DETAILED SOLUTIONS

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ESE 2024 : 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.**	(a)	**61.**	(b)
2.	(a)	**17.**	(b)	**32.**	(b)	**47.**	(b)	**62.**	(b)
3.	(b)	**18.**	(b)	**33.**	(d)	**48.**	(d)	**63.**	(c)
4.	(c)	**19.**	(a)	**34.**	(b)	**49.**	(a)	**64.**	(b)
5.	(b)	**20.**	(d)	**35.**	(a)	**50.**	(b)	**65.**	(c)
6.	(d)	**21.**	(c)	**36.**	(c)	**51.**	(a)	**66.**	(a)
7.	(c)	**22.**	(d)	**37.**	(c)	**52.**	(a)	**67.**	(b)
8.	(d)	**23.**	(a)	**38.**	(c)	**53.**	(c)	**68.**	(d)
9.	(c)	**24.**	(b)	**39.**	(c)	**54.**	(d)	**69.**	(b)
10.	(b)	**25.**	(b)	**40.**	(a)	**55.**	(b)	**70.**	(c)
11.	(c)	**26.**	(a)	**41.**	(a)	**56.**	(d)	**71.**	(d)
12.	(c)	**27.**	(c)	**42.**	(a)	**57.**	(d)	**72.**	(d)
13.	(c)	**28.**	(b)	**43.**	(d)	**58.**	(c)	**73.**	(a)
14.	(d)	**29.**	(c)	**44.**	(a)	**59.**	(c)	**74.**	(a)
15.	(a)	**30.**	(a)	**45.**	(c)	**60.**	(a)	**75.**	(b)

DETAILED EXPLANATIONS

Section A : Systems & Signal Processing + Communication Systems

1. (b)

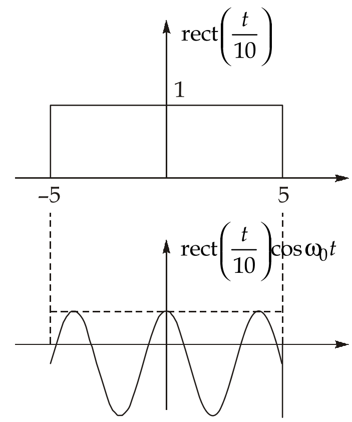
$$E = \int_{-\infty}^{+\infty} |x(t)|^2 \cdot dt = \int_{-5}^{5} \left|\cos^2 \omega_0 t\right| dt$$

$$= \int_{-5}^{+5} \left|\frac{1+\cos 2\omega_0 t}{2}\right| dt$$

$$= \frac{1}{2}[t]_{-5}^{+5} + \frac{1}{4}[\sin 2\omega_0 t]_{-5}^{5}$$

$$= 5 + \frac{1}{4}[\sin 10\omega_0 + \sin 10\omega_0]$$

$$E = 5 + \frac{1}{2}\sin 10\omega_0$$



2. (a)

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

$$X(s) = \frac{1}{(s+1)}$$

Given, $y(t) = e^{-2t} \cos t \cdot u(t)$

$$Y(s) = \frac{(s+2)}{(s+2)^2+1}$$

Impulse response, $H(s) = \dfrac{Y(s)}{X(s)} = \dfrac{\frac{(s+2)}{(s+2)^2+1}}{\frac{1}{(s+1)}}$

$$H(s) = \frac{(s+1)(s+2)}{(s+2)^2+1} = 1 - \frac{(s+2)}{(s+2)^2+1} - \frac{1}{(s+2)^2+1}$$

$$h(t) = \delta(t) - (e^{-2t} \cos t + e^{-2t} \sin t)\, u(t)$$

3. (b)

Unilateral z-transform of sequence $x(n)$ is given by

$$X(z) = \sum_{n=0}^{\infty} x[n]z^{-n} = \sum_{n=0}^{3} x[n]z^{-n}$$

$$= x[0]z^0 + x[1]z^{-1} + x[2]z^{-2} + x[3]z^{-3}$$

$$= 1 + \frac{2}{z} + \frac{2}{z^2} + \frac{1}{z^3}$$

4. (c)

Given, $x(n) = (n + 1)a^n\, u(n)$

$\Rightarrow$ $x(n) = n \cdot a^n\, u(n) + a^n\, u(n)$ ...(i)

We know $\rightarrow$ $a^n u(n) \xleftrightarrow{Z.T.} \dfrac{1}{(1-az^{-1})}$ ...(ii)

