DETAILED SOLUTIONS

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ESE 2026 : Prelims Exam
CLASSROOM TEST SERIES

ELECTRICAL ENGINEERING

Test 6

Section A : Electrical Machines [All Topics]

Section B : Control Systems-1 + Engineering Mathematics-1 [Part Syllabus]

Section C : Electrical Circuits-2 + Digital Electronics-2 [Part Syllabus]

ANSWER KEY

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

DETAILED EXPLANATIONS
Section A : Electrical Machines

1. (b)

Power input to motor, $P_1 = 60$ kW

stator losses $= 2$ kW

Power input to rotor, $P_2 =$ Input to motor – stator losses $= 60 - 2 = 58$ kW

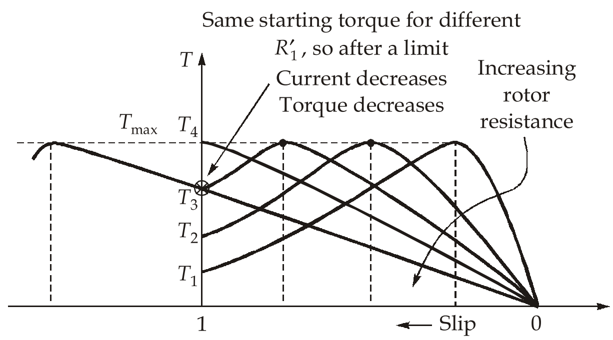
Slip, $s = 5\%$ or 0.05

Total mechanical power developed,

$$P_{mech} = P_2(1 - s)$$

$$P_{mech} = 58(1 - 0.05) = 58 \times 0.95 = 55.1 \text{ kW}$$

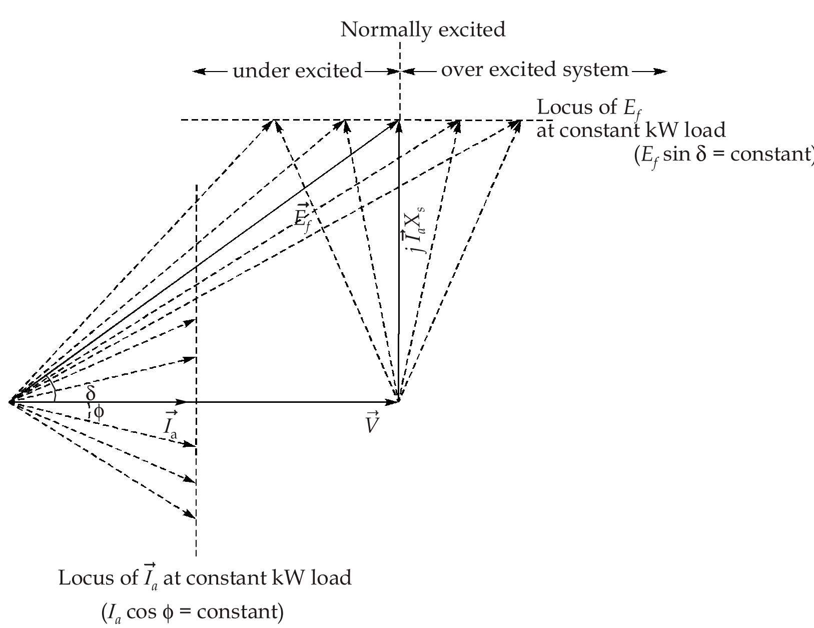
2. (b)



As R increases, starting torque increases upto maximum torque ($T_4 = T_{max} > T_3 > T_2 > T_1$) but rotor consumes more power so copper loss increases and efficiency decreases.

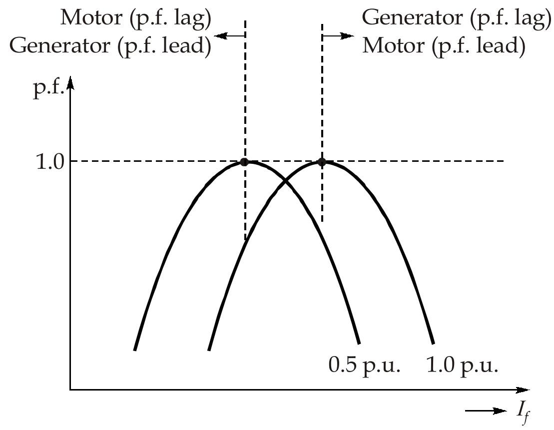
3. (a)

Case I : Power angle



For constant steam input, $E_f \sin\delta$ and $I_a \cos\phi$ remains constant. So if I_f increases then E_f increases but $\sin\delta$ decreases and δ decreases.

Case II : Inverted V curve



From the diagram above shown if I_f increases then power factor decreases when generator operates on lagging power factor.

