DETAILED SOLUTIONS

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ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

ELECTRICAL ENGINEERING

Test 14

Section A : Systems & Signal Processing + Communication Systems [All Topics]
Section B : BEE-1 + Analog Electronics-1 + Elec. & Electro. Measurements-1 [Part Syllabus]
Section C : Power Electronics and Drives-2 [Part Syllabus]

ANSWER KEY

1.	(b)	**16.**	(b)	**31.**	(b)	**46.**	(c)	**61.**	(c)
2.	(c)	**17.**	(a)	**32.**	(b)	**47.**	(c)	**62.**	(b)
3.	(a)	**18.**	(c)	**33.**	(d)	**48.**	(d)	**63.**	(b)
4.	(c)	**19.**	(a)	**34.**	(b)	**49.**	(a)	**64.**	(c)
5.	(c)	**20.**	(a)	**35.**	(d)	**50.**	(a)	**65.**	(c)
6.	(d)	**21.**	(c)	**36.**	(a)	**51.**	(b)	**66.**	(a)
7.	(c)	**22.**	(a)	**37.**	(b)	**52.**	(c)	**67.**	(a)
8.	(a)	**23.**	(a)	**38.**	(b)	**53.**	(d)	**68.**	(a)
9.	(d)	**24.**	(c)	**39.**	(a)	**54.**	(d)	**69.**	(c)
10.	(a)	**25.**	(d)	**40.**	(b)	**55.**	(a)	**70.**	(a)
11.	(c)	**26.**	(a)	**41.**	(b)	**56.**	(a)	**71.**	(c)
12.	(d)	**27.**	(c)	**42.**	(b)	**57.**	(b)	**72.**	(c)
13.	(c)	**28.**	(b)	**43.**	(c)	**58.**	(c)	**73.**	(d)
14.	(d)	**29.**	(a)	**44.**	(d)	**59.**	(a)	**74.**	(d)
15.	(a)	**30.**	(b)	**45.**	(c)	**60.**	(c)	**75.**	(d)

DETAILED EXPLANATIONS

Section A : Systems & Signal Processing + Communication Systems

1. (b)

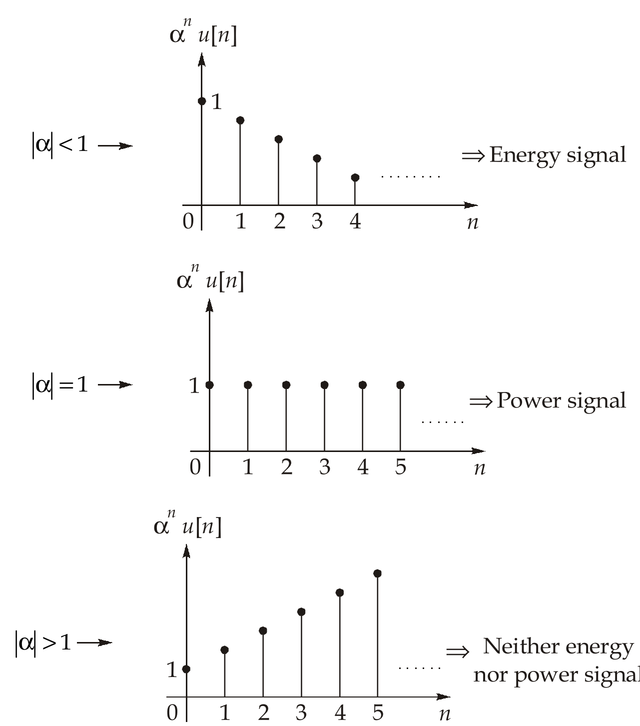
We have, $$x(t) = \underset{\substack{\downarrow \\ T_1 = 3}}{2\cos\left(\frac{2\pi}{3}t\right)} + \underset{\substack{\downarrow \\ T_2 = 2}}{\sin(\pi t)}$$

$\therefore$ Fundamental time period "T" = LCM$[T_1, T_2]$

= LCM [3, 2] = 6

Now, fundamental frequency of the signal is $\omega_0 = \frac{2\pi}{6} = \frac{\pi}{3}$ rad/s

2. (c)



3. (a)

We know,

$$\int_{t_1}^{t_2} x(t)\cdot\delta^m(t-t_0)\,dt = (-1)^m \frac{d^m}{dt^m}x(t)\bigg|_{t=t_0}$$

where, 'm' is the order of differentiation and $t_1 < t_0 < t_2$; otherwise integration attains '0' value

$$\therefore \qquad \int_2^4 t^3\cdot\ddot{\delta}(t-5)\,dt = 0$$

4. (c)

Given,

$$x[n] = 5\,\delta[n] + \delta[n-2]$$

$$h[n] = (0.1)^n\, u[n]$$

$\therefore$ Output, $y[n] = x[n] * h[n]$

$$= \{5\,\delta[n] + \delta[n-2]\} * \{(0.1)^n\, u[n]\}$$

$$= \{5\,\delta[n] * (0.1)^n\, u[n]\} + \{\delta[n-2] * (0.1)^n\, u[n]\}$$

$$= \underbrace{5(0.1)^n u[n]}_{n\geq 0} + \underbrace{(0.1)^{n-2} u[n-2]}_{n\geq 2}$$

At $n = 1$:

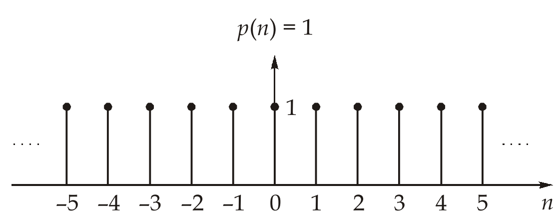
$$y[1] = 5(0.1)^1 = 0.5$$

At $n = 2$:

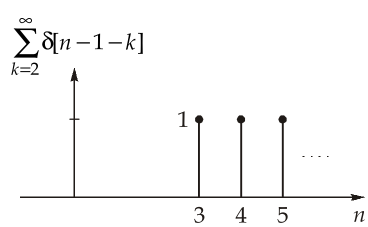
$$y[2] = 5 \times (0.1)^2 + 1 = 1.05$$

5. (c)

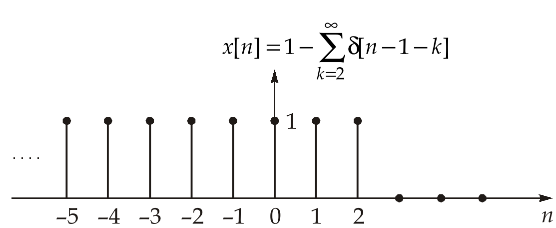
Step-1 :



Step-2 :



Step-3 :



$\Rightarrow$ $x[n] = u[-(n-2)] = u[-n+2]$

On comparing with $u[An - b_0]$,

$$A = -1,$$

$$b_0 = -2$$

$\Rightarrow$ $(A + b_0) = (-1 - 2) = -3$

6. **(d)**

Using time scaling property of Fourier series,

$$x(t) \xrightarrow{F.S.} a_k$$

$$y(t) \xrightarrow{F.S.} b_k$$

We know, $x(10t) \rightarrow a_k$ ($\because$ time scaling property)

$\Rightarrow$ $a_k = b_k$

$\therefore$ $$\sum_{k=-\infty}^{+\infty} |a_k| = \sum_{k=-\infty}^{+\infty} |b_k| = 215$$

7. **(c)**

Given, $T = 4$

We know, $$x(t) = \sum_{n=-\infty}^{+\infty} C_n e^{\frac{jn2\pi}{T}t}$$

$\Rightarrow$ $$x(t) = \sum_{n=-\infty}^{+\infty} [\delta(n-2)+\delta(n+2)+j\delta(n-4)-j\delta(n+4)]e^{\frac{jn2\pi}{4}t}$$

$\Rightarrow$ $$x(t) = \sum_{n=-\infty}^{\infty} [\delta(n-2)+\delta(n+2)+j\delta(n-4)-j\delta(n+4)]e^{j\frac{\pi}{2}nt}$$

$$\left[\sum_{n=-\infty}^{\infty} \delta(n-n_0)e^{jn\alpha t} = \sum_{n=-\infty}^{\infty} \delta(n-n_0)e^{jn_0\alpha t} = e^{jn_0\alpha t}\sum_{n=-\infty}^{\infty} \delta(n-n_0) = e^{jn_0\alpha t}\cdot 1\right]$$

$\therefore$ $$x(t) = e^{j\frac{\pi}{2}(2)t} + e^{j\frac{\pi}{2}(-2)t} + je^{j\frac{\pi}{2}(4)t} - je^{j\frac{\pi}{2}(-4)t}$$

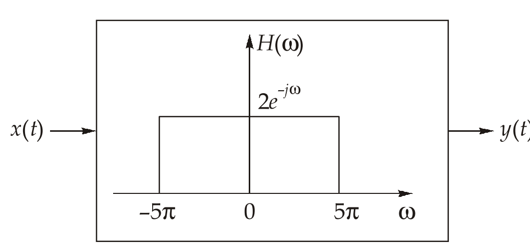
$$= 2\left[\frac{e^{j\pi t}+e^{-j\pi t}}{2}\right] - 2\left[\frac{e^{j2\pi t}-e^{-j2\pi t}}{j2}\right]$$

$$x(t) = 2\cos\pi t - 2\sin 2\pi t$$

8. **(a)**

Given, $h(t) = 10 \text{ sinc } [5(t-1)]$

$\Rightarrow$ $$h(t) = \frac{10\sin\pi[5(t-1)]}{\pi[5(t-1)]} = \frac{2\sin\pi[5(t-1)]}{\pi[(t-1)]}$$



∴ Output of the system is,

$$y(t) = 2\cos[3\pi(t-1)]$$

9. (d)

We know,

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

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

$$\Rightarrow \quad \int_{-\pi}^{\pi} X(e^{j\omega})\cdot e^{j2\omega}d\omega = 2\pi\, x[2] = 2\pi\,(2) = 4\pi$$

10. (a)

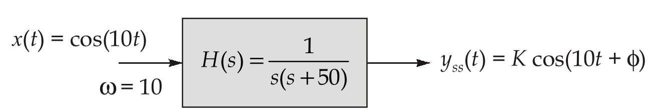
$$\begin{aligned} H(z) &= H_1(z)\cdot H_2(z) \\ &= (1 - Az^{-1})\cdot(1 + Bz^{-1}) \\ &= 1 + Bz^{-1} - Az^{-1} - ABz^{-2} \\ &= 1 + (B - A)z^{-1} - ABz^{-2} \end{aligned}$$

$$\Rightarrow \quad h[n] = \{\underset{\uparrow}{1}, (B-A), -AB\}$$

∴ On comparing, $-AB = -1$

$\Rightarrow$ $AB = 1$

11. (c)



$$H(s)\big|_{s=j\omega=j10} = \frac{1}{j10(j10+50)}$$

$$\Rightarrow \quad K = |H(s)| = \frac{1}{10\sqrt{10^2+50^2}} = \frac{0.1}{\sqrt{2600}} = \frac{0.01}{\sqrt{26}}$$

12. (d)

