DETAILED SOLUTIONS

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ESE 2024 : 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.	(b)	17.	(d)	32.	(d)	47.	(b)	62.	(a)
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13.	(d)	28.	(d)	43.	(d)	58.	(a)	73.	(c)
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15.	(a)	30.	(a)	45.	(a)	60.	(d)	75.	(c)

Detailed Explanation
Section A : Electromagnetics + Computer Organization and Architecture

1. (d)

The volume charge density is
$$\rho = \vec{\nabla}.\vec{D} = \frac{\partial D_x}{\partial x} + \frac{\partial D_y}{\partial y} + \frac{\partial D_z}{\partial z}$$
$$= 3x^2$$

The charge enclosed by the cube is
$$Q = \int_{-1.5}^{1.5}\int_{-1.5}^{1.5}\int_{-1.5}^{1.5} \rho dxdydz = \int_{-1.5}^{1.5}\int_{-1.5}^{1.5}\int_{-1.5}^{1.5} 3x^2 dxdydz$$
$$= 3\frac{x^3}{3}\Bigg|_{-1.5}^{1.5} \times 9 = 2 \times (1.5)^3 \times 9$$
$$= 2 \times \frac{27}{8} \times 9 = \frac{243}{4}\text{C}$$

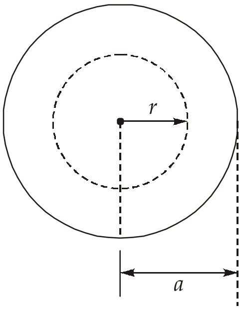
2. (b)

By Ampere's circuital law, $\oint \vec{H} \cdot \vec{dl} = \int_s \vec{J} \cdot \vec{da}$

For current flowing in z-direction, the magnetic field is in the $\hat{\phi}$ direction.

For **$r < a$**

$$H{\cdot}2\pi r = \int_{\phi=0}^{2\pi}\int_{r=0}^{r} J_0 r^2 dr d\phi = 2\pi J_0 \frac{r^3}{3}\Bigg|_0^r$$
$$H = \frac{2\pi}{2\pi r}\frac{J_0 r^3}{3} = \frac{J_0 r^2}{3}\text{A/m}$$



For $r > a$,

The enclosed current is only within $r < a$. Hence,

$$(2\pi r)H = 2\pi\int_0^a J_0 r^2 dr$$
$$H = \frac{J_0 a^3}{3r}\text{A/m}$$

3. **(c)**

If the electric field is conservative, it means that the work done by the electric field in moving a charge around a closed path is path-independent. Hence, the net work over a closed path is zero. Therefore, we have

(i) $\oint E.dl = 0$ i.e. it's circulation is identically zero.

(ii) Using $\int E.dl = \iint(\nabla \times E).ds = 0$ which implies $\nabla \times E = 0$ i.e. it's curl is identically zero.

(iii) For conservative field, the electric field is the gradient of the scalar potential i.e. $E = -\nabla V$.

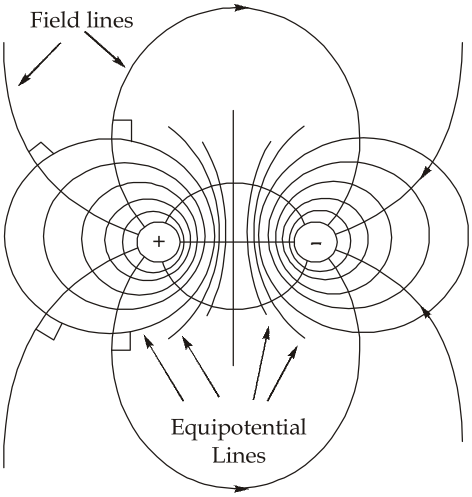
For an equipotential surface, the potential difference between any two points is zero. Hence, statement 2 is incorrect.

4. **(d)**

For homogeneous dielectric material, $D = \in E$ and $J = \sigma E$.

5. **(b)**

For equal and opposite line charge, the equipotential surface is non concentric cylinders as shown in the figure below:



6. **(d)**

Given

$$\vec{E}(z,t) = 3\sin(\omega t - kz + 30°)\hat{a}_y - 4\cos(\omega t - kz + 45°)\hat{a}_x \text{ V/m}$$

As the magnitude of orthogonal components are not equal and

$$\phi_x - \phi_y = 15°, \text{ so it is elliptically polarised.}$$

Since, the wave is travelling in +z-direction and the locus of the electric field on x-y plane with advancing time is counter-clockwise, hence as per the right hand rule, the wave is right circularly polarized.

7. (a)

The loss tangent is

$$\tan\delta = \frac{\sigma}{\omega \in_0 \in_r}$$

$$\sigma = \omega \in_0 \in_r \tan\delta$$

$$= 2\pi \times 10^8 \times \frac{1}{36\pi} \times 10^{-9} \times 18 \times 10^{-3}$$

$$= 10^{-4}\ \mho/\text{m}$$

Since the loss-tangent is very small, the dielectric is a low-loss dielectric, and we can approximately get the attenuation constant of the wave as

$$\alpha = \frac{\sigma}{2}\sqrt{\frac{\mu_0}{\in_0 \in_r}} = \frac{\sigma}{2}\sqrt{\frac{\mu_0}{\in_0}} \cdot \frac{1}{\sqrt{\in_r}} = \frac{10^{-4}}{2} \times 120\pi \frac{1}{\sqrt{18}}$$

$$= 4.44 \times 10^{-3} \text{ nepers/m}$$

The distance over which the wave amplitude reduces to $1/e$ of its original value is given by skin depth obtained as

$$\delta = \frac{1}{\alpha} = \frac{10^3}{4.44} = 225.08 \text{ m} \cong 225 \text{ m}$$

8. (a)

