DETAILED SOLUTIONS

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ESE 2026 : Prelims Exam
CLASSROOM TEST SERIES

E & T ENGINEERING

Test 14

Section A : Electromagnetics + Computer Organization and Architecture

Section B : Advanced Comm.-1 + Electronic Measurements & Instrumentation-1

Section C : Signals and Systems-2 + Basic Electrical Engineering-2

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2.	(d)	17.	(a)	32.	(b)	47.	(b)	62.	(c)
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14.	(a)	29.	(d)	44.	(c)	59.	(d)	74.	(b)
15.	(a)	30.	(d)	45.	(a)	60.	(d)	75.	(b)

Detailed Explanation

Section A : Electromagnetics + Computer Organization and Architecture

1. (d)

Given: $\in_r = 9, \quad f_c = 12 \text{ GHz}$

$$f_{c10} = \frac{c}{\sqrt{\in_r} \cdot 2a}$$

$$12 \times 10^9 = \frac{3 \times 10^8}{2a\sqrt{9}}$$

$$a = 4.167 \times 10^{-3} \text{ m}$$

$$a = 0.4167 \text{ cm}$$

2. (d)

According to Snell's law, the permeabilities of the two media are related as

$$\mu_0 \tan\theta_1 = \mu \tan\theta_2$$

$$\tan\theta_1 = 15 \tan\theta_2 \quad \ldots(i)$$

Now, the given flux density in medium 2 is

$$\overrightarrow{B_2} = 1.2\hat{a}_y + 0.8\hat{a}_z$$

Thus, the normal and tangential components of the magnetic flux density in medium 2 are:

$$\overrightarrow{B_{2n}} = 0.8\hat{a}_z$$

$$\overrightarrow{B_{2t}} = 1.2\hat{a}_y$$

From the above figure, we have:

$$\tan\theta_2 = \frac{B_{2n}}{B_{2t}} = \frac{0.8}{1.2} = \frac{2}{3}$$

or, $$\theta_2 = \tan^{-1}\left(\frac{2}{3}\right)$$

From equation (1):

$$\tan\theta_1 = 15 \tan\theta_2$$

$$\tan\theta_1 = 15 \times \frac{2}{3}$$

$$\theta_1 = \tan^{-1}(10)$$

Thus, the angular deflection is

$$\theta_1 - \theta_2 = \tan^{-1}(10) - \tan^{-1}\left(\frac{2}{3}\right)$$

3. (d)

Electromagnetic waves propagating in a medium (bounded) that has a velocity greater than the velocity in free space (velocity of light in space) is given as

$$V_p = \frac{c}{\sqrt{1-(f_c/f)^2}}$$

or $$V_p > c$$

The velocity V_p is called phase velocity of the wave.

4. (d)

$\nabla \cdot \vec{D} = \rho_V$ → Gauss's law

$\nabla \cdot \vec{B} = 0$ → Magnetic monopoles doesn't exists

$\nabla \times \vec{E} = \frac{-\partial \vec{B}}{\partial t}$ → Faraday's law

$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$ → Ampere's circuital law

5. (a)

In phasor form, the magnetic field intensity can be written as

$$H_s = 1.2\cos(15\pi y)e^{-jbx}\, a_z \text{ A/m}$$

We know that,

In free space, every field component must satisfy the wave equation.

$$\nabla^2 H = \mu_0 \in_0 \frac{\partial^2 H}{\partial t^2}$$

given, $\cos(k_y y)\sin(\omega t - k_x x)$

$$\therefore \quad k^2 = k_x^2 + k_y^2$$

where, $$k = \frac{\omega}{c};\ k_y = 15\pi,\ k_x = b$$

$$k = \frac{6\pi \times 10^9}{3\times 10^8} = 20\pi$$

$$\therefore \quad b^2 = (20\pi)^2 - (15\pi)^2$$

$$\therefore \quad b = 5\pi\sqrt{7}$$

6. (d)

Given:

Frequency of the wave propagation, f = 0.75 MHz

Conductivity of medium, $\sigma = 3 \times 10^7$ S/m

Relative permeability of medium, $\mu_r = \in_r \approx 1$

So, the angular frequency of wave propagation is

$$\omega = 2\pi f = 2\pi \times 0.75$$

$$\omega = (1.5\pi \times 10^6) \text{ rad/s}$$

$$\frac{\sigma}{\omega\in} = \frac{3\times 10^7}{1.5\pi \times 10^6 \times 8.85 \times 10^{-12}} = 7.2\times 10^{11} >>> 1$$

