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INSTRUMENTATION ENGINEERING

Objective Practice Sets

Measurements

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1 CHAPTER
Static and Dynamic Characteristics, Error Analysis

MCQ and NAT Questions

Q.1 The scale of a barometer has 300 uniform divisions. Full scale reading of the barometer is 150 Pa and 1/20th of the scale reading can be measured accurately. The resolution of the barometer is

(a) 0.050 Pa (b) 0.075 Pa
(c) 0.025 Pa (d) 0.041 Pa

Q.2 The following terms used in the context of an instrument are numbered as shown:

1. accuracy 2. sensitivity
3. precision and 4. resolution

Match these with their possible definitions listed below:

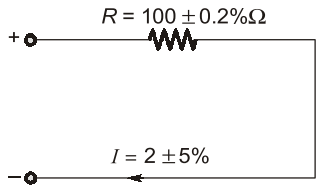
P. Repeatability of readings on successive observations.
Q. Smallest perceptible change in the output
R. Deviation of the output from the true value
S. Minimum value of the input from the true value
T. Ratio of the change in the instrument reading to the change in the measured variable.

(a) 1-P, 2-Q, 3-R, 4-S (b) 1-S, 2-Q, 3-P, 4-T
(c) 1-R, 2-T, 3-P, 4-Q (d) 1-T, 2-Q, 3-P, 4-R

Q.3 A utility type voltmeter with an accuracy of ±3% of full scale (at 25°C) is used on 300 V scale to measure 230 V. (a) What is the possible percentage limiting error ? (b) What range will the actual voltage fall within if the instrument reads 200 V?

(a) 3.9%, 196-204 V (b) 3.9%, 191-209 V
(c) 7.6%, 221-239 V (d) 7.6%, 195-204.5 V

Q.4 In the circuit given in the figure, the limiting error in the power dissipation 'I^2R' across the resistor R is



(a) 1.2% (b) 5.2%
(c) 10.2% (d) 25.2%

Q.5 Two resistance 100 Ω ± 5 Ω and 150 Ω ± 15 Ω are connected in series. If the errors are specified as standard deviations, the resultant error will be

(a) ±10 Ω (b) ± 10.5 Ω
(c) ± 15.8 Ω (d) ± 20 Ω

Q.6 A 0–300 V voltmeter has a guaranteed accuracy of 1 % full scale reading. The voltage measured by the instrument is 83 V. The percentage limiting error is

(a) 0.95% (b) 1.81%
(c) 3.62% (d) 4.85%

Q.7 A first order system behave as per equation below

$$A\frac{d}{dt}p(t) + B\,p(t) = 3u(t)$$

The static sensitivity and time constant of the system is 0.51 and 2 sec respectively, the value of the constant A in the equation is

(a) 10.8 (b) 5.8
(c) 11.7 (d) 7.2

Q.8 The transducer with an output resistance of 25 kΩ is connected to an amplifier. The minimum input resistance of the amplifier so that the error in recording the transducer output does not exceed 2% is

(a) 7.2 MΩ (b) 1.2 MΩ
(c) 22.6 MΩ (d) 2.4 MΩ

Q.9 Two branches are connected in parallel having branches currents I_1 and I_2 as 100 ± 3 A and 200 ± 4 A respectively. Considering the error to be the standard deviations, the value of the total current $I = I_1 + I_2$, is

(a) 300 ± 7 A (b) 300 ± 1 A
(c) 300 ± 5 A (d) 300 ± 2.6 A

Q.10 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 ± 3) A (b) (400 ± 2.24) A
(c) $(400 \pm 1/5)$ A (d) (400 ± 1) A

Q.11 Which one of the following statements correctly represents the systematic errors?

(a) These errors can be calculated from the details of the instruments
(b) These are the residual errors
(c) These errors may occur under controlled conditions
(d) These are the errors committed by the experiments

Q.12 Temperature of water in a geyser is measured with the help of a thermometer. The initial temperature of the water inside the geyser is 35°C. When the geyser is turned on, the temperature of the water in the geyser rises at a rate of unit step input and reaches a final level of 80°C. If the temperature of water reaches to 65°C in 5 sec, then the time constant of the thermometer is _____ sec.

