DETAILED SOLUTIONS

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ESE 2026 : Prelims Exam
CLASSROOM TEST SERIES

ELECTRICAL ENGINEERING

Test 4

Section A : Control Systems [All Topics] + Engineering Mathematics [All Topics]

Section B : Electrical Circuits - 1 [Part Syllabus]

Section C : Digital Electronics - 1 [Part Syllabus] + Microprocessors - 1 [Part Syllabus]

ANSWER KEY

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

DETAILED EXPLANATIONS
Section A : Control Systems + Engineering Mathematics

1. (b)

$$H(s) = \frac{C(s)}{R(s)} = \frac{\dfrac{K}{10s+1}}{1+\dfrac{KK'}{10s+1}} = \frac{K}{10s+1+KK'}$$

$$\frac{dH}{dK} = \frac{(10s+1+KK')-KK'}{(10s+1+KK')^2} = \frac{10s+1}{(10s+1+KK')^2}$$

$$S_K^H = \frac{dH}{dK}\cdot\frac{K}{H}$$

$$= \frac{10s+1}{(10s+1+KK')}\times\frac{K}{\dfrac{K}{(10s+1+KK')}}$$

$$= \frac{10s+1}{10s+1+KK'} = \frac{10j+1}{10j+1+99} = \frac{10j+1}{10j+100}$$

$$\left|S_K^H\right| = \sqrt{\frac{10^2+1}{10^2+100^2}} = 0.1$$

2. (c)

$$G(s) = \frac{20}{(s+1)(s+5)}$$

$$\frac{C(s)}{R(s)} = \frac{20}{s^2+6s+25}$$

Comparing it with general second order,

$$\text{TF} = \frac{K}{s^2+2\xi\omega_n s+\omega_n^2}$$

$$\omega_n^2 = 25, \qquad \omega_n = 5 \text{ rad/sec}$$

$$2\xi\omega_n = 6$$

$$\Rightarrow \qquad \xi = \frac{3}{5} = 0.6$$

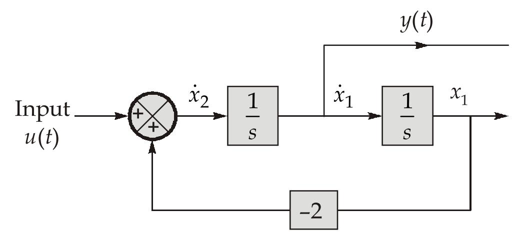
$$\omega_d = \omega_n\sqrt{1-\xi^2} = 5\sqrt{1-\frac{9}{25}} = 4 \text{ rad/sec}$$

$$\text{Time period of oscillation} = \frac{2\pi}{\omega_d} = \frac{2\pi}{4} = 1.56 \text{ sec}$$

3. (b)

Derivating control increases ξ and decreases setting time.

4. (c)



$$y = x_2$$

$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = u - 2x_1$$

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -2 & 0 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix}u$$

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

$$A = \begin{bmatrix} 0 & 1 \\ -2 & 0 \end{bmatrix},\ B = \begin{bmatrix} 0 \\ 1 \end{bmatrix},\quad C = [0 \ \ 1]$$

$$Q_C = [B \quad AB]$$

$$= \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \qquad \Rightarrow |Q_C| \neq 0$$

$$Q_0 = \begin{bmatrix} C \\ CA \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -2 & 0 \end{bmatrix} \Rightarrow |Q_0| \neq 0$$

System is both controllable and observable.

5. (c)

$$G(s) = \frac{K}{s(s+2)} \text{ for type-1 system}$$

$$\frac{C(s)}{R(s)} = \frac{K}{s^2 + 2s + K}$$

$$2\xi\omega_n = 2$$

$$\Rightarrow \qquad \xi = \frac{1}{\omega_n} = \frac{1}{\sqrt{K}}$$

$$K = \frac{1}{\xi^2} = \frac{1}{(0.4)^2} = 6.25$$

Steady state error for $r(t) = 4\ tu(t)$

$$e_{ss} = \frac{4}{K_v}$$

$$K_v = \lim_{s\to 0} sG(s) = \lim_{s\to 0} s\frac{6.25}{s(s+2)} = \frac{6.25}{2}$$

$$e_{ss} = \frac{4}{K_v} = \frac{8}{6.25} = 1.28$$

6. (d)

$$G(j\omega) = \frac{100}{(j\omega+1)^4}$$

At phase cross over frequency,

$$-4\tan^{-1}\left(\omega_{pc}\right) = -180°$$

$$\omega_{pc} = 1 \text{ rad/sec}$$

$$|G(j\omega)|_{\omega=\omega_{pc}} = \left|\frac{100}{(j\omega+1)^4}\right|_{\omega_{pc}=1} = 25$$

$$\text{GM} = \frac{1}{|G(j\omega)|_{\omega_{pc}}} = \frac{1}{25} = 0.04$$

7. (a)

$$G(s) = \frac{5(1+0.25s)}{1+0.01s}$$

$$G(s) = \frac{\alpha(1+Ts)}{(1+\alpha Ts)}$$

On comparing, $T = 0.25$; $\alpha T = 0.01$

Maximum phase compensation occurs at frequency

$$\omega_m = \sqrt{\frac{1}{T}\times\frac{1}{\alpha T}} = \sqrt{\frac{1}{0.01}\times\frac{1}{0.25}} = \frac{100}{5} = 20 \text{ rad/sec}$$

8. (c)

If frequency response has sharp cut-off characteristic, then bandwidth is small.

