ME8501-METEROLOGY AND MEASUREMENT

Lecture by

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SYLLABUS

UNIT I BASICS OF METROLOGY

Introduction to Metrology – Need – Elements – Work piece, Instruments – Persons – Environment – their effect on Precision and Accuracy – Errors – Errors in Measurements – Types – Control – Types of standards.

UNIT II LINEAR AND ANGULAR MEASUREMENTS

Linear Measuring Instruments – Evolution – Types – Classification – Limit gauges – gauge design – terminology – procedure – concepts of interchange ability and selective assembly – Angular measuring instruments – Types – Bevel protractor clinometers angle gauges, spirit levels sine bar – Angle alignment telescope – Autocollimator – Applications.

UNIT III ADVANCES IN METROLOGY

Basic concept of lasers Advantages of lasers – laser Interferometers – types – DC and AC Lasers interferometer – Applications – Straightness – Alignment. Basic concept of CMM – Types of CMM – Constructional features – Probes – Accessories – Software – Applications – Basic concepts of Machine Vision System – Element – Applications.

UNIT IV FORM MEASUREMENT

Principles and Methods of straightness – Flatness measurement – Thread measurement, gear measurement, surface finish measurement, Roundness measurement – Applications.

UNIT V MEASUREMENT OF POWER, FLOW AND TEMPERATURE

Force, torque, power – mechanical , Pneumatic, Hydraulic and Electrical type. Flow measurement: Venturimeter, Orifice meter, rotarmeter, pitot tube – Temperature: bimetallic strip, thermocouples, electrical resistance thermometer – Reliability and Calibration – Readability and Reliability

UNIT I-BASICS OF METROLOGY

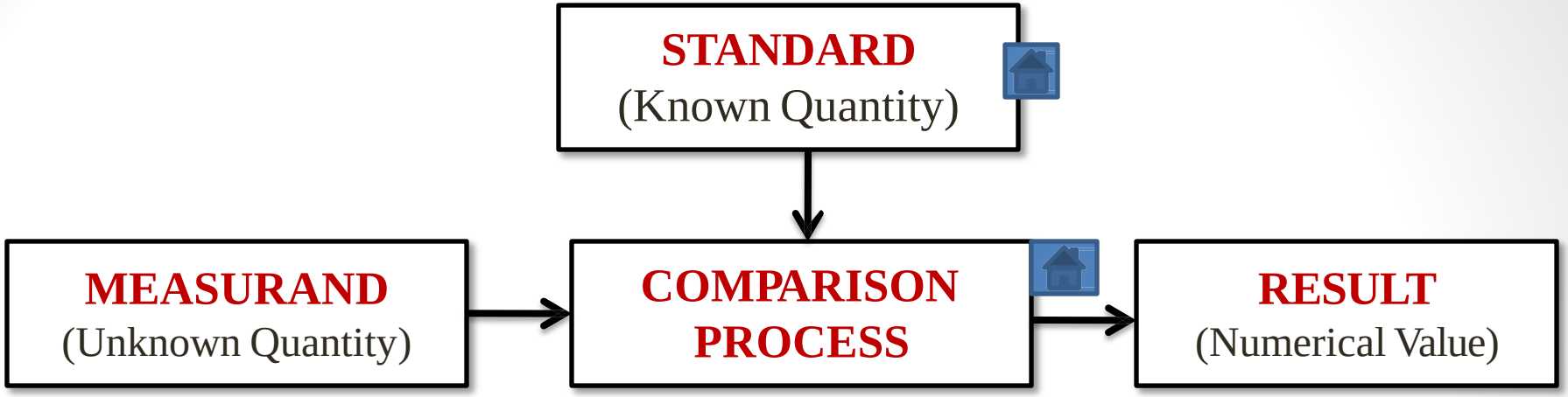
- ✓ Introduction to Metrology
- ✓ Need
- ✓ Elements
- ✓ Work piece, Instruments – Persons – Environment – their effect on Precision and Accuracy
- ✓ Errors
- ✓ Errors in Measurements
- ✓ Types
- ✓ Control
- ✓ Types of standards.

MEASUREMENTS - *Introduction*

- Measurement is a **process of comparing** inputs with pre-defined standard and giving the output.