We know,
$$\frac{\Omega_{PB}}{\Omega_{SB}} = \frac{\frac{2}{T}\tan\left(\frac{\omega_{PB}}{2}\right)}{\frac{2}{T}\tan\left(\frac{\omega_{SB}}{2}\right)}$$

$$\Rightarrow \qquad \frac{\Omega_{PB}}{\Omega_{SB}} = \frac{\tan\left(\frac{2\pi\times 2K}{2\times 8K}\right)}{\tan\left(\frac{2\pi\times 6K}{2\times 8K}\right)} = \frac{\tan\left(\frac{\pi}{4}\right)}{\tan\left(\frac{3\pi}{4}\right)} = \frac{1}{\tan\left(\frac{3\pi}{4}\right)}$$

$$= \cot\left(\frac{3\pi}{4}\right)$$

13. (c)

We know, $$X(k) = \sum_{n=0}^{N-1} x[n]e^{-j\frac{2\pi nk}{N}}$$

$$\Rightarrow \qquad X(0) = \sum_{n=0}^{N-1} x[n]e^{-j0} = \sum_{n=0}^{N-1} x[n]$$

$$\Rightarrow \qquad X(0) = \sum_{n=0}^{8-1}\left[\frac{3+\cos\left(\frac{8\pi n}{N}\right)}{2}\right] = \sum_{n=0}^{7}\left[\frac{3+\cos\left(\frac{8\pi n}{N}\right)}{2}\right]$$

$$= \sum_{n=0}^{7}\left(\frac{3}{2}+\frac{1}{2}(-1)^n\right)$$

$$= \left[8\times\frac{3}{2}\right]+\frac{1}{2}-\frac{1}{2}+\frac{1}{2}-\frac{1}{2}+\frac{1}{2}-\frac{1}{2}+\frac{1}{2}-\frac{1}{2}$$

$$= \frac{24}{2} = 12$$

15. (a)

Using Parseval's theorem,

$$P = \sum_{n=0}^{N-1}|x[n]|^2 = \frac{1}{N}\sum_{k=0}^{N-1}|X(k)|^2$$

$$14 = \frac{1}{4}\sum_{k=0}^{3}|X(k)|^2$$

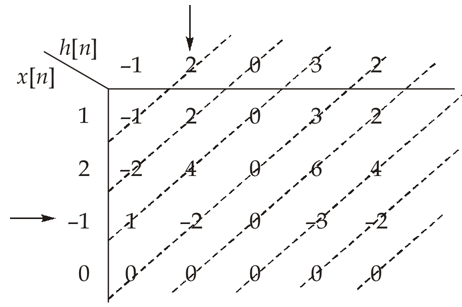
$$56 = (6)^2 + (X^2+Y^2) + (-2)^2 + (X^2+Y^2)$$

$$\Rightarrow \qquad 2(X^2+Y^2) = 56 - 36 - 4$$

$$\Rightarrow \qquad X^2+Y^2 = \frac{16}{2} = 8$$

16. (b)

We know; $$y[n] = x[n] * h[n]$$



$$y[n] = \{-1, 0, 5, \underset{\uparrow}{1}, 8, 1, -2, 0\}$$

$\therefore$ $$y[0] = 1$$

17. (a)

We know, $e^{-a|t|} \xleftrightarrow{FT} \dfrac{2a}{\omega^2 + a^2}$

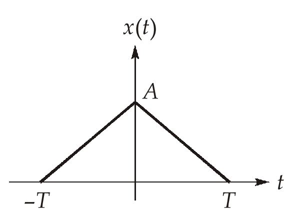
$\because$ $$G(\omega) = \frac{2}{\omega^2 + 2^2} = \frac{1}{2}\left[\frac{2\cdot(2)}{\omega^2 + 2^2}\right]$$

Taking inverse Fourier transform

$$g(t) = \frac{1}{2}\cdot e^{-2|t|}$$

at $t = 0$ $$g(0) = \frac{1}{2} = 0.5$$

18. (c)



$\xleftrightarrow{FT} AT\,\text{sinc}^2(fT)$

When; $$x(t) = A\ \text{tri}\left(\frac{t}{T}\right)$$

$$X(f) = AT\ \text{sinc}^2(fT)$$

$\because$ $$X(f) = 2\ \text{sinc}^2(f)$$

$\therefore$ $$A = 2,\ T = 1$$

hence, $$x(t) = 2\ \text{tri}(t)$$

19. (a)

Given the differential equation,

$$\frac{d^2y(t)}{dt} + \frac{5dy(t)}{dt} + 4y(t) = x(t)$$

Taking Laplace transformer on both sides and neglecting the initial conditions for forced response, we have

$$[s^2 + 5s + 4]Y(s) = \frac{3}{s}$$

$$Y(s) = \frac{3}{s(s+1)(s+4)}$$

$$Y(s) = \frac{3}{4s} + \frac{1}{4(s+4)} - \frac{1}{s+1}$$

$$\Rightarrow \qquad y(t) = \left[\frac{3}{4} + \frac{e^{-4t}}{4} - e^{-t}\right]u(t)$$

$$= \frac{1}{4}[3 - 4e^{-t} + e^{-4t}]u(t)$$

20. (a)

The given transfer function is

$$H(z) = \frac{2z(3z-4)}{(2z-1)(z-3)}, \qquad |z| > 3$$

$$\frac{H(z)}{z} = \frac{6z-8}{(2z-1)(z-3)}$$

Using partial fraction we get,

$$\frac{H(z)}{z} = \frac{A}{2z-1} + \frac{B}{z-3}$$

$$A = \left.\frac{6z-8}{z-3}\right|_{z=1/2} = \frac{-5}{-5/2} = 2$$

$$B = \left.\frac{6z-8}{2z-1}\right|_{z=3} = \frac{10}{5} = 2$$

$$H(z) = \frac{2z}{2z-1} + \frac{2z}{z-3} = \frac{1}{1-0.5z^{-1}} + \frac{2}{1-3z^{-1}}$$

For $|z| > 3$

ROC is outside the outermost pole hence it is causal. It does not include unit circle, therefore, it is not stable.