Using property of z-domain differentiation

$$n \cdot a^n u(n) \xleftrightarrow{Z.T.} -z \cdot \frac{d}{dz}\left[\frac{1}{(1-az^{-1})}\right]$$

$$\xleftrightarrow{Z.T.} \frac{az^{-1}}{(1-az^{1})^2} \quad \text{...(iii)}$$

From equation (i),

$$X(z) = \frac{az^{-1}}{(1-az^{-1})^2} + \frac{1}{(1-az^{-1})}$$

$$X(z) \longleftrightarrow \frac{1}{(1-az^{-1})^2}$$

5. (b)

The system has poles at $z = \frac{1}{2}$ and $z = 2$. Now consider the different ROC :

- $|z| > 2$

  Since ROC does not include unit circle. Hence system is not stable ROC is exterior to outermost pole ($Z = 2$), system is causal S_1 is true.
- $0.5 < |z| < 2$

  Since ROC include unit circle. Hence system is stable.

  ROC is not exterior to outer most pole, hence system is not causal S_2 is true.
- ROC : $|z| > 0.5$

  Since ROC include unit circle. System is stable.

  Since ROC is not exterior to outermost pole. System is no causal. S_3 is incorrect.

6. (d)

- Given function $f(t)$ is even function therefore $b_n = 0$.
- $f(t)$ is a non-zero average value function, so it will have a non-zero value of a_0.
- As $f(t)$ has hidden HWS symmetry, so a_n will be zero for all even values of n.

So Fourier series of $f(t)$ will have

a_0 and a_n, $n = 1, 3, 5 \ldots\ldots \infty$

7. (c)

Given,
$$y(t) = \int_{-\infty}^{t} x(\tau)\cdot d(\tau)$$
$$= \int_{-\infty}^{t} [\delta(\tau+2)-\delta(\tau-2)]\cdot d(\tau)$$
$$= u(t+2) - u(t-2)$$
$$= \begin{cases} 1 & -2 < t < 2 \\ 0, & \text{otherwise} \end{cases}$$

Therefore,
$$E_y = \int_{-\infty}^{\infty} |y(t)|^2 \cdot dt = \int_{-2}^{2} 1\cdot dt = 4 \text{ units}$$

8. (d)

The first term is a constant

The second term $= e^{j4\pi n/7}$

$$\Rightarrow \quad \omega_1 = \frac{4\pi}{7}$$

The third term $= e^{j2\pi n/5}$

$$\Rightarrow \quad \omega_2 = \frac{2\pi}{5}$$

Now,
$$N_1 = \frac{2\pi}{\omega_1} m_1$$

and
$$N_2 = \frac{2\pi}{\omega_1} m_2$$

$$N_1 = \frac{2\pi}{\frac{4\pi}{7}} m_1 = \frac{7}{2} m_1 = 7$$

$$N_2 = \frac{2\pi}{\frac{2\pi}{5}} = 5$$

$$\frac{N_1}{N_2} = \frac{7}{5} = \text{a rational number}$$

Therefore, $x(n)$ is periodic with fundamental time period

$$N = \text{LCM}(N_1, N_2) = \text{LCM}(7, 5) = 35$$

9. (c)

$$x(t) = u(t) + \frac{1}{2} r(t) - \frac{1}{2} r(t-2) - 2u(t-2)$$

$$= u(t)+\frac{1}{2}t\,u(t)-\frac{1}{2}(t-2)u(t-2)-2u(t-2)$$

$$= \left(\frac{1}{2}t+1\right)u(t)-\left(\frac{1}{2}t+1\right)u(t-2)$$

10. (b)

Given that, $x(t) = u(t+0.5) - u(t-0.5) = \begin{cases} 1, & -0.5 < t < 0.5 \\ 0, & \text{otherwise} \end{cases}$

By definition, $y(t) = x(t) * h(t) = \int_{-\infty}^{\infty} x(\tau)\cdot h(t-\tau)\cdot d\tau = \int_{-0.5}^{+0.5} e^{j\omega_0(t-\tau)}\cdot d\tau$

Therefore, $y(t)\big|_{t=0} = y(0) = \int_{-0.5}^{0.5} e^{-j\omega_0\tau}\cdot d\tau = \frac{2}{\omega_0}\sin\left(\frac{\omega_0}{2}\right)$

at $\omega_0 = 2\pi$ $\quad y(0) = 0$

11. (c)

If $x(n) \xrightleftharpoons{\text{Z.T.}} X(z)$ has ROC : R

then :

- On time reversal i.e.,

  $x(-n) \xrightleftharpoons{\text{Z.T.}} X(z^{-1})$ has ROC : $\frac{1}{R}$

- On time expansion i.e.,

  $x\left(\frac{n}{m}\right) \xrightleftharpoons{\text{Z.T.}} X(z^m)$ has ROC : $R^{1/m}$

$\therefore$ Option (c) is correct.

