# UPPSC-AE 2025

## Uttar Pradesh
## Public Service Commission

Combined State Engineering Services Examination

**Assistant Engineer**

## Electrical Engineering

### Measurements

Well Illustrated **Theory** *with*
**Solved Examples** and **Practice Questions**

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# Measurements

## Contents

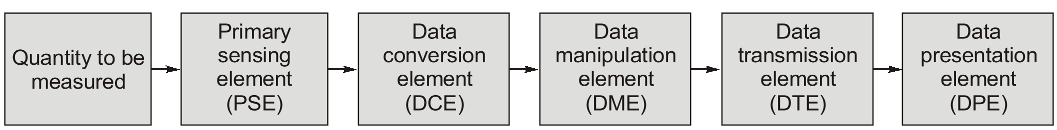
# CHAPTER 1 Basics of Measurement Systems

## 1.1 Introduction

Measurement is a process of gathering information from a physical world and comparing this information with agreed standards. The measurement of a given quantity is an act or the result of comparison between the quantity and predefined standard.

It is the process of conversion of physical parameters to meaningful numbers. For the measurement to be meaningful, the standard used for comparison purpose must be accurately defined and should be commonly accepted. Instrumentation is the use of measuring instruments to monitor and control process. It is a science of measurement and control of process variables within a production, laboratory or manufacturing area.

## 1.2 Elements of Generalized Measurement System




- **Primary Sensing Element (PSE):** These elements are in direct contact with quantity under measurement. It is used to sense the quantity to be measured.

  e.g. transducer and other sensing element.
- **Data Conversion Element (DCE):** This element converts one form of the data to another form, but the basic information carried over by the data is preserved.

  e.g. voltage to frequency converter, voltage to current converter, ADC, DAC.
- **Data Manipulation Element (DME):** This element changes the level of signal preserving its basic nature.

  e.g. amplification, modulation, attenuation etc.
- **Data Transmission Element (DTE):** This element provides transmission channel.

  e.g. optical fibres, coaxial cables, transmission lines etc.
- **Data Presentation Elements (DPE):** This element is used either to store or to display the signal receiver.

  e.g. CRO, recorder, digital display, plotters etc.

## 1.3 Methods of Measurements

The methods of measurements are classified into two categories:

(a) Direct methods

(b) Indirect methods

**Direct Methods:**

- In this method, the measured or the unknown quantity is directly compared against a standard.
- This type of measurement sometimes produces human error and hence gives inaccurate results.

**Indirect Methods:**

- This method of measurement is more accurate and more sensitive.
- These are more preferred over direct measurement.

## 1.4 Classification of Instruments

An instrument is a device for determining the value or magnitude of a quantity or variable. Various ways are there in which the instruments can be classified.

### 1.4.1 Mechanical, Electrical and Electronic Instruments

#### Mechanical Instruments

- This instruments are used for stable and static conditions:
- They are unable to respond rapidly to measurements of dynamic and transient conditions because of having moving parts that are bulky, heavy are rigid possessing high inertia.

#### Electrical Instruments

- Electrical methods of indicating the output of detectors are more rapid than mechanical methods.
- These instruments have limited time response.

#### Electronic Instruments

- These instruments require use of semiconductor devices.
- The response time of these instruments are extremely small as a very small inertia of electron is only involved.
- The sensitivity of these instruments are also very high.

### 1.4.2 Absolute and Secondary Instruments

#### Absolute Instruments

- These instruments give the magnitude of the quantity under measurement in terms of physical constants of the instruments i.e. Tangent Galvanometer, Rayleigh's current balance.
  Examples:, Tangent galvanometer, Rayleigh's current balance , etc.

#### Secondary Instruments

- In these type of instruments, the quantity being measured can only be measured by observing the output indicated by the instrument.
- These instruments are calibrated by comparing with an absolute instrument.
  Examples: Ammeter, Voltmeter, Pressure gauge etc.