Q.13 When reading is taken at half scale in the instrument, the error is

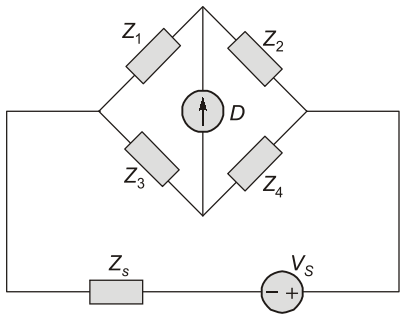
(a) exactly equal to half of full-scale error
(b) equal to full-scale error
(c) less than full-scale error
(d) more than full-scale error

Q.14 A thermocouple with a time constant of 0.5 sec and static sensitivity of 0.04 mV/°C is suddenly immersed in a bath of hot oil, which is at 100°C. The initial temperature of the thermocouple and the measuring and the reference junction was 25°C. The output of the thermocouple at $t = 0.1$ sec is _____ mV.

Q.15 A 0 to 300 V voltmeter has an error of ± 2% of fsd. What is the range of readings if true voltage is 30 V?

(a) 24 V – 36 V (b) 20 V – 40 V
(c) 29.4 V – 30.6 V (d) 20 V – 30 V

Q.16 Consider the circuit as shown below. z_1 is an unknown impedance and measured as $z_1 = \frac{z_2 z_3}{z_4}$. 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) $\pm \sqrt{11}\%$ (b) ± 4%
(c) ± 5% (d) $\pm \sqrt{5}\%$

Q.17 Temperature of a furnace is increasing at a rate of 0.2°C/sec. The maximum permissible time constant of a first order instrument that can be used, so the temperature is read with a maximum error of 5°C, is

(a) 25 sec (b) 50 sec
(c) 30 sec (d) 75 sec

Q.18 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I	List-II
A. Instrumental error	1. Loading effect
B. Observational error	2. Oversight
C. Gross error	3. Parallax

	A	B	C
(a)	3	1	2
(b)	1	2	3
(c)	1	3	2
(d)	3	2	1

Q.19 The measured value of a capacitor is 205.5 μF; whereas its true value is 202.4 μF. The relative error is

(a) 1.87% (b) 1.94%
(c) 1.53% (d) 1.73%

Q.20 Temperature of an oven was measured with the help of a temperature probe and multiple readings were taken in a short time span. The reading were recorded as
105°, 105°, 108°, 105°, 107°, 105°, 105°,
The actual temperature of the oven at this time was 108°. The instrument used to measure this temperature, is

(a) highly accurate
(b) highly precise
(c) less precise but more accurate
(d) less accurate but more precise

Q.21 The standard deviation (σ) for the Gaussian curve is

(a) $\sigma = \frac{1}{\sqrt{2}\,h}$ (b) $\sigma = \frac{r}{0.7162}$

(c) $\sigma = \frac{r}{\sqrt{2}\,h}$ (d) Both (a) and (b)

Q.22 Two resistances $R_1 = 100 \pm 10\%\ \Omega$ and $R_2 = 300 \pm 5\%\ \Omega$ are connected in series. The resulting limiting error of the series combination is

(a) 5 Ω (b) 15 Ω
(c) 25 Ω (d) 30 Ω

Q.23 Uncertainty distribution is used for
(a) analysis of sample data
(b) analysis of multi sample data
(c) analysis of both single and multi sample data
(d) none of the above

Q.24 The unknown resistance R_4 measured in a Wheatstone bridge by the formula $R_4 = \frac{(R_2 R_3)}{R_1}$ with
$R_1 = 100 \pm 0.5\%\ \Omega$,
$R_2 = 1000 \pm 0.5\%\ \Omega$,
$R_3 = 842 \pm 0.5\%\ \Omega$
resulting in R_4

(a) 8420 ± 0.5% Ω (b) 8420 ± 1.0% Ω
(c) 8420 ± 1.5% Ω (d) 8420 ± 0.125% Ω

Q.25 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.26 The expected value of the voltage across a resistor is 100 V. However, the measured value while measured with the help of a voltmeter is 96 V. The accuracy of the instrument is _____%.