The medium is a perfect conductor.
Therefore, the phase constant of the propagating wave is given as

$$\beta = \sqrt{\frac{\omega\mu\sigma}{2}} = \sqrt{\frac{1.5\times\pi\times10^{6}\times4\pi\times10^{-7}\times3\times10^{7}}{2}} = 3000\pi$$

7. (a)

We know that,

$$\text{Characteristics impedance, } Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}}$$

and Propagation constant, $\gamma = \alpha + j\beta = \sqrt{(R+j\omega L)(G+j\omega C)}$

Now, for a lossless line: $R = G = 0$

So, the characteristics impedance of a lossless transmission line is

$$Z_0 = \sqrt{\frac{L}{C}}$$

and the propagation constant of a lossless transmission line is

$$\gamma = \alpha + j\beta = j\omega\sqrt{LC}$$

or $\alpha = 0$

Thus, the attenuation constant of a lossless line is always zero (real)

Again, for a distortionless line:

$$\frac{R}{L} = \frac{G}{C}$$

Hence, $Z_0 = \sqrt{\frac{L}{C}} = \sqrt{\frac{R}{G}}$

and $\gamma = \alpha + j\beta = \sqrt{RG} + j\omega\sqrt{LC}$

$$\alpha = \sqrt{RG} \neq 0$$

Therefore, the attenuation constant of a distortionless line is not zero, but it is real.

8. (b)

The amplitude of a voltage wave after travelling a distance l along a transmission line is given as

$$V_1 = V_0 e^{-\alpha l}$$

where, V_0 is the amplitude of the source voltage wave.

Now, in the given problem, after travelling 20 m along the transmission line, the voltage wave remains 10% of its source amplitude. So, we get

$$V_1 = V_0 e^{-\alpha l} = 10\% \text{ of } V_0$$

$$e^{-20\alpha} = \frac{10}{100}$$

$$e^{-20\alpha} = \frac{1}{10}$$

$$-20\alpha = \ln 0.1$$

$\Rightarrow$ $-20\alpha = -2.3$

$\therefore$ $\alpha = 0.12 \text{ Np/m}$

9. **(c)**

We have, Operating frequency, $f = 5$ MHz

Characteristic impedance, $Z_0 = 80\ \Omega$

Phase constant, $\beta = 1.5$ rad/m

So, the inductance of the transmission line is given as

$$\beta \times z_0 = \omega L$$

$$\therefore \quad L = \frac{\beta \times z_0}{\omega} = \frac{1.5 \times 80}{2\pi \times 5 \times 10^6}$$

$$\therefore \quad L = 3.82\ \mu\text{H/m}$$

10. **(c)**

Given, the length of the transmission lines 1 and 2

$$l_1 = l_2 = \frac{\lambda}{4}$$

So, the input impedance for line 1 is given as:

$$Z_{in1} = \frac{Z_{01}^2}{Z_L} = \frac{(100)^2}{150} = \frac{200}{3}\ \Omega$$

From the shown arrangement of the transmission line, it is clear that the effective load for line 2 will be equal to the input impedance of line 1.

$$\text{i.e.,} \quad Z_L' = Z_{in1} = \frac{200}{3}\ \Omega$$

11. **(c)**

Distance between maxima of an EM wave propagating along a transmission line is $\lambda/2$. So, we get

$$\frac{\lambda}{2} = (36 - 12)\text{ cm}$$

$$\lambda = 48\text{ cm}$$

$$\text{Operating frequency, } f = \frac{c}{\lambda} = \frac{3 \times 10^8}{48 \times 10^{-2}}$$

$$f = 0.0625 \times 10^{10}$$

$$f = 625\text{ MHz}$$

12. **(a)**

Length of the dipole is $\frac{\lambda}{2}$

$$l = \frac{\lambda}{2} = \frac{c}{2f} = \frac{3 \times 10^8}{2 \times 50 \times 10^6} = 3\text{ m}$$

13. **(d)**

Maximum radiation intensity: $U_{max} = 1.5$ W/sr

Directivity of antenna, $D = 20$

Since the directivity of an antenna is defined as

$$D = \frac{4\pi U_{\max}}{P_{rad}}$$

Therefore, the radiated power of the antenna is:

$$P_{\text{rad}} = \frac{4\pi U_{\max}}{D}$$

$$P_{\text{rad}} = \frac{4\pi(1.5)}{20}$$

$$P_{\text{rad}} = \frac{4\pi\times 3}{40} = 0.3\pi \text{ Watt}$$

14. (a)

The effective length of a half-wave dipole antenna is

$$l_e(\theta) = \frac{2}{\beta}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}\right]$$

i.e., l_e is a function of θ.

