders. Electro Cardio Graph (ECG).

Course Outcomes

At the end of the course the student will be able to:

CO1: Explain the significance and methods of Measurements, elements of generalized measurement system and errors in measurements. (L2)

CO2: Identify the suitable bridges to Measure resistance, inductance and capacitance by different methods. (L3)

CO3: Explain the construction, working and characteristics of various instrument transformers. (L3)

CO4: Summarize the working of different electronic instruments and display devices. (L2)

Reference Books:

1. **Electrical and Electronic Measurements and Instrumentation, R.K. Rajput, S Chand, 5th Edition, 2012**

2. **Electrical Measuring Instruments and Measurements, S.C. Bhargava, BS Publications, 2013**

3. **Modern Electronic Instrumentation and Measuring Techniques, Cooper D and A.D. Heifrick, Pearson, First Edition, 2015**

4. **Electronic Instrumentation and Measurements, David A Bell, Oxford University, 3rd Edition, 2013**

5. **Electronic Instrumentation, H.S.Kalsi, Mc Graw Hill, 3rd Edition,2010**

CIE :

1. For the Assignment component of the CIE, there are 25 marks and for the Internal Assessment Test component, there are 25 marks. But test will be conducted for 40 marks and average of best of two will be considered.
2. The first test will be administered after 40-50% of the syllabus has been covered
3. second test will be administered after 85-90% of the syllabus has been covered
4. Any two assignment methods, if an assignment is project-based then only one assignment for the course shall be planned. The teacher should not conduct two assignments at the end of the semester if two assignments are planned.
5. For the course, CIE marks will be based on a scaled-down sum of two tests and other methods of assessment.

Few Stuffs: Measurement to Day- Day life activities→ we buy everything after measuring them→ Measurement is very essential in scientific studies as well → human are curious to understand we perform experiments and use measurement to analysis the results

We measure a sugar as 10 kg we compare the known quantity 1kg with the amount of sugar.

Height of man as 2 meter lets say we compare 2 meter with known 1 meter quantity = 100CM,

1cm= 10mm or 0.01m

1Km=1000m

1m= 3.28Ft

1. Foot and handspan are **non standard , non uniform units** of measurement larger and smaller in hands and feet
2. Similarly ,measurement of an any object using paper clips and a straw are an example for **Non standard and uniform units** of measurement.
3. 4 level of measurements are

Nominal scale: customer survey ask which brand do you performed Samsung,iphone,vivo ,nokia this case only names or brands are significant for researcher not any order. Gender specify the category not an order.

2nd level measurement : **ordinal Scale**: ex : hot , hotter, hottest which had a definite order with nominal features

3rd level of measurement : **Interval Scale** : A space in between Ex..Temperature Celsius 20degree is not twice as hot as 10 degree C.

4th level of measurement **Ratio Scale** : height of 2 people weight age

Measurement: It is the act, or the result of quantitative comparison between a predetermined std. and or an unknown magnitude. Since two quantities are compared and the result are expressed in numerical value.

Measurand: The physical quantity or the characteristic conditions which is the object of measurement in an instrumentation system is termed as measurand or measurement variable or process variable.

e.g. Fundamental Quantity: length, mass, time et.

Derived Quantity : Speed, Velocity, Pressure etc.

Basics Requirement :

- The Standard used for comparison purposes must be accurately defined and should be commonly accepted and
- The apparatus used and the method adopted must be provable.

Significance of Measurement

"When you can measure, what you are speaking and express it in numbers, you know something about and can express it in numbers, you know something about it, when you cannot express in it numbers in knowledge is of meagre and unsatisfactory kind" – Lord Kelvin

The measurement confirms the validity of a hypothesis and also add to it the understanding. This eventually leads to new discoveries that require new and sophisticated measuring techniques.

Through measurement a product can be designed or a process be operated with max. efficiency , minimum cost and with desired degree of reliability and maintainability

he was suggesting that knowledge that cannot be expressed in numbers or measured is unsatisfactory ,in essence, the inability to measure or express something numerically might indicate a lack of comprehensive understanding or a superficial grasp of the subject.

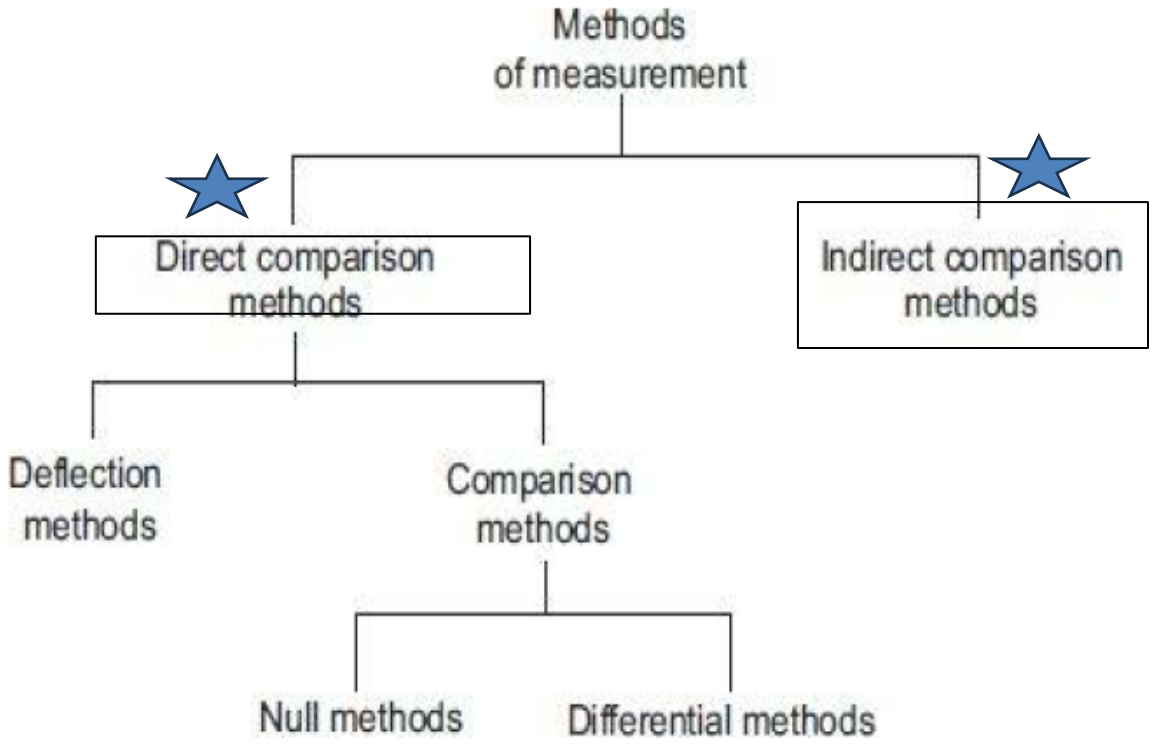
Significance of Measurement:

- Measurement helps us to compare unknown quantities with the known quantities.
- Measurement helps us make quantitative statements about how big, how long, how fast things are. Without measurement, the final product will be full of errors.
- Examples:- Speedometer is used to measure the speed of the vehicles.
- The Measurement , No doubt, confirm the validity of a hypothesis but also add to its understanding . This leads to new discoveries and it requires new techniques and need better Measurement tools.
- Economical design of equipment, Proper operation and maintenance of equipment require measurements because it plays a significant role in achieving goals and objectives of engineering and also it act as back data or feedback of information.

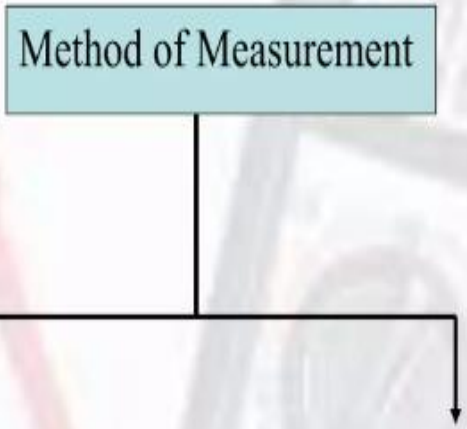
The validity of a hypothesis refers to its accuracy and reliability as a proposed explanation or prediction for a phenomenon. In scientific terms, a hypothesis is a testable statement that suggests a relationship between variables or offers an explanation for observed phenomena. **Validity is crucial because it assesses whether the hypothesis accurately represents reality and whether the conclusions drawn from it are reasonable and trustworthy.**

- The **measurement** has to be exact.
- The **measurements** must be precise.
- Precise **measurements** are required.
- Precise **measurements** are necessary.

METHODS OF MEASUREMENT



Methods of Measurement



Direct Method

The unknown quantity (measurand) is directly compared against a standard. The result is expressed as a numerical number and a unit. Direct methods are common for the measurement of physical quantities like length, mass and time

Indirect Method

In this method the comparison Is done with a standard through the use of a calibration s/m. These methods are used those cases where the desire parameter to be measured. E.g. Acceleration, power

Direct Method : Value of a quantity can be obtained directly by comparing the unknown quantity (measurand) with the standard quantity.

- Results usually expressed as numerical or unit.
- Direct methods are for the measurement of physical quantities like length, mass and time.
- For example: Measurement of length (unknown) by a graduated scale(standard quantity). The method is not very accurate because it depends on human insensitiveness in making judgement.

Indirect method: In this method several parameters are measured directly and then the value is determined by mathematical relationship Ex: measurement of density by measuring mass and geometrical dimensions or acceleration, Power etc..,

0r

In this method the comparison is done with a standard through the use of calibration system. These methods used those cases where the desired parameters to be measured.

Why Direct methods are not Preferred???

Measurement by direct methods are not always possible, feasible and practicable. These methods are inaccurate because they involve human factors. They are sensitive hence they are not preferred and rarely used.