The attenuation constant for the compartment material (assuming the compartment material as non magnetic),

$$\alpha = \sqrt{\pi f \mu_0 \sigma} = \sqrt{\pi \times 500 \times 10^3 \times 4\pi \times 10^{-7} \times 4 \times 10^6}$$

$$= 4\pi \times 100\sqrt{5}$$

$$= 400 \times 3.14 \times 2.23$$

$$\cong 2800 \text{ Np/m}$$

The wave amplitude after passing through the compartment wall will be

$$E = E_0 e^{-\alpha z}$$

$$= 0.8 e^{-2800 \times 5 \times 10^{-3}}$$

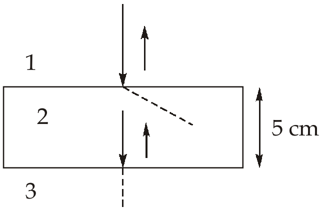
$$= 0.8 e^{-14}$$

$$= 0.8 \times 8.315 \times 10^{-7}$$

$$= 6.652 \times 10^{-7} \text{ V/m}$$

9. (c)

Intrinsic impedance of the dielectric is



$$\eta_d = \frac{\eta_0}{\sqrt{9}} = \frac{\eta_0}{3}$$

$$\Gamma_{12} = \frac{\eta_d - \eta_0}{\eta_d + \eta_0} = \frac{\frac{\eta_0}{3} - \eta_0}{\frac{\eta_0}{3} + \eta_0} = -\frac{1}{2}$$

$$\Gamma_{23} = -\Gamma_{12} = \frac{1}{2}$$

$$\tau_{12} = \frac{2\eta_d}{\eta_d + \eta_0} = \frac{1}{2}$$

$$\tau_{23} = \frac{2\eta_0}{\frac{\eta_0}{3} + \eta_0} = \frac{3}{2}$$

$$\beta_2 = \omega\sqrt{\mu_0 \epsilon_0 \epsilon_r} = \frac{2\pi \times 10^9}{3 \times 10^8} \times \sqrt{9} = 20\pi \text{ rad/m}$$

$$\beta_2 d = 20\pi \times 5 \times 10^{-2} = \pi \text{ rad/m}$$

The transmission coefficient

$$\tau = \frac{E_t}{E_i} = \frac{\tau_{12}\tau_{23}e^{-j\beta_2 d}}{1 - \Gamma_{12}\Gamma_{23}e^{-j2\beta_2 d}}$$

$$= \frac{\frac{1}{2} \times \frac{3}{2} e^{-j\pi}}{1 - \left(-\frac{1}{2}\right) \times \frac{1}{2} e^{-j2\pi}} = \frac{-3}{4+1} = \frac{-3}{5}$$

Power density of the transmitted wave,

$$= |\tau|^2 \times \text{Power density of the incident wave}$$

$$= \frac{9}{25} \times 10 = \frac{18}{5} \text{W/m}^2$$

10. (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_O is the geometric mean of extreme case input impedances. For maximum power transfer $Z_L = Z_0 = \sqrt{(Z_{SC} Z_{OC})}$, i.e. somewhere in between Z_{SC} and Z_{OC}.
3. $Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$, hence Z_0 is frequency dependent.

11. (a)

The wavelength of radiation

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

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

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

Directivity of the antenna

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

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

$$\theta_{HPBW} = \frac{4}{\sqrt{1000}} = \frac{4}{10\sqrt{10}} = \frac{4}{10 \times 3.16}$$

$$= \frac{4}{31.6} = 0.126 \text{ rad}$$

The effective aperture

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

$$= \frac{0.9}{4\pi} = \frac{0.9 \times 0.159}{2}$$

$$= \frac{0.1431}{2} = 0.0715 \text{ m}^2$$

12. **(b)**

Given,

$$Z_0 = 70 \ \Omega$$

$$S = 1.6$$

$$\theta_\Gamma = 300° = -60°$$

$$l = 0.6\lambda$$

For voltage minima,

$$2\beta x_{\min} = (2n+1)\pi + \theta$$

$$2 \times \frac{2\pi}{\lambda} x_{\min} = (2n+1)\pi + 300°$$

Considering $n = 0$ for the first minima,

$$\frac{4\pi}{\lambda} x_{\min} = \pi - \frac{\pi}{3}$$

$$\frac{4}{\lambda} x_{\min} = \frac{2}{3}$$

$$x_{\min} = \frac{\lambda}{6}$$

13. **(d)**

- If two or more modes have same cutoff frequency, they are said to be degenerate modes. e.g. – TE_{11} and TM_{11} are degenerate modes.
- If more than one mode is propagating, the waveguide is said to be overmoded. e.g., A discontinuity in the waveguide, like a bend or slot in the guide wall, will always produce multitude of modes.

14. (b)

$$f_{TE_{20}} = 15 \text{ GHz} = \frac{c}{a} = \frac{3\times10^8}{a}$$

$$a = \frac{3\times10^8}{15\times10^9}\times100 = 2 \text{ cm}$$

$$\Rightarrow \quad b = 1 \text{ cm}$$

$$f_{TE_{02}} = \frac{c}{b} = \frac{3\times10^8\times100}{1} = 30 \text{ GHz}$$

15. (a)

For propagation inside a waveguide, $f > f_c$ i.e. $\lambda < \lambda_c$. Further, the guide wavelength λ_g is greater than the free space wavelength λ. We have,

$$\frac{1}{\lambda_g^2} = \frac{1}{\lambda^2} - \frac{1}{\lambda_c^2}$$

16. (b)

End fire array has

$$\theta_{\max} = 0°/180° \text{ giving } \psi \to 0$$

$$\psi = \beta d \cos\theta + \alpha = 0$$

$$\alpha = \pm\beta d$$

Hence, there exists a phase difference between elements in the end-fire array.