9. (c)

Since, the system is minimum phase system, it has no poles or zeros in the right hand side of s-plane.

There are four corner frequencies for the transfer function $G(s)$.

(i) Two poles at $\omega_1 = 5$ rad/sec as slope changes by –40 dB/dec.

(ii) Two zeros at ω_2 = 20 rad/sec as slope changes by +40 dB/dec.

(iii) Two poles at ω_3 = 40 rad/sec as slope changes by –40 dB/dec.

(iv) A pole at ω_4 = 100 rad/sec as slope changes here by –20 dB/dec.

Therefore open loop transfer function in time constant form;

$$G(s) = \frac{K\left(1+\frac{s}{20}\right)^2}{\left(1+\frac{s}{5}\right)^2\left(1+\frac{s}{40}\right)^2\left(1+\frac{s}{100}\right)}$$

$\because$ Initial slope = 0 dB

then, $20 \log K = 40$ dB

or $K = 100$

Now open loop transfer function,

$$G(s) = \frac{100\times 25\times 40^2\times 100(s+20)^2}{20^2(s+5)^2(s+40)^2(s+100)} = \frac{10^6(s+20)^2}{(s+5)^2(s+40)^2(s+100)}$$

10. (c)

For the given system, characteristic equation is

$$\left(1+\frac{16}{s(s+1.4)+16sT_d}\right) = 0$$

or, $s^2 + 1.4s + 16s\,T_d + 16 = 0$

or, $s^2 + (1.4 + 16T_d)\,s + 16 = 0$

Comparing with $s^2 + 2\,\xi\omega_n s + \omega_n^2 = 0$, we have:

$$\omega_n = \sqrt{16}\text{ rad/s} = 4\text{ rad/sec}$$

and $2\,\xi\omega_n = (1.4 + 16T_d)$

or, $2\times 0.7\times 4 = 1.4 + 16T_d$ $\quad(\because \xi = 0.7$, given)

or, $5.6 - 1.4 = 16T_d$

or, $T_d = \frac{4.2}{16} = 0.2625$

11. (d)

- PD controller increases the value of 'ξ'. As a result, peak overshoot will decrease
- PD controller does not change e_{ss}
- P, I, PI, D controllers change e_{ss}

12. (c)

Given, $$\frac{C(s)}{R(s)} = \frac{16}{s^2+4.8s+16} = \frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2}$$

Here, $\omega_n = 4$ rad/s, $2\xi\omega_n = 4.8$

or, $\xi = \dfrac{4.8}{2 \times 4} = 0.6$

Peak time, $t_p = \dfrac{n\pi}{\omega_d} = \dfrac{n\pi}{\omega_n\sqrt{1-\xi^2}}$

For overshoots, $n = 1, 3, 5, \ldots$

For undershoots, $n = 2, 6, 8, \ldots$

For 3rd peak, $n = 5$ (3rd overshoot is the third peak)

So, $t_p = \dfrac{5\pi}{4\sqrt{1-0.6^2}} = \dfrac{5\pi}{4 \times 4/5} = \dfrac{25\pi}{16} = 1.56\,\pi$

13. (c)

The characteristic equation of the given closed loop system is

$$1 + \frac{16}{s(s+2.4)} = 0 \text{ or } s^2 + 2.4s + 16 = 0$$

Comparing above equation with $s^2 + 2\xi\omega_n s + \omega_n^2 = 0$, we have

$$\omega_n = 4 \text{ rad/s}$$

and $2\,\xi\omega_n = 2.4$

or $\xi\omega_n = 1.2$

Thus, settling time for 2% tolerance band is

$$t_s = 4T = \frac{4}{\xi\omega_n}$$

or, $t_s = \dfrac{4}{1.2} = 3.33$ sec.