A calibration system refers to a set of processes, standards, equipment, and procedures used to ensure that measuring instruments or devices provide accurate and reliable measurements. Calibration is crucial because over time, instruments may drift or lose accuracy due to wear, environmental factors, or other influences. Calibration ensures that these instruments remain accurate and provide trustworthy measurements

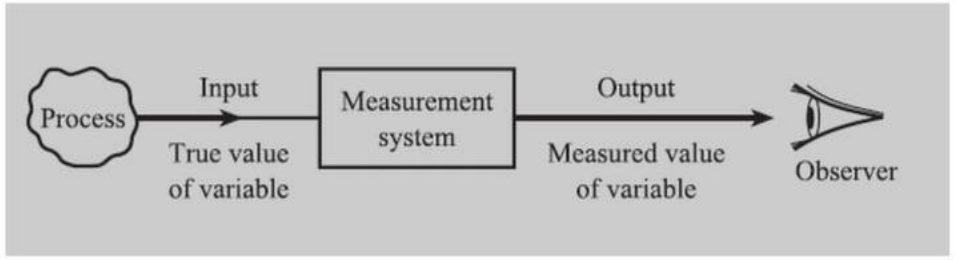
Instruments and Measurement Systems:

- **Measurements involve the use of instruments as a physical means of determining quantities or variable**
- **Measurement system and the instruments may be classified based on the function they perform.**

- Measurement
  - A method to obtain information regarding the physical values of the variable.
  - the process of determining the amount, degree or capacity by comparison with the accepted standards of the system units being used

- Instrumentation
  - Devices used in measurement system
  - device for determining the value or magnitude of a quantity or variable

Purpose of a measurement system



Measurand | Sensor, signal conditioning, display | Man, tracking control etc

A ***measuring system*** exists to provide information about the physical value of some variable being measured.

- Instrumentation is a technology of measurement which serves sciences, engineering, medicine and etc.
- Measurement is the process of determining the amount, degree or capacity by comparison with the accepted standards of the system units being used.
- Instrument is a device for determining the value or magnitude of a quantity or variable.
- Electronic instrument is based on electrical or electronic principles for its measurement functions.

Instrumentals and Measurement Systems/ Functions of Instrument and Measurement system

4 main functions performed

Indicating Function: This function involves providing data related to the variable being measured. Various methods can be used in instruments and systems to achieve this objective. Typically, this data is acquired by observing the movement or displacement of a pointer on a measuring instrument.

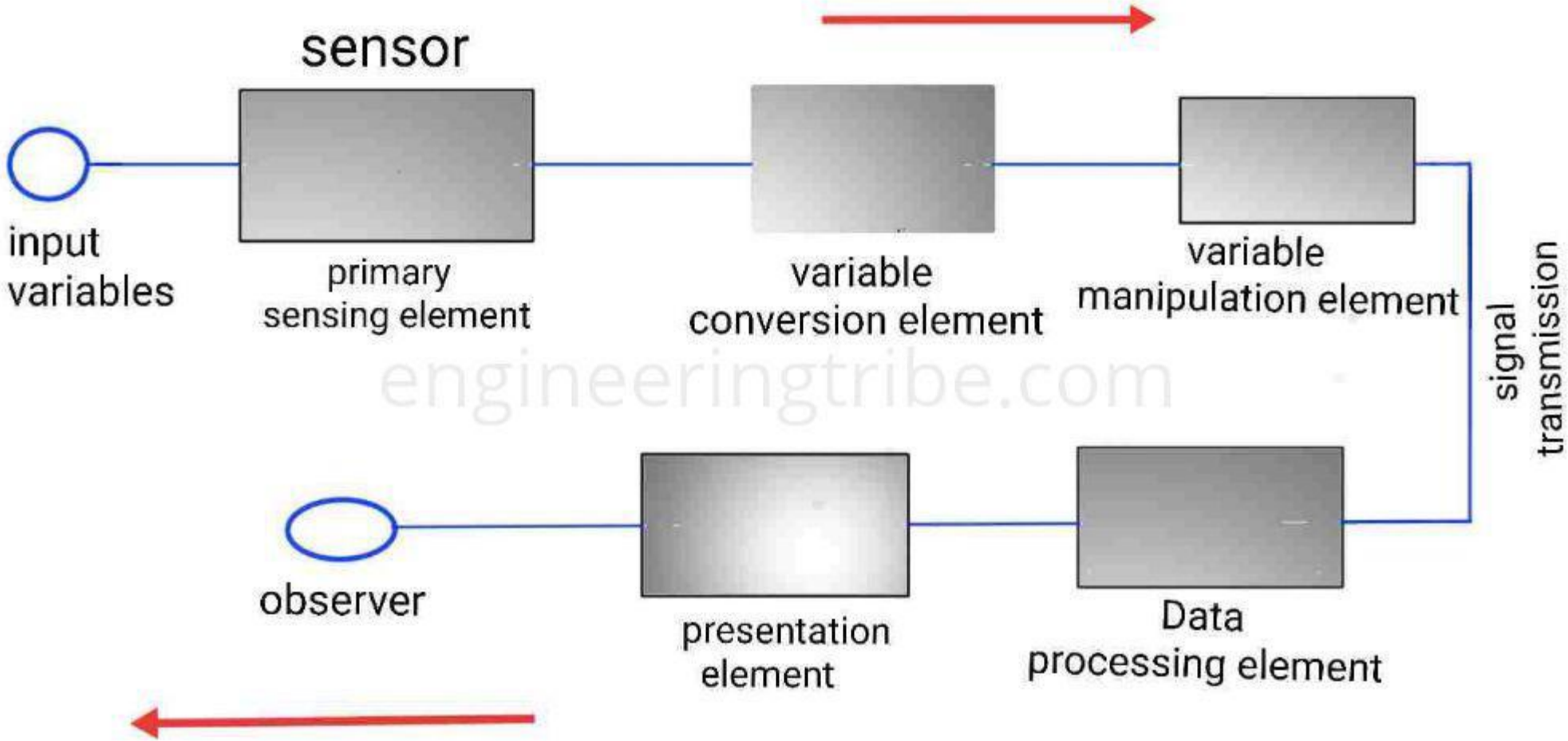
Recording Function: Instrument makes a written record, usually on paper, of the value of the quantity under measurement against time or against some other variable, Ex HTST pasteurizer gives the instantaneous temperatures on a strip chart recorder.

Signal Processing: This function is performed to process and modify the measured signal to facilitate recording / control.

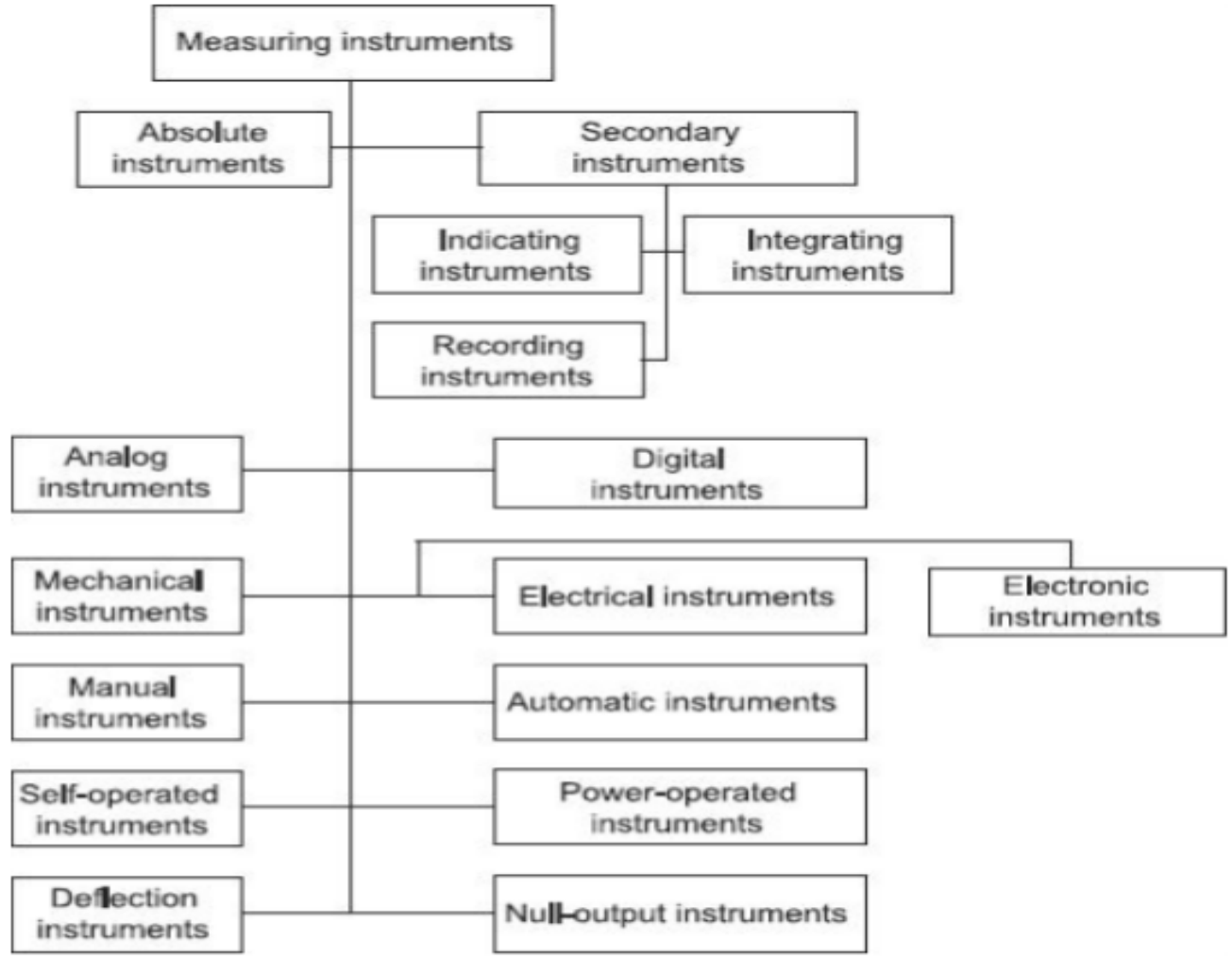
Controlling Function: This is one of the most important functions, especially in the food processing industries where the processing operations are required to be precisely controlled. In this case, the information is used by the instrument or the systems to control the original measured variable or quantity.

