MEC 3102 – PRODUCTION ENGINEERING I AND ELECTRICITY & ELECTRONICS II

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2nd Series Lecture 1[4]

Review of Measuring Requirements

- Measurement techniques have been of immense importance ever since the start of human civilization, when measurements were first needed to regulate the transfer of goods in barter trade to ensure that exchanges were fair.
- The industrial revolution during the nineteenth century brought about a rapid development of new instruments and measurement techniques to satisfy the needs of industrialized production techniques.
- Since that time, there has been a large and rapid growth in new industrial technology, spearheaded by developments in electronics in general and computers in particular.
- This, in turn, has required a parallel growth in new instruments and measurement techniques.

- Measurement is the process of determining the amount, degree or capacity by comparison with the accepted standards of the system units being used.

- Instrumentation is a technology of measurement which serves sciences, engineering, medicine etc.

- Instrument is a device for determining the value or magnitude of a quantity or variable.

- Electrical instrument is based on electrical or electronic principles for its measurement functions.

Unit of Measurement

- A unit of measurement is a definite magnitude of a quantity, defined and adopted by convention or by law, that is used as a standard for measurement of the same quantity
- Magnitude of a physical quantity can be written as: numerical ratio * unit
- Numerical ratio is the number of times the unit occurs in any given amount of the same quantity and, therefore, is called the number of measures

Absolute Units

- When units are expressed in terms of fundamental units (length, time and mass) are known as absolute units.
- The term absolute does not imply any special standard of accuracy; normally, it is associated with fundamental units.
- Absolute measurements do not compare the measured quantity with arbitrary units of the same type but are made in terms of fundamental units

Fundamental and Derived Units

- In science and Engineering, two kinds of units are used: fundamental units and derived units.

❖ Fundamental Units

Quantity	*Standard unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Luminous intensity	candela	cd
Matter	mole	mol

❖ Derived Units

Quantity	*Standard unit*	*Symbol*	*Derivation formula*
Magnetic flux	weber	Wb	V s
Magnetic flux density	tesla	T	Wb/m^2
Magnetic field strength	ampere per metre	A/m	
Frequency	hertz	Hz	s^{-1}
Luminous flux	lumen	lm	cd sr
Luminance	candela per square metre	cd/m^2	
Illumination	lux	lx	lm/m^2
Molar volume	cubic metre per mole	m^3/mol	
Molarity	mole per kilogram	mol/kg	
Molar energy	joule per mole	J/mol	

- All other units which can be expressed in terms of the fundamental units are called derived units.
- Every derived unit originates from some physical law or equation deriving that unit.

❖ A derived unit is always recognised by its dimension, which can be defined as the complete algebraic formular for the derived unit.

Quantity	*Standard unit*	*Symbol*	*Derivation formula*
Area	square metre	m^2	
Volume	cubic metre	m^3	
Velocity	metre per second	m/s	
Acceleration	metre per second squared	m/s^2	
Angular velocity	radian per second	rad/s	
Angular acceleration	radian per second squared	rad/s^2	
Density	kilogram per cubic metre	kg/m^3	
Specific volume	cubic metre per kilogram	m^3/kg	
Mass flow rate	kilogram per second	kg/s	
Volume flow rate	cubic metre per second	m^3/s	
Force	newton	N	$kg\,m/s^2$
Pressure	newton per square metre	N/m^2	
Torque	newton metre	N m	
Momentum	kilogram metre per second	kg m/s	
Moment of inertia	kilogram metre squared	$kg\,m^2$	
Kinematic viscosity	square metre per second	m^2/s	
Dynamic viscosity	newton second per square metre	$N\,s/m^2$	
Work, energy, heat	joule	J	Nm
Specific energy	joule per cubic metre	J/m^3	
Power	watt	W	J/s
Thermal conductivity	watt per metre kelvin	W/m K	
Electric charge	coulomb	C	A s
Voltage, e.m.f., pot. diff.	volt	V	W/A
Electric field strength	volt per metre	V/m	
Electric resistance	ohm	Ω	V/A
Electric capacitance	farad	F	A s/V
Electric inductance	henry	H	V s/A
Electric conductance	siemen	S	A/V
Resistivity	ohm metre	Ωm	
Permittivity	farad per metre	F/m	
Permeability	henry per metre	H/m	
Current density	ampere per square metre	A/m^2	