4. (a)

To eliminate n^{th} harmonic, $\dfrac{n\alpha}{2} = 90°$

α = chording angle to eliminate 5^{th} harmonic

$$\Rightarrow \quad \frac{5\times\alpha}{2} = 90°$$

$$\Rightarrow \quad \text{chording angle, } \alpha = \frac{180°}{5} = 36°$$

5. (c)

$$\text{Synchronous reactance, } X_s = \frac{1440}{240} = 6\ \Omega$$

$$\text{Internal voltage drop} = 6 \times 120 = 720\ \text{V}$$

6. (a)

$$\text{Rotor emf/phase at stand still} = \frac{156}{\sqrt{3}} = 90\ \text{V}$$

$$\text{Rotor impedance/phase} = \sqrt{3^2 + 4^2} = 5\ \Omega$$

$$\text{Rotor current/phase} = \frac{90}{5} = 18\ \text{A}$$

7. (a)

No. of coils = 40

Each coil has 5 turns

Total no. of turns = 40 × 5 = 200

Each turn has 2 conductors

So total no. of conductors = $Z = 200 \times 2 = 400$

For wave wound armature no. of parallel paths = A = 2

Expression of induced emf,

$$E = \frac{PZ\phi N}{60\,A}$$

$$= \frac{6 \times 400 \times 0.08 \times 300}{60 \times 2} = 480 \text{ V}$$

8. (c)

Induced emf equation of transformer, $E \propto \phi\, f$

for same emf, $\phi\,.f$ = constant

$$\phi_1\, f_1 = \phi_2 \cdot f_2$$

$$B_1 A_1 f_1 = B_2 A_2 f_2$$

For constant flux density, $B_1 = B_2$

$$A_1 f_1 = A_2 f_2$$

For high frequency, $f_2 > f_1$

$$A_2 < A_1$$

Therefore at high frequencies transformer size gets reduced and also light weight.

9. (c)

Given, $T \propto N^2$

Also, $T \propto \phi\, I_a$

or, $T \propto I_a^2$ (Since, $\phi \propto I_a$ in unsaturated region)

Hence, $$\left(\frac{N_2}{N_1}\right)^2 = \left(\frac{I_{a2}}{I_{a1}}\right)^2 \text{ or } \frac{I_{a2}}{I_{a1}} = \frac{N_2}{N_1}$$

or, $$I_{a2} = \frac{1000}{600} \times 30 = 50 \text{ A}$$

10. (c)

For 750 rpm, back emf $E_{a1} = 240 - 40\,(0.5) = 220$ V ...(i)

For 500 rpm, back emf $E_{a2} = 240 - 40\,(R_s + 0.5)$ ...(ii)

As we know that,

back emf $E_a \propto N$ ($\because \phi \propto I_a$ = constant)

or, $$\frac{E_{a2}}{E_{a1}} = \frac{N_2}{N_1}$$

From equation (i) and (ii), we get

$$\frac{240 - 40(R_s + 0.5)}{220} = \frac{600}{900}$$

$$240 - 20 - 40\,R_s = \frac{2}{3}\times 220$$

$$R_s = \left(220 - \frac{2}{3}\times 220\right)\times\frac{1}{40}$$

$$= \frac{1}{3}\times\frac{220}{40} = \frac{11}{6} = 1.8\,\Omega$$

11. (a)

Pullout torque is the maximum value of torque at given speeds that the motor can generate while running in synchronism. If the motor is run outside of slew range, it will stall.

12. (b)

Pole changing method of speed control is easily applicable in squirrel cage induction motor because a cage winding automatically reacts to create the same number of poles as the stator.

13. (b)

The rotor emf frequency, $f' = \frac{120}{60} = 2$ Hz

$$\text{Slip, } s = \frac{f'}{f} = \frac{2}{50} = \frac{1}{25}$$

Rotor copper loss per phase,

$$P_{cu} = \frac{s.P_g}{3} = \frac{\left(\frac{1}{25}\right)\times 75}{3} = \frac{3}{3} = 1\text{ kW}$$

$$\text{Rotor resistance per phase} = \frac{P_{cu}}{(I_{rotor})^2} = \frac{1000}{(25)^2} = 1.6\ \Omega$$

14. (a)

Single phase induction motor is not a self starting motor. By splitting the single phase into two phases which are at 90° to each other, rotating magnetic field is produced. This concept is used to start the motor known as split phase technique. The starting winding also called as auxiliary (or temporary) winding is connected in parallel to main winding through centrifugal switch in order to get isolated under running condition.

15. (c)

Space harmonic fields are developed by the windings, slotting, magnetic saturation, gap-length irregularity. These harmonic fields induce emfs and circulate harmonic currents in the rotor windings and develope harmonic torque, vibration and noise. 5^{th} and 7^{th} space harmonics are of more concern as their amplitude is considerable. Time harmonics are of little significance because the torques developed by such harmonics are usually very small throughout the operating range of motor. The time harmonics voltages are usually small in proportion to fundamental voltage, the motor reactance to the time harmonics is high and consequently harmonic currents and therefore harmonic torque developed are very small, responsible for crawling.