- Scientific instruments used three essential elements as our modern instruments these elements are
  1. A detector
  2. An intermediate transfer device
  3. An indicator recorder or a storage device.
- The history of development of instruments encompasses three phases of instruments
  1. Mechanical instrument
  2. Electrical instrument
  3. Electronics Instrument

Simple block diagram for functions to be performed



CLASSIFICATION OF INSTRUMENTS



Mechanical instruments:

- The mechanical instruments are mainly used for measuring physical quantities.
- This instruments is suitable for measuring the static and stable conditions , because these instruments is unable to give the response to the dynamic condition or transient condition.
- These instruments have moving parts that are rigid, heavy and bulky, consequently have a large mass. Mass presents inertia problems hence these measurements cannot follow rapid changes (dynamic conditions).
- These instruments cause noise pollution.

Electrical Instruments :

- Electrical Instruments has quick response time and are more rapid compared to mechanical instruments.
- Unfortunately electrical system depends on mechanical meter movement as indicating devices and mechanical movement have some inertia and again they have limited time and frequency response.

Electronics Instruments:

- The need for rapid response and dynamic parameter monitoring has driven the continuous development of semiconductor devices and electronics instruments.
- The response time of semiconductor devices is only that electrons to electrons which have very small inertia.
- Electronics instruments are more reliable due to improvements in design and manufacturing processes of semiconductor devices.
- They are light, compact and have a high degree of reliability and power consumption is very small.
- With the help of transducer, Non- electrical quantity is converted into electrical form therin electronic instrument have a significant role.
- Electronic instrument helps in detection of electromagnetically produced signals like radio, video and microwaves.
- Electronics instruments have higher sensitivity , greater flexibility.
- This development has been essential in various fields and industries
- **Telecommunications, Medical Devices, Industrial Automation, Aerospace and Defense, Environmental Monitoring, Automotive Industry, Scientific Research**

1) Definition of instruments :

An instrument is a device in which we can determine the magnitude or value of the quantity to be measured. The measuring quantity can be voltage, current, power and energy etc.

Classification of instrument :

1.Absolute and Secondary instruments
2.Direct measuring and comparison instruments
3.Analog and Digital instruments
4. indicating, Recording, integrating and controlling instruments
5. Automatic and manual instruments
6.Active and passive instruments/Self and Power operated instruments
7.Deflection and Null type instruments
8.Mechanical/ Electrical and Electronics instruments

One cubic foot per second is a unit of measurement for the rate of fluid flow, particularly through a pipeline. One cubic foot per second is also known as cusec. 1 Cusec = 28.32 Litres per second

1 Absolute instrument:

An absolute instrument determines the magnitude of the quantity to be measured in terms of the instrument parameter. This instrument is really used, because each time the value of the measuring quantities varies. So we have to calculate the magnitude of the measuring quantity, analytically which is time consuming. These types of instruments are suitable for laboratory use. Example: Tangent galvanometer.

Secondary instrument:

This instrument determines the value of the quantity to be measured directly. Generally these instruments are calibrated by comparing with another standard secondary instrument. Examples of such instruments are voltmeter, ammeter and wattmeter etc. Practically secondary instruments are suitable for measurement.

Absolute or Primary/Secondary Instruments

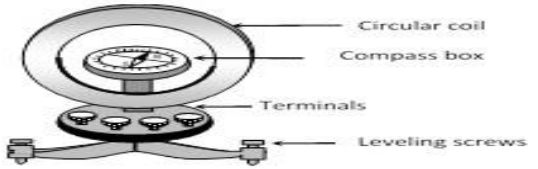
Absolute Instruments

- It gives the magnitude of quantity under measurement in terms of physical constants of the instrument e.g. Tangent Galvanometer
- In this type of instruments no calibration or comparison with other instruments is necessary.
- They are generally not used in laboratories and are seldom used in practice by electricians and engineers.

Secondary Instruments

- These instruments are so constructed that the quantity being measured can only be determined by 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. e.g. Ammeter, Voltmeter etc.

Tangent Galvanometer



Direct measuring instruments: These instruments converts the energy of the measured quantity directly into energy that actuates the instrument and the value of the unknown quantity is measured or displayed or recorded directly Examples are Ammeter, Voltmeter, Watt meter etc.

• **Comparison instruments:** These instruments measure the unknown quantity by comparison with a standard. Examples are dc and ac bridges and potentiometers. They are used when a higher accuracy of measurements is desired

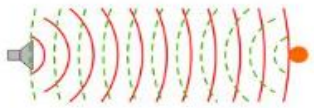
Measurement can be **direct**, like measuring length directly with a measuring tape. It can also be **indirect**, like **measuring distance** by emitting a sound, listening for it, & **measuring the delay** the sound is received after bounced back by an object.

Measuring fluid volume by measuring height

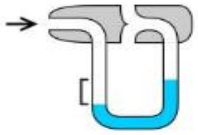
Measuring mass by measuring electrical resistance

Measuring wind speed by measuring angular speed

Measuring temperature by measuring length



Measuring distance by measuring time



Measuring airspeed by measuring height

Direct measuring instruments convert the energy of the unknown quantity directly into energy that deflects the moving element of the instruments (energy generates or come up from position of moving component).

The value of the unknown quantity being measured by reading the resulting deflections or by observing the resulting displacement.

Comparison Instruments are devices used to compare, measure or evaluate various quantities by comparing them to known reference or standard. For higher accuracy this is preferred.

Note: Direct Measuring Instruments are most widely used in engineering practice because they are simple and in expensive.

3. Analog and Digital Instruments:

Analogue Instruments: The signal of an analog unit vary in a continuous fashion and can take an infinite no. of values in a given range. E.g. ammeters, voltmeter, wrist watch , speedometer etc.

Digital instruments: Signals varying in discrete steps and taking on a finite no. of different values in a given range are digital signals e.gs timer on a score board, odometer of an automobile

Produce analog signal as output which varies continuously as the quantity under measurement changes. Where in digital will varies discrete steps and so can have a finite number of values.

Note: Digital instruments are more accurate and has higher resolution and drawbacks like lower sensitivity and higher cost when compared to analog

4. Indicating, Recording, Integrating and controlling instrument

Indicating Instruments: Simply indicates the quantity being measure **Ex: pointer which moves on a scale.**

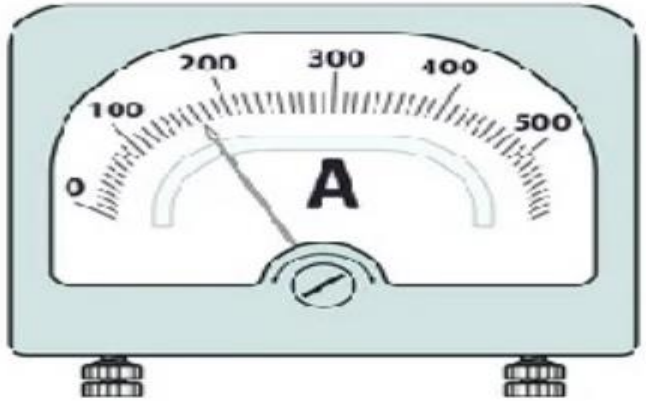
Recording instruments: Continuously record the variation of any physical quantity wrt time. Indication is made on chart or dial and usually done in digital form **Ex : ECG Machine to record cardiac rhythms.**

Integrating instrument: Measures the total amount of quantity supplied over a period of **time Ex : Energy meter shows the consumption of total quantity of electricity during a particular period of time.**

Controlling Instruments: uses the information obtained by it to control the original measured quantity. **Ex : Electrical relays.**

SECONDARY : INDICATING INSTRUMENT

Voltmeter



Ammeter

Wattmeter

INTEGRATING INSTRUMENT

Energy Meters (Watt-hour meter)

RECORDING INSTRUMENT

CONTROLLING INSTRUMENT

5. Automatic and Manual instrument

Manual instruments requires “the service of an operator” is required for measurement Ex : Traditional weighing scale

Automatic instruments does not require the service of an operator for measurement .Ex: an Electronic weighing machine

Manual colony counter

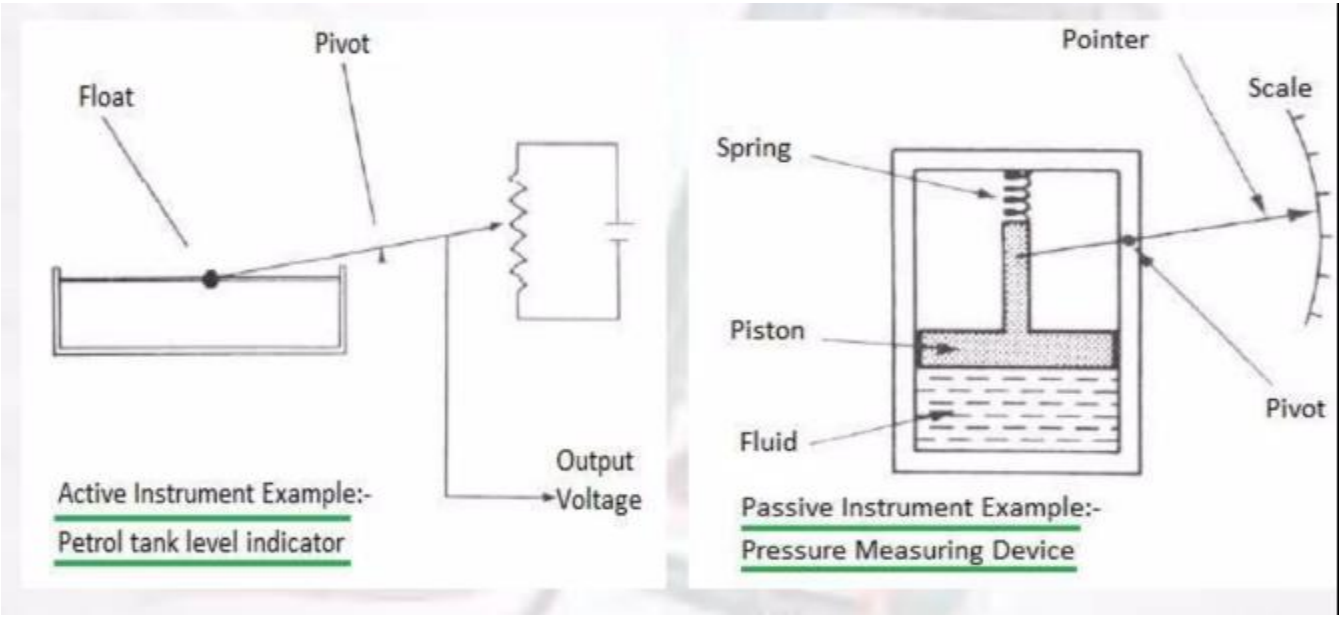
Automatic colony counter

6. Passive Instruments and Active instruments / Self operated and Power operated instrument

Self operated are those which requires no external power for operation. It draws power from the measuring environment. They are also called Passive instruments. Ex: In Ammeter and Voltmeter , the meters takes power from the system under measurements.

