



POSTAL BOOK PACKAGE 2027

INSTRUMENTATION ENGINEERING

OBJECTIVE PRACTICE SETS VOLUME - III

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MEASUREMENTS

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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/ $^\circ\text{C}$ 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.

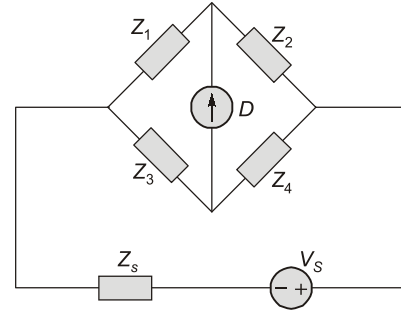
Q.15 A 0 to 300 V voltmeter has an error of $\pm 2\%$ of fsd. What is the range of readings if true voltage is 30 V?

- (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 $\pm 1\%$, $\pm 1\%$ and $\pm 3\%$ respectively.



the overall uncertainty in the measured value of z_1 is

- (a) $\pm \sqrt{11}\%$ (b) $\pm 4\%$
(c) $\pm 5\%$ (d) $\pm \sqrt{5}\%$

Q.17 Temperature of a furnace is increasing at a rate of $0.2^\circ\text{C}/\text{sec}$. 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

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) $y = \frac{1}{0.56 \exp[x^2]}$
 (c) $y = 1.13 \exp[-4x]$
 (d) $y = \frac{1}{0.56 \exp[x]}$
- 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

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

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

$$\text{So, range of reading for 200 V is} = 200 \pm 9 \\ = 191 - 209 \text{ V}$$

4. (c)

$$P = I^2 R$$

$$\frac{dp}{p} \% = 2 \frac{dI}{I} \% + \frac{dR}{R} \% \\ = 2 \times 5\% + 0.2\% = 10.2\%$$

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

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

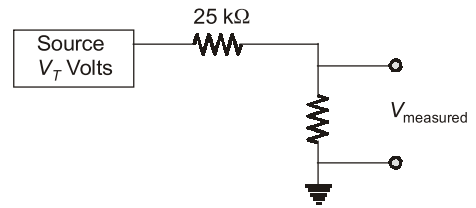
by comparing,

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

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

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

8. (b)



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

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

$$2R + 50 = 2500$$

$$2R = 2450$$

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

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

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

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

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

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

12. (4.55)

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

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

\therefore

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

13. (c)

Accuracy is defined as 'percentage of true value'.

14. (0.54)

The maximum difference between measuring and reference junctions = $100 - 25 = 75^\circ\text{C}$

For a step input of $\theta_1 = 75^\circ\text{C}$, the solution for voltage output is

$$V = K \left[1 - e^{-\frac{t}{\tau}} \right] \theta_1$$

COMMUNICATION

OBJECTIVE PRACTICE SETS

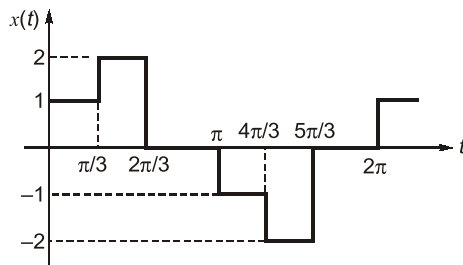
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Fourier Analysis of Signal Energy and Power Signals

MCQ and NAT Questions

- Q.1** If $G(f)$ represents the Fourier transform of a signal $g(t)$ which is real and odd symmetric in time then
- $G(f)$ is complex
 - $G(f)$ is imaginary
 - $G(f)$ is real
 - $G(f)$ is real and non-negative

- Q.2** Compute the amplitude of the fundamental component of the waveform given in figure.



- 0
- 1.00
- 1.603
- 1.712

- Q.3** Let $x(t)$ be a signal with its Fourier transform $X(j\omega)$ suppose we are given the following facts.

- $x(t)$ is real.
- $x(t) = 0$ for $t \leq 0$.
- $\frac{1}{2\pi} \int_{-\infty}^{\infty} \text{Re}\{X(j\omega)\} e^{j\omega t} d\omega = 2|t|e^{-|t|}$.

then a closed form expression for $x(t)$ is

- $2e^{-t} u(t)$
- $e^{-|t|}$
- $te^{-2t} u(t)$
- $2te^{-t} u(t)$

- Q.4 Assertion (A):** If two signals are orthogonal they will also be orthonormal.

Reason (R): If two signals are orthonormal they also will be orthogonal.

- Both A and R are true, and R is the correct explanation of A.
- Both A and R are true, but R is not a correct explanation of A.
- A is true, but R is false.
- A is false, but R is true.

- Q.5** Consider the following statements:
The normalized power, $S \equiv v^2(t)$ can be defined as the
- instantaneous power divided by the maximum power in the circuit.
 - time average power that appears in a one ohm resistor.
 - Total power consumed by the circuit divided by the average power consumed in that circuit.
 - the mean square value of $v(t)$.

Which of the above statements is/are correct?