- Metrology is a **science** of measurement.
- Metrology is also concerned with the **industrial inspection** and its various techniques.
- For every kind of quantity measured, there must be a **unit** to measure it.

MEASUREMENTS - *Introduction*



1. **Measurand**, a physical quantity such as length, weight, and angle to be measured

2. **Reference**, to compare the measurand (physical quantity) with a known **Standard** for evaluation

3.**Standard/Reference**, the physical quantity or property to which quantitative comparisons are to be made, which is **internationally accepted.**

NEED FOR MEASUREMENT

1. To convert physical parameters into **meaningful numbers**.
2. To determine the **true dimensions** of a part.
3. To increase our **knowledge** and **understanding** of the world.
4. Needed for ensuring public **health** and human **safety**.
5. To test if the elements that constitute the system function **as per the design**.
6. For evaluating the **performance** of a system.
7. To ensure **interchangeability** with a view to promoting mass production.
8. To establish the validity of design and for finding **new data and new designs**.

TYPES OF METROLOGY

- **Industrial Metrology** - Industrial metrology's purpose is to ensure that instruments, used in a wide variety of industries, are **functioning properly**.

- **Scientific Metrology** - This form of metrology deals with the **organization and development** of measurement standards and with their maintenance.

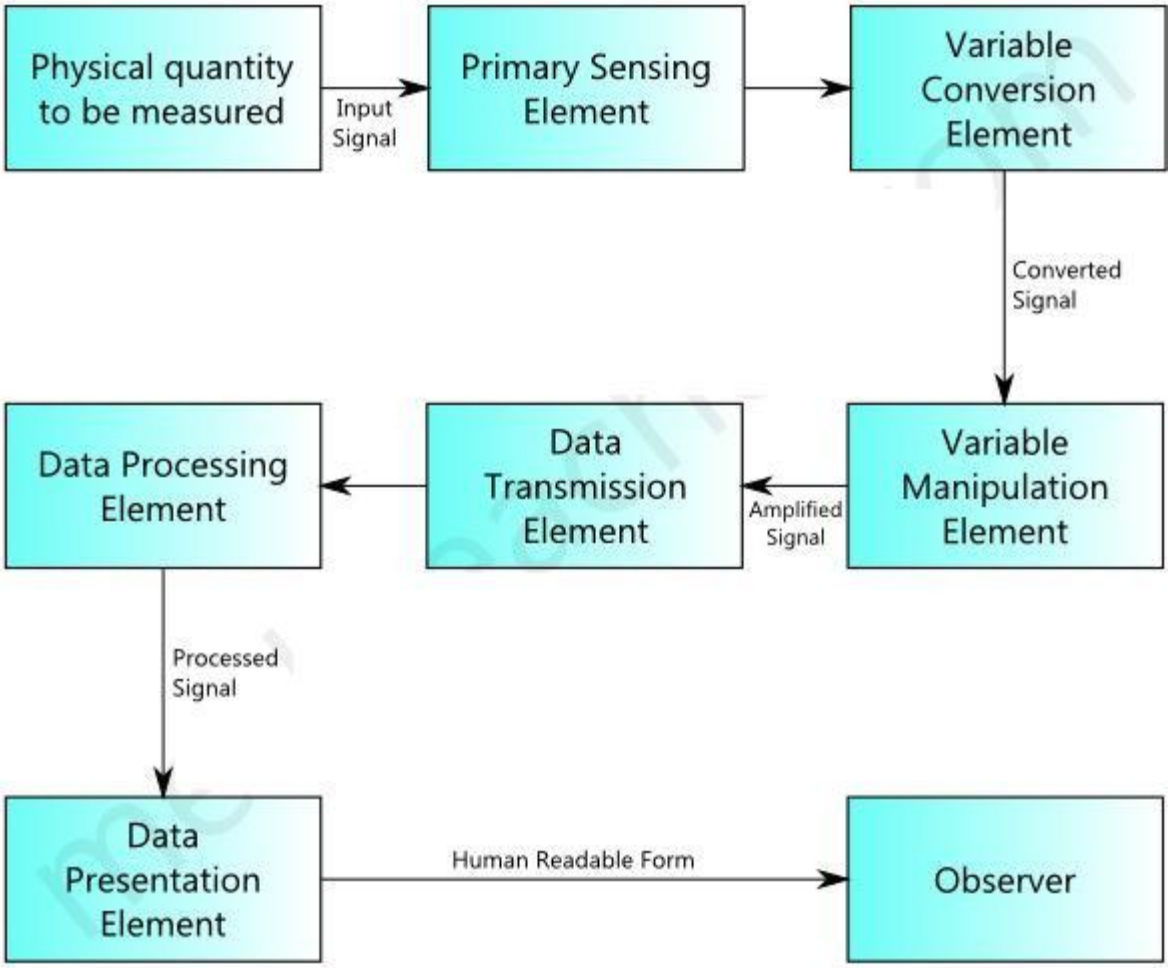
- **Legal Metrology** - Concerned with the measurements that influence **economic transactions**, legal metrology is a very refined type of metrology.