Standard Prefixes

- Standard prefixes are commonly used for multiple and sub-multiple quantities, in order to cover the wide range of values used in measurement units.
- These are given in the table below:

Standard Prefixes Table

Multiple	Prefix	Symbol	Multiple	Prefix	Symbol
10^{18}	exa	E	10^{-1}	deci	d
10^{15}	peta	p	10^{-2}	centi	c
10^{12}	tera	T	10^{-3}	milli	m
10^{9}	giga	G	10^{-6}	micro	µ
10^{6}	mega	M	10^{-9}	nano	n
10^{3}	kilo	k	10^{-12}	pico	p
10^{2}	hecto	h	10^{-15}	femto	f
10	deka	da	10^{-18}	atto	a

Elements of a measurement system

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

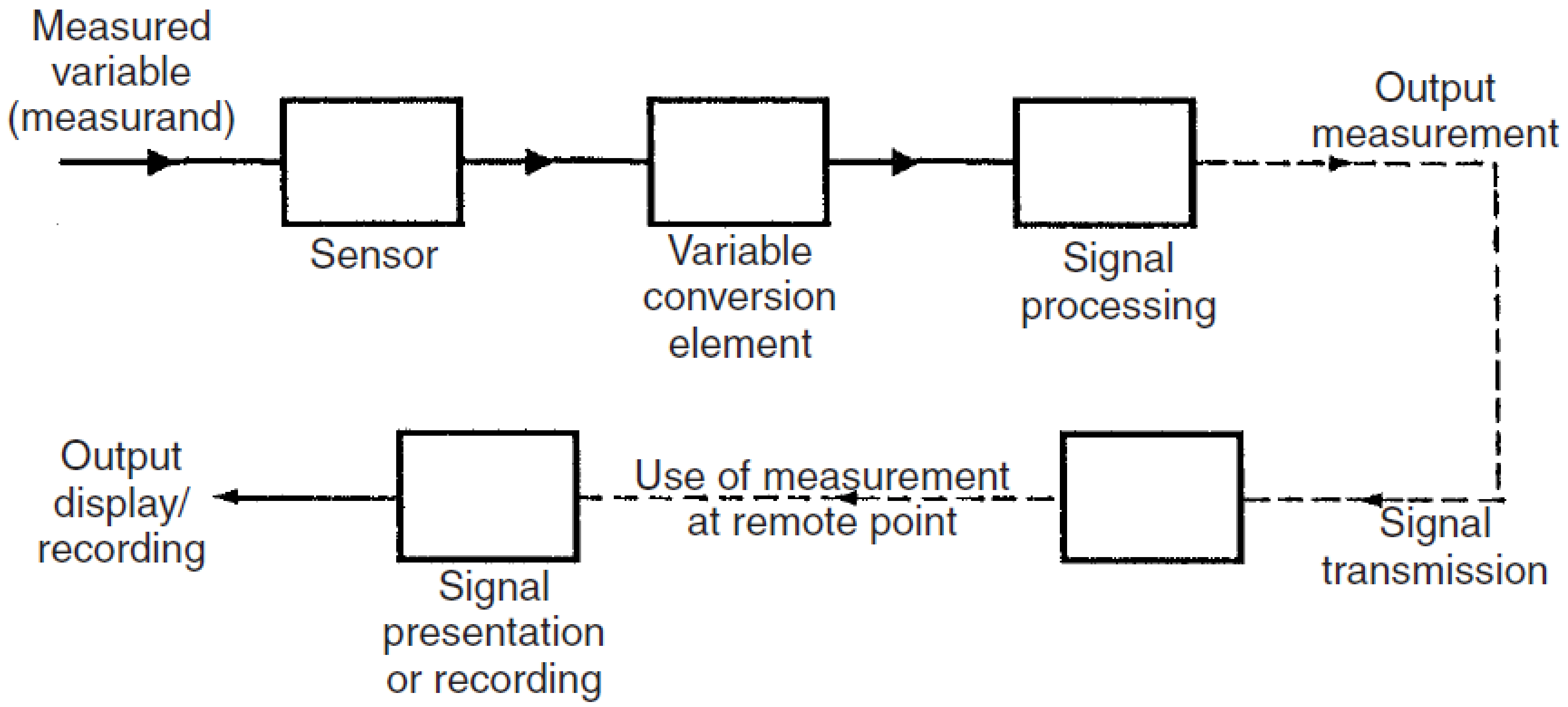

Fig 5.1: Elements of a measurement system

- The first element in any measuring system is the primary sensor: this gives an output that is a function of the measurand (the input applied to it). For most but not all sensors, this function is at least approximately linear.
- Variable conversion elements are needed where the output variable of a primary transducer is in an inconvenient form and has to be converted to a more convenient form.
- In some cases, the primary sensor and variable conversion element are combined, and the combination is known as a transducer.
- Signal processing elements exist to improve the quality of the output of a measurement system in some way. A very common type of signal processing element is the electronic amplifier, which amplifies the output of the primary transducer or variable conversion element, thus improving the sensitivity and resolution of measurement.
- The final optional element in a measurement system is the point where the measured signal is utilized. In some cases, this element is omitted altogether because the measurement is used as part of an automatic control scheme, and the transmitted signal is fed directly into the control system.

Application of Measurement System

- Monitoring of process and operation- simply indicating the value or condition of parameter under study. For example- water and electricity meter.
- Control of process and operations- automatic control system a very strong association between measurement and control for example: refrigeration with thermostatic control.