- 2 only
- 1 and 2
- 2 and 3
- 2 and 4

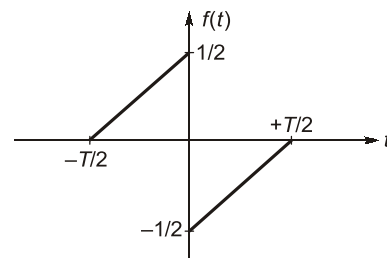
- Q.6** The auto correlation function of a rectangular pulse of duration T is

- A rectangular pulse of duration T
- A rectangular pulse of duration $2T$
- A triangular pulse of duration T
- A triangular pulse of duration $2T$

- Q.7** The amplitude spectrum of Gaussian pulse is

- uniform
- a sine function
- gaussian
- an impulse function

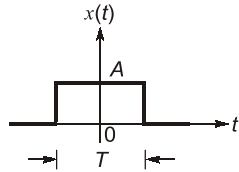
- Q.8** A function $f(t)$ is shown in figure.



The Fourier transform $F(\omega)$ of $f(t)$ is

- real and even function of ω
- real and odd function of ω
- imaginary and odd function of ω
- imaginary and even function of ω

Q.9 What is the total energy of the rectangular pulse shown in the figure below?



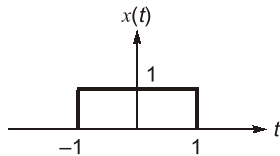
- (a) AT (b) A^2T
(c) A^2T^2 (d) AT^2

Q.10 Which one of the following is not a property of auto correlation function ($R(\tau)$)?

- (a) $R(0) \leq R(\tau)$
(b) $R(\tau) = R(-\tau)$
(c) $R(0) = s =$ average power of the waveform
(d) Power spectral density is Fourier transform of auto correlation function for a periodic waveform

Q.11 $x(t)$ is a positive rectangular pulse from $t = -1$ to $t = +1$ with unit height as shown in figure.

The value of $\int_{-\infty}^{\infty} |X(\omega)|^2 d\omega$ (where $X(\omega)$ is Fourier transform of $x(t)$) is



- (a) 2 (b) 2π
(c) 4π (d) 4

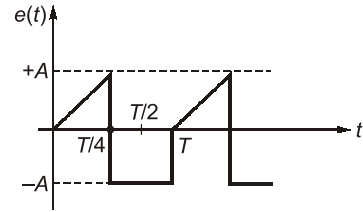
Q.12 The Fourier transform of $x(t) = \frac{2a}{a^2 + t^2}$ is

- (a) $2\pi e^{-a|\omega|}$ (b) $\pi e^{-2a|\omega|}$
(c) $\pi e^{-a\omega}$ (d) $\pi e^{-2a\omega}$

Q.13 Out of the four signal waveforms-sinusoid, rectangular, triangular and saw-tooth, all of them having the same periodicity, the minimum bandwidth corresponds to which one of the following?

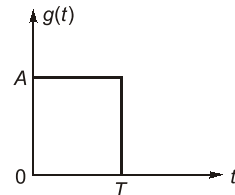
- (a) Sinusoidal (b) Rectangular
(c) Triangular (d) Saw-tooth

Q.14 The rms value of the periodic waveform $e(t)$ shown in figure is



- (a) $\sqrt{\frac{3}{2}} A$ (b) $\sqrt{\frac{2}{3}} A$
(c) $\sqrt{\frac{1}{3}} A$ (d) $\sqrt{\frac{5}{6}} A$

Q.15 The energy density spectrum $|G(f)|^2$ of a rectangular pulse shown in the given figure is



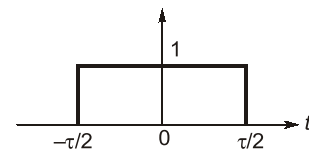
- (a) $AT \left(\frac{\sin \pi f T}{\pi f T} \right)$ (b) $(AT)^2 \left(\frac{\sin \pi f T}{\pi f T} \right)^2$
(c) $(AT)^2 \left(\frac{\sin \pi f T}{\pi f T} \right)$ (d) $A^2 \left(\frac{\sin \pi f T}{\pi f T} \right)$

Q.16 Fourier transform of the gate function as shown below is

$$f(t) = 1 \text{ for } -\tau/2 \leq t < \tau/2$$

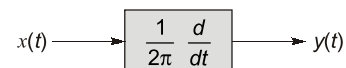
$$= 0 \text{ otherwise}$$

(where τ is the width of the gate function).
The value of $F(\omega)$ is



- (a) $\frac{\tau \sin(\omega\tau)}{\omega\tau}$ (b) $\frac{\tau \sin(2\omega\tau)}{2\omega\tau}$
(c) $\frac{\tau \sin(\omega\tau/2)}{(\omega\tau/2)}$ (d) $\frac{\tau}{2} \cdot \frac{\sin(\omega\tau/2)}{(\omega\tau/2)}$

Q.17 A deterministic signal $x(t) = \cos 2\pi t$ is passed through a differentiator as shown in figure.



what is its power spectral density $S_{yy}(f)$?

