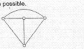
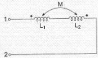
Answers with Hints

1. (B) A Tree should have all the nodes present in the graph. But no loop possible.



2. (D) Equivalent inductance between the terminal 1 and 2 for the given figure

$$L_{eq} = L_1 + L_2 - 2M$$



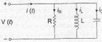
(because current enters in one coil while exit at the other)

3. (A) Given that,

$$R = \frac{1}{3}\Omega$$

$$L = \frac{1}{4}H$$

$$C = 3F$$



From figure

$$i(t) = i_R(t) + i_L(t) + i_C(t)$$

$$= \frac{V(t)}{R} + \frac{1}{L}\int V(t)\,dt + C\frac{d}{dt}v(t)$$

$$= \frac{\sin 2t}{1/3} + \frac{1}{1/4}\int \sin 2t\,dt + 3\frac{d}{dt}\sin 2t$$

$$= 3\sin 2t - 2\cos 2t + 6\cos 2t$$

$$= 3\sin 2t + 4\cos 2t$$

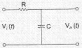
$$= \sqrt{3^2 + 4^2}\sin(2t + \phi)$$

$$= 5\sin(2t + 53{\cdot}1^\circ)$$

where $\phi = \tan^{-1}\left(\frac{4}{3}\right) = 53{\cdot}1^\circ$

4. (A) Given that, $RC = 1\text{ms} = 1 \times 10^{-3}$ sec.

$$V_i(t) = \sqrt{2}\sin 10^3 t$$



From figure,

$$V_0(t) = \frac{\frac{1}{SC}}{R + \frac{1}{SC}} \cdot V_i(t)$$

$$= \frac{1}{RSC + 1} \cdot V_i(t)$$

$$= \frac{1}{j\omega RC + 1} V_i(t)$$

$$= \frac{1}{j10^3 \times 10^{-3} + 1}\sqrt{2}\sin 10^3 t$$

$$= \frac{1}{\sqrt{2}\angle 45^\circ}\sqrt{2}\sin 10^3 t$$

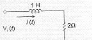
$$= \sin(10^3 t - 45^\circ)$$

4. (A) By taking Laplace transform, we have

$V_i(s) = LS\,I(s) + RI(s)$

$\Rightarrow \quad V_i(s) = (1\cdot s + 2)\,I(s)$

$\Rightarrow \quad I(s) = \frac{V_i(s)}{2+s}$



given that $\quad V_i(t) = u(t)$

so $\quad V_i(s) = \frac{1}{s}$

Now, $\quad I(s) = \frac{1}{s(2+s)}$

In time domain, $I(t) = \frac{u(t)}{2} - \frac{u(t)}{2}e^{-2t}$

or $\quad I(t) = \frac{u(t)}{2}(1 - e^{-2t})$

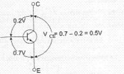
at $t = \frac{1}{2}, i(t) = 0{\cdot}31$

and at $t = \infty, i(t) = 0{\cdot}5$

6. (C) Boron is used for realizing the base region of a silicon *n-p-n* transistor.

7. (A) Given that, $V_{BE} = 0{\cdot}7V$

$V_{CB} = 0{\cdot}2V$



for a CE transistor

$V_{CE} = (0{\cdot}7 + 0{\cdot}2)\,V$

$= 0{\cdot}9V$

Since V_{CE} is 0·9V, so surely *n-p-n* transistor is operating in the normal active mode.

Alternative Method :

Given : $V_{BE} = 0{\cdot}7V$ (forward biased)

$V_{BC} = -0{\cdot}2V$ (reverse biased since given that $V_{CB} = 0{\cdot}2V$)

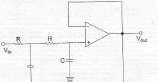
This shows that transistor operator in normal active mode.

8. (D) According to the statement S1 the β of a bipolar transistor reduces if the base width is increased is true since $\beta = \frac{I_c}{I_b}$, so if base width is increases, there will be more chances of recombination, resulting base current increases and finally β of a bipolar transistor decreases. According to the statement S2 the β of a bipolar transistor increases if the doping concentration in the base region is increased, since higher the doping concentration in the base means higher the recombination of charge carrier in the base resulting larger base current and ultimately reducing β of a bipolar transistor.

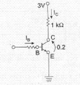
9. (B) An Ideal op-amp is an ideal voltage controlled voltage source (VCVS).

10. (C) In voltage series feedback (also called series-shunt feedback) results in increase in input impedance and decrease in output impedance.

11. (A) The given circuit represents the second order low pass filter.



12. (A) The minimum value of base current (I_B) required to drive the transistor into saturation is given by relation



$(I_B)_{min} = \frac{I_C}{h_{FE}}$ or $\frac{I_C}{B_{dc}}$

from the given figure,

$I_C = \frac{V_{CC} - V_{CE,\,sat}}{R_C} = \frac{3 - 0{\cdot}2}{1k\Omega} = 2{\cdot}8mA$

$(I_B)_{min} = \frac{2{\cdot}8mA}{50} = 56\mu A.$

13. (C) A Master-slave flip-flop has the characteristic that change in output occurs when the state of the slave is affected.

14. (A) ∵ 6 bit binary number 0 <u>00000</u>

↑

MSB Signed No.

= (+0), 1's complement of this No. = 1 <u>11111</u>

↑

MSB

= (– 31)

(0 11111) = (+ 31) 1's complement of this No. = 100000 (– 0).

15. (D) since $2^6 = 64$

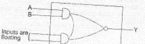
and $2^7 = 128$

so, for 100 Increments minimum 7 bits are required.

16. (B)

- Shift register in used for serial to parallel data conversion.
- Counter is used for frequency division.
- Decoder is used for addressing in memory chips.