### 1.4.3 Deflection and Null Type Instruments

#### Deflection Type

- The deflection of the instrument provides a basis for determining the quantity under measurement i.e. PMMC ammeter, electrodynamometer and moving iron instruments.
- They are less accurate, less sensitive and have faster response.

#### Null Type

- In null type instruments, a zero or null indication leads to determination of the magnitude of measured quantity.
- These instruments are more accurate and highly sensitive.
- These instruments are less suited for measurements under dynamic conditions.

**Example - 1.1** A null type of instrument as compared to a deflecting type instrument has

(a) a higher accuracy (b) a lower sensitivity
(c) a faster response (d) all of these [UPPSC]

***Solution : (a)***

- In null type instruments, the null condition depends upon some other unknown conditions and thus are more accurate and highly sensitive as compared to deflection type instruments.
- Deflection type instruments are having faster response, while null type instruments are less suited for dynamic measurements.

## 1.5 Static Characteristics of Instruments and Measurement Systems

Static characteristics of a measurement system are considered when the system is used to measure a condition not varying with time.

### 1.5.1 Accuracy

- Closeness with which an instrument reading approaches the true value of the variable being measured.
- The accuracy can be specified in terms of limit of error.
- The accuracy of a measurement means conformity to truth.

### 1.5.2 Precision

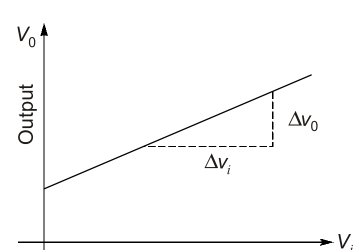
- It is the measure of consistency of the result.
- For a fixed value of variable, precision is a measure of the degree to which successive measurements differ from one another i.e. a measure of the reproducibility of the measurements.
- Precision depends upon number of significant figures. The more is significant figures the more is precision.

**NOTE:** Precision does not guarantee accuracy. The high precision does not means high accuracy always.

### 1.5.3 Static Sensitivity

- It is the ratio of the magnitude of the output signal or response to the magnitude of the input signal or the quantity being measured.

$$\text{Sensitivity} = \frac{\text{Small change in output}}{\text{Small change in input}} = \frac{\Delta V_0}{\Delta V_i}$$



***(Sensitivity)***

- The sensitivity of an instrument should be high.

$$\text{Deflection Factor} = \frac{1}{(\text{Static Sensitivity})}$$

**Example - 1.2** A Wheatstone bridge required a change of 9.2 Ω in the unknown arm of the bridge to produce a change in deflection of 5 mm of the galvanometer. The value of deflection factor is

(a) 1.84 Ω/mm (b) 0.54 mm/Ω
(c) 2.84 Ω/mm (d) 1.56 mm/Ω

***Solution : (a)***

$$\because \quad \text{Sensitivity} = \frac{\text{Change in output}}{\text{Change in input}}$$

Here deflection of 5 mm of galvanometer produces a change of 9.2 Ω in the bridge.

Hence,
$$\text{Sensitivity} = \frac{5}{9.2} = 0.54 \text{ mm}/\Omega$$

$$\because \quad \text{Deflection factor} = \frac{1}{\text{sensitivity}} = 1.84\ \Omega/\text{mm}$$

### 1.5.4 Resolution

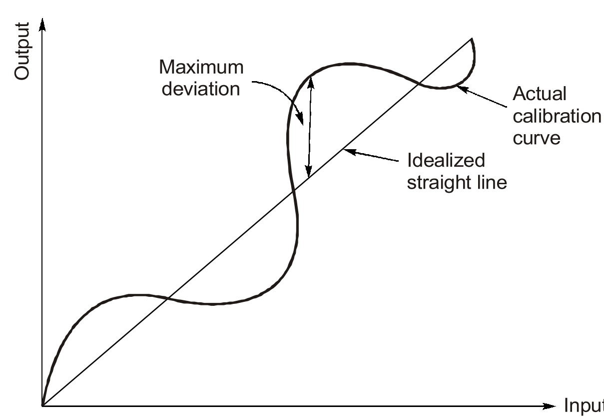
- The smallest change in measured value to which the instrument will respond.
- If the input is slowly increased from some arbitrary (non-zero) input value, it will be found that output doesn't change at all until a certain increment is executed. This increment is called resolution.