16. (b)

Load, $P = 1000 \text{ kW}$

Load kVA, $S = \dfrac{P}{\cos\phi} = \dfrac{1000}{0.707} = 1000\sqrt{2} \text{ kVA}$

Power factor angle, $\phi = \cos^{-1} 0.707 = 45°$

$$\text{Load kVAR} = S \times \sin\phi = 500\sqrt{2} \times \sin 45°$$
$$= 500 \text{ kVAR}$$

Thus a synchronous motor when connected to improve power factor in over-excited condition will operate as a synchronous condenser. The power required to be supplied by synchronous condenser, therefore is 500 kVAR and p.f is zero (leading).

17. (c)

At no-load, AT required to generate a voltage of 400 V is

$$AT_0 = 4.0 \times 1600 = 6400 \text{ AT's}$$

At full-load, AT required to generator a voltage of 400 V is

$$AT_{FL} = 6.0 \times 1600 = 9600 \text{ AT's}$$

Hence, additional AT required at full-load

$$= AT_{FL} - AT_0$$
$$= 9600 - 6400 = 3200 \text{ AT's}$$

Given, full-load current,

$$I_{FL} = 200 \text{ A}$$

∴ Number of series field turns required

$$= \frac{3200}{200} = 16 \text{ turns}$$

18. (a)

To compute the value of the external resistance in the rotor circuit for occurrence of maximum torque at starting, $s_{\max}$ must then be set equal to $s = 1$.

$$s_{\max} = 1 = \frac{R_2' + R_{ext}'}{\sqrt{R_1^2 + X_{eq}^2}}$$

[Here R_1 is stator resistance and R_2' is rotor resistance referred to stator side]

$$R'_{ext} = \sqrt{R_1^2 + X_{eq}^2} - R_2' = \sqrt{36+64} - 4 = 6\ \Omega$$

$$\text{Rotor resistance, } R_{ext} = \frac{6}{3^2} = 0.66\ \Omega$$

19. (d)

Since after connecting the stator to supply, flux per pole is reduced to 25 mWb from initial value of 30 mWb, therefore effect of armature reaction is demagnetizing i.e. $F_f > F_r$. Due to which motor is over-excited and runs at leading power factor.

20. (c)

Due to the difference of air gap the reluctance power is added to the real power generated by machine

$$\text{Real power, } P = \underbrace{\frac{VE_f}{X_d}\sin\delta}_{\substack{\text{Excitation}\\ \text{Power}}} + \underbrace{\frac{V^2}{2}\left(\frac{1}{X_q}-\frac{1}{X_d}\right)\sin 2\delta}_{\substack{\text{Reluctance}\\ \text{Power}}}$$

21. (c)

$$V_1 I_0 = 350$$

$$I_0 = \frac{350}{V_1} = \frac{350}{230} = 1.52 \text{ A}$$

$$\text{No-load power factor} = \cos\phi_0$$

$$\text{core loss} = V_1 I_0 \cos\phi_0$$

$$110 = 350\cos\phi_0$$

$$\cos\phi_0 = \frac{110}{350} = 0.314$$

Core-loss component of no-load current,

$$I_W = I_0\cos\phi_0$$

$$= 1.52 \times 0.314 = 0.478$$

22. (c)

$$\frac{P_i}{f} = a + bf$$

$$\frac{100}{40} = a + 40b \qquad \text{...(i)}$$

and $$\frac{72}{30} = a + 30b \qquad \text{...(ii)}$$

By solving equation (i) and (ii),

$$a = 2.1, \qquad b = 0.01$$

Therefore, hysteresis loss at 50 Hz

$$= af = 2.1 \times 50 = 105 \text{ W}$$

Eddy-current loss at 50 Hz

$$bf^2 = 0.01 \times (50)^2 = 25 \text{ W}$$

$$\text{Total core loss} = 105 + 25 = 130 \text{ W}$$

23. (d)

Thus, there are four possible connections for a 3-phase transformer bank:

1. Δ - Δ (Delta primary - Delta secondary)
2. Y - Y (Star primary - Star secondary)

3. D - V (Delta primary - Star secondary)
4. Y - Δ (Star primary - Delta secondary)

24. (b)

$$f = \frac{PN_s}{120} = \frac{6\times1000}{120} = 50 \text{ Hz}$$

Total number of stator conductors

$$= \text{Conductors per slop} \times \text{Number of slots}$$
$$= 8 \times 90 = 720$$

Stator conductors per phase,

$$Z_P = \frac{720}{3} = 240$$

Turns per phases, $$p = \frac{240}{2} = 120 \text{ turns/phase}$$

Winding factor, $K_\omega = 0.96$

Generated voltage per phase,

$$E_p = 4.44 f\,\phi\, N_P \times K_\omega$$
$$= 4.44 \times 0.96 \times 50 \times 0.05 \times 120 = 1278.7 \text{ V}$$