The maximum value of l_e is at $\theta = \frac{\pi}{2}$

$$l_e\left(\frac{\pi}{2}\right) = \frac{2}{\beta}\left[\frac{\cos\left(\frac{\pi}{2}\cos\frac{\pi}{2}\right)}{\sin\frac{\pi}{2}}\right] = \frac{2}{\beta} \quad \text{...(i)}$$

From the equation, we get that the maximum value of l_e is less than its actual value $\frac{\lambda}{2}$.

The effective length is same for the antenna in transmitting and receiving modes.

So, statements 1, 2 and 4 are correct.

15. (a)

1. When $Z_L = Z_0$, the reflection coefficient $\Gamma = 0$; hence, the reflected wave does not exist.
2. We have, $Z_0 = \sqrt{Z_{SC}\, Z_{OC}}$; Z_0 is the geometric mean of the extreme-case input impedances.

   For maximum power transfer, $Z_L = Z_0 = \sqrt{(Z_{SC}Z_{OC})}$, i.e., somewhere between Z_{SC} and Z_{OC}.
3. $Z_0 = \sqrt{\dfrac{R + j\omega L}{G + j\omega C}}$, hence Z_0 is frequency dependent.

16. (a)

The wavelength of radiation is

$$\lambda = \frac{c}{f} = \frac{3\times 10^8}{10\times 10^9} = 0.03 \text{ m}$$

Since the dish is circularly symmetric, the antenna beam will be circular. If the *HPBW* is θ_{HPBW}, the solid angle of the beam is

$$\Omega \cong \frac{\pi}{4}[\theta_{HPBW}]^2$$

Directivity of the antenna:

$$D = 30 \text{ dB} = 10^3$$

We know,

$$D = \frac{4\pi}{\Omega}$$

$$10^3 = \frac{4\pi}{\frac{\pi}{4}(\theta_{HPBW})^2}$$

$$\theta_{HPBW} = \frac{4}{\sqrt{1000}} = \frac{4}{10\sqrt{10}} = \frac{4}{10 \times 3.16} = \frac{4}{31.6} = 0.126 \text{ rad}$$

The effective aperture

$$A_e = \frac{\lambda^2}{4\pi}G = \frac{(0.03)^2 \times 1000}{4\pi}$$

$$= \frac{0.9}{4\pi} = \frac{0.9 \times 0.159}{2} = \frac{0.1431}{2} = 0.0715 \text{ m}^2$$

17. (a)

- Write-back + write–allocate writes to memory only on eviction, reducing traffic for many writes. Thus, statement 1 is correct.
- Write-through writes immediately to lower levels, making coherence protocols simpler. Therefore, statement (ii) is also correct.
- No-write-allocate could reduce cache utilization. Performance depends on work load, but it does not always enhance the miss rate.

18. (c)

- TLB miss ≠ Page fault; a TLB miss may be serviced by walking the page table. Hence, statement 1 is incorrect.
- Large pages ⇒ Fewer pages ⇒ Fewer TLB entries needed ⇒ Lower TLB miss rate; but internal fragmentation increases. Thus, statement 2 is correct.
- Inverted pagetables reduce total memory for page tables, but they depend on address-space size and require hashing; they are not universally independent of process size.
  Thus, statement 3 is incorrect.

19. (a)

Speedup = k when the pipeline is perfectly balanced and no stalls.

20. (a)

- Modern architectures (x86, ARM) use hybrid RISC-CISC designs, and pipelined ALUs are a standard feature in these mixed designs.
- CISC instructions are complex, so:
  - Hardware handles complexity.
  - Compiler does less work.