### 1.5.5 Repeatability and Reproducibility

- Repeatability: It's the repetition of reading of an instrument taken over a period of time.
- Reproducibility: It is the measure of repeatability of reading an instrument over a period of time.

### 1.5.6 Linearity

- If the output is proportional to input then, it is called linear.
- Non-linear behavior of an instrument doesn't essentially lead to inaccuracy.

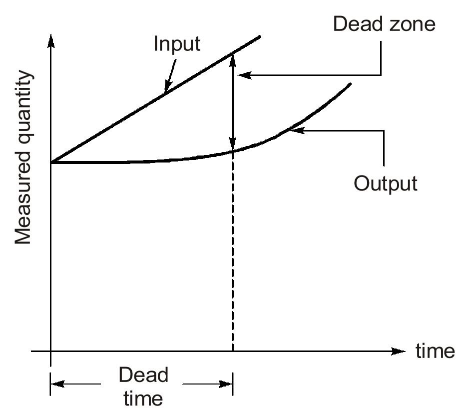



*(Linearity w.r.t. actual calibration curve and idealized straight line)*

### 1.5.7 Dead Time and Dead Zone

- Dead Time: The time required for the measurement to begin to respond to the changes in the measured is known as dead time. It is the time after which the instrument begin to respond after the measured quantity has been changed.

- **Dead Zone:** Dead zone is the largest change of input quantity for which there is no output of the instrument.




*(Dead Zone and Dead Time)*

### 1.5.8 Drift

- Variation in output of an instrument from the desired value for a particular value of the input.
- Perfect reproducibility means that the instrument has no drift.
- No drift means that with a given input the measured values do not vary with time.

### 1.5.9 Signal to Noise Ratio (S/N)

- Noise is an unwanted signal superimposed upon the signal of interest thereby causing a deviation of the output from it's expected value.
- The ratio of desired to the unwanted noise is called signal to noise ratio and is expressed as

$$\frac{S}{N} = \frac{\text{Signal Power}}{\text{Noise Power}}$$

- In any measurement system, it is desired to have a large signal-to-noise ratio.

## 1.6 Errors in Measurements and their Analysis

There is always a discrepancy between measured result and actual value of quantity under measurement. The deviation from the true value of the measured variable is also known as error.

### 1.6.1 Limiting Errors or Guarantee Errors

- Manufacturer has to specify the deviations from the nominal value of a particular quantity.
- Limits of these deviations from the specified value are defined as 'Limiting Errors'.

$$\delta_A = A_m - A_T$$

where,
$\delta_A$ = Absolute static error of quantity 'A'
$A_m$ = Measured value of quantity 'A'
$A_T$ = True value or Nominal value of quantity 'A'

### 1.6.2 Relative Limiting Error

The relative (fractional) error is defined as the ratio of the error to the specified (nominal) magnitude of a quantity.

$$\text{Relative limiting error, } \varepsilon_r = \left(\frac{\text{Measured value} - \text{True value}}{\text{True value}}\right) \times 100$$

$$\% \, \varepsilon_r = \left(\frac{A_m - A_T}{A_T}\right) \times 100$$

$$A_T = \left(\frac{1}{1+\varepsilon_r}\right) A_m$$

Here, $\frac{1}{1+\varepsilon_r}$ = Correction factor

**Example - 1.3** A wattmeter has a full scale range of 2500 Watt. It has an error of 1% of true value. What would be the range of reading if true power is 1250 Watt?