- Experimental Engineering analysis: engineering problem, theoretical and experimental methods may be used depending upon the nature of the problem

Choosing appropriate measuring instruments

- The starting point in choosing the most suitable instrument to use for measurement of a particular quantity in a manufacturing plant or other system is the specification of the instrument characteristics required, especially parameters like the desired measurement accuracy, resolution, sensitivity and dynamic performance.
- To summarize therefore, instrument choice is a compromise between performance characteristics, ruggedness and durability, maintenance requirements and purchase cost.
- To carry out such an evaluation properly, the instrument engineer must have a wide knowledge of the range of instruments available for measuring particular physical quantities, and he/she must also have a deep understanding of how instrument characteristics are affected by particular measurement situations and operating conditions.

Active and passive instruments

- Instruments are divided into active or passive ones according to whether the instrument output is entirely produced by the quantity being measured or whether the quantity being measured simply modulates the magnitude of some external power source.
- This is illustrated by examples:

❖ An example of a passive instrument is the **pressure-measuring** device shown in figure 5.2.

✓ The pressure of the fluid is translated into a movement of a pointer against a scale.

✓ The energy expended in moving the pointer is derived entirely from the change in pressure being measured: there are no other energy inputs to the system.

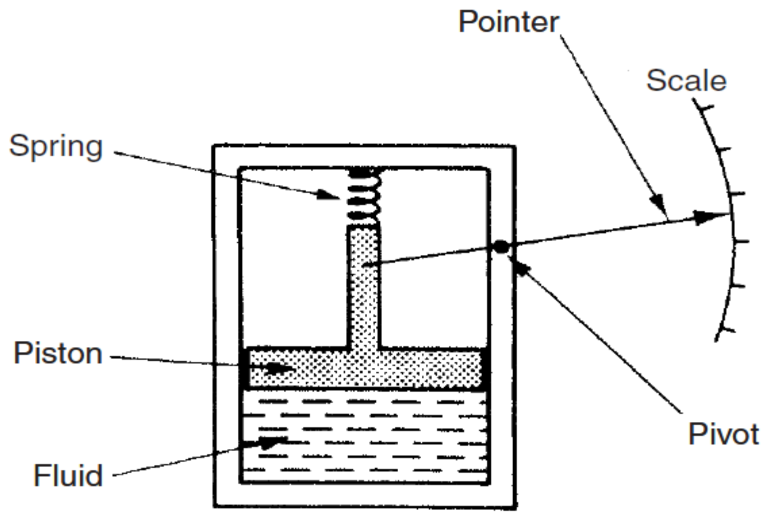

Figure 5.2 passive instrument type

- An example of an active instrument is a float-type petrol tank level indicator as given in figure 5.3.
- Here, change in petrol level moves a potentiometer arm, and the output signal is a proportion of external voltage applied across the potentiometer.
- The energy in the output signal comes from the external power source: the primary transducer float system is merely modulating the value of the voltage from this external power source.