The array factor is a function of the geometry of the array and the excitation phase. By varying the separation d and/or the phase β between the elements, the array factor and the total field of the array can be controlled.

17. (d)

(i) $$Z_0 = \sqrt{Z_{OC}Z_{SC}} = \sqrt{50k}$$

If $k > 50$

$$Z_0 > k$$

$$k \le Z_0 \le 50 \text{ is possible}$$

(ii) $$Z_0 = \sqrt{50k}$$

If $k < 50$

$$Z_0 < k$$

$$50 \le Z_0 \le k \text{ is possible}$$

18. (b)

- The origin corresponds to the condition $|\Gamma_L| = 0$, i.e., no reflection on the line. This point represents the best matching of the load. For the outer most circle, since $|\Gamma_L| = 1$, we get the worst impedance matching as the entire power is reflected on the transmission line.
- $\Gamma(x) = \Gamma_L\, e^{-j2\beta x}$

  Negative angle means clockwise movement with increasing distance x from load to generator.

- The outermost scale is used to determine distances in wavelengths towards the generator and the next scale is used to determine distances in wavelength towards the load. The innermost scale is a protractor (in degrees) and is primarily used to determine the phase of the reflection coefficient. However, only only one scale can be sufficient.

19. (d)

Round Robin is a CPU scheduling algorithm where each process is cyclically assigned a fixed time quantum, T_Q. Hence, we get

Queue chart

P_2	P_4	P_1	P_2	P_3	P_4	P_1	P_3

0

Gantt Chart:

P_2	P_4	P_1	P_2	P_3	P_4	P_1	P_3

0 3 6 9 11 14 17 18 19

Process table:

P_{id}	AT	BT	CT	TAT	WT
1	3	4	18	15	11
2	0	5	11	11	6
3	4	4	19	15	11
4	1	6	17	16	10

Where:

TAT → Total access time
TAT = CT – AT
WT = TAT – BT

CT : Completion time
BT : Burst time
WT : Waiting time

$$\text{Average Waiting time} = \frac{11+6+11+10}{4} = 9.5 \text{ msec}$$

20. (d)

Deadlock is a situation where the execution of two or more processes is blocked because each process holds some resource and waits for another resource held by some other process. The necessary conditions for deadlock to occur are:

- **Mutual Exclusion:** There must exist at least one resource in the system which can be used by only one process at a time.
- **Hold and Wait:** There must exist a process which holds some resource and waits for another resource held by some other process.
- **No pre-emption:** A resource cannot be preempted from a process by force. A process can only release a resource voluntarily.
- **Circular Wait:** A process is waiting for the resource held by the second process, which is waiting for the resource held by the third process and so on, till the last process is waiting for a resource held by the first process. This forms a circular chain.

21. (c)

In direct mapped cache, each main memory address maps to exactly one cache block. Considering 4 lines, main memory blocks B0 and B4 are mapped to cache line 0; B1 and B5 mapped to cache line 1; B2 and B6 mapped to cache line 2 and B3 and B7 mapped to cache line 3.

0	B0 B4 B0
1	B5
2	B2
3	B3 B7 B3

B0M : 0 mod 4 = 0
B4M : 4 mod 4 = 0
B3M : 3 mod 4 = 3
B2M : 2 mod 4 = 2
B7M : 7 mod 4 = 3
B5M : 5 mod 4 = 1
$\boxed{\text{B2M : 2 mod 4 = 2}}$ Hit
B3M : 3 mod 4 = 3
$\boxed{\text{B4M : 4 mod 4 = 0}}$ Hit
B0M : 0 mod 4 = 0

$$\text{Hit Ratio} = \frac{2}{10} = 0.2$$

22. (a)

$$T_{avg} = H_1T_1 + (1 - H_1)H_2(T_1 + T_2) + (1 - H_1)(1 - H_2)H_3(T_1 + T_2 + T_3)$$

$$T_{avg} = 0.6 \times 40 + 0.4 \times 0.8\,(140) + 0.4 \times 0.2 \times 1 \times (40 + 100 + 200)$$

$$= 96 \text{ nsec}$$

23. (b)

- In a fully-associative cache, any block of the main memory can be mapped to any line of the cache. Hence, there is no fixed mapping and it also gives a higher hit rate.
- When there's no room for a new line, a replacement algorithm is required for selecting which line in the cache is going to be replaced.
- While fully associative caches offer more flexibility and potentially reduce cache misses, they also have higher hardware complexity and cost.

24. (c)

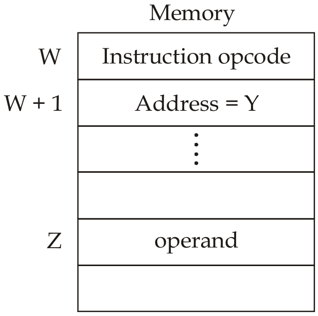
To evaluate an expression in stack CPU, first it is converted to Postfix Notation given as X = AB+CD+*. It can be implemented as below:

I_1 : PUSH A
I_2 : PUSH B
I_3 : ADD
I_4 : PUSH C
I_5 : PUSH D
I_6 : ADD
I_7 : MUL
I_8 : POP X

Thus, 8 instructions are required.

25. (c)

The given scenario can be represented graphically as follows:



In direct addressing mode, address field of instruction contains the effective address (address of operand). Hence, given value *Y* is equal to *Z*.