12. (c)

Using time reversal property

$$x(-t+1) \xleftrightarrow{\text{F.T.}} X(-\omega)e^{-j\omega}$$

$$x(-t-1) \xleftrightarrow{\text{F.T.}} X(-\omega)e^{j\omega}$$

$$x_1(t) = x(1-t) + x(-1-t)$$

$$x_1(t) \xleftrightarrow{\text{FT}} X_1(\omega)$$

$$x_1(1-t)+x(-1-t) \xleftrightarrow{\text{FT}} X(-\omega)e^{-j\omega} + X(-\omega)\cdot e^{j\omega}$$

$$X_1(\omega) = 2\,X(-\omega)\cos\omega$$

13. (c)

$$\text{Sampling frequency, } f_s = \frac{2f_H}{[f_H/B]} = \frac{2\times 22\,\text{kHz}}{\left[\dfrac{22}{f_H - f_L}\right]} = \frac{44\,\text{kHz}}{\left[\dfrac{22}{4}\right]}$$

$$= \frac{44\,\text{kHz}}{[5.5]} = \frac{44}{5} = 8.8\text{ kHz}$$

14. (d)

$$x(t) = |t|\cdot e^{2t}u(-t)$$

$$x(t) = |-t|\cdot e^{2t}u(-t)$$

We know that,

$$-e^{2t}u(-t) \xleftrightarrow{\text{LT}} \frac{1}{s-2} \quad : \text{Re}\{s\} < 2$$

$$t\cdot\left[-e^{2t}u(-t)\right] \xleftrightarrow{\text{L.T.}} \frac{-d}{ds}\left(\frac{1}{s-2}\right) : \text{Re}\{s\} < 2$$

$$-te^{2t}u(-t) \xleftrightarrow{\text{L.T.}} \frac{1}{(s-2)^2} \quad : \text{Re}\{s\} < 2$$

15. (a)

Given, $x(t) = 5\ u(t)$

So, $X(s) = \dfrac{5}{s}$

$$Y(s) = X(s)\cdot H(s) = \frac{5}{s}\cdot\frac{(s+3)}{(s^2+4s+5)}$$

Since all the poles of $sY(s)$ lies in the left half of s-plane, so final value theorem is applicable

$$\lim_{t\to\infty} y(t) = \lim_{s\to 0} sY(s) = \lim_{s\to 0} s\left[\frac{5(s+3)}{s(s^2+4s+5)}\right]$$

$$= \frac{5\times 3}{5} = 3$$

16. (b)

Let, peak carrier amplitude $= A_c$

The carrier power, $P_c = \dfrac{A_c^2}{2R}$

$$400 = \frac{A_c^2}{2\times 50} = 200\text{ Volts}$$

The AM expression is given by

$$S_{AM}(t) = A_c[1 + \mu \cos 2\pi f_m t] \cos 2\pi f_c t$$

$$= 200\left[1+0.8\cos(10^4 \pi t)\right]\cos(2\pi\times10^6 t)$$

17. (b)

For faithful demodulation, the time constant should satisfy the following condition

$$\frac{1}{f_c} < RC < \frac{1}{f_m}$$

where $f_m \rightarrow$ maximum frequency component in message signal

$$f_m = 2 \text{ kHz}$$

$$\frac{1}{1\times10^6} < \text{RC} < \frac{1}{2\times10^3}$$

$$1 \ \mu\text{sec} < RC < 0.5 \text{ msec}$$

18. (b)

Less BW requirement in SSB-SC allow more no. of signals to be transmitted in same frequency range.

19. (a)

The modulating signal consists of three signal,

The maximum modulating frequency is $f_{\max} = 2$ kHz

Maximum frequency deviation

$$\Delta f = V_{\text{effective}} \times K$$

$$V_{\text{effective}} = \sqrt{2^2+6^2+7^2} = 9.43 \text{ volt}$$

$$\Delta f = 9.43 \times 10 \times 10^3 = 94.3 \text{ kHz}$$

$$\text{Bandwidth, BW} = 2(\Delta f + f_{\max})$$

$$= 2[94.3 + 2]$$

$$= 192.6 \text{ kHz}$$

20. (d)

Given, $K_f = 2\pi \times 10^5$ rad/volt

$= 10^5$ Hz/volt

Frequency deviation, $\Delta f = K_f \cdot A_m$

$= 10^5 \times 1$

$= 10^5$ Hz

Modulating index, $(\beta) = \dfrac{K_f \cdot A_m}{f_m} = \dfrac{10^5}{f_m}$

$\because$ $$f_m = \frac{1}{T} = \frac{1}{2\times10^{-4}} = 5\text{ kHz}$$

$$\beta = \frac{10^5}{5\times10^3} = 20$$

21. (c)

Capture effect is found in FM signal.