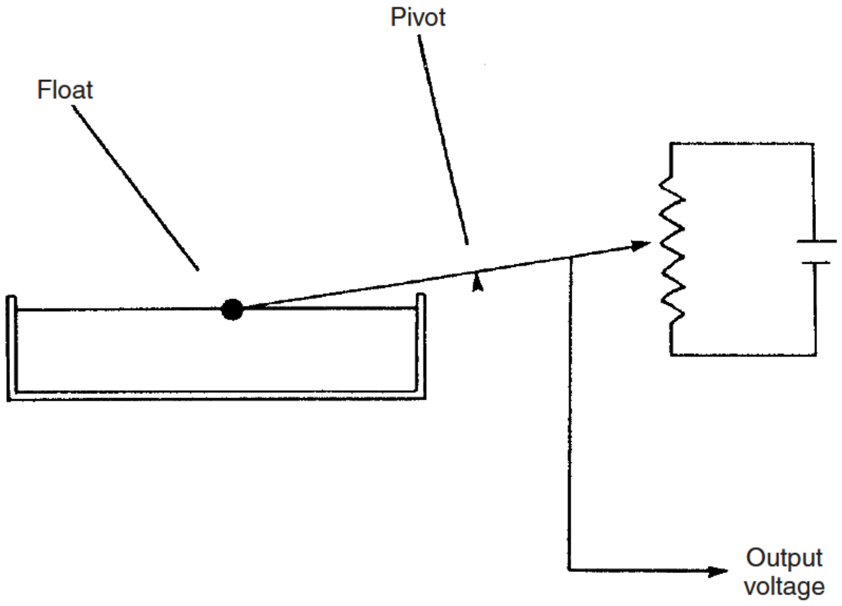

Figure 5.3 active instrument type

Other forms of energy in active instruments

- In active instruments, the external power source is usually in electrical form, but in some cases, it can be other forms of energy such as a pneumatic or hydraulic e.t.c.

Comparison between passive and active instrument

❖ One very important difference between active and passive instruments is the level of measurement resolution that can be obtained.

✓ With the simple pressure gauge shown, the amount of movement made by the pointer for a particular pressure change is closely defined by the nature of the instrument.

Whilst it is possible to increase measurement resolution by making the pointer longer, such that the pointer tip moves through a longer arc, the scope for such improvement is clearly restricted by the practical limit of how long the pointer can conveniently be.

✓ In an active instrument, however, adjustment of the magnitude of the external energy input allows much greater control over measurement resolution.

Whilst the scope for improving measurement resolution is much greater incidentally, it is not infinite because of limitations placed on the magnitude of the external energy input, in consideration of heating effects and for safety reasons.

Cost evaluation

- In terms of cost, passive instruments are normally of a more simple in construction than active ones and are therefore cheaper to manufacture.
- Therefore, choice between active and passive instruments for a particular application involves carefully balancing between the measurement resolution requirements against cost.

MODES OF MEASUREMENTS

- There are three modes of measurement:

  1. Primary measurements
  2. Secondary measurements
  3. Tertiary measurements

1. Primary measurements

- In this mode the sought value of the measurand is determined by comparing it directly with “reference standards”. There is no conversion into another related quantity.

2. Secondary measurements

- The indirect measurements involving ‘one translation’ are called secondary measurements

Examples

The pressure measurement by manometer.

The temperature measured by mercury-in-glass thermometers.

3. Tertiary measurements

- This mode utilizes indirect measurements involving two conversions.

Examples

- The measurement of temperature of an object by thermocouple

Static and Dynamic characteristics of measurent system

I. Static characteristics: The set of criteria defined for the instruments, which are used to measure the quantities which are slowly varying with time or mostly constant, i.e., do not vary with time, is called ‘static characteristics’.

