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ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

E & T ENGINEERING

Test 16

Section A : Advanced Electronics + Materials Science

Section B : Electromagnetics + Computer Organization and Architecture

Section C : Advanced Comm.-2 + Electronic Measurements & Instrumentation-2

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

Detailed Explanation
Section A : Advanced Electronics + Materials Science

1. **(b)**
Thin and thick film ICs do not use a semiconductor substrate for passive components, unlike monolithic ICs. Instead, they utilize an insulating substrate (such as glass or ceramic) for depositing resistors, capacitors and interconnections.

2. **(d)**
Cost is high for Ion implantation doping process because the process is carried out in high vacuum.

3. **(a)**
- Sputtering is a widely used physical vapour deposition (PVD) method in thin-film technology to deposit precise layers of materials onto a substrate. The atoms are ejected from a target material that is to be deposited on a substrate when bombarded by energetic particles in vacuum resulting in thin film deposition.
- Screen printing is a widely used technique in thick film IC fabrication to deposit thick layers of conductive, resistive and insulating materials onto ceramic or glass substrates. It is done by forcing the pastes or inks through engineered stencils by using a squeegee onto a flat or cylindrical surface of a substrate.

4. **(d)**
The CMOS fabrication process involves the following sequence of steps:
Wafer preparation → Oxidation → Well formation → Gate formation → Source/Drain Doping → Inter layer dielectric → Metallization → Passivation

5. **(b)**
SiO_2 is used as the gate oxide because it provides excellent insulation and and forms a low-defect interface with silicon.

6. **(b)**
Polysilicon (Poly-Si) is used as the gate electrode because it has good conductivity and is compatible with the CMOS process.

7. **(d)**

Level of Integration	Transistors per unit area (Q)	Packing Density, $P = \log_{10}Q$
Small scale integration (SSI)	1 – 10	$P < 1$
Medium scale integration (MSI)	10 – 100	$1 < P < 2$
Large scale integration (LSI)	$100 - 10^4$	$2 < P < 4$
Very large scale integration (VLSI)	$10^4 - 10^6$	$4 < P < 6$
Ultra large scale integration (ULSI)	$> 10^6$	$P > 6$

8. (c)

We have,

Doping concentration of Boron, $N_B = 10^{10}/\text{cm}^3$

Predeposition time, t = 2 hour = 2 × 60 × 60 = 7200 sec

Diffusion constant, $D = 5 \times 10^{-13}$ cm^2/sec

Solid solubility of Boron, $N_s = 10^{18}/\text{cm}^3$

We know that, $$N(x, t) = N_s erfc\left(\frac{x}{2\sqrt{Dt}}\right)$$

At $x = x_j$ (junction depth), the dopant concentration is equal to the background doping concentration. Hence,

$$N(x, t) = N_B = N_s erfc\left[\frac{x_j}{2\sqrt{Dt}}\right]$$

$$10^{10} = 10^{18} erfc\left(\frac{x_j}{2\sqrt{5\times 10^{-13}\times 7200}}\right)$$

$$erfc^{-1}(10^{-8}) = \frac{x_j}{2\times 60\times 10^{-6}}$$

$$4.05 \times 120 \times 10^{-6} = x_j$$

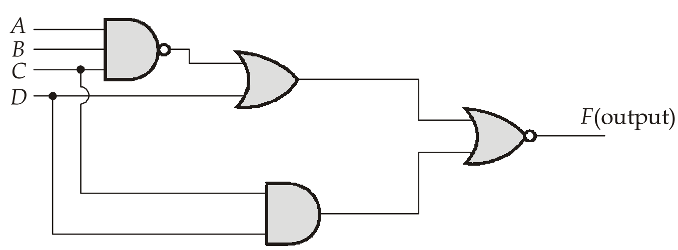
$$x_j \approx 480 \times 10^{-6} \text{ cm}$$

$$= 480 \times 10^{-6} \times 10^{-2} \text{ m}$$

$$x_j = 480 \times 10^{-8} \text{ m} = 4.80\ \mu\text{m}$$

9. (c)

Consider the given logic circuit as shown below:



The boolean expression for the output (F) of the circuit, under no fault condition, can be given as,

$$(F)_{NF} = \overline{\overline{ABC} + D + CD}$$

$$(F)_{NF} = \overline{\overline{ABC} + D} = ABC\bar{D} \qquad \text{...(1)}$$

The boolean expression for the output (F) of the circuit, when the line "T" is connected to the ground, can be given as

$$(F)_F = \overline{\overline{ABC} + D + 0}$$

$$(F)_F = ABC\bar{D} \qquad \text{...(2)}$$

∴ from the equation (1), (2), it is clear that the boolean expression for the output (F) is same for both the situations (with and without fault). So, no input combination can detect the fault occurred in the circuit, when the line "T" is connected to the ground.

10. (c)

Ion implantation involves bombarding the semiconductor with high-energy ions, which causes damage to the crystal lattice. While annealing significantly reduces the damage, however it may not recover completely.

11. (d)

In a Mealy machine, the output depends on both the current state and input, whereas in Moore machine, the output depends only on the current state.

To convert a Mealy machine with K states into an equivalent Moore machine, we need to create a separate Moore state for each unique (state, input) pair that produces a different output.

At most, a Moore machine may require $K \times M$ states where M is the number of different outputs associated with transitions in the Mealy machine i.e., atmost 2 K states for binary machine.