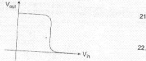
17. (A)



Inputs are floating means these are connected to logic 1. So

$$Y = \overline{AB + 1} = \overline{1} = 0$$

18. (C) The given figure represents the voltage transfer characteristic of a CMOS inverter.



19. (A) Given that, impulse response $h[n]$ of a linear time-invariant system

$$h[n] = u[n+3] + u[n-2] - 2u[n-7]$$

Now,

$$\sum_{k=-\infty}^{+\infty} h[k] = \sum_{k=-3}^{+\infty} u[k+3] \sum_{k=2}^{+\infty} u[k-2] - 2\sum_{k=7}^{+\infty} u[k-7]$$

$$= \sum_{k=-3}^{6} u[k+3] + \sum_{k=7}^{\infty} u[k-7] + \sum_{k=2}^{6} u[k-2] + \sum_{k=7}^{\infty} u[k-7] - 2\sum_{k=7}^{\infty} u[k-7]$$

$$= \sum_{k=-3}^{6} u[k+3] + \sum_{k=2}^{6} u[k-2]$$

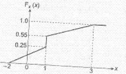
$= 10 + 5$

$= 15$ (which is less than ∞)

i.e. $15 < \infty$

It means the given system is stable and obviously the given system is non-causal.

20. (D) From the given figure, the probability that X = 1 is given by



$$P(X \le 1) = \int_{-2}^{1} F_x(x)\,dx$$

where $Fx(x) = \frac{0.25}{3}(x+2)$

$$= \int_{-2}^{1} \frac{0.25}{3}(x+2)\,dx$$

$$= \frac{0.25}{3}\left[\frac{x^2}{2} + 2x\right]_{-2}^{1} = 0.375$$

21. (D) Given $H(z) = \frac{z}{z-0.2}, |z| < 0.2$

then $h(n) = -(0.2)^n u[-n-1]$

since the given z-transform is left-hand sided.

22. (C) Fourier transform of a conjugate symmetric function is always real.

23. (B) $G(s)H(s) = \frac{2(1+s)}{s^2}$

put $s = j\omega$,

$$G(j\omega)H(j\omega) = \frac{2(1+j\omega)}{-\omega^2} = \frac{2}{-\omega^2} - \frac{j2}{\omega}$$

for phase crossover frequency $\frac{2}{\omega_1} = 0$, $\omega_1 = 0$

$$\text{G.M.} = 20\log_{10}\frac{1}{|G(j\omega_1)H(j\omega_1)|}$$

$$= 20\log_{10}\frac{1}{\sqrt{\left(\frac{2}{\omega^2}\right)^2 + \left(\frac{2}{\omega}\right)^2}}$$

at $\omega = \omega_1$

G.M. $= 20\log_{10} 0$

G.M. $= 0$

24. (C) For the given open loop transfer function,

$$G(s)H(s) = \frac{K}{s(s+1)(s+3)}$$

The point of intersection of the asymptotes of the root loci with real axis is,

$$\sigma = \frac{-[\text{Sum of the Real part of all poles} - \text{Sum of real parts of all zeros}]}{m-n}$$

$$= \frac{-[4-0]}{3-0} \quad \left[\begin{array}{l}\text{where } m = \text{no. of poles} \\ n = \text{no. of zeros}\end{array}\right]$$

$= -1.33$

In a PCM system SNR is given by relation

$$(SNR)_{dB} = 1{\cdot}76 + 6{\cdot}02n$$

where n = no. of bits

for n = 6 bits

$$(SNR)_{dB} = 1{\cdot}76 + 6{\cdot}02 \times 6 = 37{\cdot}88$$

for n = 8 bits

$$(SNR)_{dB} = 1{\cdot}76 + 6{\cdot}02 \times 8 = 49{\cdot}92$$

$(SNR)_{dB}$ is improved by a factor (49·92 – 37·88) = 12.

In an envelop detector the RC time constant of the diode should be greater than period of the lowest modulating frequency, *i.e.*,

$$\frac{1}{\omega_c} < RC \angle \frac{1}{2\pi f_m}$$

where, RC = time constant

f_m = highest frequency of modulating signal $m(t)$

$\omega_c = 2\pi f_c$ (carrier frequency)

given that, f_m = message bandwidth

$$= 2 \times 2 \times 10^3 = 4 \times 10^3 \text{ Hz} = 4\text{kHz}$$

$$f_c = 1 \text{ MHz} = 1 \times 10^6 \text{ Hz}$$

RC = time constant

Now, $$\frac{1}{2\pi \times 10^6} < RC < \frac{1}{2\pi \times 4 \times 10^3}$$

$$10^{-6} < RC < {\cdot}25 \times 10^{-3}$$

$$1\mu s < RC < 250\ \mu s$$

27. (B) 28. (A)

29. (D) The phase velocity of an electromagnetic wave propagating in a hollow metallic rectangular waveguide in the TE_{10} mode is greater than the velocity of light in free space.

Since for TE_{10} mode, phase velocity

$$(v_p) = \frac{v_c}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

where, $f_c = \frac{1}{2\sqrt{\mu\epsilon}}\sqrt{\frac{m^2}{a^2}+\frac{n^2}{b^2}}$

[$m = 1, n = 0$ for TE_{10} mode]

$$= \frac{c}{2a}$$

$$\therefore \quad \frac{f_c}{f} < 1$$

Therefore, phase velocity is greater than the velocity of light in free space.