- (a) The Fourier transform of $y(t)$ and $z(t)$ is real-valued.
- (b) The Fourier transform of $x(t)$ is conjugate symmetric.
- (c) $\int_{-\infty}^{\infty} X(j\omega) \cdot d\omega = 0$
- (d) $\int_{-\infty}^{\infty} Z(j\omega) \cdot d\omega = 0$

Q.27 Consider a continuous-time ideal low pass filter having the frequency response

$$H(j\omega) = \begin{cases} 1, & |\omega| \leq 80 \\ 0, & |\omega| > 80 \end{cases}$$

The input to this filter is a signal $x(t)$ with fundamental frequency $\omega_0 = 10$ rad/sec and Fourier series coefficients $X[k]$. If $y(t)$ represents the output of the filter and it is given that

$Y[k] = X[k]$, then the values of k for which $X[k]$ is non-zero are:

- (a) 3
- (b) 7
- (c) 10
- (d) 12

Q.28 For a periodic signal $x(t)$, the Fourier series coefficients are given as below:

$$X[k] = \begin{cases} 5, & k = 0 \\ j\left(\frac{1}{2}\right)^{|k|}, & \text{otherwise} \end{cases}$$

Which of the below statements are correct?

- (a) $x(t)$ is real signal.
- (b) $x(t)$ is an even signal.
- (c) $\frac{dx(t)}{dt}$ is an odd signal.
- (d) $x(t)$ is an energy signal.



Answers Fourier Analysis of Signal Energy and Power Signals

- 1. (b) 2. (a) 3. (d) 4. (d) 5. (d) 6. (d) 7. (c)
- 8. (c) 9. (b) 10. (a) 11. (c) 12. (a) 13. (a) 14. (d)
- 15. (b) 16. (c) 17. (b) 18. (b) 19. (b) 20. (a) 21. (b)
- 22. (a) 23. (4.5) 24. (3.14) 25. (1.57) 26. (b, c) 27. (a, b) 28. (b, c)

Explanations Fourier Analysis of Signal Energy and Power Signals

1. (b)

Function, $g(t)$	Fourier Transform, $G(f)$
Real and odd	Imaginary and odd
Real and even	Real and even
Imaginary and odd	Real and odd
Imaginary and even	Imaginary and even

2. (a)

$$a_0 = \frac{1}{T} \cdot \int_0^T f(t) dt$$

$$a_0 = \frac{1}{2\pi} \int_0^{2\pi} f(t) dt = \frac{1}{2\pi} \times \left[\int_0^{2\pi/3} f(t) dt + \int_{\pi}^{5\pi/3} f(t) dt \right]$$

$$= \frac{2}{2\pi} \left[1 \cdot \frac{\pi}{3} + 2 \cdot \frac{\pi}{3} - 1 \cdot \frac{\pi}{3} - 2 \cdot \frac{\pi}{3} \right] = 0$$

3. (d)

$$x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} X(j\omega) e^{j\omega t} d\omega$$

$$\Rightarrow \text{Real}(x(t)) = 2|t|e^{|t|}$$

Since, $x(t) = 0, \quad t \leq 0$

$$\Rightarrow x(t) = 2te^{-t} \quad t > 0$$

$$\Rightarrow x(t) = 2te^{-t} u(t)$$

4. (d)

Orthogonal: Two vector are perpendicular i.e. their dot product is zero.

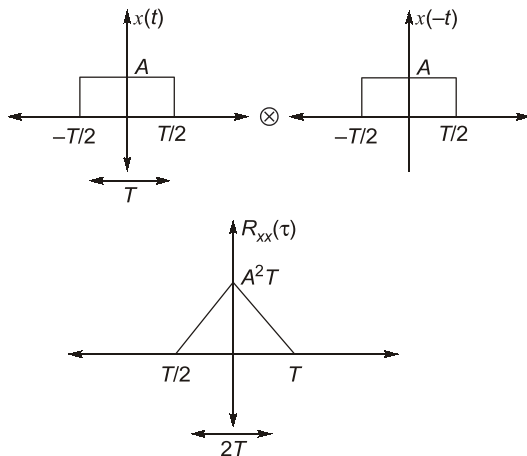
Orthonormal: Two vectors are perpendicular and are of unit length.

5. (d)

- Normalized power \rightarrow Power in 1Ω resistor
- $P_N = V^2(t)$, normalized power is average and mean of voltage required.
- $V_{rms} = \sqrt{P_N}$

6. (d)

ACF or Auto correlation function is nothing but convolution of $x(t)$ with time reversed form of $x(t)$, i.e. $x(t)$



ACF is a triangular pulse of duration $2T$.

7. (c)

Amplitude spectrum of Gaussian pulse is Gaussian.

8. (c)

Signal is odd,

$$x(t) = -x(-t)$$

Signal is half symmetric

$$x(t) = x\left(t + \frac{T_0}{2}\right)$$

\therefore contains odd harmonic.

Signal $f(t)$ is real and odd,

$\therefore F(\omega)$ is imaginary and odd.

9. (b)

$$x(t) = A; \quad -\frac{T}{2} \leq t \leq \frac{T}{2}$$

$$= 0; \quad \text{for all other } t$$

$$E = \int_{-\infty}^{\infty} |x(t)|^2 dt$$

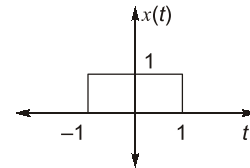
$$= \int_{-T/2}^{T/2} A^2 dt = [A^2 t]_{-T/2}^{T/2} = A^2 T$$

10. (a)

For autocorrelation function

$$R(0) \geq R(\tau)$$

$R(0) \rightarrow$ Maximum value of autocorrelation function.