23. (a)

The intermediate frequency (IF),

$$IF = f_0 - f_s$$

where $f_0 \rightarrow$ local oscillator frequency and fs $\rightarrow$ signal frequency

$$f_0 = IF + f_s = 455 + 900 = 1355 \text{ kHz}$$

$$\text{Image rejection ratio} = \text{IRR} = \sqrt{1+P^2Q^2} \approx PQ$$

$$P = \frac{f_{si}}{f_s} - \frac{f_s}{f_{si}}$$

$$f_{si} = f_s + 2IF$$

$$= 900 + 2 \times (455) = 1810 \text{ kHz}$$

$$P = \frac{1810}{900} - \frac{900}{1810} = 1.51$$

$$IRR = \alpha = PQ = 1.51 \times 80 = 120.8$$

24. (b)

For granular distortion to take place

$$\frac{\Delta}{T_s} > \frac{d}{dt}m(t)$$

$$\Delta \cdot f_s > 2\pi f_m \cdot A$$

$$f_m \cdot A < \frac{0.5\times20\times10^3}{2\pi} = 1591.54$$

Only option (b) does not satisfying the condition.

25. (b)

A high pass filter can be used as a pre-emphasis circuit.

26. (a)

For a PM signal

$$\theta(t) = 2\pi f_c t + K_p \cdot m(t)$$

$$f_i = \frac{1}{2\pi}\frac{d\cdot\theta(t)}{dt} = f_c + \frac{K_p}{2\pi}\frac{dm(t)}{dt}$$

Maximum frequency deviation,

$$(\Delta f)_{max} = (f_i - f_c)_{max} = \frac{K_p}{2\pi}\left|\frac{dm(t)}{dt}\right|_{max}$$

$$\left|\frac{dm(t)}{dt}\right|_{max} = \frac{4V}{2ms} = 2000 \text{ V/s}$$

$$(\Delta f)_{max} = \frac{10\pi}{2\pi}\times 2000 = 10 \text{ kHz}$$

27. (c)

For a uniform quantizer, the maximum quantization error is $\Delta/2$

$$\frac{\Delta}{2} \le \frac{0.1}{100}(a)$$

$$\frac{2a}{2.2^n} \le \frac{1}{1000}a$$

$$2^n \ge 1000$$

$$n \ge 10$$

$$n_{min} = 10$$

28. (b)

Given, $(f_m)_{max} = 20$ kHz

Sampling rate, $f_s = 2 \times (f_m)_{max} = 2 \times 20$

$= 40$ kHz

Bits/sample $n = 3$

Bit rate $R_b = nf_s = 3 \times 40$

$= 120$ kHz

Minimum channel bandwidth

$$(\text{BW})_{min} = \frac{R_b}{2} = \frac{120}{2} = 60 \text{ kHz}$$

29. (c)

Maximum value of envelope,

$$A_{max} = A_c(1 + \mu)$$

$$= 20(1 + 0.6) = 32 \text{ V}$$

Minimum value of evevelop,

$$A_{min} = A_c(1 - \mu) = 20(1 - 0.6) = 8 \text{ V}$$

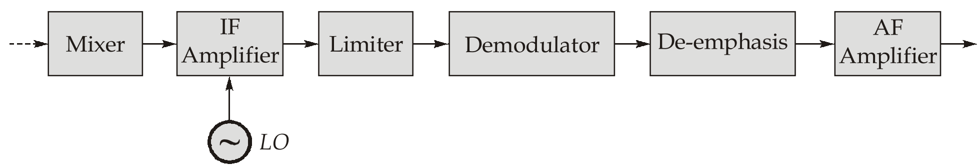
30. (a)

Modulation index:

$$\beta = \frac{K_f \cdot A_m}{f_m} = \pi \text{ rad}$$

$$\beta' = \frac{K_f \cdot (2A_m)}{2f_m} = \beta = \pi \text{ rad}$$

31. (b)



32. (b)