30. (A)

$$G_d = +6 \text{ dB}$$

$$G_d = 10 \log_{10} G_d \text{ (dB)}$$

$$G_d = 3{\cdot}98$$

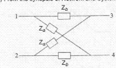
$$3{\cdot}98 = G_d = \frac{\text{Total Power Radiated}}{\text{Total Power Fed}}$$

$$= \frac{\text{Total Power Radiated}}{1 \text{ mW}}$$

Total radiated power = 3·98 × 1 mW

$$= 4 \text{ mW}$$

31. (D) From the synopsis of Network and System



$$Z_{11} = Z_{22} = \frac{Z_b + Z_a}{2} = \frac{2 + j2}{2} = 1 + j$$

$$Z_{12} = Z_{21} = \frac{Z_a - Z_b}{2} = \frac{j2 - 2}{2} = j - 1$$

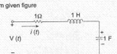
32. (B) Given that

$$i_L(0^-) = 1\text{A}$$

$$V_C(0^-) = -1\text{V}$$

$$V(t) = u(t)$$

From given figure



$$V(t) = R\,i(t) + L\frac{di(t)}{dt} + \frac{1}{C}\int i(t)\,dt$$

or $$u(t) = i(t) + \frac{d}{dt}i(t) + \int i(t)\,dt \qquad \ldots(A)$$

By taking Laplace transform of equation (A)

$$\frac{1}{s} = I(s) + sI(s) - L\,i(0^+) + \frac{I(s)}{sC} + \frac{i(0^+)}{s}$$

or $$\frac{1}{s} = I(s) + sI(s) - 1 + \frac{I(s)}{sC} - \frac{1}{s}$$

$$\left[\because \begin{array}{l} V_C(0^-) = V_C(0^+) \\ i_L(0^-) = i_L(0^+) \end{array}\right]$$

or $$\frac{2}{s} + 1 = I(s)\left[1 + s + \frac{1}{s}\right]$$

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

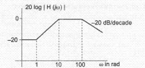
33. (C) From given figure we conclude that at $\omega = 1$, slope changes from 0 dB/decade to 20 dB/decade, and at $\omega = 10$, slope changes from 20 dB/decade to 0 dB /decade and at $\omega = 100$, slope changes from 0 dB/decade to – 20 dB/decade.

Hence, there is a zero at $\omega = 1$ and poles at $\omega = 10$ and $\omega = 100$.

Transfer function looks like

$$T(s) = \frac{K(s+1)}{(s+10)(s+100)}$$

or $$T(s) = \frac{K(s+1)}{1000\left(\frac{s}{10}+1\right)\left(\frac{s}{100}+1\right)}$$



$$20 \log_{10} \left(\frac{K}{1000} \right) = -20$$

or $$\frac{K}{1000} = 10^{-1}$$

or $$K = 100$$

Now, $$T(s) = \frac{10^2 (s+1)}{(s+10)(s+100)}$$

34. (B) Given that the transfer function of RLC circuit is

$$H(s) = \frac{V_0(s)}{V_i(s)} = \frac{10^6}{s^2 + 20s + 10^6}$$

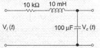
$$\omega_n = \sqrt{10^6}$$

$$\omega_n = 10^3 \text{ rad/sec}$$

$$\frac{\omega_n}{Q} = 20$$

$$Q = \frac{\omega_n}{20} = \frac{10^3}{20} = 50$$

35. (D) From the given figure



$$V_c(s) = \left(\frac{\frac{1}{sC}}{R + Ls + \frac{1}{Cs}} \right) \cdot V_i(s)$$

$$\frac{V_c(s)}{V_i(s)} = \frac{1}{LCs^2 + RCs + 1}$$

or $$H(s) = \frac{V_c(s)}{V_i(s)} = \frac{10^6}{s^2 + 10^6 s + 10^6}$$

36. (A) The given differential equation

$$\frac{d^2y}{dt^2} + \frac{3dy}{dt} + 2y = x(t) \qquad \text{...(A)}$$

Given that $x(t) = 2u(t)$ and the system is initially at rest *i.e.*, all the initial conditions are zero.

Taking Laplace transform both side in equation (A)

$$s^2 Y(s) + 3s\, Y(s) + 2Y(s) = \frac{2}{s} \qquad \{\because x(t) = 2u(t)\}$$

or $$(s^2 + 3s + 2)\, Y(s) = \frac{2}{s}$$

or $$Y(s) = \frac{2}{s(s^2 + 3s + 2)}$$

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

By using partial fraction Y(s) can be written

as $$y(s) = \frac{1}{s} - \frac{2}{s+1} + \frac{1}{s+2} \qquad \text{...(B)}$$

Now, by taking inverse laplace transform both side in equation (B), we get

$$y(t) = (1 - 2e^{-t} + e^{-2t})\, u(t)$$

37. (A) (1) At resonant frequency the impedance of a series RLC circuit is purely resistive,

i.e. Impedance = R

(2) In a parallel G-L-C circuit the quality factor $Q = \frac{\omega L}{R}$,

here $G = \frac{1}{R}$, $Q = \omega LG$

then increasing G means Q increases.