  Thus: simpler compiler → CISC

- Separate instruction and data caches are used by both modern RISC and CISC processors (split caches) → Mixed (RISC-CISC)
- RISC uses: Simple instructions, simple-cycle execution, uniform CPI values.
  Thus: Lesser cycles per instruction → RISC

21. (c)

The kernel contains the core components of the OS such as process management, memory management, network management etc.

22. (c)

Multitasking is the ability to run multiple tasks (processes/programs) concurrently, appearing simultaneous by rapidly switching the CPU between them, managed by the Operating System (OS) to share resources like CPU and memory, boosting efficiency and responsiveness, allowing users to switch tasks without losing data, and involves CPU scheduling, memory managements, and process synchronization to handle resource sharing and avoid conflicts.

23. (a)

	FCFS	Round Robin	SJF	SRJF	HRRN	Feedback	LRJF
Selection function	Max (w)	Constant	min[s]	min[$s - e$]	max $\left(\frac{w+s}{s}\right)$	–	–
Decision mode	Non-preemptive	Preemptive (at time quantum)	Non-preemptive	Preemptive (at arrival)	Non-preemptive	Preemptive (at time quantum)	Preemptive
Throughput	Not emphasized	May be low if quantum is too small	High	High	High	Not emphasized	Low
Response time	May be high, especially if there is a large variance in process execution times	Provides good response time for short processes	Provides good response time for short processes	Provides good response time	Provides good response time	Not emphasized	Good
Overhead	Minimum	Minimum	Can be high	Can be high	Can be high	Can be high	High
Effect on processes	Penalizes short processes/ I/O bound processes	Fair treatment	Penalizes long processes	Penalizes long processes	Good balance	May favour I/O bound processes	Favours high CPU-bound processes
Starvation	No	No	Possible	Possible	No	Possible	No

24. (b)

Process	Arrival Time	Burst Time	Priority	Completion time	Turn around time	W.T
P_1	2	4	3	14	12	8
P_2	0	5	1	7	7	2
P_3	3	3	4	10	7	4
P_4	1	2	2	3	2	0

P_2	P_4	P_4	P_2	P_2	P_3	P_1	
0	1	2	3	4	7	10	14
$P_2:5$	$P_2:4$ $P_4:2$	$P_2:4$ $P_4:1$ $P_1:4$	$P_2:4$ $P_1:4$ $P_3:3$	$P_2:3$ $P_1:4$ $P_3:3$	$P_1:4$ $P_3:3$	$P_1:4$	

Average waiting time, $WT = \frac{8+2+4+0}{4} = \frac{14}{4} = 3.5$

25. (d)

We know that,

$$\text{T.A.T} = \text{C.T} - \text{A.T}$$
$$\text{W.T} = \text{T.A.T} - \text{B.T}$$
$$= \text{C.T} - \text{A.T} - \text{B.T}$$
$$\text{T.A.T} - \text{W.T} = \text{T.A.T} - \text{T.A.T} + \text{B.T} = \text{B.T}$$

26. (c)

- Files and programs can be shared, but printers cannot.
- Files and shared programs do not cause deadlock because they are sharable resources.
  - → Multiple processes can read the same file simultaneously.
  - → Shared program, (such as code segments) are also shareable. They don't require exclusive access.
- A printer is a non-sharable resource. Only one process can use it at a time. If multiple processes wait for the printer while holding other resources, deadlock can occur.

27. (a)

Effective access time, $T_e = HT_C + (1 - H)(T_m + T_C)$

where, $T_c = 100$ ns

$T_m = 1400$ ns

$T_e = 1.1$ Tc

$$(1.1)(100) = 100\text{H} + (1 - \text{H})(1400 + 100)$$
$$110 = 100\text{ H} + 1500 - 1500\text{ H}$$
$$110 = 1500 - 1400\text{ H}$$
$$1400\text{ H} = 1390$$
$$H = \frac{139}{140} = 0.99$$

28. (d)

5 (M)	5	5	0(M)	0	0
	7(M)	7	7	7(H)	1 (M)
		6(M)	6	6	6

0	2(M)	2	2	7(M)	7
1	1	0(M)	0	0	0
7(M)	7	7	1(M)	1	1(H)

7	
0(H)	
1	

Miss = Page faults = 9

29. (d)

The instruction format of the given computer:

← 32 bits →

Opcode	Address Part

Each memory word has 32 bits, and each instruction is stored in one memory word.