$\therefore$ option (a) is correct.

21. (c)

Let $x[n] = ax_1[n] + bx_2[n]$

then $y[n] = ax_1[n-1] + bx_2[n-1]$

$= ay_1[n] + by_2[n]$

∴ System is linear.

22. (a)

Energy of the signal, $$E = \int_{-\infty}^{\infty} |x(t)|^2\, dt = \int_{-2}^{0} (t-2)^2\, dt + \int_{0}^{2} (2-t)^2\, dt$$

$$= \frac{64}{3} \text{ Joules}$$

Power of the signal, $$P = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} |x(t)|^2\, dt = \lim_{T\to\infty} \frac{1}{2T}\left[\frac{64}{3}\right] = 0$$

Since energy is finite and power is zero, it is an energy signal.

23. (a)

Impulse response of the system is

$$h(t) = e^{-4t}\, u(t)$$

The transfer function of the system is

$$H(\omega) = F\left[e^{-4t}u(t)\right] = \frac{1}{j\omega + 4}$$

Input to the system is:

$$x(t) = 3e^{-t}\, u(t)$$

$$X(\omega) = 3F\left[e^{-t}u(t)\right] = 3 \times \frac{1}{j\omega + 1}$$

$$Y(\omega) = H(\omega)\, X(\omega)$$

$$= \frac{1}{j\omega + 4} \cdot \frac{3}{j\omega + 1} = \frac{3}{(j\omega + 4)(j\omega + 1)}$$

So the output of system is:

$$y(t) = F^{-1}[Y(\omega)]$$

$$Y(\omega) = \frac{3}{(j\omega + 4)(j\omega + 1)} = \frac{A}{j\omega + 4} + \frac{B}{j\omega + 1}$$

$$= \frac{1}{j\omega + 1} - \frac{1}{j\omega + 4}$$

Taking inverse fourier transform on both sides we get the output of system as:

$$y(t) = e^{-t}\, u(t) - \mathrm{e}^{-4t}\, u(t)$$

24. (c)

Information content in a signal will be high if its probability of occurrence is less. If the probability of occurrence of message is P. Then its information content I will be

$$I = \log_2 \frac{1}{P} \text{ bits} = -\log_2 P \text{ bits}$$

25. (d)

Message signal, $m(t) = 5 \cos (2\pi \times 1000t)$

$$f_m = 1000 \text{ Hz}$$

$$\text{B.W.} = 2f_m = 2 \times 1000 = 2 \text{ kHz}$$

26. (a)

The signal $x(t)$ is band limited to

$$f_m = 10 \text{ kHz}$$

According to the Nyquist sampling theorem, to avoid aliasing, the sampling frequency. f_s must be at least-twice the highest frequency component present in the signal.

$$f_s \geq 2 f_m$$

$$f_s \geq 2 \times 10 \text{ kHz}$$

$$f_s \geq 20 \text{ kHz}$$

So minimum sampling frequency is 20 kHz

27. (c)

$$f_{IF} = 455 \text{ KHz}$$

$$f_s = 10 \text{ MHz}$$

high side mixing, $f_{IF} = |f_{LO} - f_S|$

$$f_{LO} = (f_{IF} + f_S) = (455 + 10 \times 10^3) \text{ kHz}$$

$$= 10.455 \text{ MHz}$$

At low side mixing,

$$f_{LO} = F_S - F_{IF} = (10 - 0.455) \text{ MHz}$$

$$= 9.545 \text{ MHz}$$

28. (b)

$$(\text{SNR})_{\text{in}} = 60 \text{ dB}$$

$\Rightarrow$ $(\text{SNR})_{\text{in}} = 10^6$

$$\eta = 80\% = 0.8$$

$$\text{SNR}_{\text{out}} = ?$$

The demodulation efficiency η is given by

$$\eta = \frac{(SNR)_{\text{out}}}{(SNR)_{\text{in}}}$$

$$(\text{SNR})_{\text{out}} = \eta \times \text{SNR}_{\text{in}} = 0.8 \times 10^6$$
$$= 8 \times 10^5$$
$$(\text{SNR})_{\text{out}} \text{ (dB)} = 59 \text{ dB}$$

29. (a)

Given, $K_p = 2.5$ rad/V

$$V_m(t) = 2\cos(2\pi \times 2000t)$$
$$\text{Peak phase deviation} = K_p A_m$$
$$= 2.5 \times 2 = 5 \text{ rad}$$

30. (b)

- The modulation index (β) in NBFM is defined as :

$$\beta = \frac{\Delta f}{f_m} << 1$$

- For NBFM, the approximate bandwidth is given by:

$$B_T \approx 2f_m$$

- This is in constrast to wide band FM (WBFM), which has a much larger bandwidth given by, Carson's rule,

$$B_T \approx 2(\Delta f + f_m)$$

- Wideband FM (WBFM) bas better noise immunity than NBFM due to its larger frequency deviation.
- The improvement in noise immunity is given by the figure of merit in FM, which is proportional to the square of the modulation index i.e. β^2.
- Since NBFM has a lower β, it offers poorer noise immunity than WBFM.
- NBFM does not have better power efficiency than AM.