14. (b)

Response due to unit step input,

$$c(t) = tu(t) - \frac{1}{4}u(t) + \frac{1}{8}e^{-2t}u(t)$$

$$C(s) = \frac{1}{s^2} - \frac{1}{4s} + \frac{1}{8(s+2)}$$

$$\text{Impulse response} = \frac{C(s)}{1/s} = \frac{\dfrac{1}{s^2} - \dfrac{1}{4s} + \dfrac{1}{8(s+2)}}{1/s}$$

$$= \frac{1}{s} - \frac{1}{4} + \frac{s}{8(s+2)} = \frac{1}{s} - \frac{1}{4} + \frac{1}{8}\left[1 - \frac{2}{s+2}\right]$$

$$\text{Impulse response} = \frac{1}{s} - \frac{1}{8} - \frac{1}{4(s+2)}$$

Taking Laplace inverse, we get,

$$\text{Impulse response} = -\frac{1}{8}\delta(t) + u(t) - \frac{1}{4}e^{-2t}u(t)$$

15. (c)

Using Routh-Hurwitz criterion

$$\begin{array}{c|ccc} s^4 & 1 & 13 & K \\ s^3 & 4 & 36 & 0 \\ s^2 & 4 & K & 0 \\ s^1 & \dfrac{144-4K}{4} & 0 & 0 \\ s^0 & K & 0 & 0 \end{array}$$

For oscillation to occur

$$\frac{144-4K}{4} = 0$$

or $K = 36$

∴ Auxiliary equation, $4s^2 + 36 = 0$

or, $s = \pm 3j$

$$\omega_n = 3 \text{ rad/sec.}$$

16. (b)

The state equations from the given signal flow graph can be written as:

$$\dot{x}_1 = x_2 \quad \text{... (i)}$$

and $\dot{x}_2 = -4x_1 - 5x_2 + 3u(t)$ ... (ii)

In matrix form,

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -4 & -5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 3 \end{bmatrix} u(t)$$

Also, output is

$$y(t) = 8x_1 + 3x_2 + 6u(t) \quad \text{... (iii)}$$

In matrix form

$$y(t) = \begin{bmatrix} 8 & 3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + 6u(t)$$

17. (c)

The introduction of a time delay element decreases both phase margin and gain margin.

18. (a)

$$G(s) = \frac{K}{(s+2)(0.3s+3)}$$

Since input is unit step, therefore steady state error is

$$e_{ss} = \lim_{s \to 0} \left(\frac{1}{1+K_p} \right) = 0.2 \quad \text{(Given)}$$

Here, $K_p = \lim_{s\to 0}[G(s)] = \lim_{s\to 0}\frac{K}{(s+2)(0.3s+3)} = \frac{K}{6}$

$\therefore$ $0.2 = \frac{1}{1+K/6}$

or, $1+\frac{K}{6} = 5$

or, $K = 24$

19. **(d)**

Lag compensator shifts the gain cross over frequency point to a lower value hence improvement in steady state is noted. Whereas in lag-lead compensator, both compensators are connected in cascade.

20. **(d)**

From the polar plot, we can observe;

$$\text{Gain margin} = \frac{1}{0.667} = 1.5$$

$$\text{Phase margin} = 90° - 20° = 70°$$

21. **(c)**

As the Nyquist plot passes through (–1, 0) means it is marginal stable system and $|GH| = 1$;

$$\angle GH = -180°$$

So, $\text{PM} = 180° + \angle GH(\omega_{gc}) = 180° - 180° = 0°$

22. **(d)**

Phase margin is calculated at gain crossover frequency. Thus, statement 2 is not correct.

24. **(d)**

Substituting, $s = s' - 1$ in the given characteristic equation, we get

$$(s'-1)^3 + 10(s'-1)^2 + 37(s'-1) + 52 = 0$$

$$s'^3 + 7s'^2 + 20s' + 24 = 0$$

Now, its Routh's array is,

$$\begin{array}{c|cc} s'^3 & 1 & 20 \\ s'^2 & 7 & 24 \\ s'^1 & 16.57 & \\ s'^0 & 24 & \end{array}$$

Since there is no sign change in the first column of Routh array, it indicates that no root lies to the right of the $s = -1$. Therefore all roots are more negative than $s = -1$.

25. (a)

$$(s^4 + 5s^3 + 8s^2 + 6s + 3)\,Y(s) = U(s) \qquad \text{...(i)}$$

Let
$$x_1 = y \qquad \text{..(ii)}$$
$$x_2 = \dot{x}_1 \qquad \text{...(iii)}$$
$$x_3 = \dot{x}_2 \qquad \text{...(iv)}$$
$$x_4 = \dot{x}_3 \qquad \text{...(v)}$$

So, transfer function equation can be written as

$$\dot{x}_4 + 5x_4 + 8x_3 + 6x_2 + 3x_1 = u$$

or,
$$\dot{x}_4 = -3x_1 - 6x_2 - 8x_3 - 5x_4 + u \qquad \text{...(vi)}$$

Writing above equations in matrix from,

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -3 & -6 & -8 & -5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} u$$

i.e.
$$\dot{x} = Ax + Bu$$

26. (c)

Since this is a first order system with a delay time, let the transfer function be,

$$G(s) = \frac{Ke^{-T_d s}}{1+\tau s}$$

Where the terms have their usual meanings.