Power operated instruments are those in which external power supply is required for operation and they are also called as active instruments. Ex : An Electronic weighing machine we need to plug into 240V Supply to operate it.

Note : Active instruments need not be always electrical, it can also be Pneumatic or hydraulic



7. Deflection and Null type instruments:

- In Deflection type instruments, the magnitude of unknown quantity is indicated by the deflection of a pointer
- Only one source of input is required.
- Output reading is based on the deflection from the initial condition of the instrument
- The measurand value of the quantity depends on the calibration of the instruments
- Ex: Ammeter and Voltmeter

- Null type instrument reads to determination of the magnitude of the unknown quantity
- Require two input measurand and balance input
- Must have feedback operation that compares the measurand with the standard value
- Ex: Wheatstone bridge (nullifying the indication of the galvanometer by adjusting the resistance.

Application of measurement Systems

(i)Monitoring of processes and operations.

(ii)Control of processes and operations.

(iii) and Experimental Engineering analysis.

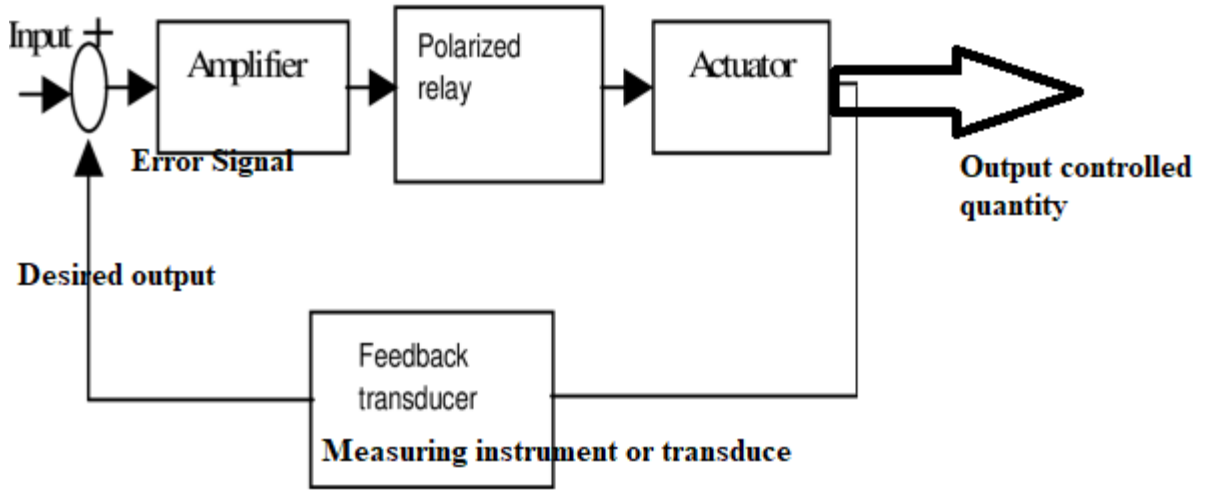
Monitoring of processes and operation

1) Indicate the value or condition of parameter under study and their reading do not serve any control function
2) Measuring device is used to keep track of some quantity
3) Ex Thermometer: Measures the temperature
   Barometer: Measures the Pressure
   Radars: Measures the signals

We just monitoring the quantities and not controlling
Water , gas and electric meters only monitors the value at home.

Control of Processes and operation

- Let us assume that the output is controlled variable and it is a non electrical and control action is by electrical.
- I /p and o /p is compared with the help of comparator the output is a non electrical quantity and is converted into electrical form by transducer which is connected in feedback loop.



If input and output differ there is a resultant error signal, these signals are amplified and then fed to an actuator to produces power to drive the controlled circuitry

Ex: 1) Refrigeration system which employs a thermostatic control temperature measuring device (bimetallic elements) senses the room temperature provides the information regarding function of control system

2) Car speed control system

3) Air conditioning system

Measured value is compared with the desired value and controlling, functioning is done over it.

Experimental Engineering Analysis

Design

Development

Research → Theory and Experimentation

They have many uses listed below

- ❖ Testing the validity of theoretical predictions
- ❖ Formulations of Empirical Formulas
- ❖ Determination of system parameters, Variables, and Performance indices.

Types of Instrumentation system

The invention of microprocessors has revolutionized the field of instrumentation and control, Microprocessor based application are used in process instrumentation. Classification of instrumentation system are

- ❑ Intelligent Instrumentation system
- ❑ Dumb Instrumentation System

Intelligent Instrumentation system

- ❑ Are the system which include a microprocessor and memory there by acting as a micro computer.
- ❑ Intelligent instrumentation system is to evaluate a physical variable employing a digital computer, to perform all signal and information processing.
- ❑ Where, after the measurement of the variable is made, further processing either in digital or analog form is carried out to refine the data, for the purpose of presentation to an observer or the other computer.

Dumb Instrumentation system: In this system once the measurement is made, the data must be processed by the observer.

Information and signal Processing

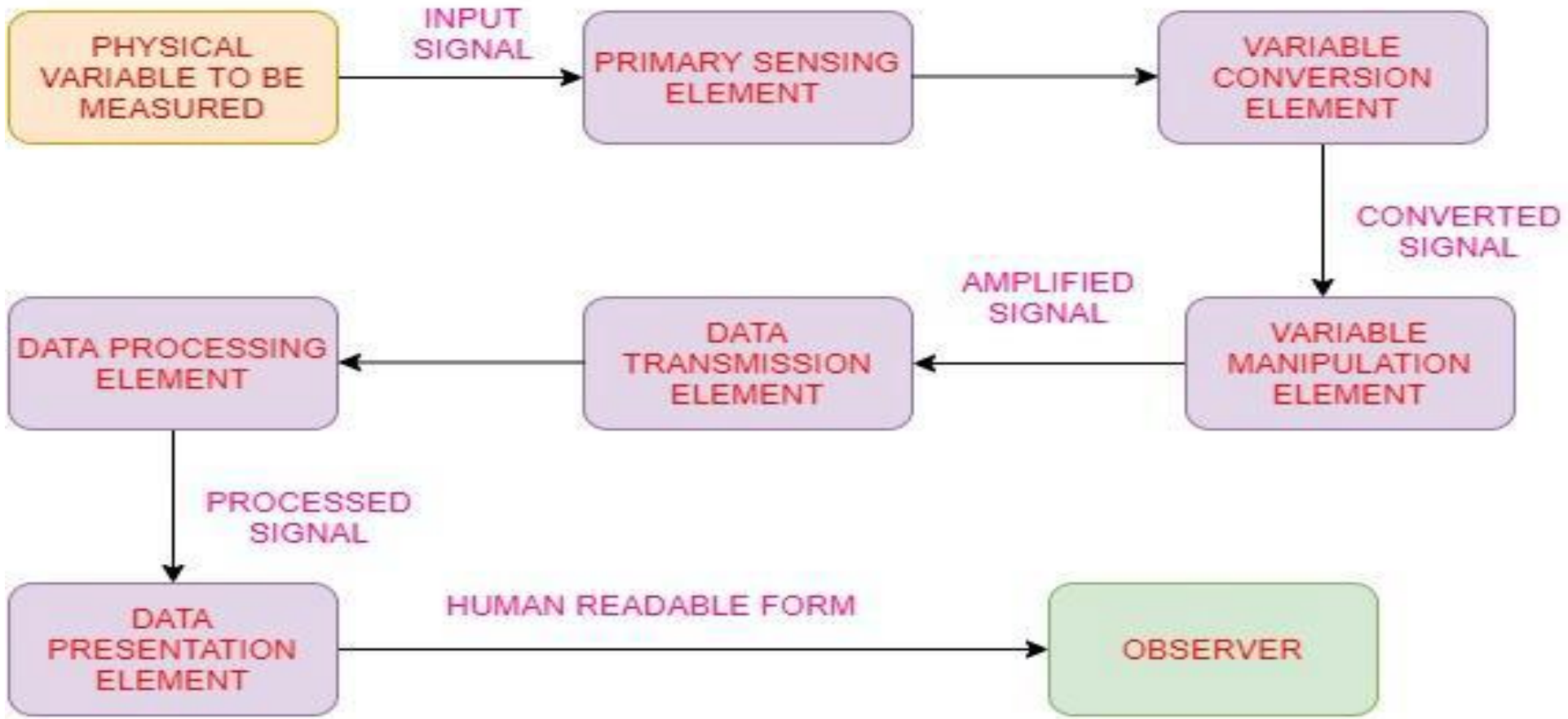
Information: it is the data or details relating to an object or event.