(a) 1225 Watt - 1275 Watt (b) 1245 Watt - 1255 Watt
(c) 1200 Watt - 1300 Watt (d) 1237.5 Watt - 1262.5 Watt [UPPSC]

***Solution:(d)***

Given,

$$P_t = \text{true value of power} = 1250 \text{ W}$$

$$\text{Error} = 1\% \text{ of true value}$$

$$= \frac{1}{100} \times 1250 = 12.5 \text{ W}$$

Hence, range of reading of wattmeter will be [(1250 – 12.5) W to (1250 + 12.5) W]
i.e. [1237.5 W to 1262.5 W]

**Example - 1.4** A (0 - 25 A) ammeter has a guaranteed accuracy of 1% of full scale reading. The current measured by this ammeter is 10 A. The percentage limiting error for this measurement is

(a) 0.025% (b) 0.25%
(c) 0.5% (d) 2.5% [UPPSC]

***Solution:(d)***

Given,

$$I_m = \text{measured value of current} = 10 \text{ A}$$

$$I_{FS} = \text{full scale value of ammeter} = 25 \text{ A}$$

$$\text{Accuracy} = 1\% \text{ of } I_{FS}$$

$$= \frac{1}{100} \times 25 = 0.25 \text{ A}$$

$$\text{Percentage limiting error} = \frac{\text{guaranteed accuracy}}{\text{measured value}} \times 100$$

$$= \frac{0.25}{10} \times 100 = 2.5\%$$

## 1.7 Limiting Error due to Combination of Quantities

### 1.7.1 Sum or Difference of Quantities

Let,
$$x_1 = a \pm \varepsilon_{r1}$$
$$x_2 = b \pm \varepsilon_{r2}$$
$$x_3 = c \pm \varepsilon_{r3}$$

$\therefore$ $x = x_1 + x_2 + x_3$

or, $x = -x_1 - x_2 - x_3$

So, $x = \pm (x_1 + x_2 + x_3)$

Relative limiting error in $x$ is given by

$$\varepsilon_x = \pm\left(\frac{a}{a+b+c}\cdot\varepsilon_{r1} + \frac{b}{a+b+c}\cdot\varepsilon_{r2} + \frac{c}{a+b+c}\varepsilon_{r3}\right)$$

### 1.7.2 Multiplication or Division of Quantities

Let, $x = \dfrac{x_1\, x_2}{x_3}$ or $\dfrac{x_2\, x_3}{x_1}$ or $x_1 x_2 x_3$ or $\dfrac{x_1}{x_1 x_3}$

Then, relative limiting error is, $\varepsilon_x = \pm(\varepsilon_{r1} + \varepsilon_{r2} + \varepsilon_{r3})$

**NOTE**

When, $x = \dfrac{x_1\, x_2}{x_2 + x_3}$ or $\dfrac{x_1}{x_2 + x_3}$ or $\dfrac{x_1\, x_2}{x_2 - x_1}$

Then, multiplication or division form is not applicable for finding relative limiting error.

### 1.7.3 Composite Factors

Let, $x = x_1^m \cdot x_2^n \cdot x_3^p$ or $\dfrac{x_1^m x_2^n}{x_3^p}$ or $\dfrac{x_1^m}{x_1^n x_3^p}$

Then, relative limiting error is $\varepsilon_r = \pm(m\,\varepsilon_{r1} + n\,\varepsilon_{r2} + p\,\varepsilon_{r3})$

**NOTE**

When $x$ is of the form $\dfrac{x_1^m}{x_2^n + x_3^p}$ or $\dfrac{x_1^m + x_2^n}{x_3^p}$

Then, above method is not applicable for finding relative limiting error.

### 1.7.4 Uncertainty Error

Let, $x = f(x_1, x_2, \ldots, x_n)$

$W_{x_1}, W_{x_2}, \ldots, W_{x_n}$ be the uncertainties of $x_1, x_2, \ldots x_n$ respectively.