Given
$$K = 1,$$
$$\tau = 1 \text{ sec},$$
$$T_d = 0.1 \text{ sec}$$

therefore,
$$G(s) = \frac{e^{-0.1s}}{1+s}$$

27. (b)

$$\text{Transfer function} = C \cdot [sI - A]^{-1} \cdot B$$

$$= [1 \;\; 1] \begin{bmatrix} s+1 & 0 \\ 0 & s+3 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$= [1 \;\; 1] \begin{bmatrix} \frac{1}{s+1} & 0 \\ 0 & \frac{1}{s+3} \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

$$= [1 \;\; 1] \begin{bmatrix} 0 \\ \frac{1}{s+3} \end{bmatrix} = \frac{1}{s+3}$$

28. (c)

If λ is an eigen value of matrix-A

Then, $$AX = \lambda X$$

$$\Rightarrow \begin{bmatrix} 4 & 1 & 2 \\ 17 & 2 & 1 \\ 14 & -4 & 10 \end{bmatrix}\begin{bmatrix} 1 \\ 2 \\ k \end{bmatrix} = \lambda \begin{bmatrix} 1 \\ 2 \\ k \end{bmatrix}$$

$$\Rightarrow \quad 6 + 2k = \lambda \quad \text{...(i)}$$

$$\Rightarrow \quad 21 + k = 2\lambda \quad \text{...(ii)}$$

Solving (i) and (ii), we get

$$\lambda = 12$$

and $$k = 3$$

29. (d)

$$\lim_{x \to \pi^-} \cot(x) = -\infty$$

$$\lim_{x \to \pi^+} \cot(x) = \infty$$

$\therefore \lim_{x \to \pi} \cot(x)$ does not exist.

30. (a)

$$f(x) = (x + 2)^3 \times (x - 3)^4$$

$$f'(x) = 4(x + 2)^3 \cdot (x - 3)^3 + 3(x - 3)^4 \cdot (x + 2)^2$$

$$= (x + 2)^2 \cdot (x - 3)^3 \{4(x + 2) + 3(x - 3)\}$$

Consider, $$f'(c) = 0$$

$$\Rightarrow (c + 2)^2 (c - 3)^3\{4(c + 2) + 3(c - 3)\} = 0$$

$$c = -2, 3, \frac{1}{7}$$

Only $$c = \frac{1}{7} \in [-2, 3]$$

31. (c)

The directional derivative of $f(x, y, z)$ at $P(1, -2, -1)$ in the direction of

$$\hat{a} = 2\vec{i} - \vec{j} - 2\vec{k} \text{ is } (\text{grad}\,\phi)_P \cdot \frac{\vec{a}}{|\vec{a}|}$$

$$\nabla\phi = \left[\left(2xyz + 4z^2\right)i + \left(x^2 z\right)j + \left(x^2 y + 8xz\right)k\right]$$

$$\nabla\phi \text{ at } P = \frac{2i - j - 2k}{|2i - j - 2k|}$$

Required directional derivative

$$= (8\vec{i} - \vec{j} - 10\vec{k}) \cdot \frac{(2\vec{i} - \vec{j} - 2\vec{k})}{\sqrt{4+1+4}}$$

$$= \frac{16+1+20}{3} = \frac{37}{3}$$

32. (d)

$$\text{Required probability} = \frac{3}{6} \times \frac{3}{6} = \frac{1}{4}$$

33. (c)

$$|A - \lambda I| = 0$$

$$\begin{bmatrix} 1-\lambda & 2 & 3 & 4 & 5 \\ 5 & 1-\lambda & 2 & 3 & 4 \\ 4 & 5 & 1-\lambda & 2 & 3 \\ 3 & 4 & 5 & 1-\lambda & 2 \\ 2 & 3 & 4 & 5 & 1-\lambda \end{bmatrix} = 0$$

Sum of all elements in any one Row must be zero

i.e. $15 - \lambda = 0$

$\Rightarrow$ $\lambda = 15$

34. (b)

The conditional probability is given as:

$$P\,(\text{bag}_1/\text{Red}) = \frac{P(bag_1 \cap \text{Red})}{P(\text{Red})} = \frac{\frac{1}{2} \times \frac{3}{7}}{\frac{1}{2} \times \frac{3}{7} + \frac{1}{2} \times \frac{2}{8}} = \frac{12}{19}$$

35. (a)

$$I = \int_0^{2\pi} \left(\frac{4}{16 + \sin^2\theta}\right) d\theta$$

$$= 4 \times \int_0^{\pi/2} \left(\frac{4}{16 + \sin^2\theta}\right) d\theta = 16 \int_0^{\pi/2} \frac{\sec^2\theta}{16\sec^2\theta + \tan^2\theta} d\theta$$

$$= 16 \int_0^{\pi/2} \frac{\sec^2\theta\, d\theta}{16 + 17\tan^2\theta} = \frac{16}{17} \int_0^{\pi/2} \frac{\sec^2\theta d\theta}{\frac{16}{17} + \tan^2\theta}$$

Limits:

Let, $\tan\theta = t$

$\sec^2\theta\, d\theta = dt$

$\theta = 0,\ t = 0$

$$\theta = \frac{\pi}{2};$$
$$t \to \infty$$

$$= \frac{16}{17}\int_0^{\pi/2} \frac{dt}{t^2 + \left(\sqrt{\frac{16}{17}}\right)^2} = \frac{16}{17} \times \frac{\sqrt{17}}{4}\left[\tan^{-1}\left(\frac{t\sqrt{17}}{4}\right)\right]_0^{\infty}$$

$$= \frac{4}{\sqrt{17}}\left[\frac{\pi}{2} - 0\right] = \frac{2\pi}{\sqrt{17}}$$

36. (a)

By vector identities $\text{div}\,(\text{curl}\,\vec{F}) = 0$

37. (b)

Given, $$\lim_{n\to\infty} \frac{2^{n+1} + 3^{n+1}}{2^n + 3^n} = \lim_{n\to\infty} \frac{2\cdot 2^n + 3\cdot 3^n}{2^n + 3^n} = \lim_{n\to\infty} \frac{3^n\left[2\left(\frac{2}{3}\right)^n + 3\right]}{3^n\left[\left(\frac{2}{3}\right)^n + 1\right]}$$

When, $n \to \infty$

$$r^n \to 0\,;\ \text{if } |r| < 1$$
$$r^n \to \infty\,;\ \text{if } |r| > 1$$

$\therefore$ Given limit becomes $= \dfrac{0+3}{0+1} = 3$

38. (c)

Every diagonal matrix can be written in row echelon form, using elementary transformations,

Ranking of diagonal matrix = Number of non-zero rows in the row-echelon form of A

= Number of non-zero elements in the diagonal matrix.

39. (c)

$$A = \begin{bmatrix} 1 & 2 \\ 2 & -1 \end{bmatrix}$$

The characteristic equations is

$$|A - \lambda I| = 0$$

$\Rightarrow$ $$\lambda^2 - 5 = 0$$

$\Rightarrow$ $$\lambda^8 = 625$$

By Caley-Hamilton's theorem,

$$A^8 = 625I$$

40. (b)

$$f(a) = 0,$$

$$f(b) = \frac{1}{2}\left(-\frac{1}{2}\right)\left(-\frac{3}{2}\right) = \frac{3}{8}$$

$$f(x) = x(x-1)(x-2) = x^3 - 3x^2 + 2x$$

$$f'(x) = 3x^2 - 6x + 2$$

$$f'(c) = 3c^2 - 6c + 2$$

$$\frac{f(b)-f(a)}{b-a} = f'(c)$$

$$\frac{\frac{3}{8}-0}{\frac{1}{2}-0} = 3c^2 - 6c + 2$$

$$\frac{3}{8} = \frac{3c^2-6c+2}{2}$$

$$\frac{3}{4} = 3c^2 - 6c + 2$$

$$3 = 12c^2 - 24c + 8$$

$$12c^2 - 24c + 5 = 0$$

$$c = \frac{24 \pm \sqrt{(24)^2 - 12\times 5\times 4}}{24} = 1 \pm 0.764$$

$$= 1.764 \text{ ; } 0.236$$

Hence, $c = 0.236,$

Since it only lies between 0 and $\frac{1}{2}$.

41. (c)

Additional pole will reduce the bandwidth of the system, as the system becomes slower, and bandwidth ∝ speed.

42. (a)

$$t_r = \frac{0.35}{\text{Bandwidth}}$$

Also $\omega_d = \omega_n\sqrt{1-\xi^2}$

Increasing ω_n increases ω_d and thus bandwidth increases and rise time decreases.

43. (c)

Phase margin gives the better estimate of damping ratio than the gain margin. Hence, Statement (II) is not correct.

44. (c)

The transient response in a closed loop system decays more quickly than in open loop system.

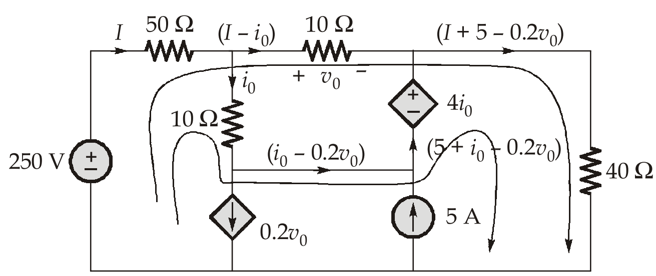
45. (c)

- In a closed-loop negative feedback control system, the control action is dependent on ouput.
- $S_G^M = \dfrac{1}{1+GH}$ is less than unity i.e. in-sensitive to the parameter variations.

Section B : Electrical Circuits-1

46. (c)

Let V_1 be the node voltage.