11. (c)

From Parseval's theorem,

$$\int_{-\infty}^{\infty} |x(t)|^2 dt = \frac{1}{2\pi} \int_{-\infty}^{\infty} |X(\omega)|^2 d\omega$$

$$\Rightarrow 2\pi \int_{-\infty}^{\infty} |x(t)|^2 dt = \int_{-\infty}^{\infty} |X(\omega)|^2 d\omega$$

$$= 2\pi \int_{-1}^1 1^2 dt = 2\pi \times 2 = 4\pi$$

$$\int_{-\infty}^{\infty} |X(\omega)|^2 d\omega = 4\pi$$

12. (a)

$$e^{-a|t|} \longleftrightarrow \frac{2a}{a^2 + \omega^2}$$

$$\frac{2a}{a^2 + t^2} \longleftrightarrow 2\pi e^{-a|\omega|} = 2\pi e^{-a|\omega|}$$

As per duality property.

13. (a)

Fourier transform of a sinc wave is an impulse. So, it has infinitesimally narrow bandwidth and out of these, sinusoid have minimum BW.

14. (d)

$$V_{rms} = \sqrt{\frac{1}{T} \int_{-T/2}^{T/2} (f(t))^2 dt}$$

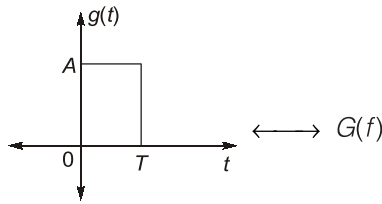
$$V_{rms}^2 = \frac{1}{T} \cdot \int_0^{T/4} \left(\frac{4A}{T} \cdot t\right)^2 dt + \int_{+T/4}^T (-A)^2 dt$$

$$V_{rms}^2 = \frac{1}{T} \cdot \left[\frac{3A^2 T}{4} + \frac{16A^2}{T^2} \cdot \frac{1}{3} \frac{T^3}{16 \times 4} \right]$$

$$V_{rms}^2 = A^2 \left[\frac{3}{4} + \frac{1}{12} \right] = A^2 \cdot \frac{10}{12}$$

$$V_{rms} = A \sqrt{\frac{5}{6}}$$

15. (b)



$$|G(f)| = AT \operatorname{sinc}(f \cdot T)$$

$$|G(f)|^2 = A^2 T^2 \operatorname{sinc}^2(fT)$$

$$= A^2 T^2 \left(\frac{\sin(\pi f T)}{\pi f T} \right)^2 \quad \left(\operatorname{sinc} fT = \frac{\sin \pi f T}{\pi f T} \right)$$

16. (c)

$$F(\omega) = \int_{-\tau/2}^{\tau/2} 1 \cdot e^{-j\omega t} dt$$

$$= \frac{1}{-j\omega} [e^{-j\omega\tau/2} - e^{+j\omega\tau/2}]$$

$$= \frac{2}{\omega} \left[\frac{e^{j\omega\tau/2} - e^{-j\omega\tau/2}}{2j} \right]$$

$$= \frac{\sin \frac{\omega\tau}{2}}{\frac{\omega}{2}} = \frac{\tau \sin \frac{\omega\tau}{2}}{2}$$

17. (b)

$$S_0 = S_i(\omega) \cdot |H(\omega)|^2$$

$$H(\omega) = \frac{j\omega}{2\pi} = \frac{j2\pi f}{2\pi} = jf$$

$$|H(\omega)|^2 = \frac{\omega^2}{4\pi^2} = f^2$$

$$S_i(f) = \frac{1}{2} \cdot [\delta(f-1) + \delta(f+1)]$$

$$S_0(f) = \frac{f^2}{2} \cdot [\delta(f-1) + \delta(f+1)]$$

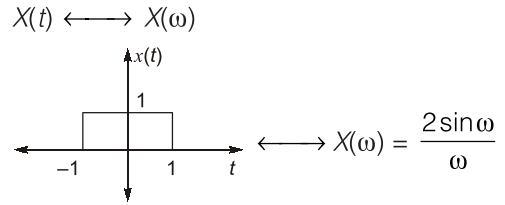
We know,

$$f^2 \cdot \delta(f-1) = (+1)^2 \cdot \delta(f-1)$$

$$f^2 \cdot \delta(f+1) = (-1)^2 \cdot \delta(f+1)$$

$$S_0(f) = \frac{1}{2} (\delta(f-1) + \delta(f+1))$$

18. (b)



$$x(t) \longleftrightarrow X(\omega)$$

$$x(2t) \longleftrightarrow \frac{1}{2} X\left(\frac{\omega}{2}\right)$$

$$x\left(\frac{t}{2}\right) \longleftrightarrow 2 X(2\omega)$$

$$y(t) = x(2t) \otimes x\left(\frac{t}{2}\right) \longleftrightarrow \frac{1}{2} X\left(\frac{\omega}{2}\right) \cdot 2X(2\omega)$$

$$Y(\omega) = X\left(\frac{\omega}{2}\right) \cdot X(2\omega)$$

$$= 4 \cdot \frac{\sin \frac{\omega}{2}}{\frac{\omega}{2}} \cdot \frac{\sin 2\omega}{2\omega}$$

$$= \frac{4}{\omega^2} \sin\left(\frac{\omega}{2}\right) \cdot \sin(2\omega)$$

19. (b)