Types of static characterisics

- Accuracy: It is the degree of closeness with which the reading approaches the true value of the quantity to be measured. The accuracy can be expressed in following ways:
  - ✓ Point accuracy: Such accuracy is specified at only one particular point of scale. It does not give any information about the accuracy at any other Point on the scale.
  - ✓ Accuracy as percentage of scale span: When an instrument has a uniform scale, its accuracy may be expressed in terms of scale range.
  - ✓ Accuracy as percentage of true value: The best way to conceive the idea of accuracy is to specify it in terms of the true value of the quantity being measured. Precision: It is the measure of reproducibility i.e., given a fixed value of a quantity, precision is a measure of the degree of agreement within a group of measurements. The precision is composed of two characteristics:

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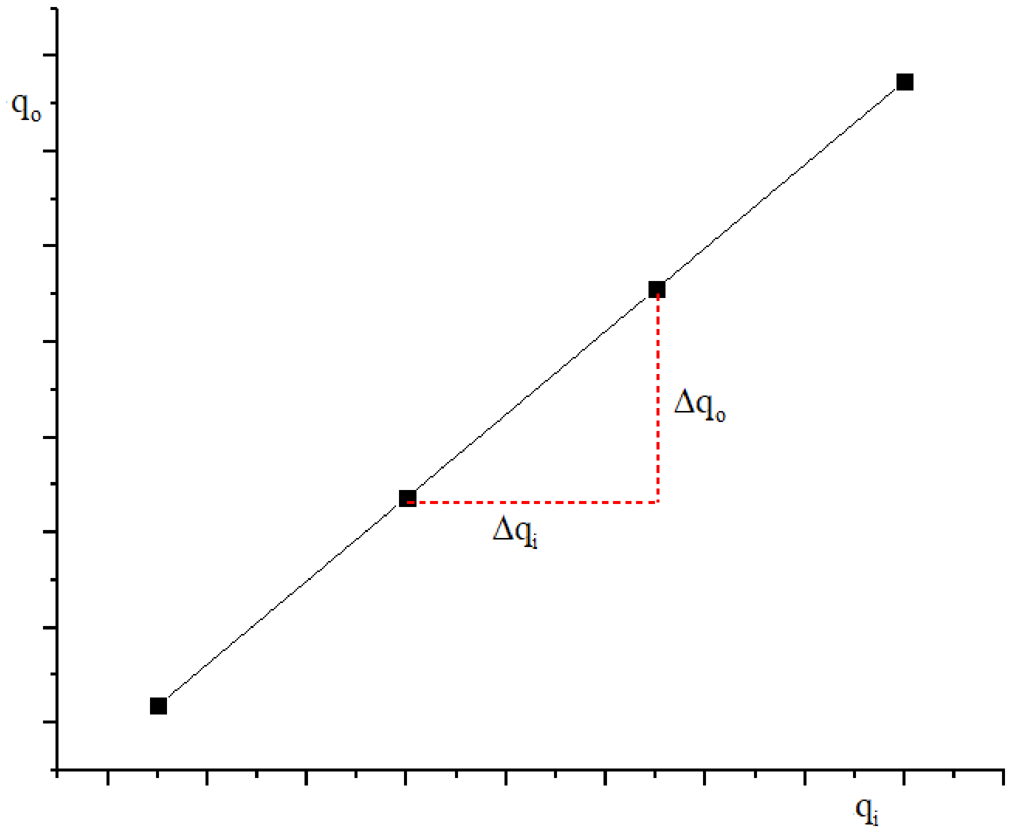
- Precision: It is the measure of reproducibility i.e., given a fixed value of a quantity, precision is a measure of the degree of agreement within a group of measurements. The precision is composed of two characteristics:
  - ✓ Conformity: Consider a resistor having true value as 2385692, which is being measured by an ohmmeter. But the reader can read consistently, a value as 2.4 M due to the nonavailability of proper scale. The error created due to the limitation of the scale reading is a precision error.
  - ✓ Number of significant figures: The precision of the measurement is obtained from the number of significant figures, in which the reading is expressed. The significant figures convey the actual information about the magnitude & the measurement precision of the quantity.