Applying KVL around the outer loop,

$$-250 + 50I + 10(I - i_0) + 40(I + 5 - 0.2v_0) = 0$$

$$100I - 10i_0 - 8v_0 = 50 \quad [\text{Here, } v_0 = 10(I - i_0)]$$

$$100I - 10i_0 - 80\,(I - i_0) = 50$$

$$\Rightarrow \quad 2I + 7i_0 = 5 \quad \ldots(i)$$

On applying KVL,

$$-250 + 50I + 10i_0 - 4i_0 + 40(I + 5 - 0.2v_0) = 0$$

$$90I + 6i_0 + 200 - 8v_0 = 250$$

$$90I + 6i_0 + 200 - 80(I - i_0) = 250$$

$$I + 8.6i_0 = 5$$

$$\Rightarrow \quad I = 5 - 8.6i_0$$

Using equation (i),

$$2(5 - 8.6i_0) + 7i_0 = 5$$

$$\Rightarrow \quad i_0 = 0.49 \text{ A}$$

47. (c)

The input impedance is,

$$Z_{in} = 5 + [-j4 \,||\, (2 + j2)]$$

$$= 5 + \frac{-j4(2 + j2)}{-j4 + 2 + j2}$$

$$= 5+\frac{8-8j}{2-2j}$$

$$= 5+\frac{(8-8j)(2+2j)}{8}$$

$$= 5+\frac{16+16j-16j+16}{8}$$

$\Rightarrow$ $Z_{in} = 9\ \Omega$

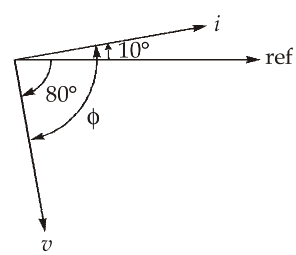
As the input impedance is purely resistive, the p.f. would be unity.

48. (b)

Given, $v = 100\cos(100t - 80°)$V

$i = 10\cos(100t + 10°)$A

The vector diagram is



As $\phi = 90°$ and i leads V, it implies that the element is capacitor.

$$X_C = \frac{V_m}{I_m} = \frac{100}{10} = 10\ \Omega$$

$\therefore$ $$C = \frac{1}{\omega X_C} = \frac{1}{100\times 10} = 1\times 10^{-3} = 1\text{ mF}$$

49. (a)

At resonance, imaginary part of input impedance must be zero.

We have, $$Z_{in} = \frac{-j}{2\omega}+[j\omega \| 1] = \frac{-j}{2\omega}+\frac{j\omega}{1+j\omega}$$

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

$$= \frac{-j}{2\omega}+\frac{j\omega}{1+\omega^2}+\frac{\omega^2}{1+\omega^2}$$

At resonance, $$\frac{-1}{2\omega}+\frac{\omega}{1+\omega^2} = 0$$

$$\frac{\omega}{1+\omega^2} = \frac{1}{2\omega}$$

$$2\omega^2 = 1+\omega^2$$

$\Rightarrow$ $\omega = 1$ rad/sec

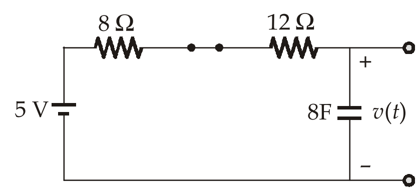
50. (c)

At $t = 100^-$, it is given that $v(100^-) = -3$ V.

Since the voltage across the capacitor cannot change instantaneously, $v(100^-) = v(100^+) = -3$ V.

The switching takes place at time $t = 100$.

For $t \geq 100$:



The voltage across the capacitor is,

$$v(t) = v(\infty) + [v(100) - v(\infty)]e^{-(t-100)/\tau} \quad \text{...(i)}$$

After a long time, the circuit reaches steady state and capacitor acts like an open circuit.

$\therefore \quad v(\infty) = 5$ V

The thevenin resistance across the capacitor terminals is,

$$R_{Th} = 8 + 12 = 20\ \Omega$$

and the time constant is,

$$\tau = R_{Th}C = 20 \times 8 = 160 \text{ sec}$$

Thus, from equation (i),

$$v(t) = 5 + [-3 - 5]e^{-(t-100)/160}$$

$$v(t) = 5 - 8e^{-(t-100)/160} \text{ V}$$

At $t = 200$ seconds,

$$v(200) = 5 - 8e^{-(200-100)/160} = (5 - 8e^{-5/8}) \text{ V}$$

51. (a)

V-i relation is non-linear, active and non-bilateral.

52. (a)

An ideal voltage source has the following features.

- It is a voltage generator whose output voltage remain absolutely constant whatever be the value of output current.
- It has zero internal resistance so that voltage drop in the source is zero.
- The power drawn by the source is zero.

53. (a)

The loop (or mesh) analysis method is based on Kirchhoff's voltage law.

To relate voltages and currents in the circuit elements ohm's law is used.

So, the loop method requires KVL +ohm's law.

54. (d)

According to reciprocity theorem in any linear, bilateral network, if a voltage source in branch A produces a current in branch B, then placing the same source in branch B will produce the same current in branch A.

So, interchanging the position of source and measuring instrument gives the same result.