26. (b)

Architecture = 32 bit, mean 1 word = 32 bits

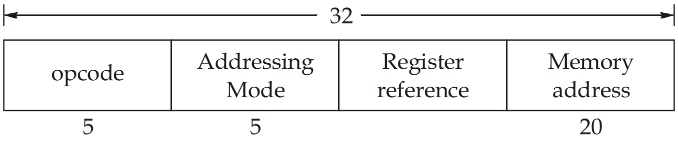
Number of distinct instructions supported = 25

$$\Rightarrow \qquad \text{Opcode} = \lceil \log_2(25) \rceil = 5 \text{ bits}$$

Number of addressing modes = 32 $\Rightarrow$ Mode field = $\log_2 32$ = 5 bits

Memory size = 1 MB $\Rightarrow$ Memory address = 20 bits (2^{20} = 1 MB)

Instruction format:



Register reference = 32 – (20 + 5 + 5)

= 2 bits

Maximum number of registers possible = 2^2 = 4

27. (d)

Types of machines instruction:

1. Data transfer instruction: MOVE, LOAD, STORE, etc.
2. Data manipulation instruction (computation): Arithmetic, logical and shift and rotate instruction.
3. Program control instruction: JUMP, CALL, etc.

28. (d)

Hardwired control unit uses fixed logic to interrupt instruction and generate appropriate control signal. Micro-programmed control unit is flexible in nature as a code is used to generate the control signals.

Since, the control signals in horizontal microprogram control unit are not encoded, 1 bit is required per control signal. Hence, no signal decoder is needed.

29. (d)

- In Vertical micro-programmed control unit, the control signals are represented in the encoded binary format. Here 'n' control signals require $\log_2 n$ bit encoding.
- Hardwired control unit 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 the set of microinstructions is often referred to as firmware.

30. (a)

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

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

$$\text{Pipeline time} = (m + n - 1) \text{ cycles}$$

In a pipelined system, only 1st takes takes n cycles, other (m - 1) tasks takes 1 cycle. Hence, pipeline time = $m + n - 1$.

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

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

31. (a)

If Machine A is n% faster than machine B, we have

$$\frac{(\text{Execution time})_B}{(\text{Execution time})_A} = 1 + \frac{n}{100}$$

$$\frac{n}{100} = \frac{(\text{Execution time})_B - (\text{Execution time})_A}{(\text{Execution time})_A}$$

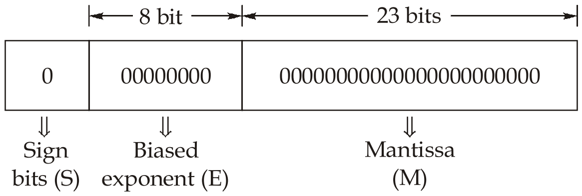
$$\frac{n}{100} = \frac{30-20}{20} = \frac{10}{20} = 0.5 \quad \Rightarrow \quad n = 50$$

i.e., A is 50% faster than B.

32. (d)

Using *IEEE* single precision floating point representation, the floatin point number can be represented as

$$N = (-1)^S * (1.\text{M}).2^{E-127}$$



It represents a special value +0 as 0 × 0000000 cannot be represented in the form 1.M

33. (c)

The processor executes a program that is stored as a sequence of machine language instructions.

34. (d)

Deadlock is a situation where the execution of two or more processes is blocked because each process holds some resource and waits for another resource held by some other process. For a single resource, the necessary conditions of hold and wait and circular wait are not met. Therefore, deadlock will never occur for a single resource.

35. (a)

$(\text{Execution Time})_{\text{pipeline}}$ = max (1,1,3,1,1) = 3 units. On average, one instruction is completed every 3 units of time, hence, resulting in a throughput of 1/3 instructions per time unit.

36. (c)

A compiler is a software program that accepts a program written in a high level language and generate object code (machine code). Therafter, a linker links several object files to generate an executable file.

37. (a)

In the far field (Fraunhofer) region ($r > 2D^2/\lambda$), the field components are essentially transverse and the angular distribution is independent of the radial distance from the antenna.

38. (a)

A floating point number x, is said to be in 'normalized form' if it has a single non-zero digit to the left of the decimal point called the mantissa. For example, the number 0.000423 may be written in normalized floating point decimal point representation as 4.23×10^{-4}. Hence, zero cannot be normalized, since all the bits in its representation are zero.

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

39. (b)

We have,

$$\text{critical angle, } \theta_c = \sin^{-1}\left[\frac{n_2}{n_1}\right] = 45°$$

$$\sin 45° = \frac{n_2}{n_1}$$

$$\frac{1}{\sqrt{2}} = \frac{n_2}{n_1}$$

$$n_2 = \frac{n_1}{\sqrt{2}}$$

$$n_2^2 = \frac{n_1^2}{2} \quad \text{...(i)}$$

According to question we have,

$$(NA)^2 = 5.86\Delta$$

And we know that $NA = n_1\sqrt{2\Delta}$

then $(NA)^2 = 2n_1^2\Delta$

On comparison, we get

$$2n_1^2 = 5.86$$

$$n_1^2 = 2.93$$

Put n_1^2 in (i), we get,

$$n_2^2 = \frac{n_1^2}{2}$$

$$n_2^2 = \frac{2.93}{2}$$

$$n_2^2 = 1.465$$

$$n_2 = 1.21$$

Hence, option (b) is correct.

40. **(a)**

We have,

$$n_1 = 1.5, n_2 = 1.2$$

$$\text{Critical angle } \theta_c = \sin^{-1}\left(\frac{1.2}{1.5}\right)$$

$$\theta_c = \sin^{-1}(0.8)$$

$$\theta_c = 53.13°$$

For TIR to occur, angle of incidence (θ) must be greater than critical angle ($\theta_c = 53.13°$). Hence, statement (1) is correct. However, it also must be less than acceptance angle.

Mathematically,

$$\theta > 53.13° \qquad ...(i)$$

$$\theta < \theta_A \qquad ...(ii)$$

Combining (i) and (ii), we get

$$53.13° < \theta < \theta_A$$

Hence, statement (4) is correct.