Then, uncertainty of $x$ is given by

$$W_x = \sqrt{\left(\frac{dx}{dx_1}\right)^2 \cdot W_{x_1}^2 + \left(\frac{dx}{dx_2}\right)^2 \cdot W_{x_2}^2 + \left(\frac{dx}{dx_3}\right)^2 \cdot W_{x_3}^2 + \ldots + \left(\frac{dx}{dx_n}\right)^2 \cdot W_{x_n}^2}$$

**NOTE:** Error at any desired scale is $\%\in_r = \dfrac{\%\text{full scale error} \times \text{Full scale value}}{\text{Desired value}}$

**Example - 1.5** A 1 kΩ resistor with an accuracy of ± 10% carries a current of 10 mA. The current was measured by an analog ammeter on a 25 mA range with an accuracy of ± 2%. The accuracy in calculating the power dissipated in the resistor would be

(a) ± 4% (b) ± 12%
(c) ±15% (d) ± 20% [UPPSC]

***Solution : (d)***

Resistance is measure with ± 10% accuracy and current of 10 mA is measured on a 25 mA ammeter with accuracy of ±2%.

So for full scale reading of ammeter, error is ±2% i.e. ±0.5 mA

So for 10 mA the error is ±5%

Now to find accuracy in power measurement,

$$P = I^2R$$

So,
$$\frac{\Delta P}{P} = \frac{2\Delta I}{I} + \frac{\Delta R}{R} = (2 \times 5 + 10)\%$$

$$\frac{\Delta P}{P} = 20\%$$

**Example - 1.6** A resistor of 10 kΩ with 5% tolerance is connected in series with a 5 kΩ resistor of 10% tolerance. What is the tolerance limit of the series network?

(a) 5% (b) 6.67%
(c) 10% (d) 8.33%

***Solution : (b)***

$$R_1 = 10^4 \pm 5\%\ \Omega$$

$$= 10^4 + \frac{5}{100} \times 10^4 = 10^4 \pm 500\Omega$$

$$R_2 = 5000 \pm 10\%\ \Omega$$

$$= 5000 \pm \frac{10}{100} \times 5000 = 5000 \pm 500\Omega$$

$$\therefore \quad R = R_1 + R_2$$

$$= 15000 \pm 1000\ \Omega$$

$$\therefore \quad \text{Tolerance limit} = \frac{1000}{15000} \times 100 = 6.666\% \approx 6.67\%$$

## 1.8 Statistical Analysis

A statistical analysis of measurement data is common practice because it allows an analytical determination of the uncertainty of the final test result.

### 1.8.1 Mean Value

Let $X_1$, $X_2$, ... $X_n$ be the '$n$' no. of set of readings of an instrument then,

$$\text{Mean or average value} = \bar{X} = \frac{X_1 + X_2 + \ldots . X_n}{n} = \frac{\Sigma X}{n}$$

### 1.8.2 Mean Deviation

- Let the deviation of first reading $X_1$ be '$d_1$' and that of reading $X_2$ be '$d_2$' and so on then deviation from the mean value can be expressed as,

$$d_1 = X_1 - \bar{X},\ d_2 = X_2 - \bar{X}, \ldots\ldots d_n = X_n - \bar{X}$$

- Mean or average deviation $= \bar{d} = \dfrac{|d_1| + |d_2| + \ldots |d_n|}{n}$