$$\text{Power} = \sum_{n=-\infty}^{\infty} |C_n|^2 = \frac{1}{T} \int_{-T/2}^{T/2} |f(t)|^2 dt$$

$$= |C_{-2}|^2 + |C_2|^2 + |C_{-1}|^2 + |C_1|^2 + |C_0|^2$$

$$= 2^2 + 2^2 + 8^2 + 8^2 + 0^2 = 136$$

20. (a)

$$X(\omega) = \int_{-\infty}^{\infty} x(t) e^{-j\omega t} dt$$

$$x(t) = \begin{cases} e^{j10t} & |t| < 1 \\ 0 & |t| > 1 \end{cases}$$

$$\Rightarrow X(\omega) = \int_{-1}^1 e^{j10t} \cdot e^{-j\omega t} dt$$

$$X(\omega) = \frac{e^{-j(\omega-10)} - e^{j(\omega-10)}}{-j(\omega-10)}$$

$$X(\omega) = \frac{2 [e^{j(\omega-10)} - e^{-j(\omega-10)}]}{2j(\omega-10)}$$

$$X(\omega) = \frac{2 \sin(\omega-10)}{\omega-10}$$

SENSORS AND INDUSTRIAL INSTRUMENTATION

OBJECTIVE PRACTICE SETS

Page No. 125 - 189

Introduction to Transducers

MCQ and NAT Questions

Q.1 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.2 Which one of the following transducers is classified as an active transducer?

- (a) Metallic strain gauge
- (b) Capacitive microphone
- (c) LVDT
- (d) Piezoelectric transducer

Q.3 Inverse transducers

- (a) converts electrical energy to any other form of energy
- (b) converts electrical energy to light energy
- (c) converts mechanical displacement into electrical signal
- (d) converts electrical energy to mechanical form

Q.4 Match **List-I (Transducers)** with **List-II (Measured Quantity)** and select the correct answer using the codes given below the lists:

List-I	List-II
A. Capacitive transducer	1. Pressure
B. Thermocouple	2. Torque
C. Load cell	3. Displacement
D. Diaphragm	4. Temperature

Codes:

	A	B	C	D
(a)	2	4	3	1
(b)	3	1	2	4
(c)	2	1	3	4
(d)	3	4	2	1

Q.5 Very small displacements are effectively measured using

- (a) LVDT
- (b) Strain gauge
- (c) Thermistor
- (d) Tachogenerator

Q.6 Which one of the following transducers requires power supply for its operation?

- (a) Thermocouple
- (b) Photovoltaic cell
- (c) Piezoelectric crystal
- (d) Thermistor

Q.7 Which one of the following transducers is the most suitable for the measurement of linear displacement?

- (a) Strain gauge
- (b) LVDT
- (c) Piezoelectric crystal
- (d) Microphone

Q.8 Match **List-I (Transducers)** with **List-II (Types of transducer)** and select the correct answer using the code given below the lists:

List-I	List-II
A. LVDT	1. Resistive
B. Strain Gauge	2. Inductive
C. Dielectric Gauge	3. Capacitive
D. Thermocouple	4. Self generating

Codes:

	A	B	C	D
(a)	2	3	1	4
(b)	4	3	1	2
(c)	2	1	3	4
(d)	4	1	3	2

- Q.9** Dynamics of a thermocouple can be modeled as,
a
- (a) zero order equation
 - (b) first order equation
 - (c) second order equation
 - (d) none of the above

- Q.10** The lower limit of useful working range of a transducer is determined by
- (a) minimum useful input level
 - (b) cross sensitivity
 - (c) transducer error and noise
 - (d) dynamic response of the transducer

- Q.11** Match the contents of **List-I (Transducer)** with the contents of **List-II (Application for which they are used)**:

List-I	List-II
A. Dielectric Gauge	1. Temperature
B. Reluctance pick-up	2. Thickness
C. Pirani Gauge	3. Gas Flow
D. RTD	4. Position

Codes:

A	B	C	D
(a) 2	4	3	1
(b) 3	2	4	1
(c) 2	3	4	1
(d) 1	4	3	2

- Q.12** The output voltage of a transducer is connected to an amplifier. The amplifier has an input resistance of 490 k Ω . The output resistance of the transducer if the error in recording of the transducer output is 1% is
- (a) 10 k Ω
 - (b) 9.6 k Ω
 - (c) 49 k Ω
 - (d) 4.9 k Ω

- Q.13** In a seismic pickup, damping factor ξ is to be doubled without changing natural frequency ω_n . This can be achieved by
- (a) Double damping
 - (b) Quadruple seismic mass
 - (c) Quadruple spring constant
 - (d) Double seismic mass and spring constant

Multiple Select Questions (MSQs)

- Q.14** Signal conditioning of transmitters signal is important for faithful production of an output. Which of the following is/are performed in signal conditioning circuit :
- (a) Amplification
 - (b) Calibration & Zeroing
 - (c) Filtering
 - (d) Controlling

- Q.15** A Hall effect transducer is used to measure
- (a) Power
 - (b) Current
 - (c) Displacement
 - (d) Minority carriers in a semiconductors

- Q.16** For a seismic transducer natural frequency has to be increased. This could be achieved by
- (a) Increasing damping
 - (b) Increasing spring constant
 - (c) Increasing seismic mass
 - (d) Decreasing damping