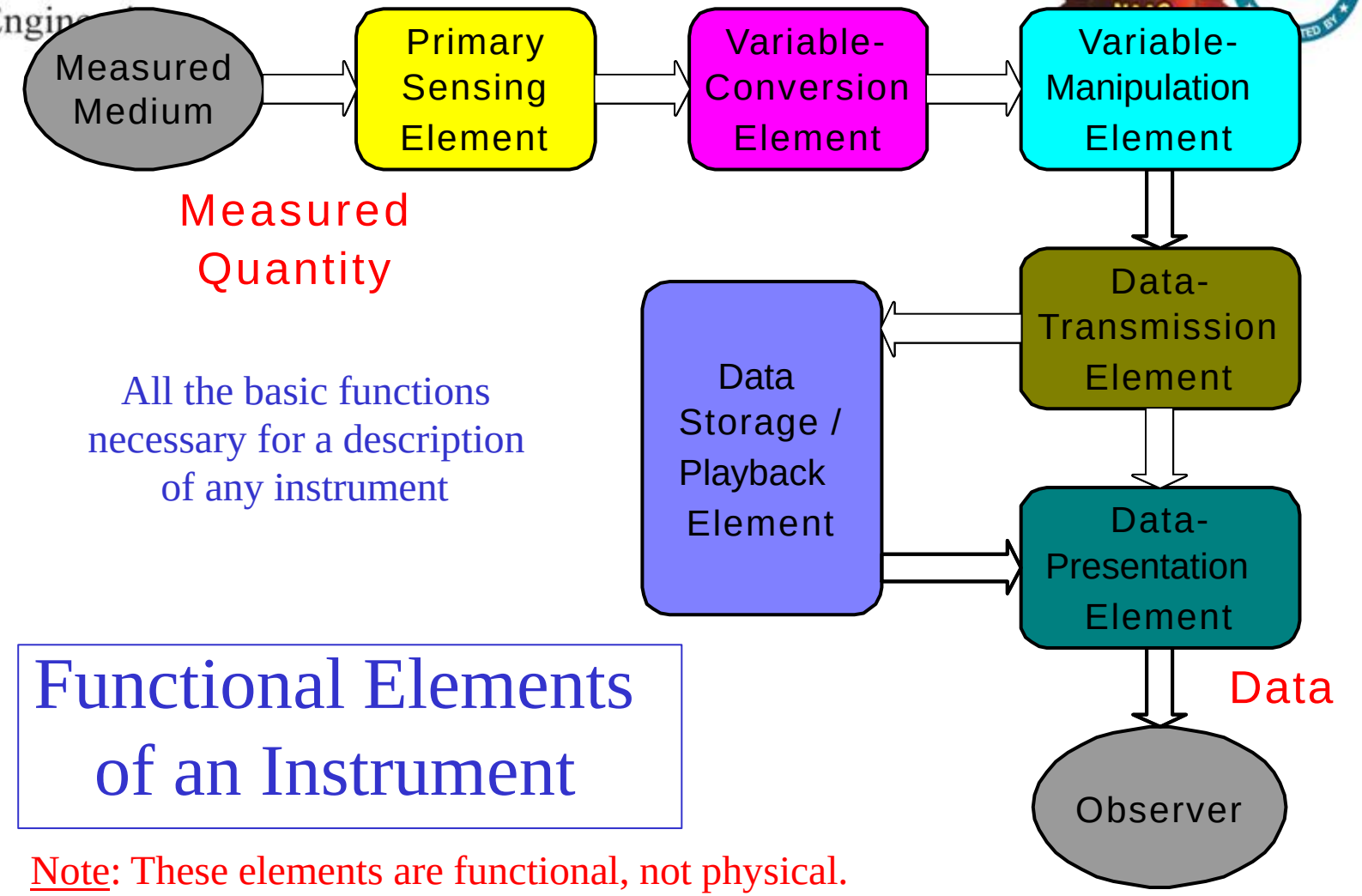
Signals: They carry the information about magnitude or time relating to an object or event ie.., a Physical quantity.

ELEMENTS OF A GENERALIZED MEASUREMENT SYSTEM

The various elements of measurement system are,

1. Input Variable
2. Primary sensing Element
3. Variable conversion element.
4. Variable manipulation element
5. Data transmission element.
6. Data processing Element
7. Data presentation element.
8. Observer


PHYSICAL VARIABLE TO BE MEASURED
INPUT SIGNAL
PRIMARY SENSING ELEMENT
VARIABLE CONVERSION ELEMENT
CONVERTED SIGNAL
VARIABLE MANIPULATION ELEMENT
AMPLIFIED SIGNAL
DATA TRANSMISSION ELEMENT
DATA PROCESSING ELEMENT
PROCESSED SIGNAL
DATA PRESENTATION ELEMENT
HUMAN READABLE FORM
OBSERVER

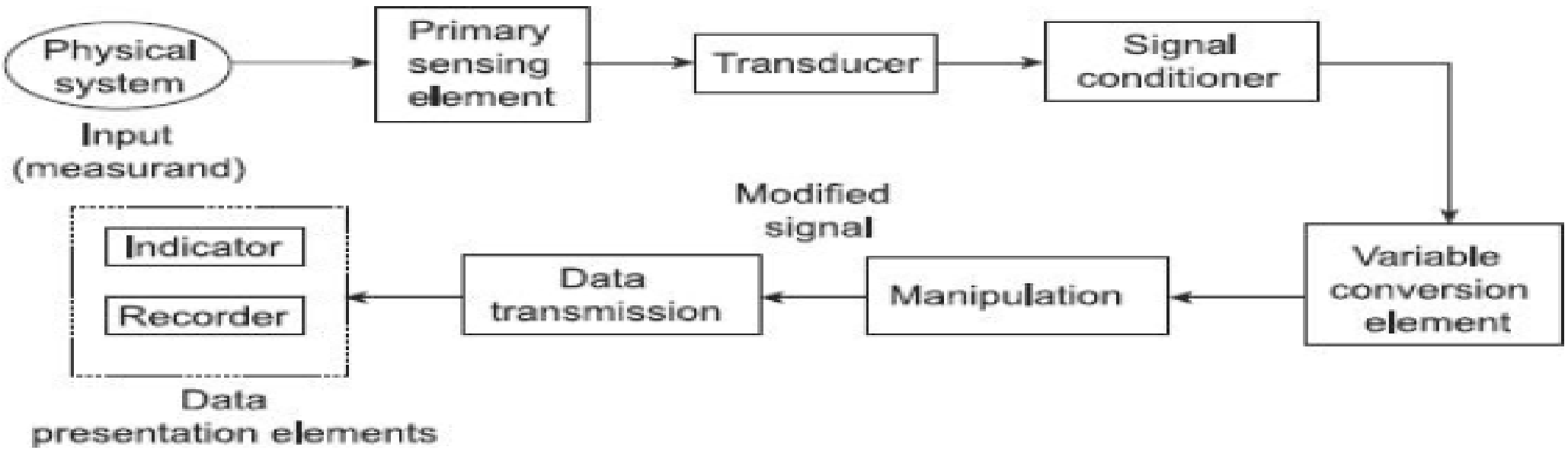


All the basic functions necessary for a description of any instrument

Functional Elements of an Instrument

Note: These elements are functional, not physical.

MEASUREMENT SYSTEM AND ITS ELEMENTS



1. **INPUT VARIABLES**

- May be any unknown variable without any input , the final results can not be achieved by the system.

2. **PRIMARY SENSING ELEMENT**

- It is the first element which receives energy from the measured medium and it produces an output corresponding to the measurand. This output is then converted into an analogous electrical signal by a transducer.
- Primary sensing element is to sense the input variable and gives the output which is non electrical term transducer is used to convert electrical form.

3. **VARIABLE CONVERSION ELEMENT.**

- It receives the output of the primary sensing elements as input. Conversion of the variable from one form to another take places. It converts the output electrical signal of the primary sensing element into a more suitable form signal without changing the information containing in the input signal.
- The requirement of this elements depend upon the measuring instrument some may need and some may not used.

4. **VARIABLE MANIPULATION ELEMENT**

- This element manipulates the input variable.
- The variable are manipulated by manipulation otherwise called as amplification. This is done for the required output from the input variable.
- Manipulation process does not depend on the variable conversion element. This can be proceed directly without conversion element.
- For example, an electronic voltage amplifier receives a small voltage as input and it produces greater magnitude of voltage as output. A variable manipulation element does not necessarily follow a variable conversion element and it may precede it.

5. DATA TRANSMISSION ELEMENT.

- It transmits the data from one element to the other. Data transmission is the main function of this element and elements such as data cables, transmitters, receivers and transmission shafts etc.., may be as shaft and gear assembly system or as complicated as a telemetry system which is used to transmit the signal from one place to another.

6. DATA PROCESSING ELEMENT

- It is an element which is used to modify the data before displayed or finally recorded. It may be used for the following purposes.

i. To convert the data into useful form
ii. To separate the signal hidden in noise
iii. It may provide corrections to the measured physical variables
iv. to compensate for zero offset, temperature error, scaling etc

7. DATA PRESENTATION ELEMENT

Finally, Data is present to the observer via the data presentation element. The Presentation elements is such as to monitor, Recorder, needle pointer, LCD and LED display, alarms, analog and digital indicators etc..,Without data Presentation element, data cannot be delivered to the observer.

8. OBSERVER

Used to record these data for further clarification in the future. The recorded data are stored either in hard copy or digital copy

Example: Bourdon Thermometer , Placed in hot or cold body, the sensing bulb senses the temperature. This is sensing stage and cause a displacement of sensing fluid through the capillary tube in the thermometer and conversion of stage starts. The fluid is displaced to the bourdon tube, where conversion process occurs. Fluid displacement is converted to link displacement and again link displacement is amplified to get the exact result. This amplification is done by gears attached to the pointer and the link. Finally the output is indicated by deflection or movement of the pointer.