41. **(c)**

The four layers of the TCP/IP stack are Application/Process, Host-to-Host, Internet, and Network Access. The Internet Layer is equivalent to the Network layer in the OSI model. It is responsible for routing packets between different networks, logical addressing, and packet forwarding.

42. **(d)**

DHCP (Dynamic host configuration protocol) is not a multiple access protocol. It is a network protocol used in Internet Protocol (IP) networks to automatically assign IP addresses and other configuration information to devices on a network.

43. **(d)**

Media access control is the function of a data link layer. The data link layer is responsible for controlling access to the physical transmission medium and ensuring that devices on a network can share the medium efficiently.

44. **(a)**

Network layer takes care of routing the packets from source to destination and is responsible for source to destination delivery of the packets across different networks. However, the transport layer is responsible for end-to-end communication, including error recovery, flow control, and sequencing of packets. Hence, S_2 is not correct.

45. **(a)**

The Equipment Identity Register (EIR) in GSM network architecture maintains a database of IMEIs, which are unique identifiers assigned to each mobile device. IMEIs serve as a means of identifying individual mobile devices within the GSM network. IMEIs are categorized into three main lists within the EIR:

- White List: Contains IMEIs of valid and authorized mobile devices.
- Black List: Contains IMEIs of stolen or unauthorized devices that are barred from accessing the network.
- Grey List: Contains IMEIs that may require further investigation. For example, devices associated with potential fraud or suspicious activities.

46. **(c)**

For private key cryptosystem, two users maintains 1 secret key.
3 users maintain 1 + 2 secret key
n users maintain 1 + 2 + ... + n – 1 secret key

$$= \frac{n(n-1)}{2}$$

For public key cryptosystem, each user maintain 2 keys, one key is public key and the other key is private key.

$\therefore$ n users maintains $2n$ keys.

47. **(b)**

$$f_b = \frac{1}{\Delta t \cdot L} = \frac{1}{10\ \text{ns/km} \times 5\ \text{km}} = 20\ \text{Mbps}$$

Note: For UPNRZ (Unipolar non-return to zero) transmissions, the maximum transmission rate is

$$f_b = \frac{1}{2\Delta t \cdot L}$$

48. **(d)**

- Kelvin (K) is defined as the fraction of $\frac{1}{273.16}$ of the thermodynamic temperature of triple point of water. Hence, statement 1 is correct.
- We have, Measured value A_a = 95.45°C

  We know that,

$$\text{absolute error} = \text{Measured value} - \text{True value}$$

$$\delta_A = A_a - A_t$$

$$\delta_A = 95.45°\text{C} - A_t \quad \text{...(i)}$$

And correction factor $\delta_{AC} = -\delta_A$ ...(ii)

According to question $\delta_{AC} = -0.10°\text{C}$ ...(iii)

From (iii) and (ii), we get $\delta_A = 0.10°\text{C}$

Put δ_A in (i) we get, $A_t = 95.45 - 0.10$

$$A_t = 95.35°\text{C}$$

Hence, statement 2 is correct.

- Accuracy means how close the measured value is to the real, actual value whereas Precision means how reproducible the measurement is. Therefore, a highly precise instrument need not to be highly accurate but a highly accurate instrument is assumed to be highly precise.

  Hence, statement 3 is correct.
- Systematic error is a consistent or proportional difference between the observed and true values and the Random error is a chance difference between the observed and true values (eg. misreading the instrument). The analysis of systematic error is an indicator of the accuracy of the instrument, whereas the analysis of random error is an indicator of the instrument precision.

  Hence, statement 4 is wrong.

  Therefore, option (d) is correct.

49. (d)

When the two resistances are connected in parallel, the resistance is:

$$R = \frac{R_1R_2}{R_1+R_2} = \frac{20\times 20}{20+20}$$

$$R = 10\Omega$$

Now,

$$\frac{\partial R}{\partial R_1} = \frac{R_2}{(R_1+R_2)} - \frac{R_1R_2}{(R_1+R_2)^2} = \frac{20}{40} - \frac{20\times 20}{40\times 40}$$

$$\frac{\partial R}{\partial R_1} = \frac{1}{2} - \frac{1}{4}$$

$$\frac{\partial R}{\partial R_1} = \frac{1}{4}$$

Similarly,

$$\frac{\partial R}{\partial R_2} = \frac{R_1}{R_1+R_2} - \frac{R_1R_2}{(R_1+R_2)^2} = \frac{20}{40} - \frac{20\times 20}{40\times 40}$$

$$\frac{\partial R}{\partial R_2} = \frac{1}{4}$$

Hence, uncertainty in total resistance is:

$$W_R = \pm\sqrt{\left(\frac{\partial R}{\partial R_1}\right)^2 W_{R_1}^2 + \left(\frac{\partial R}{\partial R_2}\right)^2 W_{R_2}^2}$$

$$W_R = \pm\sqrt{\left(\frac{1}{4}\right)^2 (0.1)^2 + \left(\frac{1}{4}\right)^2 (0.03)^2}$$

$$W_R = \pm 0.026\ \Omega$$

Hence, option (d) is correct.

50. (c)

We have

	Deviation	
Reading, x	d	d^2
101.2	–0.3	0.09
101.7	0.2	0.04
101.3	–0.2	0.04
101.4	–0.1	0.01
101.9	+0.4	0.16
$\Sigma x = 507.5$		$\Sigma d^2 = 0.34$

$$\text{Arithmetic mean, } \bar{x} = \frac{\Sigma x}{n} = \frac{507.5}{5} = 101.5\ \Omega$$

$$\text{Standard deviation, } \sigma = \sqrt{\frac{\Sigma d^2}{n-1}} \quad \text{where } \Sigma d^2 = d_1^2 + d_2^2 + \ldots . d_n^2\ ;\ \ d_i = x_i - \bar{x}$$

$$\sigma = \sqrt{\frac{0.34}{5-1}} = \sqrt{\frac{34}{400}} = 0.2915\ \Omega$$

$$\text{Probable error} = 0.6745\sigma$$

$$= 0.6745 \times 0.2915$$

$$\text{Probable error} = 0.196\ \Omega$$

Hence, option (c) is correct.