∴ The number of bits needed for the address part:

- 32 bits are required.
- Number of bits for 248 different operations = $\log_2 248 \approx 8$
- Therefore, Address bits = 32 – 8 = 24 bits

The maximum allowable size of the memory = 2^{24} bits

∴ Maximum size of the memory $= 2^{24} \times 32$

$= 2^{6} \times 2^{20} \times 8$ bits

= 64 MB

30. (d)

- In Vertical micro-programmed control units, the control signals are represented in encoded binary format. Here, 'n' control signals require $\log_2 n$ bit encoding.
- Hardwired control units generate control signals directly using dedicated logic circuits, rather than relying on microcode stored in memory. Hence, they are faster than microprogrammed control units. RISC processors, with their simpler instruction format, typically use hardwired control units.
- A microprogram consisting of a set of microinstructions is often referred to as firmware.

31. (a)

1 task execution time in a non-pipelined system = n cycles [Assuming each stage takes 1 cycle].

m tasks execution time in a non-pipelined system = $m \times n$ cycles

Pipeline time = $(m + n - 1)$ cycles

In a pipelined system, only the 1st task takes n cycles, and each of the remaining $(m - 1)$ tasks takes 1 cycle. Hence, the total pipeline time = $m + n - 1$.

$$\therefore \quad \text{Speedup} = \frac{\text{Non-pipeline time}}{\text{pipeline time}}$$

$$= \frac{mn}{m+n-1}$$

32. (b)

	4	5	7	12	4	5	13	4	5	7	13	12
0	4	4	4	4	(4)	4	4	(4)	4	4	4	12
1		5	5	5	5	(5)	5	5	(5)	5	5	5
2			7	7	7	7	13	13	13	13	(13)	13
3				12	12	12	12	12	12	7	7	7
					*	*		*	*		*	

Number of page hits = 5

Total pages = 12

$$\text{Hit ratio} = \frac{\text{Page hits}}{\text{Total pages}} = \frac{5}{12} = 0.4167$$

33. (d)

Closure of C: $(C)^+ = CEA$

Closure of A: $(A)^+ = ACE$

Closure of D: $(D)^+ = DEAC$

Closure of F: $(F)^+ = FDBEAC = ABCDEF$

34. (a)

Armstrong's Axioms :

Reflexivity → If $X \supseteq Y$, then $X \to Y$

Augmentation → If $X \to Y$, then $XZ \to YZ$ for any Z.

Transitivity → If $X \to Y$, and $Y \to Z$, then $X \to Z$.

35. (d)

8	8	8	8	8	7	7	7	7	7	5
22	7	7	7	7	8	8	8	8	5	7
7	22	9	9	9	9	9	9	5	8	[8]
9	9	22	22	22	22	5	5	9	[9]	9
31	31	31	5	5	5	22	13	[13]	13	13
5	5	5	31	13	13	13	[22]	22	22	22
13	13	13	13	[31]	31	31	31	31	31	31
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

∴ Total swappings needed = 10

36. (d)

Pipelining does not always give CPI = 1.

37. (a)

A wave mode propagates in a waveguide only if its frequency is greater than the cutoff frequency. If there is no any propagating mode inside the waveguide then energy in the propagating mode is zero. So, the average power flow down the waveguide below cutoff region is zero.

38. (b)

Force applied on a moving charge in the presence of electric and magnetic fields is defined as

$$F = F_e + F_m = q(E + v \times B)$$

Here, F_e and F_m are the electric and magnetic forces acting on the charge. This shows that the moving charge experiences both electric and magnetic forces.

The electric force is applied in a uniform direction (the direction of the electric field). i.e., it is an accelerating force. The magnetic force is applied in a direction perpendicular to both the magnetic field and the velocity of the charged particle; hence, it is a deflecting force.

Therefore, both statements are correct, but statement-II is not the correct explanation of statement (I).

Section B : Advanced Comm.-1 + Electronic Measurements & Instrumentation-1

39. (c)

The Internet layer in the TCP/IP model is equivalent to the Network layer (Layer 3) in the OSI model, both handling logical addressing (like IP addresses) and routing data packets across different networks, with the Internet layer primarily using protocols lilke IP, ARP and ICMP.

40. (d)

- IPv6 addresses require 128 bits or 16 bytes.
- IPv4 addresses require 32 bits or 4 bytes.