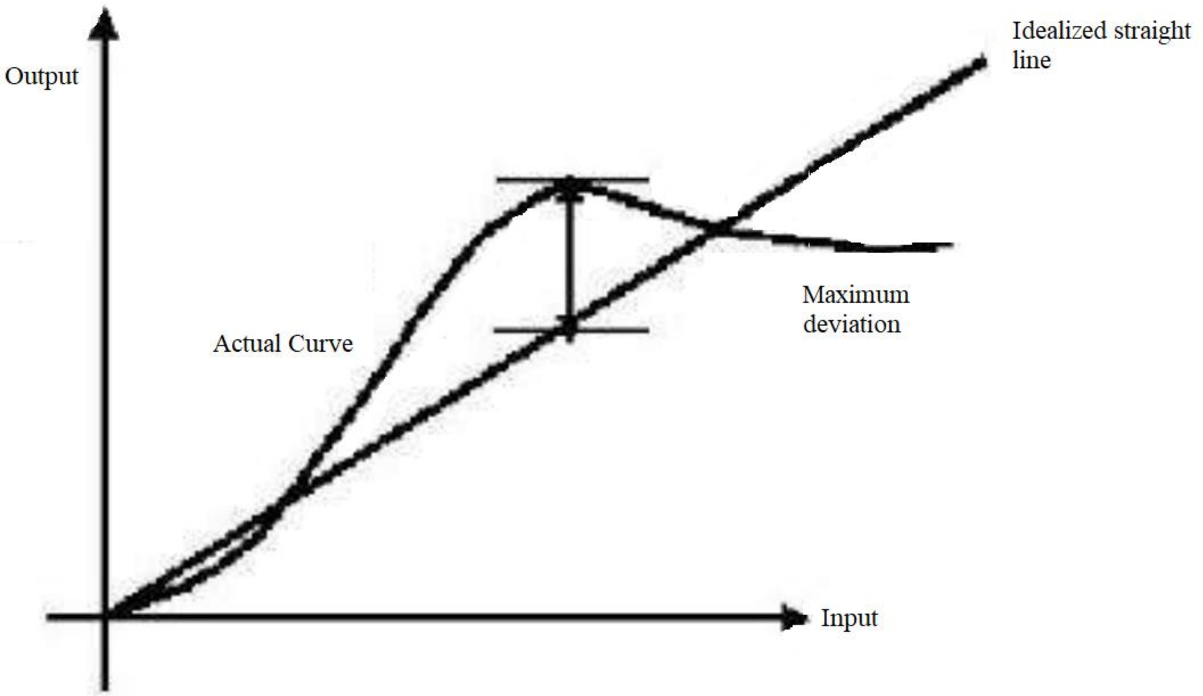
- **Sensitivity**: The sensitivity denotes the smallest change in the measured variable to which the instrument responds. It is the ratio of the change in the output of an instrument to a change in the value of the quantity to be measured.



$$\text{Sensitivity} = \frac{\text{infinitesimal change in output}}{\text{infinitesimal change in input}} = \frac{\Delta qo}{\Delta qi}$$

- Linearity: This is defined as the ability to reproduce the input characteristics symmetrically and linearly. The curve below shows the actual calibration curve and the idealized straight line.

$$\% \, non - linearity = \frac{Max. dev. of \ output \ from \ idealized \ line}{full \ scale \ reading}$$



- Reproducibility: It is the degree of closeness with which a given value may be repeatedly measured. It is specified in terms of scale readings over a given period of time.
- Repeatability: It is defined as the variation of scale reading & random in nature Drif
- Resolution: If the input is slowly increased from some arbitrary input value, it will again be found that output does not change at all until a certain increment is exceeded. This increment is called resolution.
- Threshold: If the instrument input is increased very gradually from zero there will be some minimum value below which no output change can be detected. This minimum value defines the threshold of the instrument.
- Stability: It is the ability of an instrument to retain its performance throughout is specified operating life.
- Tolerance: The maximum allowable error in the measurement is specified in terms of some value which is called tolerance. Range or span: The minimum & maximum values of a quantity for which an instrument is designed to measure is called its range or span.