Generated line voltage, $E_L = \sqrt{3}E_P = \sqrt{3}\times1278.7 = 2214.7$ V

25. (a)

$$s = 4\% = 0.04$$

$$s_M = \frac{R_2}{X_{20}} = \frac{0.01}{0.05} = 0.2$$

$$\frac{\tau_{max}}{\tau_{fl}} = \frac{s^2+s_m^2}{2s\,s_m} = \frac{(0.04)^2+(0.2)^2}{2\times0.04\times0.2} = 2.6$$

$\therefore$ $$\tau_{max} = 2.6\,\tau_{fl}$$

26. (b)

$$V = 200 \text{ V},\quad P = 30\times10^3 \text{ W}$$
$$R_a = 0.05\ \Omega,\quad R_{sh} = 50\ \Omega,$$
$$P_{i+f} = 1000 \text{ W}$$

$$I = \frac{P}{V} = \frac{30\times10^3}{200} = 150 \text{ A}$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{200}{50} = 4 \text{ A}$$

$$I_a = I + I_{sh} = 150 + 4 = 154 \text{ A}$$
$$E = V + I_aR_a = 200 + 154\times0.05 = 207.7 \text{ V}$$

27. (c)

Given, speed = 600 rpm

$$= \frac{600}{60} = 10 \text{ rps}$$

Speed, $$N = \frac{\alpha \times f}{360} \text{rps}$$

$$f = \frac{360 \times N}{\alpha} = \frac{360 \times 10}{1.8} = 2000 \text{ steps/sec}$$

28. (b)

When load torque exceeds hysteresis torque, rotor pulled out of synchronism and stall.

29. (c)

The torque-speed curve of an AC servo motor is non-linear with negative slope ensuring stability under feedback control.

30. (b)

Detent torque is defined as the maximum shaft torque with phase winding unexcited.

32. (d)

The zero relative motion between stator and rotor mmf leads to zero electromagnetic torque.

33. (c)

Magnetizing current is more for open slot configuration, and space harmonics are not present in closed slot configuration.

34. (c)

3^{rd} order harmonic do not affect torque-slip characteristic as they don't produce rotating magnetic field. 5^{th} order harmonic has opposite phase sequence hence affects braking mode. Similarly, 7^{th} order harmonic having same phase sequence affects motoring mode in torque-slip characteristic.

35. (b)

In universal motor the efficiency is low due to significant hysteresis and eddy current losses. So statement-1 is incorrect.

36. (a)

The forward slip value for 1-ϕ induction motor = s

Then backward slip value for 1-ϕ induction motor = $(2 - s)$

The effective rotor resistance depends on the slip of the rotor, so portion of circuit affected by backward slip will show a resistance equal to $\frac{R_2'}{2(2-s)}$ and the portion effected by forward slip will show resistance $\frac{R_2'}{2s}$.

37. (b)

It is almost impossible to maintain iron losses and copper losses equal in distribution transformer as load is varying. Iron to copper ratio is higher for distribution transformer compared to power transformer and hence the large size of distribution transformer for same rating. Hence only statement-1 correct.

39. (a)

The transformer with lowest per unit impedance will be fully loaded first.

40. (c)

ASA method is modified MMF method.

41. (c)

Damper winding resistance of synchronous machine is made larger, the starting (zero speed) torque increases.

42. (c)

In a dc generator, the trailing pole tips get magnetically saturated as the load reaches its rated value.

43. (b)

Power transformers step up voltage at generation end to economical transmission voltage level as transmission losses are low at high voltages.

44. (b)

Pole shoe on one hand supports the field winding on the stator and also reduces net reluctance of magnetic circuit.

Section B : Control Systems-1 + Engineering Mathematics-1

46. (c)

As,
$$x_2 = a_1 x_1 + a_5 x_3 + a_6 x_4 + a_7 x_5$$
$$x_3 = a_2 x_2$$
$$x_4 = a_3 x_3 + a_9 x_5$$
$$x_5 = a_4 x_4 + a_8 x_3$$

47. (c)

Given,
$$c(t) = (1 + 0.25e^{-50t} - 1.25e^{-10t})u(t)$$

$\therefore$
$$C(s) = \frac{1}{s} + \frac{0.25}{(s+50)} - \frac{1.25}{(s+10)}$$

or,
$$C(s) = \frac{500}{s(s+10)(s+50)}$$

$\therefore$
$$\frac{C(s)}{R(s)} = \frac{500}{(s+10)(s+50)} \qquad \left(\text{Since, } R(s) = \frac{1}{s}\right)$$

or, $$\frac{C(s)}{R(s)} = \frac{500}{s^2+60s+500} = \frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2}$$