- Q.17** Which of the following devices are non-contact type level transmitters :
- (a) Ultrasonic level meters
 - (b) Vibrating tuning fork
 - (c) Guided wave radar
 - (d) Nuclear level meters



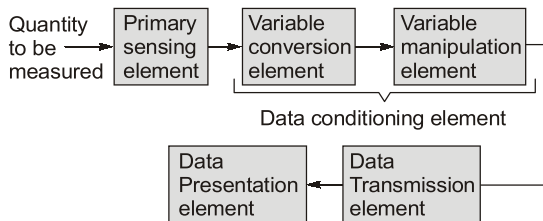
Answers Introduction to Transducers

1. (b) 2. (d) 3. (a) 4. (d) 5. (a) 6. (d) 7. (b)
 8. (c) 9. (b) 10. (c) 11. (a) 12. (d) 13. (a) 14. (a, b, c)
 15. (a, b, c, d) 16. (b, c) 17. (a, d)

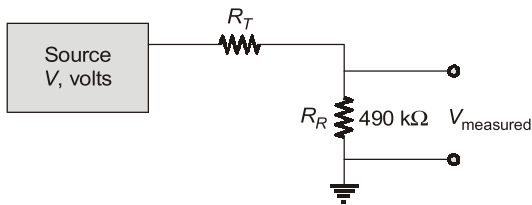
Explanations Introduction to Transducers

1. (b)

Functional elements of a measurement system are shown below:



12. (d)



For no error – R_R (Recorder resistance) should be very high and R_T (Transducer resistance) should be very low

$$V - \frac{490}{490 + R_T} \times V$$

$$\frac{\quad}{V} \times 100 = 1$$

$$\frac{V(490 + R_T) - 490 V}{(490 + R_T)V} \times 100 = 1$$

$$(490 + R_T - 490) 100 = 490 + R_T$$

$$100 R_T = 490 + R_T$$

$$99 R_T = 490$$

$$R_T = \frac{490}{99} \text{ k}\Omega = 4.9 \text{ k}\Omega$$

13. (a)

We have

$$\xi = \frac{B}{2} \sqrt{KM}$$

and

$$\omega_n = \sqrt{KM}$$

So, since ω_n is constant, \sqrt{KM} is constant.

So, to double damping factor ξ we need to double damping B .

16. (b, c)

$$\omega_n = \sqrt{KM}$$

So,

$$\omega_n \propto \sqrt{K}$$

and

$$\omega_n \propto \sqrt{M}$$

So, to increase ω_n , we need to increase either seismic mass as spring.

17. (a, d)

- (i) Guided wave radar has sensor tube which touches the liquid.
- (ii) Vibrating tuning fork changes its natural frequency of oscillation when liquid comes in contact.



OPTICAL INSTRUMENTATION

OBJECTIVE PRACTICE SETS

Page No. 190 - 218

Basic Optics

MCQ and NAT Questions

- Q.1** The refractive indices of glass and water are 1.50 and 1.33, respectively. The relative refractive index of water with respect to glass is ____.
- Q.2** Light is made to travel in glass having a refractive index of 1.72. The velocity of light in vacuum is 3×10^5 km/sec. The time taken by the light to travel a distance of 750 km in this glass is ____ msec.
- Q.3** A laser light with a wavelength of 633 nm is passed through 1 cm length of tissue and 2 cm length of glass. The refractive index of tissue and glass are 1.33 and 1.5 respectively. The velocities of laser light in the tissue and in the glass are in the ratio of
 (a) 1.33 : 0.75 (b) 1.33 : 3.00
 (c) 1.33 : 1.50 (d) 1.50 : 1.33
- Q.4** A light ray incident on air-glass interface. With an angle of 30° . If glass refractive index is 1.5. Find the refracted angle.
 (a) 20.30° (b) 18.70°
 (c) 19.47° (d) 21.80°
- Q.5** Light incident on a glass plate at an angle of 60° after reflection it gets plane polarized. The RI of glass plate is
 (a) 1.33 (b) 1.7372
 (c) 3.5 (d) 0.866
- Q.6** A light beam incident normally at a glass air interface. Glass has refractive index of 1.53 and air has refractive index of 1 then the loss of intensity through reflection is
 (a) 5.1% (b) 4.3%
 (c) 2.8% (d) 20.94%
- Q.7** If an unpolarized light of intensity 4 Cd is incident on a polarizer, then the intensity of light transmitted out from the polarizer is
 (a) 2 Cd
 (b) $\frac{4}{3}$ Cd
 (c) 1 Cd
 (d) can't be determined until angle of incidence is not given
- Q.8** The polarized light produced when two orthogonal coherent waves having different amplitudes and a constant phase difference of 90° superposed on each other is known as
 (a) circularly polarized light
 (b) partially polarized light
 (c) linearly polarized light
 (d) elliptically polarized light
- Q.9** When a light beam is made to incident on a surface which is rough as compared with the wavelength of light
 (a) specular reflection take place
 (b) transmittance takes place
 (c) absorption takes place
 (d) diffused reflection takes place
- Q.10** A beam of unpolarized light is first passed through a linear polarizer and then through a quarterwave plate. The emergent beam is
 (a) unpolarized
 (b) linearly polarized
 (c) circularly polarized
 (d) elliptically polarized
- Q.11** The dispersion in an X-ray diffractometer, $d\theta/d\lambda$ is given by the expression
 (a) $\frac{m}{2d \cos\theta}$ (b) $\frac{m}{2d \sin\theta}$
 (c) $2d \sin\theta$ (d) $2d \cos\theta$
- Q.12** Light of wavelength 630 nm in vacuum, falling normally on a biological specimen of thickness 10 μm , splits into two beams that are polarized at right angles. The refractive index of the tissue for the two polarizations are 1.32 and 1.333. When the two beams emerge, they are out of phase by