COMPONENTS OF GENERALIZED MEASUREMENT SYSTEM

A generalized measurement system consists of the following components:

1. Primary Sensing Element
2. Variable Conversion Element
3. Variable Manipulation Element
4. Data Processing Element
5. Data Transmission System
6. Data Presentation Element

GENERALISED MEASURING SYSTEM



COMPONENTS OF GENERALIZED MEASUREMENT SYSTEM

1. Primary Sensing Element:

The primary sensing element **receives signal of the physical quantity** to be measured as input. It converts the signal to a suitable form (electrical, mechanical or other form), so that it becomes easier for other elements of the measurement system, to either convert or manipulate it.

2. Variable Conversion Element:

Variable conversion element converts the output of the primary sensing element to a **more suitable form**. It is used only if necessary.

3. Variable Manipulation Element:

Variable manipulation element **manipulates and amplifies** the output of the variable conversion element. It also **removes noise** (if present) in the signal.

COMPONENTS OF GENERALIZED MEASUREMENT SYSTEM

4. Data Processing Element:

It **processes the data** signal received from the variable manipulation element and produces suitable output.

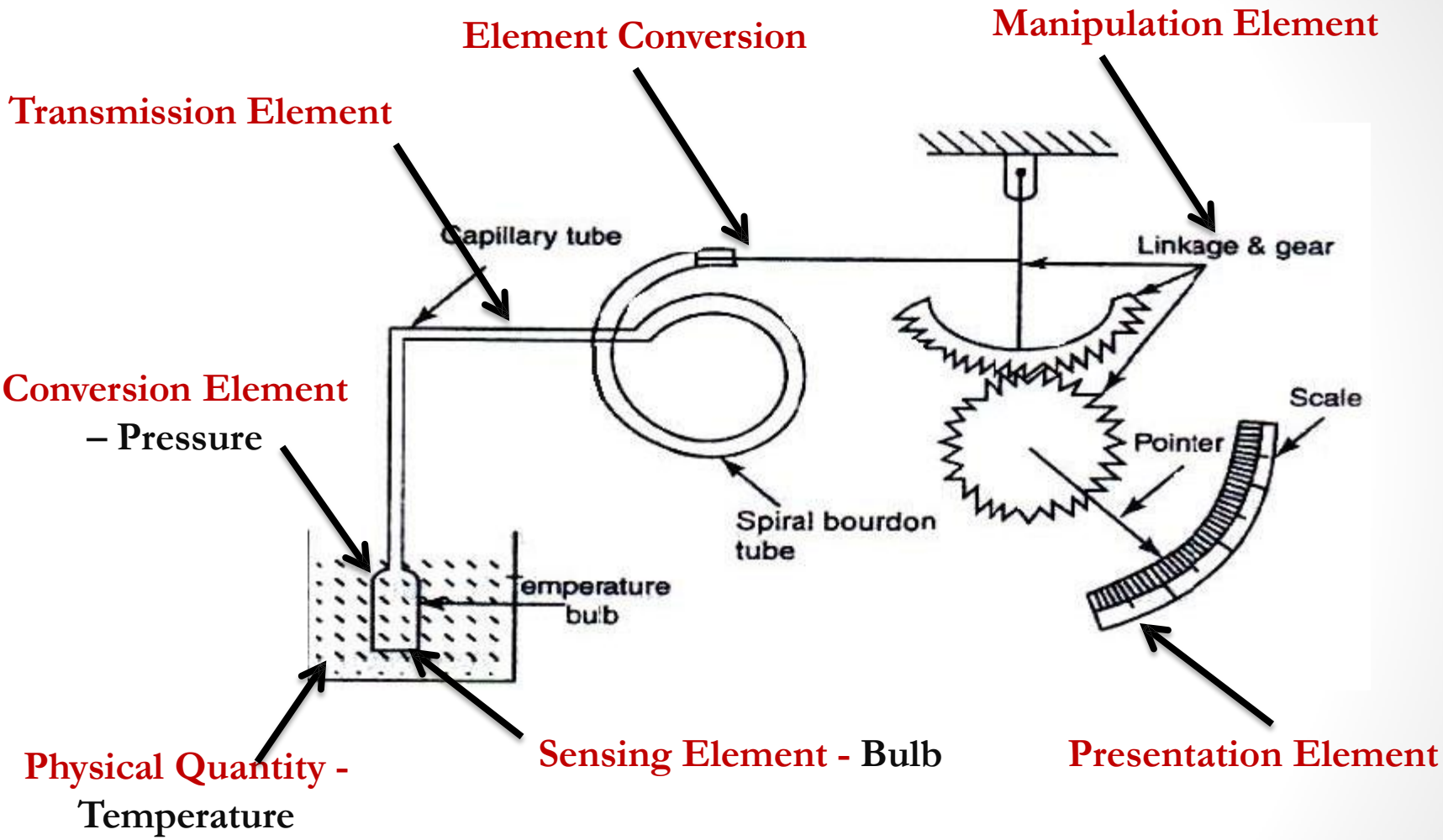
5. Data Transmission System:

Data Transmission System is simply **used for transmitting data** from one element to another. It acts as a communication link between different elements of the measurement system.

6. Data Presentation Element:

It is used to present the measured physical quantity in a **human readable form** to the observer. LED displays are most commonly used as data presentation elements in many measurement systems.

COMPONENTS OF GENERALIZED MEASUREMENT SYSTEM



STANDARDS

- In metrology (the science of measurement), a **standard is an object**, or system that bears a defined relationship to **a unit of measurement of a physical quantity**.

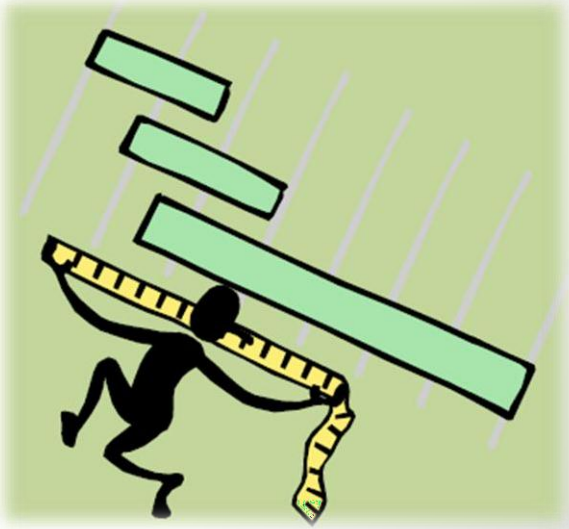
- Depending on functions and applications, standards of measurement are classified as follows:

(i) International Standards

(ii) Primary Standards

(iii) Secondary Standards

(iv) Working Standards



i. International Standards

- Defined by **International agreement**
- Periodically evaluated & checked by absolute measurements in terms of fundamental units of physics
- represent certain units of measurement to the **closest possible accuracy** attainable by the science and technology of measurement
- These standards are not available to ordinary uses like **measurement and calibrations**.

ii. Primary Standards

- Main function is the **calibration and verification** of secondary standards
- These are maintained at the National Standards Laboratories in different countries. For India, it is **National Physical Laboratory** at New Delhi.
- The primary standards are not available for the use outside the National Laboratory.
- These primary standards are absolute standards of **high accuracy** that can be used as **ultimate reference** standards to **check, calibrate and certify the secondary standards.**

iii. Secondary Standards

- Basic reference standards used by the measurement and calibration laboratories in **industries**
- These standards are maintained by the particular industry to which they belong
- Each industry has its **own secondary standard**
- Each laboratory periodically sends its secondary standard to the national standards laboratory for calibration and comparison against the primary standard
- After comparison and calibration, the National Standards Laboratory returns the secondary standards to the particular industrial laboratory with a certification of measuring accuracy in terms of primary standards

iv. Working Standards

- Main tools of a measuring **laboratory**
- Used to **check and calibrate laboratory instrument** for accuracy and performance.
- For example, manufacturing of mechanical components such as shafts, bearings, gears etc, use a standard called working standard for checking the component dimensions. **Example: Plug gauge is used for checking the bore diameter of bearings.**

UNITS

Physical quantity is **expressed** in Units.