51. (b)

- **Absolute instruments:** Absolute instruments give the value of the quantity to be measured in terms of the constants of the instrument and its deflection.
- Tangent Galvanometer, Rayleigh current Balance and Absolute electrometer are absolute instruments.
- **Secondary instruments:** Secondary instruments are the instruments in which the value of the electrical quantity is measured and is determined from the deflection of the instruments. Eg: Ammeter, Voltmeter, Wattmeter, etc.

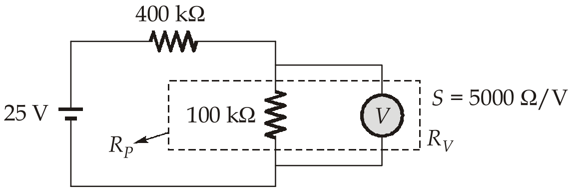
52. (b)

The damping coefficient, ξ in the indicating type instruments is generally chosen between $0.6 \le \xi \le 0.8$ (more precisely $0.7 \le \xi \le 0.8$)

Hence, by checking options we get $\xi_1 = 0.5$, $\xi_2 = 0.75$, $\xi_3 = 1.5$ and $\xi_4 = 0.9$ for option *a*, *b*, *c* and *d* respectively.

Therefore, the system represented by option (b) would be most suitable for indicating type of instrument.

53. (d)



Case-I: When 0-5 V scale is used,

$$R_V = S \times V_m$$
$$R_V = 5000 \times 5$$
$$R_V = 25\ \text{k}\Omega$$
$$R_P = R_V \,||\, 100\ \text{k}\Omega$$
$$R_P = \frac{25\times100}{25+100}$$
$$R_P = 20\ \text{k}\Omega$$
$$V_{\text{measured}} = \frac{25\times R_P}{R_P+400\ \text{K}} \quad \text{...By voltage division rule}$$
$$V_{\text{measured}} = \frac{25\times20}{420} = \frac{25}{21}\text{Volt} \qquad \text{...(i)}$$
$$V_{\text{true}} = \frac{25\times100}{500} = 5\ \text{volt}$$
$$\text{Limiting error} = V_{\text{measured}} - V_{\text{true}}$$
$$= \frac{25}{21} - 5$$
$$= \frac{25-105}{21} = \frac{-80}{21} = -3.81\ \text{volt}$$

Hence, statement 1 is correct.

Case-II: When (0-10)V scale is used

$$R_V = 5000 \times 10 = 50\ \text{k}\Omega$$
$$R_P = \frac{50\times100}{50+100} = \frac{100}{3}\text{k}\Omega$$
$$V_{\text{measured}} = \frac{25\times\frac{100}{3}}{400+\frac{100}{3}} = \frac{2500}{1300} = \frac{25}{13}\text{V}$$
$$V_{\text{measured}} = 1.92\ \text{Volt} \qquad \text{...(ii)}$$

Hence, statement 2 is correct.

$$V_{\text{measured}}\Big|_{\substack{\text{when 0-10 V scale}\\\text{voltmeter is used}}} - V_{\text{measured}}\Big|_{\substack{\text{when 0-5 V scale}\\\text{voltmeter is used}}} = 1.92 - \frac{25}{21} = 0.73\ \text{V}$$

Hence, statement 3 is correct.

Thus, none of the statements are incorrect, hence option (d) is correct.

54. (c)

We have,

$$3\frac{1}{2}\text{DVM, accuracy} = \pm 0.5\% \pm 1 \text{ digit}$$

Case (I): When FSD = 100 V, reading = 2 V

$$\text{error (1)} = \pm 0.5\% \text{ of reading}$$

$$= \pm\frac{0.5}{100}\times 2 = \pm\, 0.01 \text{ V}$$

$$\text{error (2)} = \frac{V_{FSD}}{10^N}\times \text{Number of digits}$$

$$\text{error (2)} = \frac{100}{10^3}\times 1 = 0.1 \text{ V}$$

$$\text{Total error} = 0.01 + 0.1$$

$$= 0.11 \text{ V}$$

Case (II): When FSD = 10 V, reading = 2 V

$$\text{error (1)} = \pm 0.5\% \text{ of reading}$$

$$= \pm\frac{0.5}{100}\times 2 = \pm\, 0.01 \text{ V}$$

$$\text{error (2)} = \frac{V_{FSD}}{10^N}\times \text{Number of digits}$$

$$\text{error (2)} = \frac{10}{10^3}\times 1 = 0.01 \text{ V}$$

$$\text{Total error} = 0.01 + 0.01$$

$$= 0.02 \text{ V}$$

$$\therefore \quad \text{Difference in error} = 0.11 - 0.02$$

$$= 0.09 \text{ V}$$

Hence, option (c) is correct.

55. (c)

Public key cryptography is generally considered slower than symmetric key cryptography due to the computational complexity of the algorithms. Further, it require far longer keys to offer the same level of protection as symmetric encryption. Hence, private key cryptography is used for confidentiality.

56. (d)

In moving iron type instrument (MI), the direction of the field due to the fixed coil changes with the change in polarity of the AC parameter under measurement. Hence, MI type instrument can be used to measure both AC and DC parameters. Thus, when AC parameter is put under measurement in MI type instruments, it will provide us with the root mean square value (RMS) of the parameters. Hence, statement (I) is wrong and statement (II) is correct.