41. (a)

Spam is an unwanted message sent to somebody via email, especially for advertisement.

42. (c)

- For a connection-oriented service, we need a datagram subnet.
- Start and stop bits are used in serial communication for synchronization, not error correction.

43. (b)

SCTP (Stream Control Transmission Protocol)

- It is stream-oriented protocol.
- It contains the feature of multihoming.
- It is reliable and connection-oriented protocol.
- It includes features of both UDP and TCP.
- It can detect lost, duplicate, and out-of-order data.

Note: Multi-homing: A method of configuring one computer (the host), with more than one network connection and IP address.

44. (c)

About Internet Protocol:

- It is present at the network layer.
- It is unreliable and connectionless.
- It does not have an error-control built in mechanism for sending error-control messages. It depends on the Internet Control Message Protocol (ICMP) to provide error control.
- It lacks host-query and configuration management, hence IGMP is used for group management.

45. (a)

$$N.A = \sin\theta_A = \sin 45°$$

$$= \frac{1}{\sqrt{2}}$$

$$\text{Core refractive index} = n_1 = 1.48$$

Relative refractive index of the fiber is:

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} = \frac{(N.A)^2}{2n_1^2}$$

$$= \frac{0.5}{2 \times (1.48)^2} = 0.114 = 11.4\%$$

46. (c)

For a graded-index fiber:

$$\text{Number of modes, } M = \left(\frac{\alpha}{\alpha + 2}\right) \cdot \frac{V^2}{2}$$

α = 1... for triangular profile

α = 2... for parabolic profile

V = normalized frequency

Thus, for a triangular profile:

$\therefore$
$$M = \frac{1}{3} \times \frac{V^2}{2}$$

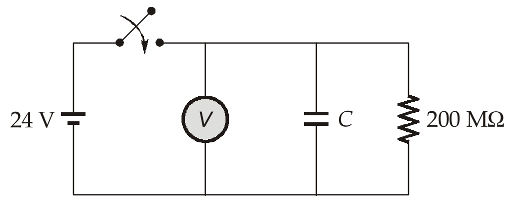
$$= \frac{V^2}{6} = \frac{(32)^2}{6} \approx 170$$

47. (b)

$$P_1 = 50\ \mu W$$
$$P_2 = 0.01\ \mu W$$
$$P_3 = 10\ \mu W$$
$$P_4 = 25\ \mu W$$

$\therefore$
$$\text{Excess loss} = \frac{P_1}{P_3 + P_4} = \frac{50}{35} = 1.428$$

48. (c)



The discharge of the capacitor is expressed by the relation:

$$V_c(t) = Ve^{-t/\tau}$$

Where, $\tau = RC$

Taking natural logarithm on both sides,

$$C = \frac{t}{R\ln\left(\frac{V}{V_c}\right)} = \frac{4\times 60}{200\times 10^6 \times \ln\left(\frac{24}{12}\right)}$$

$$= 1.731 \times 10^{-6}\text{ F}$$

$$= 1.731\ \mu\text{F}$$

49. (b)

Looking back into terminals x and y, and using Thevenin's equivalent resistance:

$$R_t = R_1 + \frac{R_2\times R_3}{R_2+R_3} = 1k + \frac{1k\times 1k}{1k+1k} = 1.5\text{ k}\Omega$$

$$\frac{I_m}{I} = \frac{R_t}{R_t + R_m}$$

$\therefore$ $$\frac{I_m}{I} = \frac{1.5\text{ k}\Omega}{1.5\text{ k}\Omega + 100\,\Omega} = \frac{1.5k}{1.6k} = 0.9375$$

$$\text{Error due to loading} = \left(1 - \frac{I_m}{I}\right)\times 100$$

$$= (1 - 0.9375) \times 100 = 6.25\%$$

50. (a)

$$R_x = \frac{C_1}{C_3}R_2 = \frac{0.5\mu\text{F}}{0.5\mu\text{F}}\times 2k = 2\text{ k}\Omega$$

$$C_x = \frac{R_1}{R_2}\times C_3 = \frac{1k}{2k}\times 0.5\mu\text{F} = 0.25\ \mu\text{F}$$

The dissipation factor is given by,

$$D = \omega R_x C_x$$

$$= 2 \times 3.142 \times 1000 \times 2 \times 1000 \times 0.25 \times 10^{-6}$$

$$= 3.1416$$

51. (b)

- The torque-weight ratio is high, which gives high accuracy.
- Since the operating forces are large due to the strong operating flux density, the errors due to stray magnetic fields are small.