Types:

1. Primary Units – m, Kg, KJ
2. Supplementary Units - rad
3. Derived Units – Kg/KJ

TYPES OF MEASUREMENTS / METHODS OF MEASUREMENTS

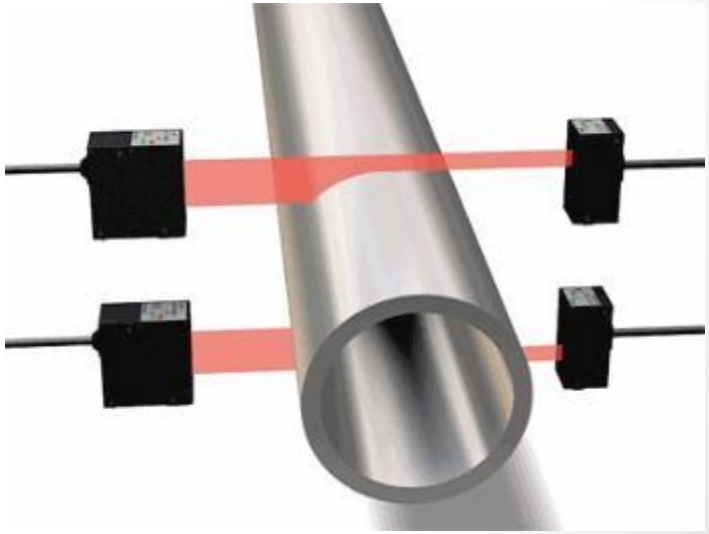
1. Direct Comparison
2. Indirect Comparison
3. Comparative Method
4. Coincidence Method
5. Fundamental Method
6. Contact Method
7. Transposition Method
8. Complementary Method
9. Deflection Method
10. Contactless method

1. Direct Method

❖ Measurements are directly obtained.

Ex.: Vernier Caliper, Scales.

2. Indirect Method



❖ Obtained by measuring other quantities.

Ex: Measurement of strain induced in a bar due to the applied force

3. Comparative Method

It's compared with other known value.

Ex: Comparators.

4. Coincidence Method:

Measurements coincide with certain lines and signals. **Ex: Comparators.**

5. Fundamental Method:

Measuring a quantity directly in related with the definition of that quantity.

6. Transposition Method:

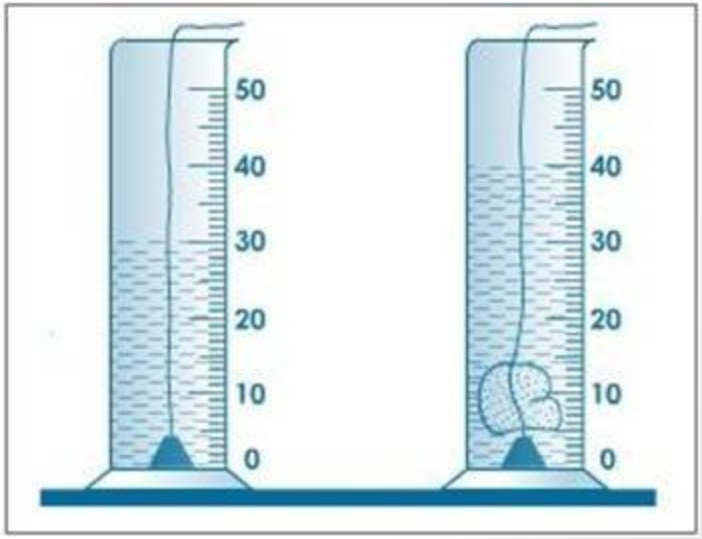
Quantity to be measured is first balanced by a known value and then balanced by an other new known value.

Ex: Determination of mass by balancing methods.

7. Complementary Method:

The value of quantity to be measured is combined with known value of the same quantity.