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

57. (d)

Given, $$Y(e^{j\omega}) = 2X(e^{j\omega}) + e^{-j\omega}X(e^{j\omega}) - \frac{dX(e^{j\omega})}{d\omega}$$

$$x(n) = \delta(n)$$

$$X(e^{j\omega}) = 1$$

∴ $$Y(e^{j\omega}) = 2(1) + e^{-j\omega}(1) - 0$$

$$= 2 + e^{-j\omega}$$

By taking inverse DTFT,

$$y(n) = 2\delta(n) + \delta(n-1)$$

58. (a)

The transfer function of the system from above given pole-zero diagram is obtained as,

$$H(z) = \frac{K(z^{-1} - a)}{(1 - az^{-1})} \text{ where } K \text{ is a constant}$$

$$H(e^{j\omega}) = \frac{K(e^{-j\omega} - a)}{(1 - ae^{-j\omega})}$$

$$\left|H(e^{j\omega})\right|^2 = \frac{K^2(e^{-j\omega} - a)(e^{j\omega} - a)}{(1 - ae^{-j\omega})(1 - ae^{j\omega})} = K^2$$

∴ $$\left|H(e^{j\omega})\right| = K$$

As the magnitude is independent of frequency, it represents an all-pass system.

59. (a)

Transfer function of RC low-pass filter,

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

$$H(f) = \frac{1}{1 + j2\pi fRC}$$

$$|H(f)| = \frac{1}{\sqrt{1 + 4\pi^2 f^2 R^2 C^2}}$$

We have, $$H(0) = 1$$

$$|H(f_1)| = \frac{1}{\sqrt{1 + 4\pi^2 f_1^2 R^2 C^2}}$$

$$\frac{|H(f_1)|}{|H(0)|} \geq 0.9$$

∴ $$|H(f_1)|^2 \geq (0.9)^2$$

$$\frac{1}{1+4\pi^2 f_1^2 R^2 C^2} \geq 0.81$$

$$1+4\pi^2 f_1^2 R^2 C^2 \leq 1.2345$$

$$4\pi^2 f_1^2 R^2 C^2 \leq 0.2345$$

$$\therefore \quad f_1 \leq \frac{\sqrt{0.2345}}{2\pi \times 10^3 \times 10^{-6}}$$

$$f_1 \leq 77.1 \text{ Hz}$$

60. (d)

Given, $$Y(z) = \frac{dX(z)}{dz}$$

We know that $$nx(n) \longleftrightarrow -z\frac{dX(z)}{dz}$$

$$-(n-1)x(n-1) \xleftrightarrow{Z.T} -z^{-1}\left[-z \cdot \frac{dX(z)}{dz}\right]$$

$$-(n-1)^3 3^{n-1} x(n-1) \xleftrightarrow{Z.T} \frac{dX(z)}{dz}$$

61. (b)

- The difference equation for an FIR filter does not involve recursion as past outputs have no influence on present outputs.
- It has an impulse response given by $H(z) = .. b_1/z^2 + b_0/z + a_0 + a_1 z + a_2 z^2$ .... with finite number of terms. Hence, it has poles possible only at $z = 0$. Therefore, FIR filters are sometimes called "all zero" because the poles are always located at $z = 0$.
- Both pole and zero locations can be chosen with IIR filters.

62. (a)

63. (c)

Given, $$G(z) = \frac{2z}{z-e^{-0.9}} + \frac{3z}{z-e^{-1.2}}$$

$$= \frac{2}{1-e^{-0.9}z^{-1}} + \frac{3}{1-e^{-1.2}z^{-1}}$$

On comparing with, $\frac{2}{1-e^{-\alpha T}z^{-1}} + \frac{3}{1-e^{-\beta T}z^{-1}}$

We get $\alpha = 3, \beta = 4$

$$\left[\because \frac{1}{s+a} \Rightarrow \frac{1}{1-e^{-aT}z^{-1}}\right]$$

$\therefore$ The equivalent analog transfer function,

$$H_a(s) = \frac{2}{s+3} + \frac{3}{s+4}$$

64. **(c)**

For 16-point DFT, number of complex multipliers, $(M)_{\text{DFT}} = N^2 = 16^2 = 256$

For 16-point radix-2 FFT, number of complex multipliers, equals the number of stages × multiplications per stage. Hence,

$$(M)_{\text{FFT}} = \frac{N}{2}\log_2 N$$

$$(M)_{\text{FFT}} = \frac{16}{2}\log_2 16 = \frac{16}{2}\times 4 = 32$$

$$\therefore \quad (M)_{\text{DFT}} - (M)_{\text{FFT}} = 256 - 32 = 224$$

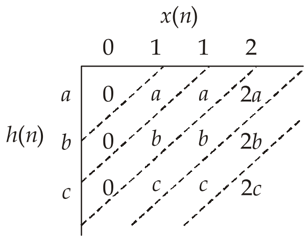
65. **(b)**

Given,

$$x(n) = \{0, 1, 1, 2\}$$

$$h(n) = \{a, b, c\}$$

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



$$\therefore \quad y(n) = \{0, a, a+b, 2a+b+c, 2b+c, 2c\}$$

given,

$$Y(e^{j0}) = 36$$

$$Y(e^{j0}) = \sum_{n=0}^{5} y(n) = a + a + b + 2a + b + c + 2b + c + 2c = 36$$

$$4(a+b+c) = 36$$

$$a + b + c = 9$$

66. **(b)**

The voltage regulation of a single phase transformer is given by

$$\%\,VR = \frac{I_2(R_{02}\cos\theta \pm X_{02}\sin\theta)}{E_2}\times 100$$

(Positive sign is for lagging power factor and negative sign is for leading power factor)

- For lagging and unity power factor, regulation is always positive.
- For leading power factor, regulation may be positive, negative or zero.
- The portion of transformer flux that links either of the two coils, primary or secondary but not both, is called leakage flux. It is present only under the load condition.