38. (B) Given,

$$N_A = 9 \times 10^{16}/\text{cm}^3$$
$$N_D = 1 \times 10^{16}\text{cm}^3$$
$$W_T = 3\mu\text{m}$$
$$W_P = ?$$

According to the charge neutrality equation, *i.e.*

$$W_P N_A = W_N N_D \qquad \text{...(i)}$$

$$W_T = W_P + W_N \qquad \text{[given] ...(ii)}$$

$$W_P = W_N \frac{N_D}{N_A}$$

$$W_P = (W_T - W_P) \frac{N_D}{N_A}$$

$$W_P \left(1 + \frac{N_D}{N_A} \right) = W_T \frac{N_D}{N_A}$$

$$W_P = \frac{W_T N_D}{N_A + N_D}$$

$$= \frac{3\mu\text{m} \times 10^{16}}{(9 \times 10^{16} + 1 \times 10^{16})}$$

$$= 0{\cdot}3\mu\text{m}.$$

39. (B) Given,

$$\rho = 0{\cdot}5\ \Omega\ \text{cm}$$
$$\mu_n = 1250\ \text{cm}^2/\text{V sec}$$
$$e = 1{\cdot}6 \times 10^{-19}\ \text{coulomb}$$
$$N_D = ?$$

We know that conductivity σ is given by relation

$$\sigma = e(N_D\, \mu_n + N_A\, \mu_p)$$

for *n*-type silicon sample, $N_D >> N_A$, so

$$\sigma \approx e\, N_D\, \mu_n$$

$$N_D = \frac{\sigma}{e\mu_n} = \frac{1}{\rho\, e\mu_n}$$

$$= \frac{1}{0{\cdot}5 \times 1{\cdot}6 \times 10^{-19} \times 1250}$$

$$= 1 \times 10^{16}/\text{cm}^3$$

40. (D) We know that transition or junction capacitance C_j is given by relation

$$C_j = \frac{C_0}{\left(1 + \frac{V_R}{V_{bi}} \right)^n} \qquad \text{...(i)}$$

where,

C_j = Junction capacitance, when reverse biased by voltage V_R

C_0 = Capacitance at zero bias condition
V_R = Applied reverse voltage
V_{bi} = Contact potential or potential barrier

$$\eta = \begin{cases} \frac{1}{2} \text{ for step or abrupt junction} \\ \frac{1}{3} \text{ for linearly graded or diffused junction} \end{cases}$$

So, equation (i) can be written as

$$C_j = \frac{C_0}{\left(1 + \frac{V_R}{V_{bi}}\right)^{1/2}}$$

or $$C_j = \frac{C_0 (V_{bi})^{1/2}}{(V_{bi} + V_R)^{1/2}}$$

or $$C_j \propto \frac{1}{(V_{bi} + V_R)^{1/2}} \quad \ldots\text{(ii)}$$

Therefore, from expression (ii) it is clear that for

$V_{bi} + V_R = 4V$, C_j will be $\frac{1}{2}$ pF or 0·5 pF

41. (C) S1 $V_T = \frac{Q_B}{C_{OX}}$

$$C_{OX} \propto \frac{1}{\text{D (thickness gate oxide)}}$$

S2 $V_T = \frac{Q_B}{C_{OX}}$

(charge density) $Q_B \propto$ substrate doping concentration (N_d) or N_a.

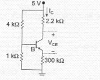
42. (D) In pinch off

$$V_{GS} = V_{DS}$$
$$V_{GS} > V_{GS} - V_T$$
$$2 > 2 - 1$$
$$I_D = K\,(V_{GS} - V_T)^2 = 1 \text{ mA}$$
$$K = 1$$
$$I_D = 1\,(3 - 1)^2 = 4 \text{ mA}$$

43. (A) $$\lambda_c\ (\mu m) = \frac{K}{E_G\ (eV)}$$
$$K = 1{\cdot}1 \times 1{\cdot}12$$
$$E_G\ (eV) = \frac{1{\cdot}1 \times 1{\cdot}12}{0{\cdot}87} = 1{\cdot}416 \text{ eV}$$

44. (B) $$J_n = qD_n \frac{dn}{dx}$$
$$= 1{\cdot}6 \times 10^{-19} \times 25 \times \frac{10^{14}}{0{\cdot}5 \times 10^{-6} \times 10^2}$$
$$= 8 \text{A/cm}^2$$

45. (C) $$R_B = \frac{4 \times 1}{4 + 1} = \frac{4}{5}$$



$$V_{BB} = 5 \times \frac{1}{5} = 1V$$
$$V_{BE} - V_{BB} + R_B I_B + I_E R_E = 0$$

or $$0{\cdot}7 - 1 + R_B \frac{I_C}{\beta} + I_E\, 300 = 0$$

$\frac{R_B I_C}{\beta}$ neglecting if $\beta >> 1$

$$I_C = I_E = \frac{0{\cdot}3}{300} = 0{\cdot}001 = 1\text{mA}$$
$$-5 + 1 \times 10^{-3} \times 2{\cdot}2 \times 10^3 + V_{CE} + 1 \times 10^{-3} \times 300 = 0$$
$$V_{CE} = 5 - 2{\cdot}2 - 0{\cdot}3 = 2{\cdot}5V$$

Hence, I_C = 1 mA and V_{CE} = 2·5 V.

46. (D) Given

$$I_C = 1 \text{ mA}$$
$$\beta = 100$$
$$V_T = 25 \text{ mV}$$
$$g_m = ?$$
$$r_\pi = ?$$

We know that

$$I_m = \frac{I_C}{V_T} = \frac{1 \text{ mA}}{25 \text{ mV}} = 0{\cdot}04 \text{ A/V} = 40 \text{ mA/V}$$
$$r_\pi = \frac{\beta}{g_m} = \frac{100}{40 \text{ mA/V}} = 2{\cdot}5 \text{ k}\Omega$$

47. (A) $$f = \frac{1}{2\pi RC}$$
$$C = \frac{1}{2\pi \times 10^3 \times 10^3}$$
$$C = \frac{1}{2\pi} \mu F$$

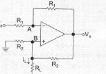
48. (A) $V_A = V_B$ (due to virtual ground)