### 1.8.3 Standard Deviation and Variance

- The standard deviation of an infinite number of data is defined as the square root of the sum of the individual deviation squared, divided by the number of readings.
- Standard deviation,

$$\sigma = \sqrt{\frac{d_1^2 + d_2^2 + \ldots.. + d_n^2}{(n-1)}} \quad (\text{for } n \le 20)$$

$$\sigma = \sqrt{\frac{d_1^2 + d_2^2 + \ldots.. + d_n^2}{n}} \quad (\text{for } n > 20)$$

where, $n$ = number of observations

- Variance $(V) = \sigma^2 = (\text{standard deviation})^2$
- When standard deviation of $x_1, x_2, \ldots, x_n$ are $\sigma_{x_1}, \sigma_{x_2}, \ldots, \sigma_{x_n}$ then standard deviation of $x$ is given by:

$$\sigma_x = \sqrt{\left(\frac{dx}{dx_1}\right)^2 \cdot \sigma_{x_1}^2 + \left(\frac{dx}{dx_2}\right)^2 \cdot \sigma_{x_2}^2 + \ldots. + \left(\frac{dx}{dx_n}\right)^2 \cdot \sigma_{x_n}^2}$$

**Example - 1.7** For the following set of readings of an ammeter, the value of variance will be

Readings: 5 A, 5.6 A, 5.8 A

(a) 0.116 A (b) 0.34 A

(c) 0.173 A (d) None

***Solution : (c)***

Let, readings be $X_1 = 5$ A; $X_2 = 5.6$ A; $X_3 = 5.8$ A

Mean value, $\bar{X} = \dfrac{X_1 + X_2 + X_3}{3} = 5.46$ A

Deviations,

$$d_1 = X_1 - \bar{X} = 5 - 5.46 = -0.46 \text{ A}$$

$$d_2 = X_2 - \bar{X} = 5.6 - 5.46 = 0.14 \text{ A}$$

$$d_3 = X_3 - \bar{X} = 5.8 - 5.46 = 0.34 \text{ A}$$

For $n \le 20$ (i.e. $n = 3$ here)

$$\text{Variance } (V) = \sigma^2 = \frac{\Sigma d^2}{n-1}$$

i.e.,

$$V = \frac{(0.46)^2 + (0.14)^2 + (0.34)^2}{3-1} = 0.173 \text{ A}$$

## Student's Assignment

**Q.1** The following is not essential for the working of an indicating instrument
(a) deflecting torque (b) braking torque
(c) damping torque (d) controlling torques

**Q.2** An ammeter reads 6.7 A and the true value of current is 6.5 A. The correction factor is
(a) 0.97 (b) 0.20
(c) 0.03 (d) none of these

**Q.3** To measure 5 volts, if one selects a (0-100) volt range voltmeter which is accurate within ±1%, then the error in this measurement may be up to
(a) ± 1.5% (b) ± 2.5%
(c) ± 7.5% (d) ± 20%

**Q.4** The sensitivity of 200 μA meter movement when it is used as a dc voltmeter is given by
(a) 500 Ω/mV (b) 5 Ω/V
(c) 0.5 Ω/mV (d) 5 Ω/mV

**Q.5** Dynamic response consists of
(a) two parts, one steady state and the other transient state response
(b) only transient state response
(c) only steady state response
(d) steady state and transient frequency response

**Q.6** If one of the control springs of a permanent magnet coil ammeter is broken, then on being connected it will read
(a) zero
(b) half of the correct value
(c) twice of the correct value
(d) an finite value

**Q.7** A voltmeter reads 110.75 volts. The error taken from the error curve is –0.25 volt. What is the true value of voltage?
(a) 110.50 V (b) 110.25 V
(c) 110.75 V (d) 111.0 V

**Q.8** The reliability of an instrument refers to
(a) the measurement of changes due to temperature variation.
(b) the degree to which repeatability continues to remain within specified limits.
(c) the life of an instrument.
(d) the extent to which the characteristics remain linear.

**Q.9** The measured value of an inductor is 208.5 mH while its true value is 205.2 mH. The relative error will be
(a) 1.58% (b) 2.17%
(c) 0.83% (d) 1.61%

**Q.10** The resistance of a circuit is found by measuring current flowing and the power fed into the circuit. If the limiting errors in the measurement of power and current are ±1.5% and ±1.0% respectively, the limiting error in the measurement of resistance will be
(a) ±1% (b) ±1.5%
(c) ±2.5% (d) ±3.5%

**Q.11** The sensitivity of an instrument is
(a) the smallest increment in the input that can be detected with certainty.
(b) the largest input change to which the instrument fails to respond.
(c) ratio of the change in the magnitude of the output to the corresponding change in the magnitude of the input.
(d) closeness of the output values for repeated application of a constant input.