52. (a)

The moving coil is wound either as a self-sustaining coil or on a non-metallic former. A metallic former cannot be used, as eddy currents would be induced in it by the alternating field.

53. (d)

All statements are correct.

54. (b)

The disadvantage of Anderson's bridge is that it is more complex than its prototype, Maxwell's bridge.

55. (a)

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

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

$$K = \frac{1}{2\theta} I^2 \frac{dL}{d\theta} = \frac{(1 \times 100 \times 10^{-3})^2}{2 \times 100 \times (\pi / 180)} \times \frac{0.1}{2\pi}$$

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

56. (d)

Acceptance angle is the maximum angle of incidence at the interface of the medium and core for which light ray enters and travels along the optical fiber.

57. (a)

A low torque/weight ratio results in low sensitivity and increased frictional losses.

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58. (c)

Given, $$X(z) = \frac{1}{z-3}$$

$$= \frac{1}{z\left[1 - 3z^{-1}\right]}$$

$$X(z) = \frac{z^{-1}}{1 - 3z^{-1}}$$

Using inverse Z-transform:

$\therefore$ $x(n) = 3^{n-1} u[n-1]$

At $n = 3$: $x(3) = 3^2 = 9$

59. (d)

For an N-point FFT sequence, the total number of complex multiplications is:

$$= \frac{N}{2} \log_2 N$$

Given: $N = 64$

$$= \frac{64}{2}\log_2 64$$

$$= 32 \times \log_2 2^6 = 32 \times 6 = 192$$

$\therefore$ Total time required = 192 × 1 μsec = 192 μsec

60. (d)

The difference equation for a Finite Impulse Response (FIR) filter defines its output $y[n]$ as a weighted sum of current and past input samples $x[n - k]$, using coefficients b_k, typically written as

$$y[n] = \sum_{k=0}^{M-1} b_k x[n-k].$$

61. (c)

The impulse response of a highpass filter is obtained from the impulse response of the low pass filter by changing the signs of the odd-numbered samples in $h_{LP}(n)$. Thus:

$$h_{HP}(n) = (-1)^n\, h_{LP}(n) = (e^{j\pi})^n \cdot h_{LP}(n)$$

$$= e^{j\pi n} \cdot h_{LP}(n)$$

Thus, the frequency response of the high-pass filter is obtained as: $H_{HP}(\omega) = H_{LP}(\omega - \pi)$.

62. (c)

The Kaiser window is often chosen when designing FIR filters with specific frequency-response requirements, as it allows precise control over the transition width and stopband attenuation.

63. (a)

64. (d)

Given, the z-transform pair:

$$3^n n^2 u[n] \xleftrightarrow{Z.T} X(z)$$

Also given: $Y(z) = X(3z)$

We know that, $\frac{1}{a^n} x[n] \xleftrightarrow{Z.T} X[az]$

Put $a = 3$

$$\frac{1}{3^n} x[n] \xleftrightarrow{Z.T} X(3z)$$

Thus, $x'(n) = \frac{1}{3^n} x[n] = \frac{1}{3^n}\left[3^n n^2 u[n]\right]$

$\therefore$ $x'(n) = n^2 u[n]$

So: $x'(0) = 0$, $x'(1) = 1$, $x'(2) = 4$, $x'(3) = 9$

$\therefore$ $$\sum_{n=0}^{3} n^2 u[n] = [0]^2 u[0] + (1)^2 u[1] + (2)^2 u[2] + (3)^2 u[3]$$

$$= 0 + 1 + 4 + 9 = 14$$

65. (d)

We define the state of a system at time n_0 as the amount of information that must be provided at time n_0, which together with the input signal $x(n)$ for $n \geq n_0$ determines the output signal for $n \geq n_0$.

66. (c)

Starting torque is given by:

$$T_{st} = \frac{K_t}{(R_e + r_2)^2 + X^2} \cdot r_2$$

Hence, the starting torque can be varied by changing the rotor-circuit resistance.

67. (a)

An induction motor is designed to operate at low values of full-load slip (typically from 0.02 to 0.05) under normal operating conditions, not high slip values.