Ex: Determination of the volume of a solid by liquid displacement Volume.



8. Deflection Method:

The value to be measured is directly indicated by a deflection of pointer.

Ex: Pressure Measurement.

9. Contact Method:

Sensor/Measuring tip touch the surface area.

Ex: Vernier Caliper.

10. Contactless method:

There is no direct contact with the surface to be measured.

Ex. measurement by optical line instruments

TYPES OF MEASURING INSTRUMENTS

1. Deflection and Null type instruments
2. Analog and Digital instruments
3. Active and passive type instruments
4. Automatic and manually operated instruments
5. Absolute and secondary instruments
6. Contacting and non-contacting instruments
7. Intelligent instruments

1. Deflection and Null type instruments

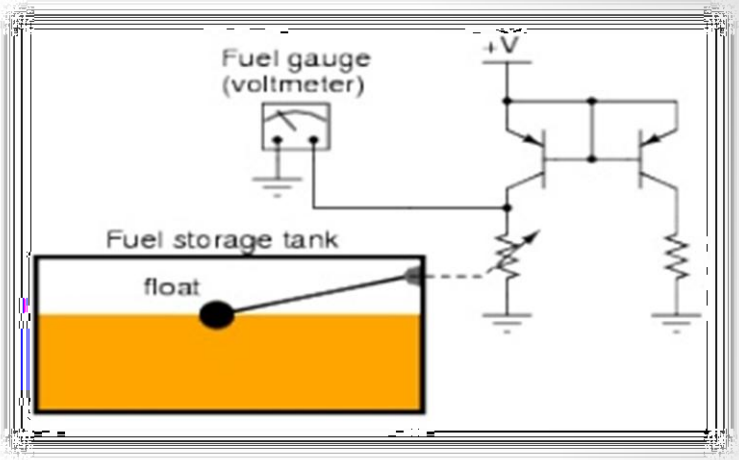
- The weight of the object is indicated by the **deflection or movement of a pointer** on a graduated scale. **Ex. Spring Balance**

- The effect caused by the quantity to be measured is nullified.
- For example, consider the measurement of weight by an ordinary beam balance as shown in fig. The unknown weight placed in one-side causes the beam and the pointer to deflect. **Ex. Beam Balance**

2. Analog and Digital Instruments

3. Active and Passive Type Instruments

- In **active** instruments, the quantity being measured just activates the magnitude of some, **external power** input source, which in turn produces the measurement.
- In this type of instruments, another external energy input source is present apart from the quantity to be measured.



- In **passive** type instruments, output is produced **entirely by the quantity** being measured.

4. Manual and Automatic Instruments

- **Manual instruments** require the services of a **human operator.**

- When the process of null balance is automated, it is known termed as **automatic** instruments.

5. Absolute and Secondary Instruments

- **Absolute instruments** are those which give the value of the quantity to be measured, in terms of the **constants** of the instrument and their **deflection** only.

- **Secondary Instrument** shows **deflection directly** in terms of electrical quantity like voltage, current, power and frequency.
- These instruments are calibrated by comparison with an absolute instrument.

6. Contacting and Non-Contacting Instruments

7. Intelligent Instrument

- Microprocessor are incorporated with measuring instrument

ACCURACY Vs PRECISION

Measurement is an act of assigning an **accurate and precise** value to a physical variable.