**Q.12** An instrument gives maximum deflection for any amount of quantity passed through it which of the following pair is present?
(a) Deflecting and controlling force
(b) Deflecting and damping force
(c) Damping and controlling force
(d) Damping, controlling and deflecting force

**Q.13** Which one of the following statements is not correct?
(a) Correctness is measurement requires both accuracy and precision.
(b) Reproducibility and consistency are expressions that best describe precision in measurements.

(c) It is not possible to have precise measurements which are not accurate.
(d) An instrument with 2% accuracy is better than another with 5% accuracy.

**Q.14** The total current $I = I_1 + I_2$ in a circuit is measured as $I_1 = 150 \pm 1$ A, $I_2 = 250 \pm 2$ A, where the limits of error are given as standard deviations. $I$ is measured as
(a) $(400 \pm 3)$ A (b) $(400 \pm 2.24)$ A
(c) $(400 \pm 1/5)$ A (d) $(400 \pm 1)$ A

**Q.15** The degree of damping of an analog indicating instrument in
(a) slightly more than critical
(b) critical
(c) slightly less than critical
(d) unity

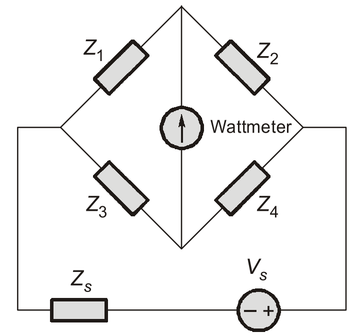
**Q.16** Loading effect is primarily caused by instruments having
(a) high resistance (b) high sensitivity
(c) low sensitivity (d) high range

**Q.17** In a laboratory of college, the number of observations recorded and measured 11. Then standard deviation will be
(a) $\sqrt{\frac{\Sigma d^2}{11}}$ (b) $\sqrt{\frac{\Sigma d^2}{10}}$
(c) $\frac{1}{11}[\Sigma d^2]$ (d) $\frac{1}{10}[\Sigma d^2]$

**Q.18** Precision is composed of two characteristics, one is the number of significant figures to which a measurement may be made, the other is
(a) Conformity (b) Meter error
(c) Inertia effects (d) Noise

**Q.19** Coaxial cables and transducers are respectively
(a) primary sensing elements both
(b) data conversion element and data manipulation element
(c) primary sensing element and data transmission element
(d) data transmission element and primary sensing element

**Q.20** Consider the circuit as shown below. $Z_1$ is an unknown impedance and measured as $Z_1 = (Z_2Z_3)/Z_4$. The uncertainties in the value of $Z_2$, $Z_3$ and $Z_4$ are ±1%, ±1% and ±3% respectively.




The overall uncertainty in the measured value of $Z_1$ is
(a) $\sqrt{11}$ % (b) ±4%
(c) ±5% (d) $\sqrt{5}$ %

**Q.21** In present day measurement systems
(a) direct methods are commonly used
(b) use of direct methods is limited but indirect methods are commonly used
(c) both direct and indirect methods are commonly used
(d) none of the above

**Q.22** A zero to 300 V voltmeter has an error of ±2% of the full-scale deflection. If the true voltage is 30 V, then the range of readings on this voltmeter would be
(a) 20 V to 40 V (b) 24 V to 36 V
(c) 29.4 V to 30.6 V (d) 29.94 V to 30.06 V