Thus, $\omega_n = \sqrt{500}$ rad/sec

and $2\,\xi\omega_n = 60$ or $\xi\omega_n = 30$

Thus, $$\xi = \frac{30}{\sqrt{500}} = \frac{3}{\sqrt{5}} = 1.34 \Rightarrow \text{overdamped}$$

48. (d)

Given, $$E(s) = \frac{5(s+6)}{s(s+8)}$$

$\therefore$ $e(\infty) = \lim_{s\to 0}[sE(s)]$ (Using final value theorem)

or, $$e(\infty) = \lim_{s\to 0}\left[s\frac{5(s+6)}{s(s+8)}\right]$$

$$= \lim_{s\to 0}\left[\frac{5(s+6)}{(s+8)}\right] = \frac{5\times 6}{8} = 3.75$$

49. (b)

Characteristic equation : $s^3 + ps^2 + (3+K)s + 2(K+1) = 0$

system will be marginally stable for $\Rightarrow 2(K+1) = p(3+K)$ ...(i)

Auxiliary equation :

$$ps^2 + 2(K+1) = 0$$

From eq. (i), $ps^2 + p(3+K) = 0$

$$s = \pm j\sqrt{3+K}$$

So, $\sqrt{3+K} = 2.5$

$3 + K = 6.25$

$K = 3.25$

s^3	1	$3+K$
s^2	p	$2(K+1)$
s^1	$2p$	0
s^0	$2(K+1)$	0

50. (b)

$$I = \int_0^{\pi/2}\frac{dx}{a^2\cos^2 x + b^2\sin^2 x}$$

divide Numerator and Denominator by $\cos^2 x$.

$$= \int_0^{\pi/2}\frac{\sec^2 x\,dx}{a^2+b^2\tan^2 x}$$

Put, $\tan x = t$

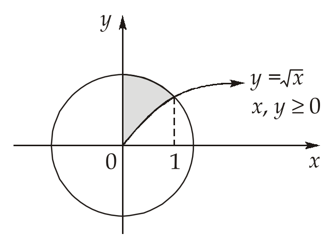
$\Rightarrow$ $\sec^2 x\,dx = dt$

$\therefore$ By changing limits, $I = \int_{t=0}^{t=\infty} \frac{dt}{a^2 + b^2t^2}$

$$\Rightarrow \quad I = \frac{1}{b^2}\int_0^{\infty}\frac{dt}{\left(\frac{a}{b}\right)^2 + t^2} = \frac{1}{b^2}\cdot\frac{1}{a/b}\cdot\left[\tan^{-1}\frac{bt}{a}\right]_0^{\infty}$$

$$= \frac{1}{ab}\left[\frac{\pi}{2} - 0\right] = \frac{\pi}{2ab}$$

51. (c)



The region formed by $y \geq \sqrt{x}$ is the outer region of the parabola $y^2 = x$, when $y \geq 0$ and $x \geq 0$ and $x^2 + y^2 < 2$ is the region inner to circle $x^2 + y^2 = 2$.

Now to find the point of intersection put $y^2 = x$ in $x^2 + y^2 = 2$

$$\Rightarrow \quad x^2 + x - 2 = 0$$

$$\Rightarrow \quad (x + 2)(x - 1) = 0$$

$$x = 1; \text{ as } x \geq 0$$

$\therefore$ The required area is,

$$= \int_0^1\left(\sqrt{2 - x^2} - \sqrt{x}\right)dx$$

$$= \left(\frac{x\sqrt{2 - x^2}}{2} + \sin^{-1}\frac{x}{\sqrt{2}} - \frac{2}{3}x^{3/2}\right)_0^1$$

as $\left(\int\sqrt{a^2 - x^2}\,dx = \frac{x\sqrt{a^2 - x^2}}{2} + \frac{a^2}{2}\sin^{-1}\left(\frac{x}{a}\right)\right)$

$$= \frac{1}{2} + \frac{\pi}{4} - \frac{2}{3} = \frac{\pi}{4} - \frac{1}{6}$$

52. (b)

For a matrix containing complex numbers, eigen values are real if and only if

$$A = A^{\theta} = \left(\bar{A}\right)^T$$

$$A = \begin{bmatrix} 10 & 2+j & 4 \\ x & 20 & 2 \\ 4 & 2 & -10 \end{bmatrix}$$

$$A^\theta = \left(\bar{A}\right)^T = \begin{bmatrix} 10 & \bar{x} & 4 \\ 2-j & 20 & 2 \\ 4 & 2 & -10 \end{bmatrix}$$