What is the difference between Precision and Accuracy 

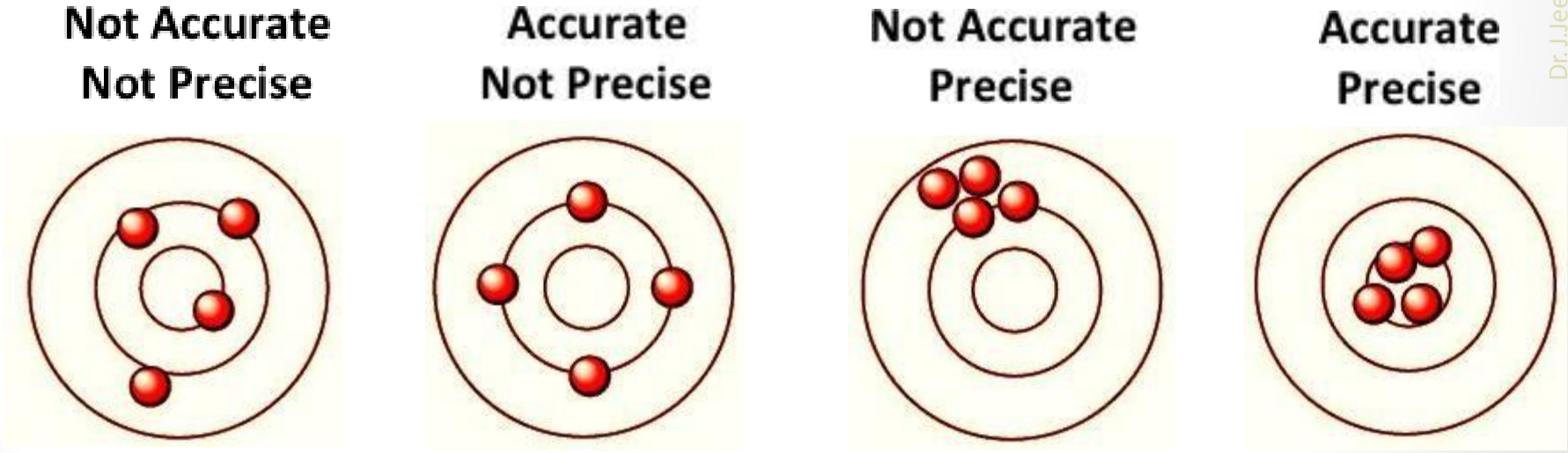
Accuracy is a measure of **rightness**.

Precision is a measure of **exactness**.

ACCURACY AND PRECISION

➢**Accuracy** is the **ability** of the instrument to measure the **accurate** value ***(Conformity)***.

➢**Precision** refers to how closely **individual measurements** agree with each other (***Repeatability)***.



FACTORS AFFECTING ACCURACY AND PRECISION OF A MEASURING SYSTEM

- A measuring system is made of **five basic elements**. These are:

1. **S**tandard
2. **W**ork piece
3. **I**nstrument
4. **P**erson
5. **E**nvironment.

FACTORS AFFECTING ACCURACY OF A MEASURING SYSTEM

1. Standard

- Coefficient of thermal expansion
- Stability with time
- Elastic properties
- Position etc.

2. Work piece:

- Cleanliness surface finish etc.
- Surface defects
- Hidden geometry

3. Instrument

- Inadequate amplification
- Scale error
- Deformation while handling heavy w/p
- Calibration error
- Repeatability & readability

FACTORS AFFECTING ACCURACY OF A MEASURING SYSTEM

4. Person

- Training skill
- Sense of precision appreciation
- Ability to select measuring instrument & standard
- Attitude towards personal accuracy achievement
- Planning for measurement technique to have minimum just with consistent in precision.

5. Environment

- Temperature, pressure and humidity
- Clean surrounding and minimum vibration
- Adequate illumination
- Temperature equalization between standard w/p & instrument

Higher accuracy can be achieved if all 5 factors are considered, analysed & steps are taken to eliminate them