- (a) 0.13° (b) 74.3°
(c) 90.0° (d) 128.6°

Q.13 A grating that has 1200 lines/mm is irradiated with a narrow beam of white light at an incident angle of 25° to the grating normal. The first order peak observed at an angle of 15° belongs to the wavelength

- (a) 567.9 nm (b) 587.8 nm
(c) 597.1 nm (d) 600.7 nm

Q.14 A light beam is incident normally on a glass-air interface. The glass has refractive index 1.53. Air is assumed to be of refractive index 1.0. The Fresnel, intensity reflection coefficient is

- (a) 0.53 (b) 0.25
(c) 0.044 (d) 0.022

Q.15 Brewster angle is the angle of incidence of monochromatic light at the interface of two media, for which

- (a) the incidence beam would be totally internally reflected
(b) a polarized beam would become unpolarised after reflected
(c) an unpolarised beam would become polarized after reflected
(d) none of the above

Q.16 For a glass of refractive index 1.732, the angle of incidence of ordinary light, for which the reflected beam is completely polarized is

- (a) 30 degrees (b) 60 degrees
(c) 45 degrees (d) 75 degrees

Q.17 When light passes from a medium of refractive index n_1 into a medium of refractive index n_2 , the reflection at the boundary is expressed as

- (a) $(n_2 - n_1)^2$ (b) $\left(\frac{n_2 - n_1}{n_2 + n_1}\right)^2$
(c) $\frac{1}{(n_2 - n_1)^2}$ (d) $(n_2 + n_1)^2$

Q.18 Two crossed polarizer's are placed in the part of a light beam. The light output is

- (a) zero
(b) plane polarized
(c) circularly polarized
(d) elliptically polarized

Q.19 The minimum number of lines that must be drawn on a grating needed to resolve the Sodium

Doublet having nominal wavelengths of 589.0 nm and 589.6 nm is

- (a) 600 (b) 1200
(c) 982 (d) 300

Q.20 To a swimmer viewing a Sodium lamp beside the pool. The colour of the lamp seen from underneath the water appears:

- (a) Yellow
(b) Yellow with a reddish
(c) Yellow with a greenish tinge
(d) White

Q.21 The refractive indices of glass and water are 1.50 and 1.33, respectively. If the glass is immersed in water, its relative refractive index is

- (a) 0.89 (b) 1.13
(c) 1.33 (d) 2.83

Q.22 Light is incident on a glass plate of refractive index 1.732. It is plane polarized on reflection when the incidence angle is

- (a) 30° (b) 45°
(c) 60° (d) 75°

Multiple Select Questions (MSQs)

Q.23 Which is/are the role of fiber optics technology?

- (a) In voice and video communication
(b) In data transfer
(c) In military defence
(d) In transportation

Q.24 A light ray is incident in a fiber optic cable from medium-1 to medium-2. The refractive indices of medium-1 and medium-2 are 1.45 and 1.3 respectively. So,

- (a) Medium-1 is core and medium-2 is cladding.
(b) Medium-1 is cladding and medium-2 is core.
(c) Acceptance angle of fiber is 41.26°.
(d) Critical angle of fiber is 63.70°.

Q.25 Choose the correct statement(s) regarding optical detector.

- (a) Optical detectors works on the principle of optical absorption.
(b) For fiber optic communication purpose most suited photodetector is PN diode as compared to PIN diode.
(c) PIN detectors can be operated in photovoltaic and photoconductive mode.
(d) Avalanche photodiode is a type of optical detector.

Answers Basic Optics

1. (0.89) 2. (4.31) 3. (d) 4. (c) 5. (b) 6. (b) 7. (a)
 8. (d) 9. (d) 10. (c) 11. (a) 12. (a) 13. (a) 14. (c)
 15. (c) 16. (b) 17. (b) 18. (a) 19. (c) 20. (a) 21. (b)
 22. (c) 23. (a, b, c, d) 24. (a, c, d) 25. (a, c, d)

Explanations Basic Optics

1. (0.89)

$$\begin{aligned} \mu_g &= 1.50 \\ \mu_w &= 1.33 \\ {}_g\mu_w &= \frac{\mu_w}{\mu_g} = \frac{1.33}{1.50} = 0.89 \end{aligned}$$

2. (4.31)

Velocity of light in vacuum
 $= 3 \times 10^5 \text{ km/sec}$
 $= 3 \times 10^8 \text{ m/sec}$

Velocity of light in this glass
 $= \frac{3 \times 10^8}{1.72} = 1.74 \times 10^8 \text{ m/sec}$

Time taken $= \frac{750 \times 10^3}{1.74 \times 10^8}$
 $= 4.31 \times 10^{-3} \text{ sec}$
 $= 4.31 \text{ msec}$