67. **(a)**

- The transformation ratio is the ratio of secondary to primary voltage. Hence, it can be less than or greater than 1, depending on its configuration.
- A two-winding transformer of a given VA rating when connected as an autotransformer can handle higher VA because the power is transferred through both conduction and induction processes.

- An auto transformer is used as a starter for induction motors and synchronous motors because it allows for voltage control during starting, which helps reduce the current and minimize voltage drops.

68. (a)

At constant $\frac{v}{f}$ ratio, hysteresis loss $P_h = Bf$

$$\text{Eddy current loss } P_e = Af^2$$

Given,
$$A(50)^2 + B(50) = 2500 \text{ W} \quad \text{...(i)}$$
$$50B - 25B = 450 \text{ W}$$
$$B = 18$$

From equation (i), $A(50)^2 + (18 \times 50) = 2500$

$$A = \frac{16}{25}$$

At 25 Hz,
$$\text{Total iron loss} = Af^2 + Bf$$
$$= \frac{16}{25}(25)^2 + 18(25) = 850 \text{ W}$$

69. (a)

- One to one transformer is also called isolation transformer is typically used to provide electrical isolation between two circuits while maintaining the same voltage level. It has a primary winding and a secondary winding with an equal number of turns i.e. a turn ratio of one.
- In the transformer primary and secondary windings are magnetically connected and electrically isolated.
- In the transformer to maintain constant induced voltage, negative magnetic coupling is preferred.
- Ideal transformer has infinite permeability and 100% efficient. The infinite permeability means less magnetizing current is required for magnetizing the core.

70. (a)

$$\text{Full load current} = \frac{12000}{2400} = 5 \text{ A}$$

$$\text{short circuit test is conducted at } I = 2.24 \text{ A} \cong \sqrt{5}\text{A}$$

$$\text{Full load copper losses, } P_{cu} = 150\left(\frac{5}{\sqrt{5}}\right)^2 = 750 \text{ W}$$

The open-circuit test gives the core or iron losses in a transformer. We get,

$$\eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + P_i + P_{cu\,\text{loss}}}$$

$$\eta = \frac{12000 \times 0.8}{(12000 \times 0.8) + 300 + 750}$$

$$\eta = 0.901$$

$$\eta\% = 90.1\%$$

71. (d)

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

The frequency of the output from the converter is given by

$$f = \frac{P(N_s \pm N)}{120}$$

$$125 = \frac{P(N_s + N)}{120}$$

$$\frac{125\times 120}{6} = N_s + N$$

$$N = 2500 - N_s$$

$$N = 2500 - 1000$$

$$N = 1500 \text{ rpm}$$

72. (a)

$$\text{rotor frequency} = s \times \text{stator frequency}$$

$$\text{rotor frequency} = \frac{1}{3}\times 60 = 20 \text{ Hz}$$

73. (c)

$$T_{st} = 0.8\ T_{\max}$$

$$T_{st} = \frac{3E_2^2(r_2 + r_{ext})}{\omega_s\left[(r_2 + r_{ext})^2 + X_2^2\right]}$$

$$T_{\max} = \frac{3E_2^2}{\omega_s \times (2X_2)}$$

It is given that $T_{st} = 0.8\ T_{\max}$. Hence, we get

$$\frac{3E_2^2(r_2 + r_{ext})}{\omega_s\left[(r_2 + r_{ext})^2 + X_2^2\right]} = \frac{0.8\times 3E_2^2}{\omega_s \times (2X_2)}$$

$$0.8\left[(r_2 + r_{ext})^2 + X_2^2\right] = (r_2 + r_{ext}) \times (2X_2)$$

Let $r_2 + r_{ext} = R$, therefore

$$0.8\left[R^2 + X_2^2\right] = 2RX_2$$

For $X_2 = 2$, On solving we get $R = 1$ and 4

neglect $R = 4\ \Omega$ (which is a higher value)

$$r_2 + r_{ext} = 1$$

$$r_{ext} = 1 - r_2 = 1 - 0.4 = 0.6\ \Omega$$

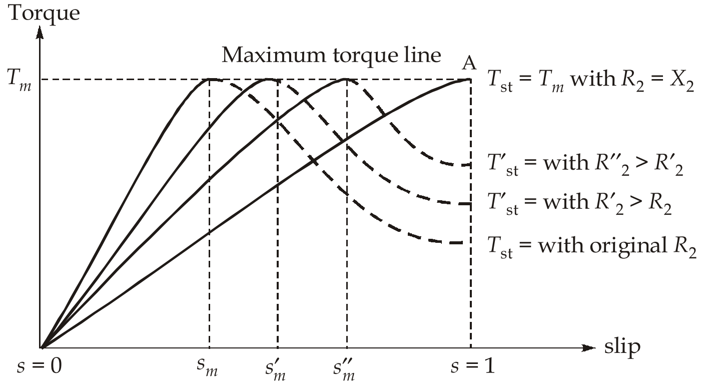
74. (a)

A recursive filter has both poles and zeros which can be selected by the designer,hence there are more free parameters than for a non-recursive filter of the same order, where only zero can be varied and the poles are always located at $z = 0$.

75. (c)

- The starting torque $T_{st} \propto \frac{R_2}{R_2^2 + (sX_2)^2}$

  As $R_2' > R_2$, the slip at which maximum torque occurs ($s_m = R_2/X_2$) increases giving the torque slip characteristics as below:



  Hence, starting torque increases with increase in rotor resistance. But it also causes more rotor losses, hence efficiency decreases.

- Negative slip occurs when Induction motor is acting as a generator, not always. Hence, Statement (II) is incorrect.

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