ERRORS IN MEASUREMENT

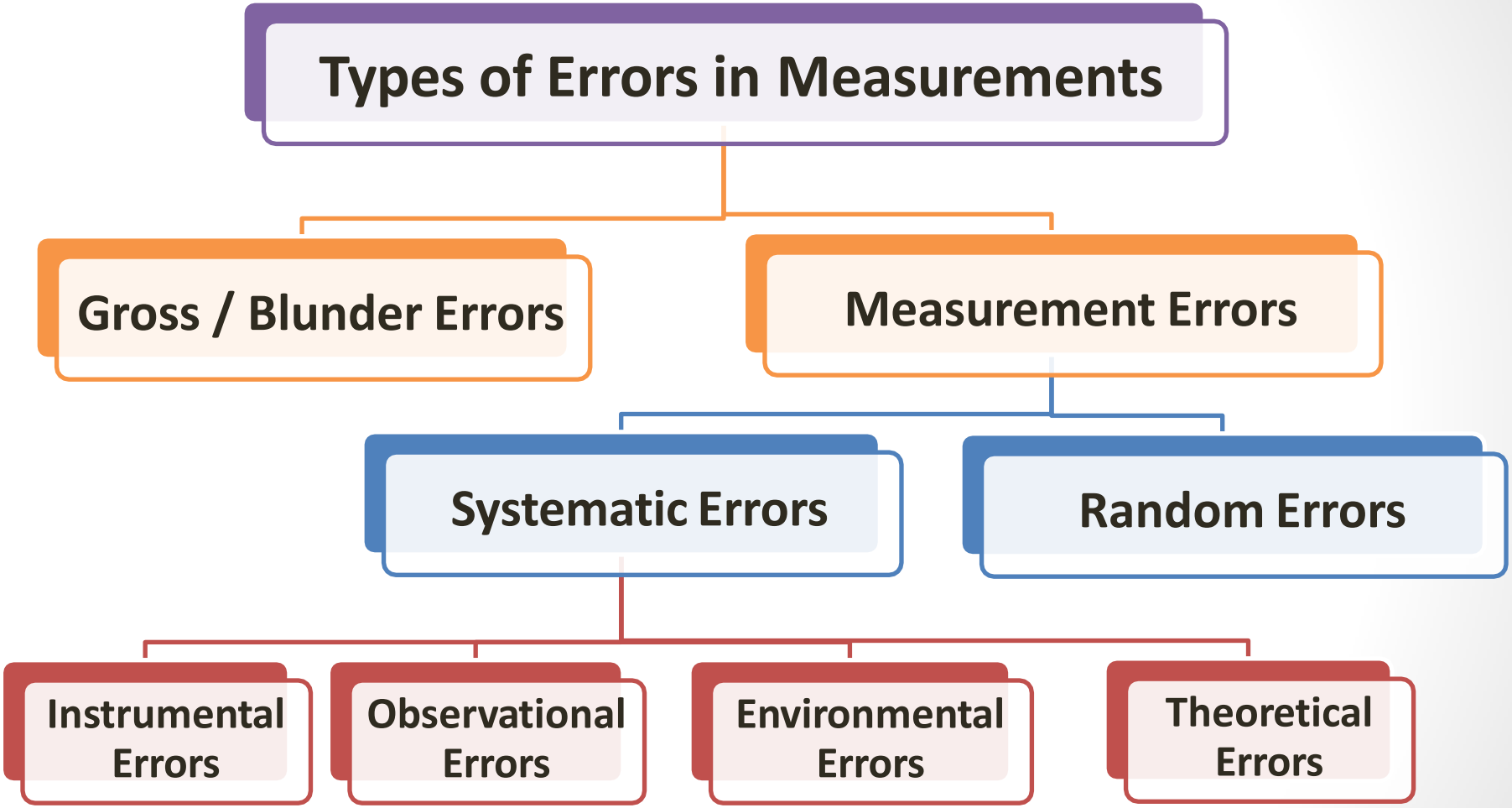
What is Error in Measurement?

- Measurement Error (Observational Error) is the difference between a **measured(actual) value and its true value**.

- **True size** → Theoretical size of a dimension which is **free from errors**.

- **Actual size** → size obtained through measurement **with permissible error**.

TYPES OF ERRORS IN MEASUREMENT



TYPES OF ERRORS IN MEASUREMENT

1) Gross or Blunder Errors:

This category of errors includes all the **human mistakes** while reading, recording the readings. The best example of these errors is a person or operator reading pressure gauge 1.01N/m2 as 1.10N/m2.

2) Measurement Error:

- The measurement error is the result of the **variation of a measurement of the true value**.

- Usually, Measurement error consists of a **random error and systematic error**.

TYPES OF ERRORS IN MEASUREMENT

a. Systematic Error (Controllable Error)

- A systematic error is a constant error that under the **same operating conditions**.
- Systematic error is caused by any factors that **systematically affect** measurement .

- ***Classification of systematic errors:***

i. Instrumental Errors – Calibration Error

ii. Environmental Errors – Temp, Pressure, Humidity

iii. Observational Errors - Parallax

iv. Theoretical - Percentage

TYPES OF ERRORS IN MEASUREMENT

Random Errors (Uncontrollable Error)

- Random (or indeterminate) errors are caused by **uncontrollable fluctuations** in variables that affect experimental results.

- Random errors are caused by the **sudden** change in experimental conditions and **noise and tiredness** in the working persons. These errors are either positive or negative.

- These errors may be reduced by taking the **average of a large number of readings.**