Q.27 A thermometer is kept at a temperature of 0°C and is suddenly dipped into a hot bath of temperature 300°C. The thermometer has a time constant of 2 sec. The temperature indicated by the thermometer after 1.2 sec is _____°C.

Q.28 The pointer scale of a vapour pressure thermometer has 200 uniform divisions. Full scale reading is 250°C and $1/10^{th}$ of the scale division can be estimated accurately. The resolution of the thermometer is ____°C.

Q.29 A voltmeter reads 40 V on its 100 V range and an ammeter reads 75 mA on its 150 mA range in a circuit. Both the instruments are guaranteed ±2% accuracy on FSD. The limiting error on the measured power is

(a) 4% (b) 5%
(c) 9% (d) 12%

Q.30 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%

Q.31 The scale of a pressure gauge having range 0- 300 psi is divided into 10 large division is divided further into 20 smaller division each representing 1.5 psi the,
(a) Threshold of gauge is 1.5 psi
(b) Threshold of gauge is 15 psi
(c) Resolution of gauge is 1.5 psi
(d) Resolution of gauge is 15 psi

Q.32 The resistance of circuit is found by measuring current flowing and the power fed into the circuit. Find the limiting error in the measurement of resistance when the limiting errors in the measurement of power and current are respectively ±1.5% and ±2.1%.

(a) ±1% (b) ±2.6%
(c) ±3.7% (d) ±5.7%

Q.33 A first order instrument measures signals with a frequency content upto 200 Hz. The maximum allowable time constant of the instrument if the amplitude inaccuracy is 10%, is

(a) 0.15 μsec (b) 0.25 μsec
(c) 1.61 μsec (d) 0.31 μsec

Multiple Select Questions (MSQs)

Q.34 Which of the following is/are base units of S.I. system?
(a) Meter (b) Ampere
(c) Degree Celsius (d) Mole

Q.35 Which of the following is/are true for standardisation of systems?
(a) Secondary standards are calibrated using primary standards.
(b) Absolute measurement of current is done using Rayleigh's current balance method.
(c) International standards are more accurate than primary standards.
(d) Working standards are more precise and accurate w.r.t. secondary standards.

Q.36 True value of current flowing through a resistance is 5.25 A. Meter A reads 5.202 A and Meter B reads 5.27 A then
(a) Meter A is more accurate.
(b) Meter B is more accurate
(c) Meter A is more precise
(d) Meter B is more precise.

Q.37 Systematic error is an error which is not determined by chance but is introduced by an inaccuracy in measurement. Which of the following is/are systematic error?
(a) Parallax error (b) Environmental error
(c) Instrumental error (d) Random error

Q.38 Precision index of curve *A* is 0.42 while precision index of curve *B* is 0.54 then
(a) Curve *B* is sharper than *A*.
(b) Curve *A* drops sharply to low values.
(c) Deviation of curve *A* is larger w.r.t. *B*.
(d) Curve B has wider error limit than *A*.

Q.39 The Gaussian distribution is mathematically expressed as :
(a) $y = 1.13\exp[-4x^2]$
(b) $y = \dfrac{1}{0.56\exp[x^2]}$
(c) $y = 1.13\exp[-4x]$
(d) $y = \dfrac{1}{0.56\exp[x]}$

Q.40 A certain resistor has uncertainty in measurement of voltage of ±0.3 V. The voltage drop and current are respectively 50 V and 15 A. Then uncertainty in measurement of power is _____.
(a) ±4.8 W (b) ±2.7 W
(c) ±3.2 W (d) ±5.7 W

■■■■

Answers — Static and Dynamic Characteristics, Error Analysis

1. (c)	**2.** (c)	**3.** (b)	**4.** (c)	**5.** (d)	**6.** (c)	**7.** (c)
8. (b)	**9.** (c)	**10.** (b)	**11.** (a)	**12.** (4.55)	**13.** (c)	**14.** (0.54)
15. (a)	**16.** (a)	**17.** (a)	**18.** (c)	**19.** (c)	**20.** (d)	**21.** (c)
22. (c)	**23.** (a)	**24.** (c)	**25.** (b)	**26.** (95.83)	**27.** (135.30)	**28.** (0.125)
29. (c)	**30.** (d)	**31.** (c)	**32.** (d)	**33.** (a)	**34.** (a, b, d)	**35.** (a, b, c)
36. (b, c)	**37.** (a, b, c)	**38.** (a, c)	**39.** (a, b)	**40.** (a, d)		