31. (b)

Given, $N = 6$

and $f_m = 4$ kHz

$$\text{Signalling rate} = \frac{R_b}{n} = Nfs$$
$$f_s = 2\,f_m = 8 \text{ kHz}$$

∴ signalling rate = 6 × 8 k = 48 kbps

Minimum transmission bandwidth required

$$B_T = Nf_m = 6 \times 4 \text{ k} = 24 \text{ kHz}$$

32. (b)

Signal to quantization error (dB) for a PCM system

$$(SQNR)_{\text{dB}} = 1.8 + 6.02\,n$$
$$1.8 + 6.02n \geq 80$$

$$6.02n \geq 78.2$$
$$n \geq 12.99$$
$$n_{\min} = 13$$
$$\text{Number of levels} = L = 2^n = 2^{13} = 8192$$

33. (d)

$$\text{No. of bits} = 8 \text{ bits}$$
$$\text{No. of levels} = 2^8 = 256$$
$$\text{Step, } \Delta = \frac{2-(-2)}{2^8} = \frac{4}{256}$$

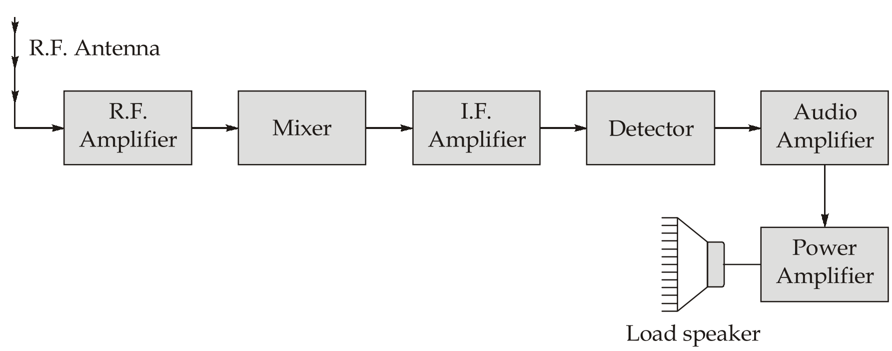
34. (b)

$$H = \sum_i P_i \log_2 \frac{1}{P_i} = \frac{1}{4}\log_2 4 + \frac{1}{4}\log_2 4 + \frac{1}{2}\log_2 2$$
$$= \frac{3}{2} \text{ bits/symbol}$$

35. (d)

$$\text{Bandwidth} = \frac{R_b}{N}(1+\alpha)$$
$$\alpha = 1 \text{ for } 50\% \text{ excess bandwidth}$$
$$20 \text{ kHz} = \frac{300\,\text{Kbps}}{N}(1+0.5)$$
$$N = 22.5 \text{ bits} \approx 23$$
$$\text{No. of symbols (M)} = 2^N = 2^{23}$$

36. (a)



37. (b)

When a white noise is applied as input an LTI system, the output need not to be a white noise.

38. (b)

The increasing order of the probability of error in data transmission is as PSK < DPSK < FSK < ASK.

39. (a)

A transponder is responsible for:

- Receiving the uplink signal.
- Amplifying and converting its frequency.
- Transmitting it back as a downlink signal.

Key components include:

- Receiver (LNA - Low noise amplifier)
- Frequency converter (local oscillator and mixer)
- Power amplifier (TWTA or SSPA)

40. (b)

Signal most likely gets affected by noise in channel in communication system.

41. (b)

From the given equation,

$$A_c = 40$$

$$\frac{\mu A_c}{2} = 10$$

$$\mu(40) = 20$$

Modulation index, $\mu = 0.50$

42. (b)

$$\text{Average power of } x(t) = \frac{A^2}{2} = \frac{6^2}{2} = 18\,\text{W}$$

43. (c)

$$(\Delta SNQR)_{\text{dB}} = (SNQR)_{8\text{-bit}} - (SNQR)_{7\text{-bit}}$$

$$= 1.67 + 6 \times 8 - 1.67 - 6 \times 7$$

$$(\Delta SNQR)_{\text{dB}} = 6 \text{ dB}$$

44. (d)

Statement-I is false statement-II is true.

The z-transform exists for some signals that do not have a DTFT. By limiting to a certain range of values of r, we may ensure that $x[n]r^{-n}$ is absolutely summable, eventhough $x[n]$ is not absolutely summable by itself.

45. (c)

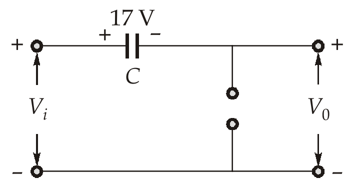
M-ary PSK and M-ary QAM are linear modulation schemes. An M-ary PSK signal has a constant envelope, whereas an M-ary QAM signal involves changes in the carrier amplitude. Accordingly, M-ary PSK can be used to transmit digital data over a non-linear band-pass channel. Whereas M-ary QAM requires the use of a linear channel.

Section B : BEE-1 + Analog Electronics-1 + Electrical & Electronic Measurements-1

46. (c)

Once the capacitor is fully charged to 17 V (during positive half cycle), it remains charged fully as the diode will not allow to discharge it in reverse biase (negative half cycle)

$\therefore D \rightarrow$ off



By KVL,
$$V_0 = V_i - 17$$
$$= 10 + 7 \sin \omega t - 17$$
$$V_0 = -7 + 7 \sin \omega t$$

$\therefore$ average output voltage,

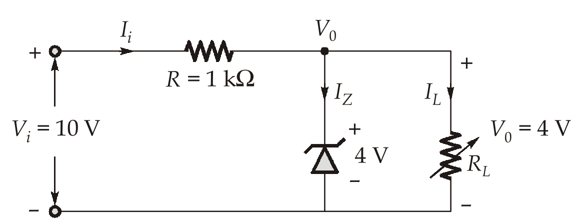
$$(V_0)_{avg} = -7 \text{ volts} \quad (\because \text{average value of } \sin \omega t \text{ is zero})$$

47. (c)