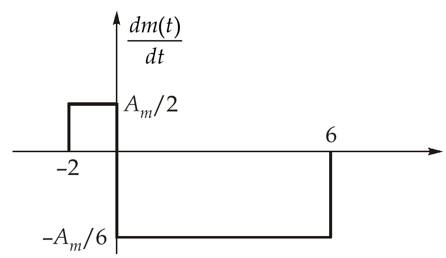
$$(\Delta f_{max})_{fm} = K_f \cdot A_m$$

$$(\Delta f_{max})_{pm} = \frac{K_p}{2\pi}\left[\frac{dm(t)}{dt}\right]_{max}$$

$$(\Delta f_{max})_{fm} = (\Delta f_{max})_{pm}$$

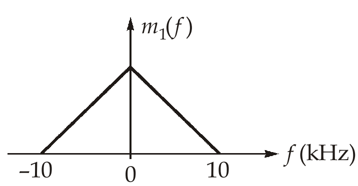
$$K_f \cdot A_m = \frac{K_p}{2\pi}\left[\frac{A_m}{2}\right]$$

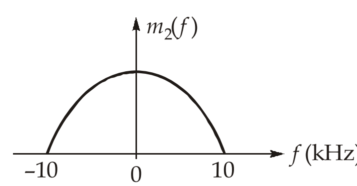
$$\frac{K_p}{K_f} = 4\pi \text{ rad/Hz}$$



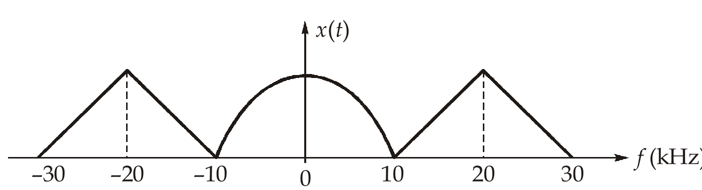
33. (d)

Let us consider two different spectral shapes for $m_1(t)$ and $m_2(t)$ as follows:





Spectrum of $x(t)$ can be given as



This signal is passing through AM modulator

$$(\text{B.W.}) = 2f_{max} = 2 \times 30$$
$$= 60 \text{ kHz}$$

34. (b)

According to Shannon Hartly law

$$C = B\log_2\left(1 + \frac{S}{N}\right)$$

35. (a)

Entropy is given as

$$H(x) = P(x_i)\log_2\left[\frac{1}{P(x_i)}\right] \text{bit/symbol}$$

$$= \frac{1}{M}\log_2\left[\frac{1}{1/M}\right]$$

M no. of message signals are given

$$H(x) = M\times\frac{1}{M}\log_2(M) = \log_2 M$$

36. (c)

For envelope detection,

$$RC \le \frac{1}{\omega_m}\sqrt{\frac{1-\mu^2}{\mu^2}}$$

$$\omega_m \le \frac{1}{RC}\sqrt{\frac{1-\mu^2}{\mu^2}}$$

$$\omega_m \le \frac{1}{0.75\times10^{-3}}\sqrt{\frac{1-0.8^2}{0.8^2}}$$

$$\omega_m \le \frac{4\times1000}{3}\times\sqrt{\frac{9}{16}} = 1000 \text{ rad/sec}$$

$$\omega_m\big|_{\max} = 1000 \text{ rad/sec}$$

$$\text{B.W.} = 2\ \omega_{\max} = 2000 \text{ rad/sec}$$

37. (c)

Frequency hopping is used in carrier system to reduce cross talk.

38. (c)

For delta modulator, $n = 1$

$f_s = 5000$ samples/sec

For error free transmission,

$$\frac{\Delta}{t_s} = \frac{dm(t)}{dt}$$

$$\Delta f_s = \frac{dm(t)}{dt}$$

$$\Delta = \frac{5}{5000} = 1 \text{ mV}$$

39. (c)

$$\text{Bandwidth} = \frac{R_b}{N}(1+\alpha)$$

$$\alpha = 1 \text{ for } 100\% \text{ excess bandwidth}$$

$$100 \text{ kHz} = \frac{200\,\text{Kbps}}{N}(1+1)$$

$$N = 4 \text{ bits}$$

$$\text{No. of symbols (M)} = 2^N = 16$$

40. (a)

Both the statements are true and statement-II is the correct explanation of statement-I.

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

41. (a)

$$I_E = I_C + I_B$$

$$\frac{I_C}{\alpha} = I_C + \frac{I_C}{\beta}$$

$$\frac{1}{\alpha} = 1 + \frac{1}{\beta}$$

$$\beta = \alpha + \alpha\beta = \alpha(1+\beta)$$

$$\alpha = \frac{\beta}{1+\beta}\ ; \quad \beta = \frac{\alpha}{1-\alpha}$$

42. (a)

The common-collector configuration is used primarily for impedance-matching purposes since it has a high input impedance and low output impedance, opposite to that of the common-emitter and common-base configurations.