55. (b)

Net energy stored over one complete ac cycle

$= 0$ for both L and C

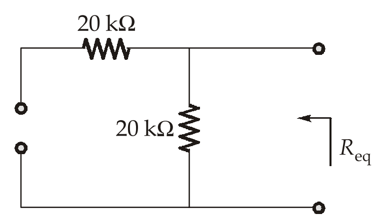
56. (b)

At $t = 0^+$, capacitor is short circuited and $t = \infty$, capacitor is open circuit,

So, $i_C(0^+) = 0.50$ mA

and $i_C(\infty) = 0$

The resistance seen from capacitor,



$$R_{eq} = 20\ \text{k}\Omega$$

The time constant, $\tau = R_{eq}C = 20 \times 10^3 \times 4 \times 10^{-6}$

$$= \frac{2}{25}\text{sec}$$

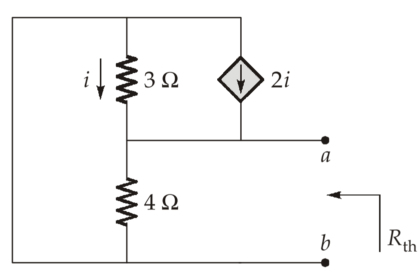
So, current equation, $i_c(t) = i_c(\infty) + \left(i_c(0) - i_c(\infty)\right)e^{-t/\tau}$

$$i_c(t) = 0 + (0.50 - 0)e^{-t/(2/25)}$$

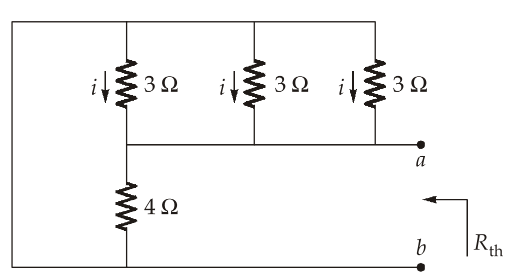
$$i_c(t) = 0.50e^{-12.5t}\ \text{mA}$$

57. (c)

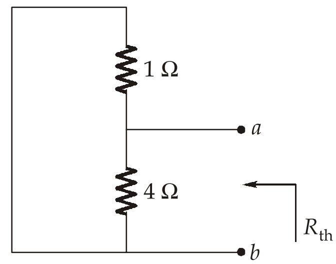
The Thevenin equivalent resistance seen from $a - b$ is



The (2i) current replaced as shown below,



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



So, $$R_{th} = 1 \parallel 4 = \frac{1 \times 4}{4+1} = \frac{4}{5} = 0.80\ \Omega$$

The load will draw maximum power if $R_L = R_{th} = 0.80\ \Omega$

58. (a)

The equivalent resistance of the given circuit can be

$$R_{eq} = mr \parallel mr + \frac{r}{m}$$

$$R_{eq} = \frac{mr}{2} + \frac{r}{m} = \left(\frac{m^2+2}{2m}\right)r$$

The current, $$I = \frac{V}{R_{eq}} = \left(\frac{2\text{m}}{m^2+2}\right)\frac{V}{r}$$

The current will be maximum, if R_{eq} is minimum

So, $$\frac{dR_{eq}}{dm} = \frac{d}{dm}\left(\frac{m}{2} + \frac{1}{m}\right)r = 0$$

$\Rightarrow$ $$\left(\frac{1}{2} - \frac{1}{m^2}\right)r = 0$$

$$m^2 - 2 = 0$$

$$m = +\sqrt{2} \qquad \text{(Since } m > 0\text{)}$$

So maximum current, $$I_{max} = \left(\frac{2 \times \sqrt{2}}{(2+2)}\right)\frac{V}{r}$$

$$I_{max} = \frac{\text{V}}{\sqrt{2}r}$$

59. (d)

Tellegan's theorem is applicable to any lumped network (linear or non-linear, active or passive) that satisfies KVL and KCL.

60. (d)

The two ideal current source with current I_1 and I_2 can be connected in parallel.

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61. (b)

The output of the MUX will be,

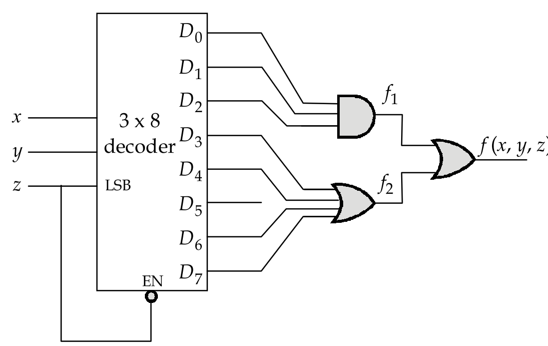
$$Y = \bar{B}\bar{A}C + \bar{B}A\bar{C} + \bar{A}B\bar{C} + ABC$$
$$= \bar{C}(\bar{A}B + A\bar{B}) + C(\bar{A}\bar{B} + AB)$$
$$= C[A \odot B] + \bar{C}[A \oplus B]$$
$$= \overline{(A \oplus B)} \cdot C + (A \oplus B)\bar{C}$$

$\therefore \quad Y = A \oplus B \oplus C$

62. (c)

The given 3 × 8 decoder is active low output type. The circuit can be redrawn as shown in the figure below:

NAND $\rightleftharpoons$ Bubbled OR
NOR $\rightleftharpoons$ Bubbled AND
AND $\rightleftharpoons$ Bubbled NOR
OR $\rightleftharpoons$ Bubbled NAND



If $z = 1$, then decoder is disabled and all outputs D_0-D_7 are 0. If $z = 0$, then EN = 1 (Since input LSB = 0, we will get output only for even values)

The outputs D_0, D_2, D_4 and D_6 are active and outputs D_1, D_3, D_5 and D_7 are inactive.