KCL at node B

$$\frac{V_B}{R_2} + \frac{V_B - V_O}{R_2} + i_L = 0 \quad \ldots\text{(i)}$$

KCL at node A

$$\frac{V_A - V_S}{R_1} + \frac{V_A - V_O}{R_1} = 0 \quad \ldots\text{(ii)}$$



$$V_A = V_S \frac{R_1}{R_1 + R_1} + V_O \frac{R_1}{R_1 + R_1}$$
$$V_A = \frac{V_S}{2} + \frac{V_O}{2} = V_B$$
$$\frac{\frac{V_S + V_O}{2}}{R_2} + \frac{\frac{V_S + V_O}{2} - V_O}{R_2} = -i_0$$
$$\frac{V_S}{R_2} = -i_0$$

or $$i_0 = -\frac{V_S}{R_2}$$

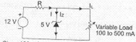
49. (D) From given circuit

$$\frac{12 - V_Z}{R} = I_L + I_Z$$

$$I_L = \left(\frac{12 - V_Z}{R}\right) - I_Z$$

$$V_Z = 5V$$

$$I_L = \frac{7}{R} - I_Z$$



Given 100 mA < I_L < 500 mA

$$100 \times 10^{-3} < \left(\frac{7}{R} - I_Z\right) < 500 \times 10^{-3}$$

I_Z = negligibly small

$$100 \times 10^{-3} < \frac{7}{R} < 500 \times 10^{-3}$$

$$14\ \Omega < R < 70\ \Omega$$

R = 14 Ω (minimum value).

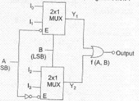
50. (B) For full-wave rectifier

$$V_{dc} = \frac{2V_m}{\pi}$$

and PIV = $2V_m$ (for centre tapped rectifier)

Since, given that full-wave rectifier using two diodes.

51. (B) The minimum number of 2-to-1 multiplexers required to realize a 4-to-1 multiplexer is 2, as given below :



Note : Here both the MUX are active low enable.

52. (D) $AC + B\bar{C} = AC(B + \bar{B}) + B\bar{C}(A + \bar{A})$

$$= ACB + AC\bar{B} + AB\bar{C} + B\bar{C}\,\bar{A}$$

$$= ABC + A\bar{B}C + AB\bar{C} + \bar{A}B\bar{C}$$

53. (C) 2's complement representation of

11001 is −7

1001 is −7

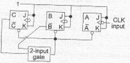
111001 is −7

54. (D) Mode 1 operation is for bidirectional data.

Mode 2 operation causes data to be stored.

55. (B) Instruction LDA required 4 memory cycle to execute while LXID required 3 memory cycle to execute.

56. (C)



Negative logic NAND gate is equivalent to OR gate

57. (A) LXI, H 9258 H ← Store the location in HL register pair

H	L
92	58

MOV A, M ← Store data on Address 9258 H moved to accumulator

CMA ← Complement the content of A

MOV M, A ← Complement data move to 9258 memory location.

So, the best option is (A) as data in moved from memory location 9258 H to the accumulator.

58. (D) From given information

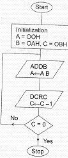
$f(0, 0) = f(0, 1) = f(1, 1) = 1$ and $f(1, 0) = 0$

i.e.,

X	Y	F
0	0	1
0	1	1
1	0	0
1	1	1

Hence 2 units are required.

59. (D)



Flow chart of multiplier

60. (C) Given $f_m = 1 \text{ kHz}$

$f_s = 1500 \text{ samples/sec}$

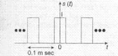
$f_c = 800 \text{ Hz}$

The sampled frequency are 2·5 kHz and 0·5 kHz (*i.e.* $f_s \pm f_m$), since LPF has cut-off frequency 800 Hz, then only output signal of frequency 0·5 kHz would pass through it.

61. (D) From given figure

$$f_s = \frac{1}{T} = \frac{1}{0 \cdot 1 \text{ m sec.}}$$

or $f_s = 10 \text{ kHz}$



General expression of rectangular pulse train $s(t)$ can be written as

$$s(t) = \frac{1}{T_s}[1 + 2\cos\omega_s t + 2\cos 2\omega_s t + \ldots\ldots + 2\cos 3\,\omega_s t + \ldots\ldots]$$

and $x(t) = \cos^2(4\pi \times 10^3 t) = \frac{(1 + \cos 8\pi \times 10^3 t)}{2}$

or $x(t) = \frac{1}{2} + \frac{1}{2}\cos 8\pi \times 10^3 t$ (say input signal)

i.e. $f_m = 4 \text{ kHz}$

According to question

$$y(t) = s(t) \times x(t)$$

$$= \int_{-\infty}^{\infty} s(\tau)\, x(t-\tau)\, d\tau$$

$$= \int_{-\infty}^{\infty} \frac{1}{T_s}[1 + 2\cos\omega_s t + 2\cos 2\,\omega_s t + 2\cos 3\,\omega_s t + \ldots\ldots] \times \frac{[1 + \cos 8\pi \times 10^3 t]}{2}\, d\tau$$

So, frequencies present will be $f_s \pm f_m$, $2f_s \pm f_m$, $3f_s \pm f_m$ from the given options we conclude that only 14 kHz sinusoid signal will present.