Input-Output Configuration of Measuring Instruments and Measurement Systems

The signals can be interfere or which try to modify or mask the original input signal which we want and the effect of modified input signal must be reduced or kept minimum by designing the measurement system

The input quantities are classified into three categories

1. Desired inputs
2. Interfering inputs
3. Modifying inputs

Desired inputs:

Are defined as quantities for which the instrument or the measurement system is **specially designed to measure and respond.**

From Block diagram

1. rD represents Desired input, cD represents output component and GD represents transfer function . The input output relationship is given by cD= GDrD
2. Let the transfer function be **K constant**, which multiplies the static input rD, the output is cD=K rD. The output can be either an amplified or an attenuated output in **linear system**
3. Note: K can be used for Non linear system.
4. For non linear systems, the transfer function is represented by either an algebraic or transcendental function
5. The input –output relationship for the systems subjected to dynamic inputs are represented by differential equation.

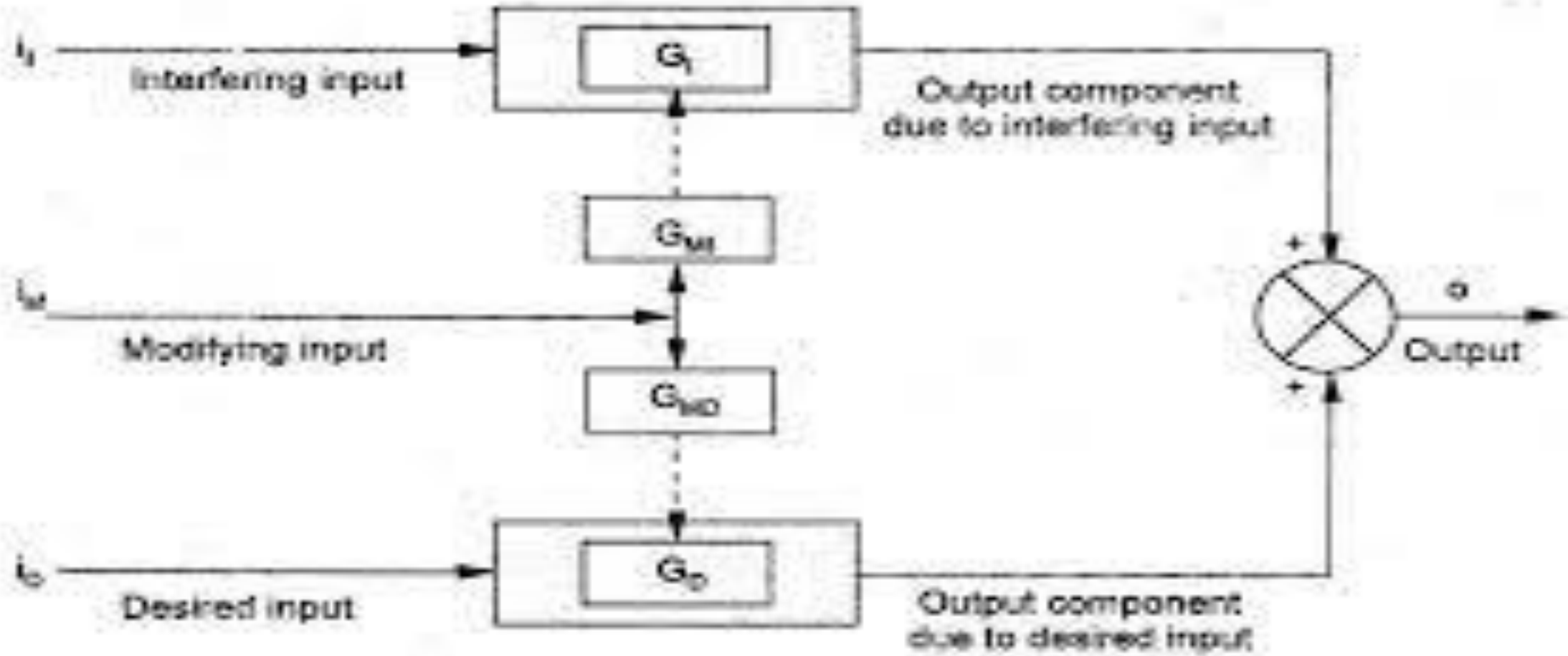
Interfering Inputs:

1. Interfering inputs represents quantities to which an instrument or a measurement system becomes **unintentionally sensitive.**
2. The instruments or measurements systems are **not desired to respond to interfering inputs** but they give an output due to interfering inputs on account of their principle of working, design and other factors like environments in which they are placed.

rI= Represents interfering input
GI= represents transfer function
cI= GIrI = represents input-output relationship.

Modifying inputs:

1. Modifying inputs are defined as inputs which cause a change in input- output relationships for either desired inputs or interfering inputs or for both.
2. This can also be included into interfering inputs, but there is a separate classification which is more significant and essential.
3. rM= Modifying inputs , that modifies GD and GI , GMD and GMI are interpreted as GD and GI
4. Ex Manometer function is to measure the pressure



Generalised input-output configuration

Example:

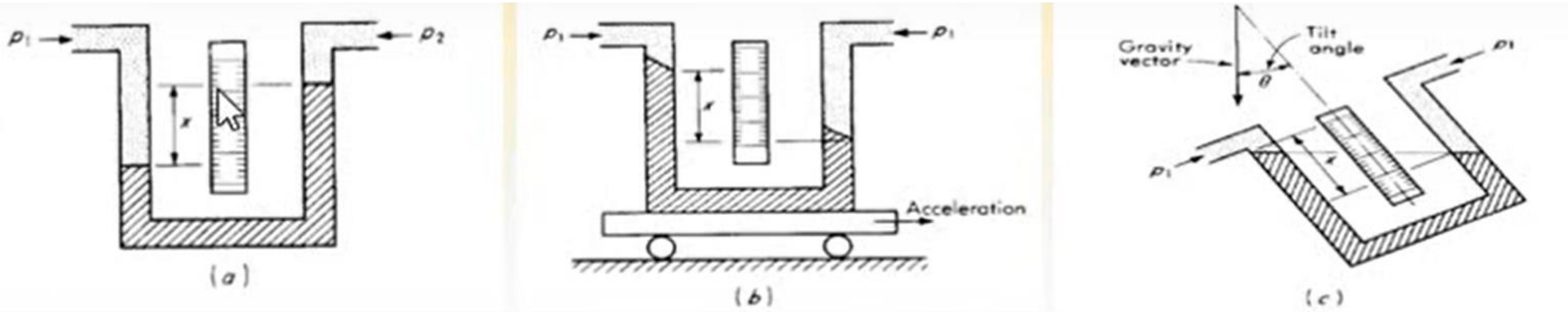


Figure . Spurious inputs for manometer.

Method of correction for interfering and modifying inputs

To nullify or reduce the effects of interfering and modifying inputs, there are many methods adopted they are:

1. Method of inherent insensitivity
2. Method of high gain feedback
3. Method of calculated output corrections
4. Method of signal filtering
5. Method of opposing inputs.

Method of inherent insensitivity

- Instruments or measurement system are so designed that they are sensitive only to desired inputs and are insensitive to both interfering and modifying inputs.
- Ex: let the desired input is to measure the side dimension of a outside wall. The outside temperature also affects the system. We call as interfering inputs.
- Measuring instruments be steel tape and to measure the side dimension and also measures the temperature of environment it might affect the total dimension of wall. Let use metal tape, this motivates one for finding to have a very low resistance temperature coefficients, so that we can control the temperature of environment will not affect measurement. Making our system inherent insensitive.

Method of High gain Feedback (Feedback Loop)

Feedback system plays a significant role in measurement and control system and makes response relatively insensitive to modifying input. (requires a derivation for open and closed loop system)

Method of calculated output correction

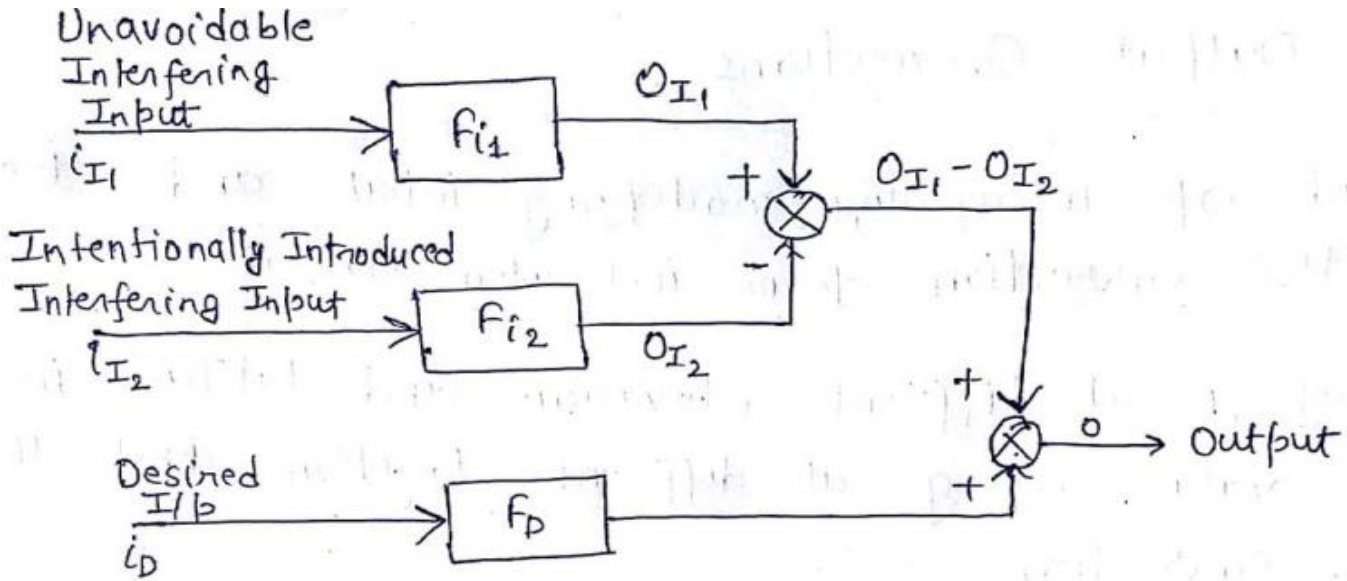
- Estimate the magnitude of interfering /modifying input and add or subtract the correction from indicated output
- Ex: gravitational force is an interfering or modifying inputs for the u tube manometer. The corrections for inputs can be easily be computed provided the elevation and latitude of the place at which manometer is used are known.