43. (d)

Operation in the cutoff, saturation and linear regions of the BJT characteristics are provided as follows:

1. Linear - region operation
   Base-emitter junction forward-biased.
   Base-collector junction reverse-biased.
2. Cutoff-region operation:
   Base-emitter junction reverse-biased.
   Base-collector junction reverse-biased.
3. Saturation-region operation:
   Base-emitter junction forward-biased.
   Base-collector junction forward-biased.

44. (a)

An operational amplifier is a very high gain amplifier having very high input impedance and low output impedance.

45. (c)

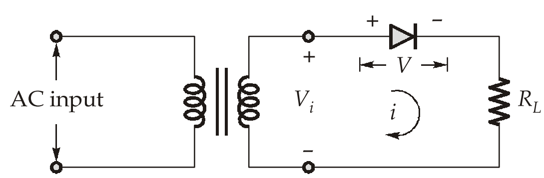
$$V_0 = 6 \text{ mV} \times 10000 = 60 \text{ V}$$

But $V_0 = \pm 15$ V in saturation

So it can never be exceeds ±15 V

$$V_0 = \pm V_{sat} = \pm 15 \text{ V}$$

46. (a)



$$\eta = \frac{\text{dc output power}}{\text{Input power}} = \frac{I_{dc}^2 R_L}{I_{rms}^2 (R_f + R_L)} \times 100\%$$

$$= \frac{\left(\frac{I_m}{\pi}\right)^2 \times R_L}{\left(\frac{I_m}{2}\right)^2 \times (R_f + R_L)} \% = \frac{400}{\pi^2} \times \frac{R_L}{R_f + R_L} \%$$

$$= 40.6 \times \frac{R_L}{R_f + R_L} \%$$

If diode is ideal than, $\eta = 40.6\%$

$P_{DC} = 500$ W, half wave rectifier

For half wave rectifier, % $\eta = 40.6\%$

$$40.6 = \frac{P_{DC}}{P_{AC}} \times 100 = \frac{500}{P_{AC}} \times 100$$

$$P_{AC} = 1231.527 \text{ W}$$

47. (b)

The given circuit is a fullwave voltage doubler.

If the no load output voltage is $10\sqrt{2}$ V, then the peak value of secondary of the transformer is

$$\frac{10\sqrt{2}}{2} = 5\sqrt{2} \text{ V}$$

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

$$\frac{5\sqrt{2}}{220\sqrt{2}} = \frac{1}{n}$$

$$n = 44$$

48. (d)

Given, $I_D = I_{D\,(ON)} = 4 \text{ mA}$

$$V_{DS} = \frac{1}{2}V_{DD} = V_{GS} \qquad (\because I_G = 0)$$

$$V_{DD} = 2 \times V_{GS} = 2 \times 6 = 12 \text{ V}$$

$$R_D = \frac{V_{DD} - V_{DS}}{I_{D(ON)}} = \frac{12 - 6}{4 \text{ mA}} = 1.5 \text{ k}\Omega$$

49. (a)

The given circuit is that of Wein bridge

The frequency of oscillations is given by

$$f = \frac{1}{2\pi RC} = \frac{1}{(2\pi)(6\,\text{k}\Omega)\times(0.003\mu\text{F})} = 8.885 \text{ kHz}$$

50. (b)

$$I_{sh} = \frac{E_m}{R_{sh}} = \frac{1\text{ mA}\times 500\,\Omega}{500\,\Omega} = 1\text{ mA}$$

and $I_T = I_{sh} + I_m = 1 \text{ mA} + 1 \text{ mA} = 2 \text{ mA}$

The equivalent dc voltage is computed as;

$$E_{dc} = 0.9 \times 10\ V_{rms}$$

$$= 0.9 \times 10\ V = 9.0 \text{ V}$$

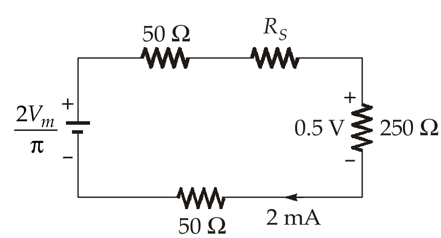
The total resistance of the meter circuit can now be computed as

$$R_T = \frac{E_{dc}}{I_T} = \frac{9.0\text{ V}}{2\text{ mA}} = 4.5 \text{ k}\Omega$$

and $$R_S = R_T + 2R_d - \frac{R_m R_{sh}}{R_m + R_{sh}}$$

$$= 4500 + 2\times 50 - \frac{500\times 500}{500+500} = 4.15 \text{ k}\Omega$$

Alternate Solution:



$$\frac{9-0.5-0.2}{2\text{ mA}} = R_S$$

$$R_S = 4.15\ \text{k}\Omega$$

51. (a)

$$L = \frac{0.01+0.2\theta}{4\pi}\text{H}$$

$$\therefore \quad \frac{dL}{d\theta} = \frac{0.1}{2\pi}\text{H/rad}$$

$$K = \frac{1}{2\theta}I^2\frac{dL}{d\theta} = \frac{(1\times100\times10^{-3})^2}{2\times100\times(\pi/180)}\times\frac{0.1}{2\pi}$$

$$= 45.6 \times 10^{-6}\ \text{Nm/rad}$$

52. (a)

We have $\quad P_1 + P_2 = 30\ \text{kW} \quad$ ...(i)

Now, $\quad \cos\phi = 0.4$

$$\cos\phi = \frac{1}{\sqrt{1+\dfrac{3(P_1-P_2)^2}{(P_1+P_2)^2}}}$$

$$0.4 = \frac{1}{\sqrt{\dfrac{(P_1+P_2)^2+3(P_1-P_2)^2}{(P_1+P_2)^2}}}$$

$$= \frac{P_1+P_2}{\sqrt{(P_1+P_2)^2+3(P_1-P_2)^2}}$$

$$0.16 = \frac{(P_1+P_2)^2}{(P_1+P_2)^2+3(P_1-P_2)^2} = \frac{900}{900+3(P_1-P_2)^2}$$

$$0.16 \times 900 + 0.48\,(P_1 - P_2)^2 = 900$$

$$0.48\,(P_1 - P_2)^2 = 900 - 144 = 756$$

$$(P_1 - P_2)^2 = 1575$$

$$P_1 - P_2 = 39.68 \approx 39.7\ \text{kW} \quad \text{...(ii)}$$

From (i) and (ii),

We get, $\quad P_1 = 34.85\ \text{kW}$

and $\quad P_2 = -4.85\ \text{kW}$

53. (c)

Energy supplied $= VI\cos\phi \times t \times 10^{-3}$

$= 230 \times 4 \times 1 \times 6 \times 10^{-3} = 5.52\ \text{kWh}$

$$\text{Meter constant} = \frac{\text{Revolutions}}{\text{kWh}}$$

$$= \frac{2208}{5.52} = 400 \text{ rev/kWh}$$

Energy consumed when the meter makes 1472 revolutions $= \dfrac{1472}{400} = 3.68$ kWh

$$\text{Now energy consumed} = VI\cos\phi \times t$$

$$230 \times 5 \times \cos\phi \times 4 = 3680$$

$$\cos\phi = \frac{3680}{230 \times 5 \times 4} = 0.8$$

54. (d)

Instrumental errors arise due to three main reason:

- Due to inherent shortcomings in the instrument.
- Due to misuse of the instruments.
- Due to loading effects of instruments.

55. (b)

Effect	Instrument
Magnetic effect	Ammeters, voltmeter, wattmeters, integrating meters.
Heating effect	Ammeters and voltmeter, wattmeters.
Electrostatic effect	Voltmeters
Induction effect	A.C. ammeter, voltmeter wattmeters, energy meters.

56. (d)

In the moving coil instrument type instruments, damping is provided by eddy current damping.

57. (d)

The main sources of errors in moving coil instruments are due to:

- Weakening of permanent magnets due to ageing and temperature effects.
- Weakening of springs due to ageing and temperature effects.
- Change of resistance of the moving coil with temperature.

58. (c)

Standardization is done in order to make the instrument more accurate and direct reading.

59. (c)

The barrier width of J_E is negligible as compared to space-charge width at J_C.

Section C : Power Electronics and Drives-2

61. (b)

For a step up chopper $V_0 = \frac{V_s}{1-\alpha}$

$$600 = \frac{200}{1-\alpha}$$

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

$$\alpha = \frac{T_{ON}}{T} = \frac{2}{3} = \frac{T - T_{off}}{T}$$

$$T_{off} = \frac{1}{3}T$$

$$T = 3 \times 50 = 150 \text{ µsec}$$

$$T_{ON} = T - T_{off} = 150 - 50$$

$$T_{ON} = 100 \text{ µsec}$$

62. (b)