62. (C) For any term to be conjugate anti-symmetric the following condition must be met *i.e.*

$$\frac{s(n) - s^*(n)}{2} = \text{conjugate anti-symmetric}$$

for term $-4 - j5$ its conjugate anti-symmetric will be

$$= \frac{-4 - j5 - (-4 + j5)}{2}$$

$$= -j5$$

and for term $j2$ its conjugate anti-symmetric will be

$$= \frac{j2 + j2}{2}$$

$$= j2$$

and for term 4 its conjugate anti-symmetric will be

$$= \frac{4-4}{2} = 0$$

63. (C) Given equation,

$$2y[n] = \alpha\, y[n-2] - 2x[n] + \beta\, x[n-1]$$

taking z-transform both side

$$2Y(z) = \alpha\, z^{-2}\, Y(z) - 2 \times (z) + \beta X(z)\, z^{-1}$$

or $Y(z)[2 - \alpha z^{-2}] = X(z)[\beta z^{-1} - 2]$

or $$\frac{Y(z)}{X(z)} = \frac{(\beta z^{-1} - 2)}{(2 - \alpha z^{-2})} \qquad \ldots(A)$$

For stable system ROC should include all the poles lies inside the unit circle equation (A) can be written as

$$\frac{Y(z)}{X(z)} = H(z) = \frac{\left(\frac{\beta z^{-1}}{2} - 1\right)}{\left(1 - \frac{\alpha z^{-2}}{2}\right)}$$

So, in order to make the system function H (z) stable, pole lies inside the unit circle.

$|\alpha| < 2$ and for any value of β.

64. (B) Given $H(s) = \frac{1}{s+2}$

Input, $x(t) = 10u(t)$

or $X(s) = \frac{10}{s}$

$\therefore$ $Y(s) = H(s) \cdot X(s)$

or $Y(s) = \frac{1}{(s+2)} \cdot \frac{10}{s}$

or $Y(s) = \frac{5}{s} - \frac{5}{s+2}$ (by partial fraction)

or $y(t) = 5[1 - e^{-2t}]$ ...(B)

From relation steady state value of output *i.e.*, when $t \to \infty$, will be

$$Y(\infty) = 5 = \text{steady state value}$$

Now, $t = ?$

when output reaches 99% of steady state value

$$5 \times 0{\cdot}99 = 5[1 - e^{-2t}]$$

or $1 - e^{-2t} = 0{\cdot}99$

or $e^{-2t} = 1 - 0{\cdot}99 = 0{\cdot}01$

or $t = 2{\cdot}5$ sec.

65. (A) Given $h[n] = \begin{cases} -2\sqrt{2} & ; n = 1, -1 \\ 4\sqrt{2} & ; n = 2, -2 \\ 0 & ; n = \text{otherwise} \end{cases}$

$$x(n) = e^{j\pi n/4}$$

$$y(n) = ?$$

We know that

$$Y(z) = H(z) \cdot X(z)$$

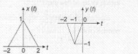
or $y(n) = h(n) * x(n)$

or $y(n) = h(n) \cdot e^{j\pi n/4}$

or $y(n) = [-2\sqrt{2} - 2\sqrt{2} + 4\sqrt{2} + 4\sqrt{2}]\, e^{j\pi n/4}$

or $y(n) = 4\sqrt{2}\, e^{j\pi n/4}$

66. (B)



From given fig, we conclude that output $y(t)$ is obtained from $x(t)$ by using following properties namely :

- Shifting 2 units left *i.e.* $y(t) = x(t+2)$
- Scaling by $\frac{1}{2}$ *i.e.* $y(t)$ is compression version of $x(t)$
- Amplitude reflection *i.e.* $y(t) = -x(t)$

Finally taking all the properties into consideration, we get

$$y(t) = -x[2(t+2)]$$

using $x(t+t_0) \leftrightarrow X(f) \cdot e^{j2\pi f}$

$$x(at) \leftrightarrow \frac{1}{|a|} \cdot X\left(\frac{f}{a}\right)$$

Therefore, $Y(f) = -\frac{1}{2} X(f) \cdot e^{j2\pi f}$

67. (C) Given poles at 0·01 Hz, 1 Hz and 80 Hz and zeros at 5 Hz, 100 Hz, 200 Hz

i.e. transfer function,

$$H(s) = \frac{K(s+5)(s+100)(s+200)}{(s+0{\cdot}01)(s+1)(s+80)}$$

or $$H(s) = K' \frac{\left(\frac{s}{5}+1\right)\left(\frac{s}{100}+1\right)\left(\frac{s}{200}+1\right)}{\left(\frac{s}{0{\cdot}01}+1\right)\left(\frac{s}{1}+1\right)\left(\frac{s}{80}+1\right)}$$

$$\angle H(s) = \tan^{-1}\left(\frac{\omega}{5}\right) + \tan^{-1}\left(\frac{\omega}{100}\right) + \tan^{-1}\left(\frac{\omega}{200}\right) - \tan^{-1}\left(\frac{\omega}{0{\cdot}01}\right) - \tan^{-1}\left(\frac{\omega}{1}\right) - \tan^{-1}\left(\frac{\omega}{80}\right)$$

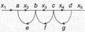
at $\omega = 20$,

$$\angle H(s) = \tan^{-1}(4) + \tan^{-1}\left(\frac{1}{5}\right) + \tan^{-1}\left(\frac{1}{100}\right) - \tan^{-1}(2000) - \tan^{-1}(20) - \tan^{-1}\left(\frac{1}{4}\right)$$

after simplify

or $$\angle H(s) = 90°$$

68. (C) From given figure



Here, forward path is one *i.e.*

$$P_1 = a\,b\,c\,d$$

and there loops *i.e.*

$$L_1 = bc$$
$$L_2 = cf$$
$$L_3 = dg$$

The gain $\frac{x_5}{x_1}$ can be calculated by using Manson's gain formula for signal flow graph

$$\frac{x_5}{x_1} = G = \sum_{k=1}^{k} \frac{(P_k\,\Delta_k)}{\Delta}$$

where, $P_1 = a\,b\,c\,d$

$$\Delta_1 = 1$$

$$\Delta = 1 - (bec + cf + dg) + bedg$$

or $$\frac{x_5}{x_1} = \frac{abcd}{1 - (be + cf + dg) + bedg}$$

69. (B) Try yourself.