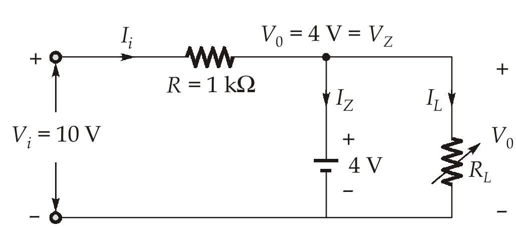
Transconductance,
$$g_m = g_{m0}\left(1 - \frac{V_{GS}}{V_P}\right)$$
$$= \frac{g_m}{\left(1 - \frac{V_{GS}}{V_P}\right)} = \frac{1}{\left[1 - \left(\frac{-3}{-4}\right)\right]} = 4 \text{ mA/V}$$

48. (d)

R_L : 1 kΩ to 10 kΩ



For every value of R_L between 1 kΩ and 10 kΩ Zener diode will be in breakdown region



$\therefore$
$$I_i = \frac{V_i - V_z}{R} = \frac{10 - 4}{1\text{k}} = 6 \text{ mA}$$

Minimum power rating or power rating of the zener diode is

$$P_Z = P_{Z\min} = V_Z I_{Z\max} = V_Z[I_i - I_{L\min}] = V_Z\left[I_i - \frac{V_Z}{R_{L\max}}\right]$$

$$= 4\left[6\times10^{-3} - \frac{4}{10\times10^3}\right] = 22.4 \text{ mW}$$

49. (a)

Stability factor is rate of change of collector current I_C w.r.t. to collector leakage current I_{CO} keeping β and V_{BE} constant

$$S = \frac{\partial I_C}{\partial I_{CO}} \qquad [V_{BE}, \beta \text{ constant}]$$

$$I_C = \beta I_B + (\beta+1)I_{CO} \quad \text{for CE configuration}$$

Differentiating w.r.t. I_C

$$1 = \frac{\beta\partial I_B}{\partial I_C} + (\beta+1)\frac{\partial I_{CO}}{\partial I_C}$$

$$= \frac{\beta\partial I_B}{\partial I_C} + \frac{\beta+1}{S}$$

$$S = \frac{\beta+1}{1-\beta\dfrac{\partial I_B}{\partial I_C}}$$

50. (a)

$$\text{CMRR} = 20\log\left|\frac{A_{dm}}{A_{cm}}\right| = 20\log\left|\frac{10^5}{0.05}\right| = 20\log\left|2\times10^6\right|$$

$$= 20\,[\log 2 + \log 10^6]$$

$$= 20\,[0.301 + 6]$$

$$= 126.02$$

51. (b)

In the active region, the base-emitter junction is forward-biased, where as the collector-base junction is reverse-biased.

52. (c)

- The quantity alpha (α) relates the collector and emitter currents and is always close to one.
- The quantity beta (β) provides an important relationship between the base and collector currents and is usually between 50 and 400.
- For linear amplification purposes, cutoff for the common-emitter configuration will be defined by $I_C = I_{CEO}$.

53. (d)

The operating point defines where the transistor will operate on its characteristics curves under dc conditions. For linear (minimum distortion) amplification, the dc operating point should not be too close to the maximum power, voltage or current rating and should avoid the regions of saturation and cutoff.

54. (d)

Voltage at a point on potentiometer is proportional to length of the slide wire

$$E \propto l$$

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

$$\frac{1.6}{550} = \frac{3.2}{x}$$

$$x = 1100 \text{ mm}$$

55. (a)

A moving iron voltmeter reads rms value

$$I_{\text{rms}} = \sqrt{\frac{1}{4T}\left((12)^2 2T + (0)^2 2T\right)} = \sqrt{\frac{288T}{4T}} = 6\sqrt{2} \text{ A}$$

Voltage read by voltmeter $= I_{\text{rms}} \times R$

$$= 6\sqrt{2} \times 4 = 24\sqrt{2} \text{ V}$$

56. (a)

At balance condition, $Z_1 Z_4 = Z_2 Z_3$

$$\left(\frac{R_1}{1 + j\omega C_1 R_1}\right) R_4 = \left(R_2 - \frac{j}{\omega C_2}\right) R_3$$

$$\frac{R_4}{R_3} = \frac{R_2}{R_1} + \frac{C_1}{C_2} + j\left(\omega C_1 R_2 - \frac{1}{\omega C_2 R_1}\right)$$

Equating the real and imaginary parts

$$\frac{R_4}{R_3} = \frac{R_2}{R_1} + \frac{C_1}{C_2}$$

and $$\omega C_1 R_2 - \frac{1}{\omega C_2 R_1} = 0$$

$$\omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$$

As given in question, $R_2 = R_1$

and $C_2 = C_1$

$$\omega = \frac{1}{R_1C_1}$$

and $$f = \frac{1}{2\pi R_1 C_1}$$

Hence option (a) is correct.

57. **(b)**

Rate of change of mutual inductance with deflection

$$\frac{dM}{d\theta} = \frac{d}{d\theta}[-6\cos(\theta+30°)] = 6 \sin(\theta + 30°) \text{ mH}$$

$\frac{dM}{d\theta}$ at a deflection of 60° is,

$$\left(\frac{dM}{d\theta}\right)_{\theta=60°} = 6 \sin(60° + 30°)\text{mH} = 6 \times 10^{-3} \text{ H/degree}$$

Deflecting torque, $$T_d = I^2\frac{dM}{d\theta} = (50 \times 10^{-3})^2 \times 6 \times 10^{-3}$$

$$= 15 \times 10^{-6} \text{ Nm} = 15 \text{ μ Nm}$$

58. **(c)**

The impedance of the voltmeter circuit at 50 Hz

$$Z = \sqrt{(R+R_s)^2 + \omega^2L^2}$$

$$= \sqrt{(2000+400)^2 + (2\pi \times 50 \times 1)^2} = 2420\ \Omega$$

with D.C., $Z = R + R_s = 2400\ \Omega$

The error is due to change of current on account of increase in impedance on a.c.