Explanations **Static and Dynamic Characteristics, Error Analysis**

1. (c)

$$\text{Pressure per division} = \frac{150}{300} = 0.5 \text{ Pa/division}$$

$$\text{Resolution} = \frac{1}{20} \times 0.5 = 0.025 \text{ Pa}$$

2. (c)

These all are the corresponding definitions.

3. (b)

Accuracy = 3%, of full scale value

$$\therefore \text{ Absolute error} = \frac{3}{100} \times 300 = \pm 9 \text{ V}$$

$$\text{So limiting error \%} = \frac{9}{230} \times 100 = 3.9\%$$

So, range of reading for 200 V is = 200 ± 9
= 191 – 209 V

4. (c)

$$P = I^2R$$

$$\frac{dp}{p}\% = 2\frac{dI}{I}\% + \frac{dR}{R}\%$$

$$= 2 \times 5\% + 0.2\% = 10.2\%$$

5. (d)

In multiplication, we add directly percentage error.
In addition, we add directly error value.

6. (c)

Magnitude of limiting error

$$= \frac{1}{100} \times 300 = 3 \text{ V}$$

$$\therefore \text{ percentage limiting error} = \frac{3}{83} \times 100 = 3.62\%$$

7. (c)

Standard equation

$$\tau \frac{dp(t)}{dt} + p(t) = Sr(t)$$

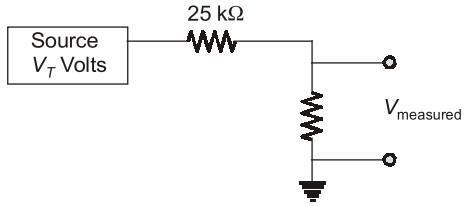
by comparing,

$$\frac{A}{B} = \tau, \quad \frac{3}{B} = S$$

$$B = \frac{3}{S} = \frac{3}{0.51} = 5.88$$

$$A = B\tau = 5.88 \times 2 = 11.76$$

8. (b)



$$\frac{V - \frac{R}{R+25} \times V}{V} \times 100 = 2$$

$$\frac{(R+25) - R}{R+25} \times 100 = 2$$

$$\frac{25}{R+25} \times 100 = 2$$

$$2R + 50 = 2500$$

$$2R = 2450$$

$$R = 1225 \text{ k}\Omega$$

$$R = 1.225 \text{ M}\Omega$$

9. (c)

$$I' = 100 + 200 = 300 \text{ A}$$

$$I_\sigma = \sqrt{\sigma^2 + \sigma_2^2} = \sqrt{3^2 + 4^2}$$

$$= \sqrt{9+16} = \sqrt{25} = 5$$

$$\therefore \quad I' = 300 \pm 5 \text{ A}$$

10. (b)

$$I' = 150 + 250 = 400 \text{ A}$$

$$I_\sigma = \sqrt{\sigma^2 + \sigma_2^2} = \sqrt{1^2 + 2^2}$$

$$= \sqrt{1+4} = \sqrt{5} = 2.24$$

$$\therefore \quad I' = 400 \pm 2.24 \text{ A}$$

12. (4.55)

$$\theta(t) = (\theta_i - \theta_f)e^{-t/\tau} + \theta_f$$

$$65 = (35 - 80)e^{-5/\tau} + 80$$

$$\therefore \quad \tau = 4.55 \text{ sec}$$

13. (c)

Accuracy is defined as 'percentage of true value'.

14. (0.54)

The maximum difference between measuring and reference junctions = 100 – 25 = 75°C
For a step input of θ_1 = 75°C, the solution for voltage output is

$$V = K\left[1 - e^{-\frac{t}{\tau}}\right]\theta_i$$