68. (b)

In a transformer, maximum efficiency is achieved when the core loss is equal to the copper loss at the operating load, i.e, $W_i = W_{cu(fl)}$

Copper losses are directly proportional to the square of the load on the transformer i.e.,

$$W_{cu} = x^2 W_{cu(fl)}$$

where x is the percentage of the full load of the transformer and $W_{cu(fl)}$ is the copper loss at full load. Thus, at maximum efficiency:

$$W_i = x^2 W_{cu(fl)}$$

$$x = \sqrt{\frac{W_i}{W_{cu(fl)}}} = \sqrt{\frac{100}{200}} = \frac{1}{\sqrt{2}}$$

Thus, the load at maximum efficiency is:

$$= x\ (\text{kVA})_{\max}$$

$$= \frac{1}{\sqrt{2}} \times 10\ \text{kVA}$$

$$= 7.07\ \text{kVA} \simeq 7\ \text{kVA}$$

69. (d)

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Output}}{\text{Output + Losses}}$$

$$\text{Output} = xs \cos\phi$$

where s = Rating of the machine
x = % of the full load
$\cos\phi$ = power factor
P_i = Iron (core) loss
P_{cu} = Full-load copper loss

For maximum efficiency:

$$P_i = x^2 P_{cu}$$

$$\text{Efficiency: } \eta = \frac{xs\cos\phi}{xs\cos\phi + P_i + x^2 P_{cu}}$$

Maximum efficiency: $$\eta_{max} = \frac{xs\cos\phi}{xs\cos\phi + 2P_i}$$

$$0.9 = \frac{1\times s\times 1}{1\times s\times 1 + 2P_i}$$

$$P_i = 0.055s$$

$$\text{Full-load copper loss} = (1)^2 P_{cu} = P_i$$

$$P_{cu} = 0.055s$$

Efficiency at half load, at UPF $\left(\text{i.e., } x = \frac{1}{2}\right)$

$$\eta = \frac{\frac{1}{2}\times s\times 1}{\frac{1}{2}\times s\times 1 + 0.055s + \left(\frac{1}{2}\right)^2 \times 0.055s}\times 100 = 87.8\%$$

70. (b)

The stroboscopic method is used to measure the slip(s) of an induction motor. The movement of the sectors gives the slip speed, $N_s - N_r$.

Given: Number of poles, $P = 6$

Supply frequency, $f = 50$ Hz

Slip speed, $N_a = 50$ rpm

The synchronous speed is given by

$$N_s = \frac{120f}{P} = \frac{120\times 50}{6} = \frac{6000}{6} = 1000 \text{ rpm}$$

Speed of induction motor, $N_r = N_s - N_a$

$= 1000 - 50 = 950$ rpm

71. (a)

The short-circuit current in an autotransformer is higher than that in a corresponding two-winding transformer.

72. (c)

Given, $$\frac{Z_{HV(\Omega)} \times I_{HV(rated)}}{V_{HV(rated)}} = 0.08$$

$$Z_{HV(\Omega)} \cdot I_{HV\text{ (rated)}} = 0.08 \times V_{HV\text{ (rated)}}$$

$$V_{SC} = 0.08 \times 2000 = 160 \text{ V}$$

73. (a)

$$T_{start} = x^2 \left(\frac{I_{sc}}{I_{fL}}\right)^2 s_{fL}$$

$\Rightarrow$ $$0.75 = x^2 (6)^2 \times 0.035$$

$\Rightarrow$ $$x = 0.77$$

74. (b)

As a two-winding transformer:

$$\eta_{TW} = \frac{10 \times 1000 \times 0.85}{10 \times 1000 \times 0.85 + P_L} = 0.97$$

$$P_L = 262.9 \text{ W}$$

Full-load output as an autotransformer at 0.85 p.f is higher, and thus efficiency increases accordingly.

$$\text{Autotransformer rating} = \left(\frac{1.25}{1.25 - 1}\right) \times 10 = 50 \text{ kVA}$$

$$= 50 \times 0.85 = 42.5 \text{ kW}$$

Efficiency of autotransformer:

$$\eta_{auto} = \frac{42.5}{42.5 + 0.2629} = 99.38\%$$

75. (b)

Statement (II) is not the direct/correct explanation that best justifies why a digital designer has better control-hence both statements are true but statement (II) does not correctly explain statement (I).

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