∴ Reading at 120 V and 50 Hz

$$= \frac{2400}{2420} \times 120 = 119 \text{ V}$$

60. **(c)**

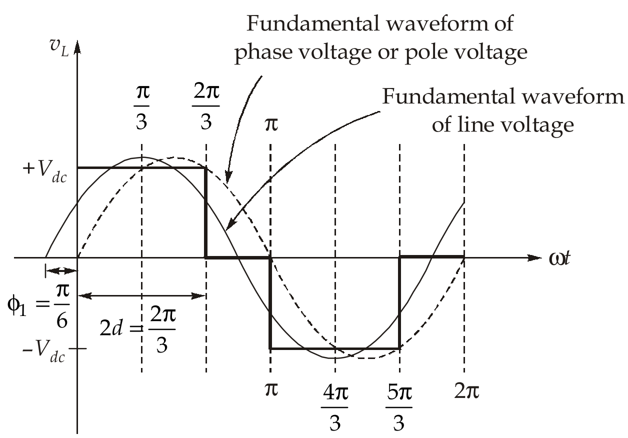
Q-point is not totally independent of β but less sensitive to β or temperature variations then encountered for fixed bias or emitter biased configuration.

Section C : Power Electronics and Drives-2

61. **(c)**

The Fourier series of line voltage of 180° mode VSI is given by

$$v_L(t) = \sum_{n=1,3,5,7,...}^{\infty} \frac{4V_{dc}}{n\pi}\sin(nd)\sin(n\omega t + \phi_n)$$



i.e. the fundamental line voltage leads the fundamental pole voltage or phase voltage by $\frac{\pi}{6}$ radians

$$\therefore \quad \phi_n = n\phi_1 = \frac{n\pi}{6}$$

$$\text{Pulse width } 2d = \frac{2\pi}{3}$$

$$\Rightarrow \quad d = \frac{\pi}{3}$$

For Quasi-square wave with pulse width $\frac{2\pi}{3}$, only odd harmonics will be present in the Fourier series expression.

i.e. $n = 1, 3, 5, 7, 9, \ldots\ldots$

$$\therefore \quad v_L(t) = \sum_{n=1,3,5,7}^{\infty} \frac{4\times 400}{n\pi}\sin\left(\frac{n\pi}{3}\right)\sin\left(n\omega t + \frac{n\pi}{6}\right)$$

$$= \sum_{n=1,3,5,7}^{\infty} \frac{1600}{n\pi}\sin\left(\frac{n\pi}{3}\right)\sin\left(n\omega t + \frac{n\pi}{6}\right)$$

62. (b)

$$\hat{v}_{0n} = \frac{4V_{dc}}{n\pi}\sin(nd)$$

For n^{th} order harmonic to be eliminated

$$nd = \pi, 2\pi, 3\pi, 4\pi, \ldots\ldots$$

$$\Rightarrow \quad 2nd = 2\pi, 4\pi, 6\pi, 8\pi, \ldots\ldots$$

Pulse width, $2d = \frac{2\pi}{n}, \frac{4\pi}{n}, \frac{6\pi}{n}, \frac{8\pi}{n} \ldots\ldots$

Provided, $2d < \pi$

For 5th order harmonic elimination

$$2d = \frac{2\pi}{5} \text{ and } \frac{4\pi}{5} \text{ only } \left(\because \frac{6\pi}{5} > \pi\right)$$

63. (b)

$$P_0 = 100 \text{ W}$$
$$I_0 = 20 \text{ A}$$
$$f = 20 \text{ kHz}$$
$$V_s = 15 \text{ V}$$
$$V_0 = \frac{P_0}{I_0} = \frac{100}{20} = 5 \text{ V}$$

Buck converter, $V_0 = \alpha\ V_s$

$$5 = \alpha \times 15$$
$$\alpha = \frac{1}{3}$$
$$t_{on} = \alpha T = \frac{\alpha}{f} = \frac{1/3}{20 \times 10^3} = 16.67\ \mu\text{sec}$$

64. (c)

$$R = 10\ \Omega$$
$$L = 80 \text{ mH}$$
$$V_s = 300 \text{ V}$$

From the waveform,

$$I_{max} = 16 \text{ A and } I_{min} = 10 \text{ A}$$

i.e., $\Delta I_L = I_{max} - I_{min} = 16 - 10 = 6$ A

Average load current, $I_0 = I_{min} + \frac{\Delta I_L}{2} = 10 + \frac{6}{2} = 13$ A

Average load voltage, $V_0 = I_0 R = 13 \times 10 = 130$ V

$\therefore$ $V_0 = \alpha V_s$

$$130 = \alpha \times 300$$
$$\alpha = \frac{13}{30}$$

$\Rightarrow$ $$\frac{t_{on}}{t_{off}} = \frac{\alpha T}{(1-\alpha)T} = \frac{\alpha}{(1-\alpha)} = \frac{13/30}{\left(1 - \frac{13}{30}\right)}$$

$$= \frac{13}{17} \approx 0.76$$

65. (c)

$$V_0 = 400 \text{ V}$$
$$V_s = 200 \text{ V}$$
$$f = 5 \text{ kHz}$$

Output boundary current,

$$I_{0B} = 25 \text{ A}$$

$$I_{0B} = \frac{\alpha(1-\alpha)V_s}{2fL_c} \quad \text{...(i)}$$

But, $$V_0 = \frac{\alpha}{(1-\alpha)}V_s$$

$$\Rightarrow \quad 400 = \frac{1}{\left(\frac{1}{\alpha}-1\right)} \times 200$$

$$\Rightarrow \quad \alpha = \frac{2}{3}$$

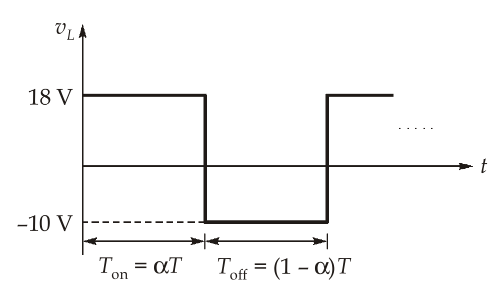
From equation (i),

$$25 = \frac{\frac{2}{3}\left(1-\frac{2}{3}\right)\times 200}{2\times 5\times 10^3 \times L_C}$$

$$\Rightarrow \quad L_C = 177.78 \ \mu\text{H}$$

66. (a)