Method of signal filtering

This is based upon introduction of filters is instruments and measurement system . The filter blocks the passage of unwanted signals in such a ways that the output is either completely eliminates or is considerably reduced.
We can eliminates the interfering/ modifying input effect by introducing filters like low pass/no pass / band pass /high pass /band reject filter etc..,

Method of opposing inputs:

Intentionally introducing into the instruments interfering and or modifying inputs that tends to cancel bad effects of the unavoidable spurious input.



In Strain gauge introducing the dummy gauge in adjacent arm of Wheatstone bridge to eliminate interfering temperature effect.

Errors in measurements:

- The accuracy of an instrument is measured or expressed in terms of its error. It is impossible to measure or get the true value of a quantity.
- The Algebraic difference between the indicated value and the true value of the quantity to be measured is called an Error

Errors in measurement can be divided into two categories Static Error and Dynamic Errors

Static Error: Error can be defined as the difference between the measured value of a quantity and its true or actual value

Dynamic Error: it is the difference between measured value and true value of a parameter or quantity which keeps changing with time, also called as measurement error.

Three other ways of defining the error are:

Absolute error $\epsilon_0 = \delta A$

Relative error $$\epsilon_r = \frac{\text{absolute error}}{\text{true value}} = \frac{\delta A}{A_t} = \frac{\epsilon_0}{A_t}$$

Percentage error Percentage static error $\% \epsilon_r = \epsilon_r \times 100$

We have $A_t = A_m - \delta A$

$= A_m - \epsilon_0 = A_m - \epsilon_r A_t$

$\delta A = A_m - A_t$

δA = error,

A_m = measured value of quantity,

A_t = true value of quantity.

Calculating the Error

Absolute error:

e_a = |True value – Approximate value|

$$e_a = \left|X - X'\right| = \left|Error\right|$$

Relative error is defined as:

$$e_r = \left|\frac{Absolute\ Error}{True\ Value}\right| = \left|\frac{X - X'}{X}\right|$$

Static Correction

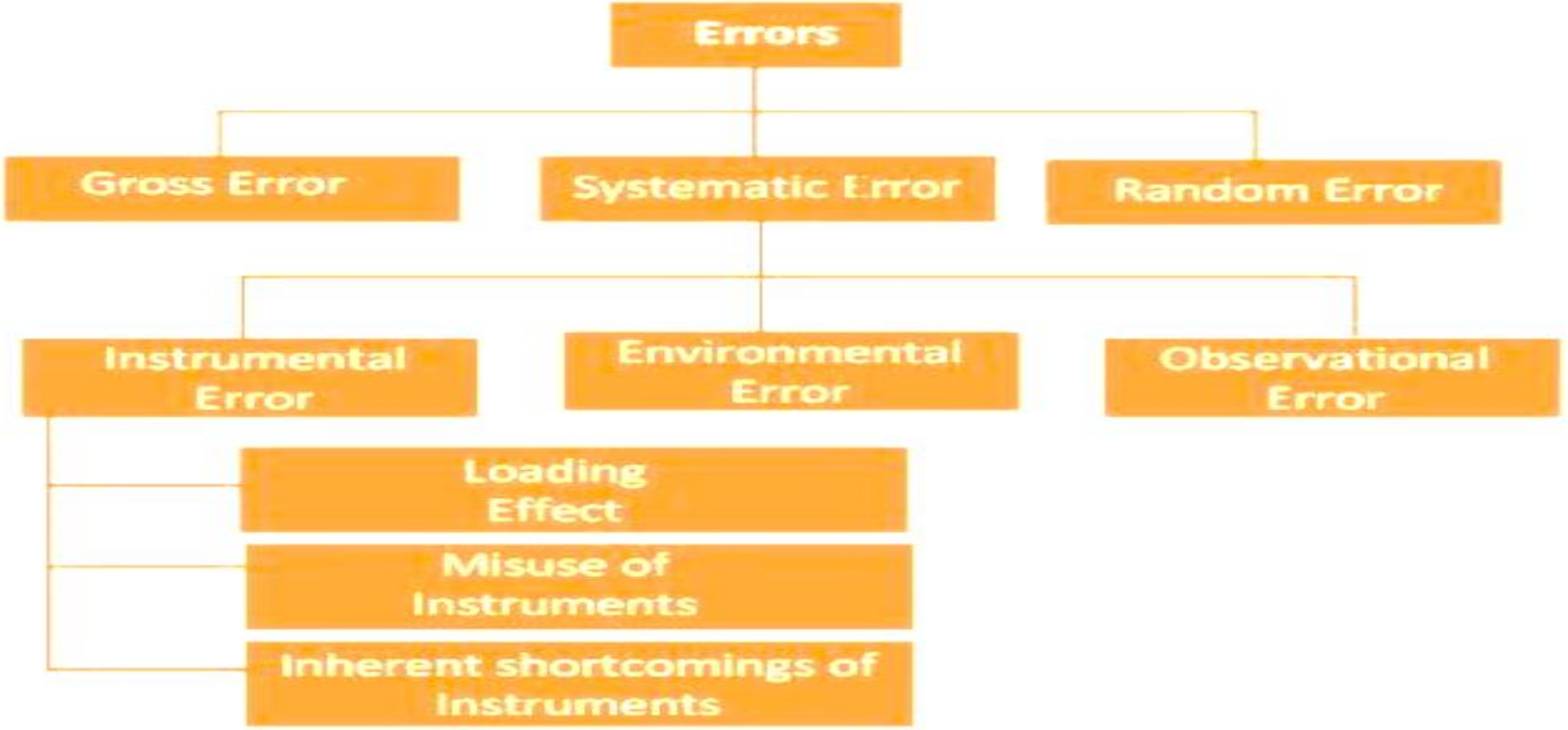
It is the difference between the true value and the measured value of the quantity, or

$$\delta C = A_t - A_m$$

δC = static correction = $-\delta A$

Types of Errors:

Static errors can be classified into 3 types



TYPES OF STATIC ERROR

1) **Gross Error**

- cause by human mistakes in reading/using instruments
- may also occur due to incorrect adjustment of the instrument and the computational mistakes
- cannot be treated mathematically
- cannot eliminate but can minimize
- Eg: Improper use of an instrument.
  - This error can be minimized by taking proper care in reading and recording measurement parameter.
- In general, indicating instruments change ambient conditions to some extent when connected into a complete circuit.
- Therefore, several readings (at three readings) must be taken to minimize the effect of ambient condition changes.

Gross errors occurs due to human mistake and errors in using measuring instruments or taking wrong reading or mistakes in recording observations. These errors can not be completely eliminated by mathematically. But we can try to minimize them by taking proper care while taking reading or recording observations.

TYPES OF STATIC ERROR (cont)

2) Systematic Error
   - due to shortcomings of the instrument (such as defective or worn parts, ageing or effects of the environment on the instrument)

- In general, systematic errors can be subdivided into static and dynamic errors.
  - Static – caused by limitations of the measuring device or the physical laws governing its behavior.
  - Dynamic – caused by the instrument not responding very fast enough to follow the changes in a measured variable.

These errors occur due to lack of quality in measuring instruments such as defective equipment or wear and tear or ageing effects or environmental effect also called as BIAS

- 3 types of systematic error :-
  - (i) Instrumental error
  - (ii) Environmental error
  - (iii) Observational error

Instrumental Errors : occur due to design and constructional features or the mechanical structure of the instrument.

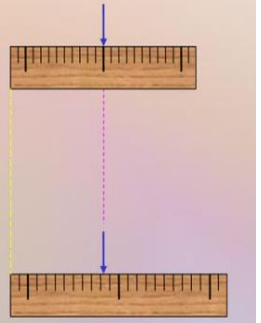
Environmental errors: occurs due to environmental effects such as temperature, pressure and humidity etc..,

Observational Errors: occurs due to errors in observation (due to instrument also ex Scale is not calibrated /movement of pointer on the scale is not deflecting proper.

Systematic errors

Example 1

Suppose you are measuring with a ruler:



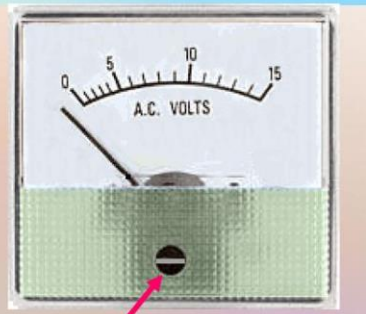
If the ruler is wrongly calibrated, or if it expands,

then all the readings will be too low (or all too high):

Zero errors

Example 6

Look at this voltmeter:



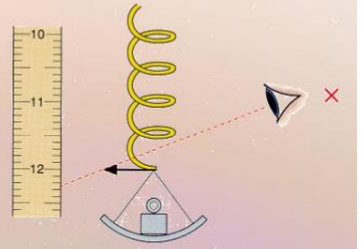
What is the first thing to do?

Use a screwdriver here to adjust the pointer.

Systematic errors

Example 2

If you have a parallax error:

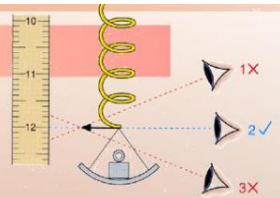


with your eye always too high

then you will get a systematic error

All your readings will be too high.

Random errors



These may be due to human error,
a faulty technique,
or faulty equipment.

To reduce the error, take a lot of readings, and then calculate the average (mean).