By comparing these, $x = 2 - j$

53. (a)

$$f(x) = x^3 + 8x - 3 = 0$$

$$f'(x) = 3x^2 + 8$$

N-R equation for iteration is,

$$x_{k+1} = x_k - \frac{f(x_k)}{f'(x_k)}$$

$$f(x_k) = x_k^3 + 8x_k - 3$$

$$f'(x_k) = 3x_k^2 + 8$$

$$x_{k+1} = x_k - \frac{(x_k^3 + 8x_k - 3)}{3x_k^2 + 8} = \frac{(3x_k^3 + 8x_k) - (x_k^3 + 8x_k - 3)}{3x_k^2 + 8}$$

$$x_{k+1} = \frac{2x_k^3 + 3}{3x_k^2 + 8}$$

54. (d)

Given, $f(x) = 2x^3 - 9x^2 + 12x + 6$

$$f'(x) = 6x^2 - 18x + 12 = 6(x^2 - 3x + 2)$$

$$= 6(x - 1)(x - 2)$$

$$f'(x) = 0;$$

$$x = 1, 2$$

$$f''(x) = 12x - 18$$

$$f''(2) = 12 \times 2 - 18 = 6 \ (+\text{ve} \therefore \text{ minima at } x = 2)$$

$$f''(1) = 12 \times 1 - 18 = -6 \ (-\text{ve} \therefore \text{ maxima at } x = 1)$$

Now consider the global values:

$$f(0) = 6$$

$$f(1) = 11$$

$$f(2) = 10$$

$\therefore$ Global maximum $= M_1 = \max(6, 10, 11) = 11$

and global minima $= M_2 = \min(6, 10, 11) = 6$

$\therefore$ $f(1) = 11$ is global maximum and $f(0) = 6$ is global minimum and $f(2) = 10$ is local minima.

55. (a)

$$y = \tan^{-1}\sqrt{\frac{1-\cos x}{1+\cos x}}$$

$$y = \tan^{-1}\sqrt{\frac{2\sin^2\frac{x}{2}}{2\cos^2\frac{x}{2}}} = \tan^{-1}\sqrt{\tan^2\frac{x}{2}}$$

$$y = \tan^{-1}\tan\left(\frac{x}{2}\right)$$

$$\Rightarrow \quad y = \frac{x}{2}$$

$$\Rightarrow \quad \frac{dy}{dx} = \frac{1}{2}$$

56. (b)

When a zero is added to the system in LHS-plane root locus shifts away from $j\omega$-axis.

Damping improves, hence less oscillatory.

Relative stability increases.

Range of K for stable operation increases.

57. (d)

From the given root locus,

$$G(s)H(s) = \frac{K}{(s+4)(s+1+j)(s+1-j)} = \frac{K}{(s+4)(s^2+2s+2)}$$

Characteristic equations:

$$1 + G(s)H(s) = 0$$

$$s(s^2 + 2s + 2) + 4(s^2 + 2s + 2) + K = 0$$

$$s^3 + 6s^2 + 10s + (8 + K) = 0$$

s^3	1	10
s^2	6	$8+K$
s^1	$\frac{60-(8+K)}{6}$	0
s^0	$8+K$	0

For $s' = 0$

at $\quad 8 + K = 60$

$$K = 52$$

For intersection with $(j\omega)$ axis,

$$6s^2 + (8 + K) = 0$$
$$6s^2 + 60 = 0$$
$$s^2 + 10 = 0$$
$$s = j\sqrt{10}$$

58. (d)

Forward path: $P_1 = 2 \times 3 \times 4 = 24$

$P_2 = 8$

Loops :

$L_1 = -1, \quad L_2 = -1$

$L_3 = -24, \quad L_4 = -24$

Non-touching loops:

$L_1L_2 = 1, \quad L_1L_3 = 24$

$\Delta_1 = 1$

$\Delta_2 = 1 - (L_1 + L_2) + L_1L_2 = 1 + 2 + 1 = 4$

$$\frac{C(s)}{R(s)} = \frac{P_1\Delta_1 + P_2\Delta_2}{1-[L_1+L_2+L_3+L_4]+[L_1L_2+L_1L_3]}$$

$$= \frac{24\times1-8\times4}{1+(1+1+24+24)+(1+24)} = \frac{56}{76} = \frac{14}{19}$$

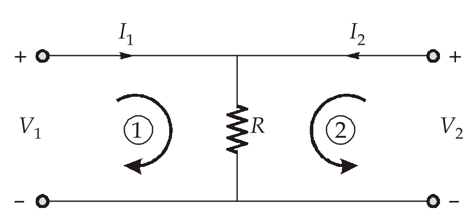
59. (c)

Time constant of open loop system is more than that of a closed loop system with negative feedback. Lesser is the time constant of the system, faster is its time response.