3. (d)

$$\begin{aligned} \mu_T &= 1.33 \\ \mu_g &= 1.5 \\ \therefore \mu &\propto \frac{1}{v} \\ \frac{v_T}{v_g} &= \frac{\mu_g}{\mu_T} = \frac{1.50}{1.33} \end{aligned}$$

4. (c)

By Snell's law,
 $n_1 \sin\theta_i = n_2 \sin\theta_r$
 $\sin\theta_r = \frac{n_1}{n_2} \sin\theta_i$
 $\sin\theta_r = \frac{1}{1.5} \times \frac{1}{2}$
 $\theta_r = 19.47^\circ$

5. (b)

By Brewster's law
 $\mu = \tan(i)$
 $\mu = \tan 60 = 1.732$

6. (b)

Total % reflection loss
 $= \left[\frac{\mu_2 - \mu_1}{\mu_2 + \mu_1} \right]^2 \times 100\%$

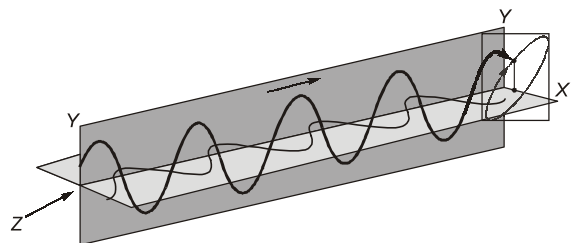
Reflection loss (RL)
 $= \left[\frac{1.53 - 1}{1.53 + 1} \right]^2 = \left[\frac{0.53}{2.53} \right]^2 = 0.043$
 $RL = 0.043 \times 100$
 $= 4.3\%$

7. (a)

Intensity of light transmitted out from the polarizer is given by

$$I = \frac{I_0}{2} = \frac{4}{2} = 2 \text{ Cd}$$

8. (d)



Elliptically polarized light is the resultant of two coherent waves having different amplitudes and a constant phase difference of 90° as shown in above figure.

11. (a)

$$2d \sin\theta = m\lambda \quad (\text{Bragg's law})$$

differentiating with respect to λ

$$2d \cos\theta \frac{d\theta}{d\lambda} = m$$

$$\boxed{\frac{d\theta}{d\lambda} = \frac{m}{2d \cos\theta}}$$

12. (a)

By Brewster's Law,

$$\theta_1 = \tan^{-1} 1.32 = 52.85$$

$$\theta_2 = \tan^{-1} 1.333 = 53.12$$

$$\Delta\theta = \theta_2 - \theta_1 = 53.12 - 52.85 \\ = 0.27^\circ$$

So, the most nearby answers is (a).

13. (a)

$$n\lambda = d(\sin i + \sin r)$$

$$d = \frac{1}{200} = 8.33 \times 10^{-4} \text{ m}$$

$$= 8.33 \times 10^{-7} \text{ mm}$$

$$\therefore \lambda = 8.33 \times 10^{-7} \times (\sin 25^\circ + \sin 15^\circ) \\ = 567.9 \text{ nm}$$

14. (c)

$$R = \left(\frac{n_2 - n_1}{n_2 + n_1} \right)^2 = \left(\frac{1.53 - 1.00}{1.53 + 1.00} \right)^2$$

$$\therefore R = 0.044$$

16. (b)

For the light beam to be completely polarized, according to Brewster's law.

$$\text{Angle of incidence (i)} = \tan^{-1}(\mu) \\ = \tan^{-1}(1.732) \\ = 60^\circ$$

19. (c)

The maximum number of lines required are

$$\frac{\text{mean}(\lambda_1, \lambda_2)}{\lambda_1 - \lambda_2} = \frac{589.6 + 589}{2} \\ (589.6 - 589) \\ = \frac{589.3}{0.6} = 982.16 \approx 982$$

21. (b)

$$\mu_g = 1.50$$

$$\mu_w = 1.33$$

$$\frac{\mu_g}{\mu_w} = \frac{1.50}{1.33} = 1.13$$

22. (c)

By Brewster's law,

$$\mu = \tan(i)$$

$$\therefore i = \tan^{-1}(\mu) \\ = \tan^{-1}(1.732) = 60^\circ$$

23. (a, b, c, d)

Fiber optics technology plays a direct role in voice and video communication and data transfer and plays an indirect role in entertainment, transportation, health care, military defence and in education process.

24. (a, c, d)

In fiber optic communication

$$\mu_{\text{core}} > \mu_{\text{cladding}}$$

So, medium-1 is core having $\mu_1 = 1.45$ and medium-2 is cladding having $\mu_2 = 1.3$.

Acceptance angle

$$\theta_o = \sin^{-1} NA$$

$$NA = \mu_1 \sqrt{\frac{2(\mu_1 - \mu_2)}{\mu_1}}$$

$$NA = 1.45 \sqrt{\frac{2(1.45 - 1.3)}{1.45}} \approx 0.659$$

$$\theta_o = \sin^{-1} NA$$

$$\theta_o = 41.26^\circ$$

$$\text{Critical angle, } \theta_c = \sin^{-1} \left(\frac{\mu_2}{\mu_1} \right)$$

$$\theta_c = \sin^{-1} \left(\frac{1.3}{1.45} \right)$$

$$\theta_c \approx 63.70^\circ$$

25. (a, c, d)

For fiber optic communication purpose most suited photodetectors are PIN diode and avalanche photodiode.