(i) Instrumental error

- inherent while measuring instrument because of their mechanical structure (eg: in a D'Arsonval meter, friction in the bearings of various moving component, irregular spring tension, stretching of spring, etc)
- error can be avoid by:

(a) selecting a suitable instrument for the particular measurement application

(b) apply correction factor by determining instrumental error

(c) calibrate the instrument against standard

(ii) Environmental error

- due to external condition effecting the measurement including surrounding area condition such as change in temperature, humidity, barometer pressure, etc
- to avoid the error :-
  (a) use air conditioner
  (b) sealing certain component in the instruments
  (c) use magnetic shields

(iii) Observational error

- introduce by the observer
- most common : parallax error and estimation error (while reading the scale)
- Eg: an observer who tend to hold his head too far to the left, while reading the position of the needle on the scale.

3) Random error
- due to unknown causes, occur when all systematic error has accounted
- accumulation of small effect, require at high degree of accuracy
- can be avoid by
  (a) increasing number of reading
  (b) use statistical means to obtain best approximation of true value

Random Errors: These errors occur due to unknown causes and reasons which are very difficulty to determine. These errors are very small in magnitude and follow laws of probability and can be treated mathematically.

Why Errors happens or Sources of Error??

1. Lack of knowledge about measurement process
2. Operational Errors
3. Poor Design and Construction
4. Lack of proper maintenance
5. Change in Proper Parameters and environmental condition

PERFORMANCE CHARACTERISTICS

- **Accuracy** – the degree of exactness (closeness) of measurement compared to the expected (desired) value.
- **Resolution** – the smallest change in a measurement variable to which an instrument will respond.
- **Precision** – a measure of consistency or repeatability of measurement, i.e successive reading do not differ.
- **Sensitivity** – ratio of change in the output (response) of instrument to a change of input or measured variable.
- **Expected value** – the design value or the most probable value that expect to obtain.
- **Error** – the deviation of the true value from the desired value.

Accuracy

- Accurate: measured value very close to actual value.
  - What affects accuracy?
  - How can you improve accuracy?

Precision

Precise: Multiple measurements close together

-What affects precision?

- How can you improve precision?

Precision – Target 1

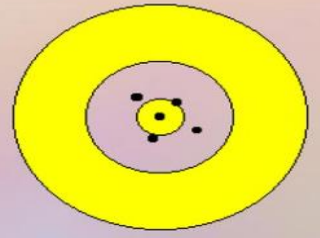
Measurement precision must be interpreted in light of measurement accuracy. Let's use a target practice example:

Accurate & Precise

The best situation, the shots are tightly clustered (high precision) on the center circle (high accuracy).

Precision – Target 2

Measurement precision must be interpreted in light of measurement accuracy. Let's use a target practice example:

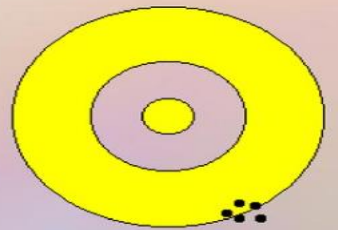


Accurate & Not Precise

The next situation, shots are near the center (high accuracy), but not tightly clustered (low precision).

Precision – Target 3

Measurement precision must be interpreted in light of measurement accuracy. Let's use a target practice example:

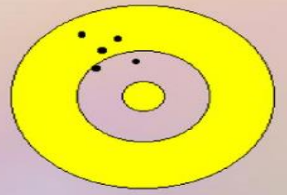


Precise & Not Accurate

In the next situation, a tight cluster (high precision) is far off center (low accuracy).

Precision – Target 4

Measurement precision must be interpreted in light of measurement accuracy. Let's use a target practice example:

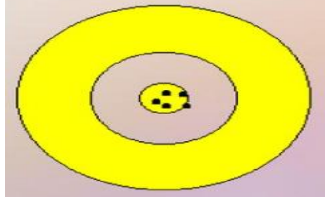


Not Precise & Not Accurate

Finally, widely scattered shots (low precision) appear away from the center (low accuracy).

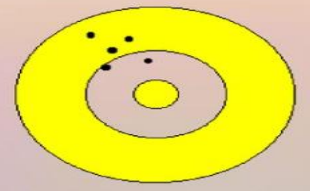
Precision - Comparison

Which is the best and which is worst?



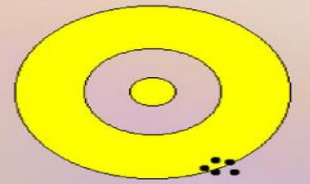
Accurate & Precise

Best



Not Precise & Not Accurate

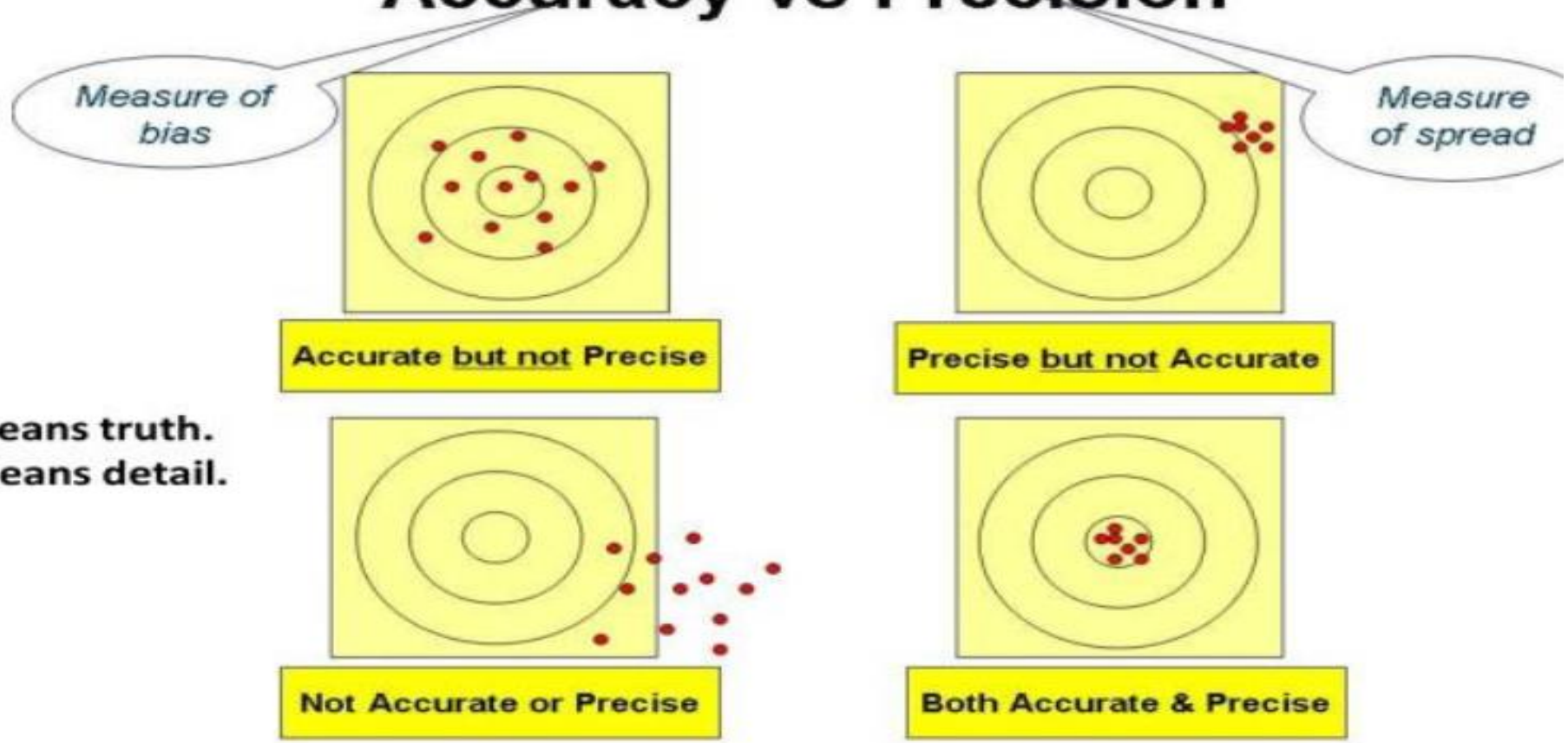
Worst



Precise & Not Accurate

Most Insidious
Why?

Accuracy vs Precision



"Accuracy" means truth.
"Precision" means detail.

Accuracy	Precision
Accuracy is closeness with the true value of the quantity being measured.	Precision is a measure of the reproducibility of the measurement.
Measurement can be accurate but not necessarily precise.	Measurement can be precise but not necessarily accurate.
It can be determined with a single measurement.	It needs serveral measurements to be determined.
Accuracy may be affected with systematic error.	Precision may be affected with random error.
Accurate values have to be precise in most cases.	Precise values may or may not be accurate.
Degree of conformity.	Degree of reproducibility.

Example 2·1. A meter reads 127·50 V and the true value of the voltage is 127·43 V. Determine :

(*a*) the static error, and (*b*) the static correction for this instrument.

Solution. From Eqn. 2·1, the error is

$$\delta A = A_m - A_t = 127{\cdot}50 - 127{\cdot}43 = +0{\cdot}07 \text{ V}$$

Static correction $\delta C = -\delta A = -0{\cdot}07$ V.

Example 2·2. A thermometer reads 95·45°C and the static correction given in the correction curve is −0·08°C. Determine the true value of the temperature.

Solution. True value of the temperature $A_t = A_m + \delta C = 95{\cdot}45 - 0{\cdot}08 = 95\,37$°C.

Example 2·3. A voltage has a true value of 1·50 V. An analog indicating instrument with a scale range of 0–2·50 V shows a voltage of 1 46 V. What are the values of absolute error and correction. Express the error as a fraction of the true value and the full scale deflection (f.s.d.).

Solution : Absolute error $\delta A = A_m - A_t = 1\,46 - 1{\cdot}50 = -0{\cdot}04$ V

Absolute correction $\delta C = -\delta A = +0{\cdot}04$ V

Relative error $$\epsilon_r = \frac{\delta A}{A_t} = \frac{-0{\cdot}04}{1{\cdot}50} \times 100 = -2{\cdot}66\%.$$

Relative error (expressed as a percentage of f.s.d.)

$$= \frac{-0{\cdot}04}{2{\cdot}5} \times 100 = -1{\cdot}60\%.$$