Section C : Electrical Circuits-2 + Digital Electronics-2

61. (c)

Redrawing the given circuit, we get,



By applying KVL in loop 1 and 2, we get,

$V_1 = (I_1 + I_2)R$

and $V_2 = (I_1 + I_2)R$

$\therefore \quad [Z] = \begin{bmatrix} R & R \\ R & R \end{bmatrix}$

also, $[Y] = [Z]^{-1} \Rightarrow$ Not possible, since $|Z| = 0$

62. (b)

From transmission parameters,

$$V_1 = AV_2 - BI_2 = V_2 - 2I_2 \qquad ...(i)$$

$$I_1 = CV_2 - DI_2 = 3V_2 + I_2 \qquad ...(ii)$$

From the given circuit, $V_2 = -5I_2$ ...(iii)

From equations (i), (ii) and (iii),

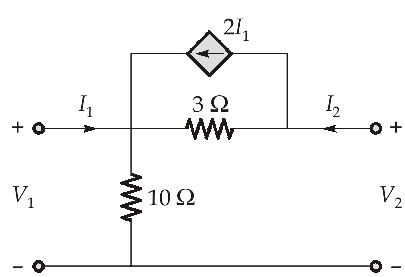
$$Z_{in} = \frac{V_1}{I_1} = \frac{-5I_2 - 2I_2}{-15I_2 + I_2} = \frac{-7}{-14} = \frac{1}{2}\ \Omega$$

63. (b)

Duality means, the mathematical representation of both the networks should be identical (KVL and KCL).

$\therefore$ Loop equations of one network are analogous to the node equations of the other.

64. (a)



KVL in the input loop,

$$V_1 = 10I_1 + 10I_2 \qquad ...(i)$$

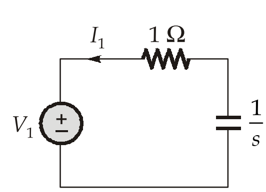
$$V_2 = 3(I_2 - 2I_1) + 10(I_1 + I_2)$$

$$V_2 = 4I_1 + 13I_2$$

So, $$[z] = \begin{bmatrix} 10\Omega & 10\Omega \\ 4\Omega & 13\Omega \end{bmatrix}$$

65. (d)

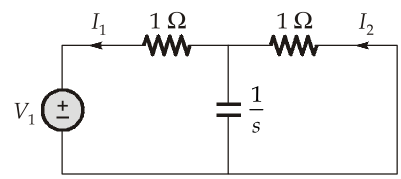
$$z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0} \quad \text{(Open circuit output terminal)}$$



$$V_1 = I_1\left(1 + \frac{1}{s}\right)$$

$$z_{21} = \frac{V_1}{I_1} = \frac{s+1}{s}$$

$$y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0} \quad \text{(Short circuit output terminal)}$$



$$V_1 = I_1\left[1+\left(\frac{1}{s}//1\right)\right]$$

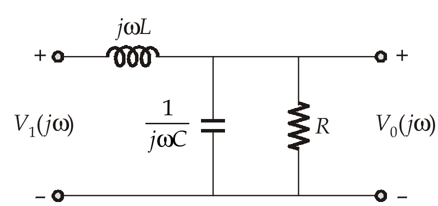
$$= I_1\left[1+\frac{\frac{1}{s}}{\frac{1}{s}+1}\right] = I_1\left[1+\frac{1}{s+1}\right]$$

$$y_{11} = \frac{I_1}{V_1} = \frac{s+1}{s+2}$$

66. (a)

The response of the circuit,

$$H(j\omega) = \frac{V_0(j\omega)}{V_i(j\omega)}$$



$$V_0(j\omega) = \frac{R//\frac{1}{j\omega C}}{j\omega L+\left[R//\frac{1}{j\omega C}\right]}\times V_i(j\omega)$$

$$= \frac{R/(j\omega CR+1)}{j\omega L+R/(j\omega CR+1)}\times V_i(j\omega)$$

$$H(j\omega) = \frac{V_0(j\omega)}{V_i(j\omega)} = \frac{R}{j\omega L(j\omega CR+1)+R}$$

At low frequencies, $\omega \to 0$

$$H(j\omega) = \frac{R}{R} = 1$$

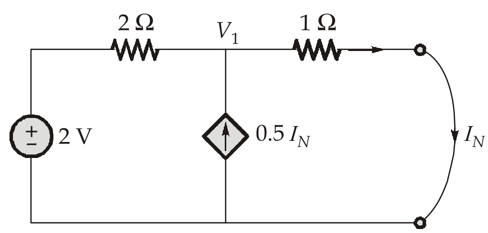
At higher frequencies, $\omega \to \infty$

$$H(j\omega) = \frac{1}{\infty} = 0$$

So the circuit behaves as a low-pass filter.