**Q.23** Some of the functional building blocks of a measurement system are:
Primary Sensing Element (PSE)
Variable Conversion Element (VCE), or Transducer
Data Transmission Element (DTE)
Variable Manipulation Element (VME)
Data Presentation Element (DPE)
The correct sequential connection of the functional building blocks for an electronic pressure gauge will be
(a) PSE, VME, VCE, DPE, DTE
(b) PSE, VCE, VME, DTE, DPE
(c) DTE, DPE, VCE, PSE, VME
(d) PSE, VCE, DTE, DPE, VME

**Q.24** Which of the following is the dimensional formula for conductivity?
(a) $M^{-1}L^{-3}T^3A^2$ (b) $ML^3T^3A^2$
(c) $M^2L^{-2}T^3A^{-2}$ (d) $ML^2T^3A^{-2}$

## ANSWER KEY — STUDENT ASSIGNMENT

| | | | | |
|---|---|---|---|---|
| **1.** (b) | **2.** (a) | **3.** (d) | **4.** (d) | **5.** (a) |
| **6.** (a) | **7.** (a) | **8.** (b) | **9.** (d) | **10.** (d) |
| **11.** (c) | **12.** (b) | **13.** (c) | **14.** (b) | **15.** (c) |
| **16.** (c) | **17.** (b) | **18.** (a) | **19.** (d) | **20.** (a) |
| **21.** (b) | **22.** (b) | **23.** (b) | **24.** (a) | |

## HINTS & SOLUTIONS — STUDENT ASSIGNMENT

**1. (b)**

Three types of forces are needed for the satisfactory operation of any indicating instrument. These are
1. Deflecting force
2. Controlling force
3. Damping force

**2. (a)**

$$\text{Error in ammeter reading} = \frac{I_m - I_T}{I_T} = \varepsilon_r$$

or, $$\frac{I_m}{I_T} = 1 + \varepsilon_r$$

or, $$\frac{I_T}{I_m} = \frac{1}{1+\varepsilon_r}$$

$$= \text{Correction factor} = \frac{6.5}{6.7} = 0.97$$

**3. (d)**

$$\text{Magnitude of error} = \frac{1}{100}\times 100 = 1\text{ V}$$

$$\%\text{ of error} = \frac{1}{5}\times 100 = \pm 20\%$$

**4. (d)**

$$S_v = \frac{1}{I_m} = \frac{1}{200\times 10^{-6}}$$

$$S_V = 5\ \Omega/\text{mV}$$

**6. (a)**

In PMMC type instruments control springs are connected in series with the moving coil. Therefore current through the coil will be zero and hence meter will read zero.

**7. (a)**

$$\text{Error} = \text{True value} - \text{Measured value}$$

$$-0.25 = A_t - 110.75$$

$$\Rightarrow \quad A_t = 110.50\text{ V}$$

**8. (b)**

The reliability of an instrument refers to the degree to which repeatability continues to remain within specified limits.

**9. (d)**

$$\text{Relative error} = \frac{\text{Measured value} - \text{True value}}{\text{True value}}\times 100$$

$$= \frac{208.5 - 205.2}{205.2}\times 100 = 1.61\%$$

**10. (d)**

$$P = I^2R$$

$$R = \frac{P}{I^2}$$

$$\frac{\delta R}{R} = +\frac{\delta P}{P} \pm \frac{2\delta I}{I} = \pm 1.5 \times (2\times 1)$$

$$\frac{\delta R}{R} = \pm 3.5\%$$

**11. (c)**

By definition, sensitivity is the ratio of change in the magnitude of the output to the corresponding change in the magnitude of the input.

i.e., $$\text{sensitivity} = \frac{\Delta V_0}{\Delta V_i}$$

**12. (b)**

As we know that mainly three types of operating forces are there in electromechanical indicating instruments. These are deflecting force, damping force and controlling force. But it's given that for any amount of quantity, instrument always gives maximum deflection. Hence, this indicates the absence of controlling force or failure of system providing controlling torque.

**13. (c)**

Accuracy and precision are two separate aspect of correctness in measurement.

Accuracy – Degree of conformity compared to true value.