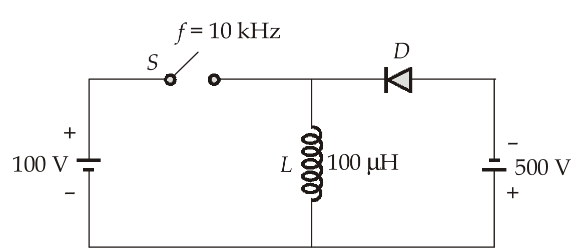
RMS value of fundament component of the phase voltage

$$= \frac{\sqrt{2}}{\pi} \cdot V_{dc}$$

$$\text{peak value} = \sqrt{2} \times \frac{\sqrt{2}}{\pi} V_{dc} = \frac{2}{\pi} V_{dc}$$

63. (c)

Given circuit



Above circuit is a Buck-Boost converter

for Buck-Boost converter

$$V_0 = \frac{\alpha}{1-\alpha} V_s$$

$$500 = \frac{\alpha}{1-\alpha} \times 100$$

$$\alpha = \frac{5}{6}$$

As we know, $\Delta I_L = \dfrac{\alpha \cdot V_s}{f \cdot L}$ ...during switch ON

Here, $\Delta I_L = I_P$

$$I_P = \frac{\alpha V_s}{f \cdot L} = \frac{5}{6} \times \frac{100}{10 \times 10^3 \times 100 \times 10^{-6}}$$

$$I_P = \frac{500}{6} = 83.33 \text{ A}$$

64. (b)

The switch must support forward conduction, forward blocking and reverse conduction.

65. (c)

Given, $E_{dc} = 220$ V, $R = 0.1\ \Omega$,

$L = 10$ mH, $E_b = 100$ V

The average load voltage is given by

$$V_0 = E_b + I_0 R$$

$$\alpha \cdot E_{dc} = E_b + I_0 R$$

$$\alpha[220] = 100 + 10 \times 0.1 \qquad \{V_0 = \alpha \cdot E_{dc}\}$$

$$\alpha = \frac{101}{220} = 0.459$$

66. (a)

Output voltage, $V_0(t) = \displaystyle\sum_{n=1,3,5}^{\infty} \frac{4V_{dc}}{n\pi} \sin n\omega_0 t$

rms value of 5th harmonic output voltge

$$V_{05} = \frac{1}{\sqrt{2}} \times \frac{4V_{dc}}{5\pi} = \frac{1}{\sqrt{2}} \times \frac{4 \times 48}{5\pi}$$

$$V_{05} = 8.64 \text{ Volt}$$

67. (b)

Carrier ratio, $m_f = \dfrac{f_c}{f_m} = \dfrac{1.2 \times 10^3}{50} = 24$

Harmonics are given by,

$$n = m_f,\ m_f \pm 2,\ m_f \pm 4 \ \ldots = 24, 20, 22, 26 \ldots$$

$$n = 2m_{f \pm 1},\ 2m_f \pm 3 \ \ldots = 47, 49, 45, 51 \ldots$$

$$h = 3m_f,\ 3m_{f \pm 2},\ 3m_{f \pm 4} = 72, 70, 74$$

69. (b)

Impedance of the load,

$$Z_L = R_L + jX_L$$
$$= 30 + j60$$
$$= 30\sqrt{5}\angle 63.43°$$
$$\phi_L = 63.43°$$

the output voltage (V_0) is controllable when $\alpha \geq \phi_L$

So for $0 < \alpha < 63.43°$, output V_0 is not controllable.

70. (c)

In a single pulse modulation of PWM inverters, the nth harmonic can be eliminated if the pulse width (2d) is made equal to $\left(\frac{2\pi}{n}\right)$.

For above case, pulse width = $\frac{2\pi}{5} = 72°$

71. (d)

Fundamental component of output voltage,

$$V_{01} = \frac{2V_s}{\pi}\sin\omega t$$

RMS value of this voltage, $V_{01} = \frac{2\times V_s}{\pi\sqrt{2}} = \frac{2\times 50}{\pi\sqrt{2}} = \frac{100}{\pi\sqrt{2}}\text{V}$

72. (d)

For step up chopper, V_o = 480 V, time period, T supply voltage, V_s = 320 V

$$T_{\text{off}} = 20\ \mu\text{sec} = 20 \times 10^{-6}\ \text{sec}$$

$$V_o = V_s \times \frac{T}{T_{\text{off}}} = 320\times\frac{T}{20} = 480 \qquad \left(\because \frac{1}{1-\alpha} = \frac{T}{T_{\text{off}}}\right)$$

$$T = \frac{480\times 20}{320} = 30\,\mu\,\text{sec}$$

To switching frequency, $f = \frac{1}{T} = \frac{1}{30\times 10^{-6}}$ = 0.333×10^5 = 33.33 kHz

73. (a)

With the help of PWM technique the total harmonic distortion is reduced with modest filtering.

❍❍❍❍