67. (c)

Let us first short circuit the terminals X - Y as shown below



Let the node voltage be V_1

Applying KCL, we have

$$\frac{V_1 - 2}{2} - 0.5 I_N + \frac{V_1}{1} = 0 \quad \text{... (i)}$$

Also, $$I_N = \frac{V_1}{1} = V_1 \text{ A} \quad \text{... (ii)}$$

Putting I_N in equation (i), we have

$$\frac{V_1 - 2}{2} - 0.5 V_1 + V_1 = 0$$

or, $$V_1 - 1 = 0$$

or, $$V_1 = 1 \text{ volt} \quad \text{... (iii)}$$

From equation (ii) and (iii), we have

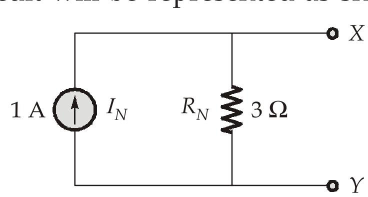
$$I_N = V_1 = 1 \text{ A}$$

For finding R_N, the terminals X-Y are open circuited and the independent voltage source is short circuited.

$\therefore$ $$i_x = 0 \text{ A}$$

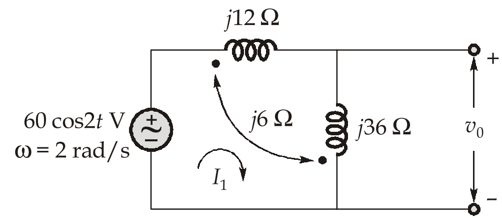
Hence, $$R_N = 2 + 1 = 3\ \Omega$$

Thus, the Norton's equivalent circuit will be represented as shown below.



68. (b)

Consider the circuit in the phasor domain,



Apply KVL in loop-1,

$$60 - j12I_1 - j36I_1 + j6I_1 + j6I_1 = 0$$

$$j12I_1 + j36I_1 - j12I_1 = 60$$

$$j36I_1 = 60$$

$$I_1 = \frac{5}{3}\angle -90°\text{ A}$$

$$V_0 = (j36 - j6)I_1$$

$$= j30 \times \frac{5}{3}\angle -90°$$

$$V_0 = 50\angle 0°\text{ V}$$

$$V_0(t) = 50\cos 2t\text{ V}$$

70. (c)

$$\text{Maximum quantization error} = \frac{5}{2^{10}-1} \approx 4.89\text{ mV}$$

71. (b)

$(0111111001)_2 - (0111110100)_2 = (101)_2 = (5)_{10}$

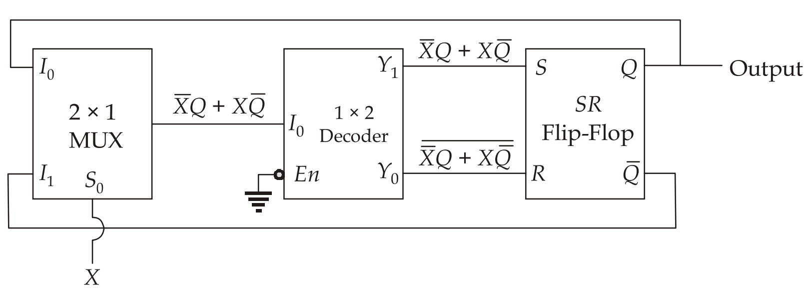
$$\text{Resolution} = \frac{25\text{ mV}}{5} = 5\text{ mV}$$

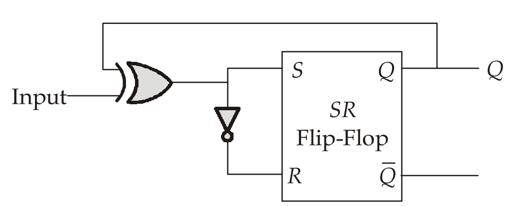
$$\text{Full scale deflection} = \text{resolution} \times (2^n - 1)$$

$$= 5 \times 10^{-3} \times 1023 = 5.115\text{ volts}$$

72. (d)

The MUX in the circuit is working as an EX-OR gate and the 1 × 2 decoder as a NOT gate. Thus the circuit could be redrawn as





Thus, the circuit will function as a T-flip flop

$$\because \quad S = X \oplus Q_n$$

$$R = \overline{X \oplus Q_n}$$

For SR-flip flop,

$$Q_{n+1} = S + \bar{R}Q_n = (Q_n \oplus X) + \overline{\overline{(Q_n \oplus X)}}Q_n$$

$$= (X \oplus Q_n)(1 + Q_n)$$

$$Q_{n+1} = X \oplus Q_n$$

Excitation equation for T-flip flop.

73. **(c)**

D_0	D_1	Q_0	Q_1
$\bar{Q}_0$	$Q_0 \oplus \bar{Q}_1$	0	0
1	1	1	1
0	1	0	1
1	0	1	0
0	0	0	0

74. **(c)**

Any combination and interconnection of network elements like resistor, capacitor, inductor or electrical energy sources are known as network, however a closed energized network is known as circuit.

A network need not contain energy source but a circuit must contain energy source.

75. **(c)**

When J = 1 and K = 1, the next state of the flip-flop is the complement of the present state.

❍❍❍❍