70. (A) Given $\quad G(s) = \frac{K}{s(s^2+s+2)(s+3)}$

$$H(s) = 1$$

C. E. $\quad 1 + G(s)H(s) = 0$

or $$1 + \frac{K}{s(s^2+s+2)(s+3)} \times 1 = 0$$

or $$(s^3+s^2+2s)(s+3) + K = 0$$

or $$s^4 + s^3 + 2s^2 + 3s^3 + 3s^2 + 6s + K = 0$$

or $$s^4 + 4s^3 + 5s^2 + 6s + K = 0$$

The range of k can be calculated by using R. H. C.

s^4	1	5	K
s^3	4	6	0
s^2	$\frac{7}{2}$	K	
s^1	$\frac{2(21-4K)}{7}$	0	
s^0	K		

for the system to be stable,

$$\frac{2(21-4K)}{7} > 0$$

and $\quad K > 0$

or $\quad 21 > 4K$

and $\quad K > 0$

or $$0 < K < \frac{21}{4}$$

71. (B) Given $P(s) = s^5 + s^4 + 2s^3 + 2s^2 + 3s + 15$

In order to determine the number of roots which lie in the RHS of the s-plane, first construct R. H. array

s^5	1	2	3
s^4	1	2	15
s^3	ϵ	-12	0
s^2	$\frac{2\epsilon+12}{\epsilon}$	15	0
s^1	$\frac{-12(12+2\epsilon)}{\epsilon} - 15$		
s^0	15		

where, ϵ is very small positive quantity.

$\because$ Number of sign changes in first column is 2.

$\therefore$ Number of roots in RHS plane is also 2.

72. (D) The given state variable equations are

$$\dot{x}_1 = -3x_1 - x_2 + u$$
$$\dot{x}_2 = 2x_1$$
$$y = x_1 + u$$

The above equations in matrix form can be written as

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}-3 & -1\\ 2 & 0\end{bmatrix} + \begin{bmatrix}1\\ 0\end{bmatrix} u$$

$$y = [1\ \ 0]\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}1\\ 0\end{bmatrix} u$$

Here, $A = \begin{bmatrix} -3 & -1 \\ 2 & 0 \end{bmatrix}$

$B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$

$C = [1 \ 0]$

Check for controllability

$Q_C = [B : AB]$

$AB = \begin{bmatrix} -3 & -1 \\ 2 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} -3 \\ 2 \end{bmatrix}$

or $Q_C = \begin{bmatrix} 1 & -3 \\ 0 & 2 \end{bmatrix} = 2 \text{ i.e. } \neq 0$

It means the system is controllable.

Now, check for observability

$Q_0 = [C^T : A^T C^T]$

$C^T = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$

$A^T C^T = \begin{bmatrix} -3 & 2 \\ -1 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} -3 \\ -1 \end{bmatrix}$

or $Q_0 = \begin{bmatrix} 1 & -3 \\ 0 & -1 \end{bmatrix} = -1 \text{ i.e. } \neq 0$

It means the system is observable.

73. (B) State transition matrix is given by

$[SI - A]^{-1}$

where $A = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

Now, $[SI - A] = \begin{bmatrix} S & 0 \\ 0 & S \end{bmatrix} - \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

$[SI - A]^{-1} = \begin{bmatrix} S-1 & 0 \\ 0 & S-1 \end{bmatrix}^{-1}$

$[SI - A]^{-1} = \begin{bmatrix} \frac{1}{S-0} & 0 \\ 0 & \frac{1}{S-1} \end{bmatrix}$

$L^{-1}[SI - A]^{-1} = L^{-1} \begin{bmatrix} \frac{1}{S-0} & 0 \\ 0 & \frac{1}{S-1} \end{bmatrix}$

$= \begin{bmatrix} e^t & 0 \\ 0 & e^t \end{bmatrix}$

74. (D)

75. (A) Given, signal power $= 1 \text{ mW} = 1 \times 10^{-3}$ W

$E[Y^2(t)] = \frac{1}{2\pi} \int_{-\infty}^{\infty} S_{yy}(\omega)\, d\omega$

$= 10^{-22}$ watt/Hz

or Noise power $= E[Y^2(t)] \times$ bandwidth

$= 10^{-22} \times 100 \times 10^6$

$= 10^{-12}$ W

Now, $\text{SNR} = \frac{\text{Signal power}}{\text{Noise power}}$

$= \frac{1 \times 10^{-3}}{10^{-12}} = 10^9$

$(\text{SNR})_{dB} = 10 \log 10^9 = 90$

Since given loss = 40 dB

Therefore, $(\text{SNR})_{dB}$ at the receiver

$= 90 - 40 = 50$ dB.