We have, $f_1 = D_3 + D_4 + D_6 + D_7$. Since D_3 and D_7 remain inactive, we have, $f_1 = \Sigma m(4, 6)$.

Here, $f_1 = 0$ because all three inputs D_0, D_1 and D_2 can never be 1 at the same time.

Thus, $\quad f(x, y, z) = f_1 + f_2 = \Sigma m(4, 6)$

63. (a)

$$F = (A+B)(A+\bar{A}+\bar{B})C + \bar{A}(B+\bar{C}) + \bar{A}B + ABC$$
$$= AC + BC + \bar{A}B + \bar{A}\bar{C} + \bar{A}B + ABC$$
$$= AC + BC + \bar{A}(B+\bar{C})$$

C \ AB	00	01	11	10
0	1	1		
1		1	1	1

Using K-map, we get $\quad F = AC + \bar{A}B + \bar{A}\bar{C}$

64. (c)

$$Z = a(b+\bar{c})$$

$$Z = ab + a\bar{c}$$

Representing the Boolean expression on K-Map,

$a \backslash bc$	00	01	11	10
0				
1	1		1	1

$\therefore \quad Z(a, b, c) = \Sigma m(4, 6, 7)$

65. (c)

Excess-3 code can be obtained by adding 3 to each decimal digit, and obtain the corresponding 4-bit binary number.

Given, Excess-3 number,

$$\underset{C}{\underline{1100}}\;\underset{A}{\underline{1010}}\;\underset{3}{\underline{0011}}\cdot\underset{7}{\underline{0111}}\;\underset{5}{\underline{0101}}$$

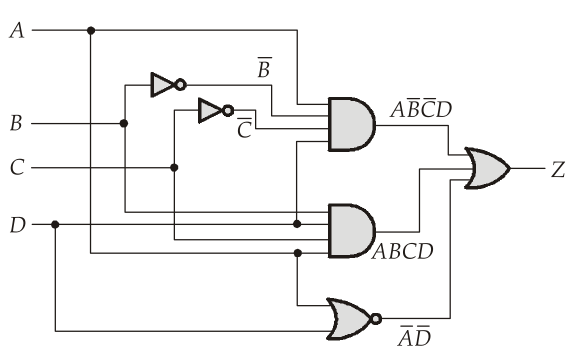
The binary code from given Excess-3 code can be obtained as,

$$\begin{array}{ccccc} 1100 & 1010 & 0011 & 0111 & 0101 \\ -0011 & -0011 & -0011\;\cdot & -0011 & -0011 \\ \hline 1001 & 0111 & 0000 & 0100 & 0010 \end{array}$$

$\therefore$ The decimal equivalent is $(100101110000 \cdot 01000010)$

$$= (970.42)_{10}$$

66. (c)



$$Z = A\bar{B}\bar{C}D + ABCD + \bar{A}\bar{D}$$

$$= AD[\bar{B}\bar{C} + BC] + \bar{A}\bar{D}$$

$$= AD(B \odot C) + \bar{A}\bar{D}$$

67. (a)

$$f(A,B,C) = (\bar{A}\overline{\overline{BC}})(A\bar{B}+ABC)$$
$$= (\bar{A}BC)(A\bar{B}+ABC) = 0$$

So, no gate is required to implement the given function.

68. (c)

IN and OUT instructions are used in I/O mapped I/O scheme.

In memory mapped I/O scheme, I/O devices limit can exceed 256.

69. (d)

Location of data within Mnemonic i.e. in CMA no operands are there but operation is done on accumulator only.

70. (c)

In DMA, bulk amount data will be transferred from the I/O to memory without involvement of CPU.

71. (d)

RAL instruction rotate the accumulator left through carry

$$D_7 \rightarrow CY,$$
$$CY \rightarrow D_0$$

ORA reset the carry

	Accumulator	CY
Before RAL,	10110111	0
After RAL,	01101110	1
	01101111	= 6F H

72. (d)

Size of MBR depends on the data pins.

73. (c)

74. (d)

The dual of a Boolean expression can easily be obtained by interchanging sums and products and interchanging 0 as well as 1 whereas to obtain the complement of the function, the variable is also complemented. Hence, the Statement (I) is incorrect.

75. (d)

Stack pointer stores address of the top of stack. So, it is of 16-bit in 8085 microprocessor.

❍❍❍❍