α : Duty cycle of the chopper



$$(v_L)_{avg} = 0$$

$$\therefore \quad \frac{18\times T_{on}}{T} + \frac{(-10)\times T_{off}}{T} = 0$$

$$\Rightarrow \quad \frac{18\times \alpha T - 10\times(1-\alpha)T}{T} = 0$$

$$\Rightarrow \quad 18\alpha - 10 + 10\alpha = 0$$

$$28\alpha = 10$$

$$\Rightarrow \quad \alpha = \frac{10}{28} = 0.357$$

67. (a)

A four quadrant chopper cannot be operated as a cyclo-converter as the later needs variable frequency.

68. (a)

For 1-ϕ full bridge VSI,

$$\hat{I}_{\text{on}} = \frac{4V_s}{n\pi Z_n}$$

and harmonic spectrum is n = 1, 3, 5, 7, ...

$\therefore$ 5$^{\text{th}}$ harmonic is the second dominant harmonic

$$\therefore \quad \hat{I}_{05} = \frac{4V_s}{5\pi Z_s}$$

where,
$$Z_5 = \sqrt{R^2 + (5X_L)^2}$$
$$= \sqrt{10^2 + (5\times 12)^2}$$
$$= \sqrt{3700} = 10\sqrt{37}$$

$$\therefore \quad \hat{I}_{05} = \frac{4\times 400}{5\pi\times 10\sqrt{37}} = \frac{32}{\pi\sqrt{37}}\text{A}$$

69. (c)

$$V_S = 300 \text{ V}$$

Pulse width,
$$2d = 2\sin^{-1}\left(\frac{7\pi}{60\sqrt{2}}\right)$$

$$\Rightarrow \quad \sin d = \frac{7\pi}{60\sqrt{2}} \quad \text{...(i)}$$

Output voltage of the 1-ϕ full bridge VSI employing single PWM technique is

$$v_0 = \sum_{n=1,3,5,7,...}^{\infty} \frac{4V_s}{n\pi}\sin(nd)\sin(n\omega t)$$

$$= \sum_{n=1,3,5,7}^{\infty} \frac{4\times 300}{n\pi}\sin(nd)$$

Fundamental rms output voltage is

$$\therefore \quad V_{01} = \frac{4\times 300}{\sqrt{2}\times 1\times\pi}\sin d = \frac{4\times 300}{\sqrt{2}\pi}\times\frac{7\pi}{60\sqrt{2}} = 70 \text{ V}$$

70. (a)

$$R = 12\ \Omega$$
$$X = 5\ \Omega$$
$$Z_n = \sqrt{R^2 + (nX)^2} = \sqrt{12^2 + (5n)^2}$$
$$= \sqrt{144 + 25n^2}$$

The Fourier series of the output current is

$$i_0 = \sum_{n=1,3,5,7}^{\infty} \frac{4V_s}{n\pi Z_n}\sin(nd)\sin(n\omega t)$$

$$I_{01} = \frac{4\times 250}{\sqrt{2}\times 1\times \pi\times\sqrt{144+25\times 1^2}} = 17.31\ \text{A}$$

71. (c)

In 180° mode of operation of 3-ϕ, VSI the fundamental phase voltage is in phase with the pole voltage.

72. (c)

Both the statements are correct.

73. (d)

$$R_r = 3\ \Omega$$
$$R_e = 1.5\ \Omega$$
$$I_r = 3\ \text{A}$$
$$P_{\text{cu}} = 89.1\ \text{W}$$
$$P_{\text{cu}} = 3I_r^2[R_r + 0.5(1-\alpha)R_e]$$
$$89.1 = 3\times 3^2[3 + 0.5(1-\alpha)\times 1.5]$$
$$\Rightarrow \qquad \alpha = 0.6$$

74. (d)

The Fourier series expression for phase current of 3-ϕ VSI operating in 180° mode is given by

$$i_{\text{ph}} = \sum_{n=6k\pm 1}^{\infty} \frac{2V_s}{n\pi|Z_n|}\sin(n\omega t - \phi_n)$$

$$k = 0, 1, 2, 3, \ldots.$$

$$= \sum_{n=1,5,7,11,13}^{\infty} \frac{2\times 400}{n\pi|z_n|}\sin(n\omega t - \phi_n)$$

$$= \frac{800}{\pi|z_1|}\sin(\omega t - \phi_1) + \frac{800}{5\pi|z_5|}\sin(5\omega t - \phi_5) + \frac{800}{7\pi|z_7|}\sin(7\omega t - \phi_7) + \ldots$$

75. (d)

- Critical inductance is the minimum inductance to get continuous conduction or it is the maximum inductance to get the discontinuous conduction.
- Average Boundary load current,

$$I_{0B} = \frac{\alpha(1-\alpha)V_s}{2fL}$$

i.e., $$I_{0B} \propto \frac{1}{f}$$

- The average output voltage in discontinuous conduction mode is more than that during continuous conduction mode.

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