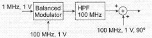
76. (C) Given, $f_c = 100 \text{ MHz} = 100 \times 10^6$ Hz

$A_c = 1$ V

$f_m = 1 \text{ MHz} = 1 \times 10^6$ Hz

$A_m = 1$ V

High pass filter with cut-off frequency = 100 MHz



The output of the balanced modulator

$s(t) = m(t) \cdot c(t)$

$= 1 \cdot \cos(2\pi\, 10^6\, t)\, 1 \cdot \cos(2\pi \cdot 100 \times 10^6\, t)$

$= \frac{1}{2}\{\cos[2\pi(10^8 + 10^6)\, t] + \cos[2\pi(10^8 - 10^6)\, t]\}$

Output after high pass filter with cut-off frequency 100 MHz

$r(t) = \frac{1}{2}\cos[2\pi(10^8 + 10^6)\, t]$

After adding another signal at the output, we have

$y(t) = \frac{1}{2}\cos[2\pi(10^8 + 10^6)\, t] + \cos[2\pi(10^8 - 10^6)\, t]$

$= \sqrt{5/4 - \sin(2\pi \times 10^6\, t)}$

77. (B) Given two sinusoidal signals of same amplitude and frequencies 10 kHz and 10·1 kHz

$s(t) = x_1(t) \cdot x_2(t)$

$= A \sin(2\pi \times 10 \times 10^3\, t) \cdot A \sin(2\pi \times 10 \cdot 1 \times 10^3 t)$

$= \frac{A^2}{2}\{\cos 2\pi(10 \cdot 1 - 10)\, 10^3 t$

$- \cos 2\pi(10 \cdot 1 + 10)\, 10^3 t\}$

Since frequency detector is acts as a high pass filter.

Therefore, the output of the detector is 20·1 kHz sinusoid.

78. (A)

79. (A) Given quantized value of X for interval given below :

$x_q = 0 \quad \text{for } 0 \le X \le 0 \cdot 3$

$x_q = 0 \cdot 7 \text{ for } 0 \cdot 3 \le X \le 1$

We know that the quantization noise

$m^2 = \int_{-\infty}^{\infty} X^2\, dx$

$= \int_0^1 X^2 f_x(x)\, dx$

or $m^2 = \int_{0 \cdot 3}^{1} x^2 \cdot 1 \cdot dx \qquad [\because f_x(x) = 1]$

or $m^2 = \left[\frac{x^3}{3}\right]_{0 \cdot 3}^{1}$

or $m^2 = \frac{1 - (0 \cdot 3)^3}{3}$

or $m^2 = \frac{1 - 0 \cdot 027}{3}$

Now, root-mean square value of quantization noise

$= \sqrt{m^2} = \sqrt{0 \cdot 324}$

$= 0 \cdot 5695$

$= 0 \cdot 57$

80. (C)

81. (C) Given three analog signals having bandwidths 1200 Hz, 600 Hz and 600 Hz are sampled at their respective Nyquist rate i.e. 2400, 1200 and 1200 samples/sec.

Now, bit rate = Total sampling frequency × bit words

$$= (2400 + 1200 + 1200) \times 12$$

$$= 57.6 \text{ kbps}$$

82. (B) Let the modulating signal, x(t) with frequency, f_m

Output after balance modulator $= 10 \pm f_m$

Output after HPF with cut-off frequency,

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

Output after next balance modulator

$$= 13 \pm (10 + f_m)$$

$$= 23 + f_m \text{ and } 3 - f_m$$

This condition is fulfilled by options given in alternative (B) only.

83. (D) Given, $A = 10^{-4}\ m^2$

$d = 10^{-7}\ m$

$V = 0.5\ V$

$f = 3.6\ GHz$

$I = ?$

$$\epsilon_0 = \frac{1}{36\pi \times 10^{-9}}\ F/m$$

We know that displacement current density

$$I_d = \frac{\epsilon_0 AV\omega}{d}\ A \quad (\because \omega = 2\pi f)$$

$$= \frac{1}{36\pi} \times \frac{10^{-9} \times 0.5 \times 3.6 \times 10^9 \times 2\pi \times 10^{-4}}{10^{-7}}$$

$$= 1.59\ mA$$

84. (C) 85. (C)

86. (D) Microwave test bench is amplitude modulated because crystal detector fails at microwave frequencies.

87. (A) We know that time-averaged Poynting vector is given by

$$P_{avg} = \frac{1}{2} \text{Re}\left[\vec{E} \times \vec{H}^*\right]$$

$$= \frac{1}{2} \text{Re}\left[\left(\hat{a}_x + j\hat{a}_y\right) e^{j(\omega t - \beta z)} \times \frac{k}{\omega\mu}\left(\hat{a}_y - j\hat{a}_x\right) e^{-j(\omega t - \beta z)}\right]$$

$$= \frac{1}{2} \text{Re}\left[\left(\hat{a}_x + j\hat{a}_y\right) \times \frac{k}{\omega\mu}\left(\hat{a}_y - j\hat{a}_x\right)\right]$$

$$= \frac{k}{2\omega\mu}\left[\hat{a}_x \times \hat{a}_y + j\hat{a}_y \times \hat{a}_y - j\hat{a}_x \times \hat{a}_x - j^2 \hat{a}_y \times \hat{a}_x\right]$$

$$= \frac{k}{2\omega\mu}\left[\hat{a}_z + j0 - j0 + \left(-\hat{a}_z\right)\right]$$

$$= \frac{k}{2\omega\mu}\left[\hat{a}_z - \hat{a}_z\right]$$

$$= 0$$

= Null vector

88. (A) Inductance is added in series when moving in clockwise direction.

89. (D)

90. (D) Given, VSWR $= 2 = \sigma$

or $$\sigma = \frac{1 + \Gamma}{1 - \Gamma}$$

where Γ = standing wave ratio

$$2 = \frac{1 + \Gamma}{1 - \Gamma}$$

or $$\Gamma = \frac{1}{3}$$

Now, the percentage of the power that is reflected back is

$$\frac{P_{ref}}{P_{in}} = \Gamma^2 \times 100$$

$$= \left(\frac{1}{3}\right)^2 \times 100$$

$$= 11.1\%$$