12. (a)

Using Deal-grove model, $t_{ox}^2 + A\,t_{ox} = B(t + \tau)$

As initial oxide thickness is zero i.e. $\tau = 0$, we get

$$t_{ox}^2 + 0.1t_{ox} = 0.2t$$

$$t_{ox}^2 + 0.1t_{ox} - 0.2t = 0$$

For t = 1 hour,

$$t_{ox}^2 + 0.1t_{ox} - 0.2 = 0$$

$$t_{ox} = 0.4\ \mu\text{m},\ -0.5\ \mu\text{m}$$

Since oxide thickness cannot be negative, hence $t_{ox} = 0.4\ \mu$m

13. (d)

- For positive photoresist, the exposed polymer becomes more soluble in a developer solution than the unexposed polymer, whereas for a negative photoresist, the exposed polymer becomes insoluble in the developer solution.
- Positive photoresist has higher resolution and can form finer patterns. This is because its dissolution characteristics in the exposed area make the edges clearer and reduce blur and diffusion. Whereas in negative photoresist, the resolution is relatively low. Due to the cross-linking reaction of the exposed part, the pattern edge may not be sharp enough and a certain degree of diffusion may occur.
- Negative photoresists are faster than positive photoresists because they require less exposure to light to trigger a change in solubility, due to the nature of their chemical reactions.

Hence, all the given statements are correct.

14. (c)

When no fault occurs,

$$f = xy + z\overline{y}$$

Test vectors that can detect $y(s - a - 1)$ fault at y are,

$$x = 1;\quad y = 0;\quad z = 0$$

or $$x = 0;\quad y = 0;\quad z = 1$$

So, Boolean expression will be : $x\,\overline{y}\,\overline{z} + \overline{x}\,\overline{y}\,z$

Alternate method: To detect the y(s-a-1) fault, we keep $y = 0$. Using Boolean difference, the boolean expression to detect the fault is given by

$$\bar{y} \cdot [f(y=0) \oplus f(y=1)]$$

$$= \bar{y} \cdot (z \oplus x) = \bar{y} \cdot (\bar{z}x \oplus z\bar{x})$$

$$= x\bar{y}\bar{z} + \bar{x}\bar{y}z$$

15. (b)

Fault Equivalence: Two faults f_1 and f_2 are equivalent, if all tests that detect f_1 can also detect f_2.
Fault Dominance: If all tests for some fault (f_1) detect another fault (f_2) but reverse relation is not true, then (f_2) is said to dominate (f_1).
For given problem:

test vector for $f_1 \rightarrow A = 0, B = 1, C = 1$ i.e., 011
test vector for $f_2 \rightarrow$ 001, 010, 011, 100, 101, 110, 000

Here, all the test vectors for f_1 (001) can detect f_1 fault whereas the reverse is not true, so f_2 dominates f_1.

16. (b)

The given state diagram is a sequence detector which detects the sequence 101 and 010.

17. (a)

For option (a), the first OR gate produces the min-terms 0, 1 and 3 i.e. $f_1 = \Sigma m(0, 1, 3)$. The output of second OR gate is $F = f_1 + \Sigma m(5, 7) = \Sigma m(0, 1, 3, 5, 7)$.

18. (d)

Given, $R = 0.5$ nm

For an FCC unit cell, edge length of the unit cell, $a = 2R\sqrt{2}$, where R is the radius of the atom.

The FCC unit cell volume is,

$$V_C = a^3$$

$$= (2R\sqrt{2})^3 = 16\sqrt{2}R^3$$

$$= 16\sqrt{2} \times (0.5 \times 10^{-9})^3$$

$$= 16\sqrt{2} \times 0.125 \times 10^{-27}$$

$$= 2\sqrt{2} \times 10^{-27}\,\text{m}^3$$

$$= 2\sqrt{2} \times 10^{-21}\,\text{cm}^3$$

19. (b)

The equilibrium number of vacancies, N_v, increases exponentially with the absolute temperature, T, given by

$$N_v = N\exp\left(\frac{-Q_v}{KT}\right)$$

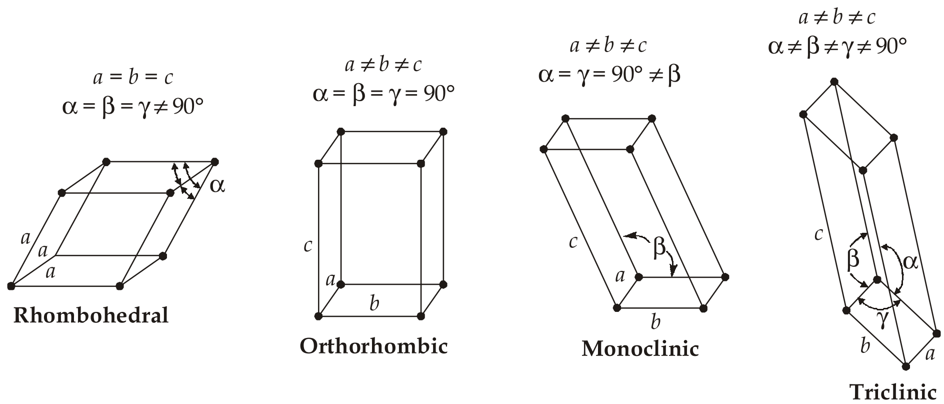
$$\Rightarrow \quad \frac{N_v}{N} = \exp\left(\frac{-Q_v}{KT}\right)$$

$$\Rightarrow \qquad \ln\left(\frac{N}{N_v}\right) = \frac{Q_v}{KT}$$

$$\Rightarrow \qquad Q_v = KT\ln\left(\frac{N}{N_v}\right)$$

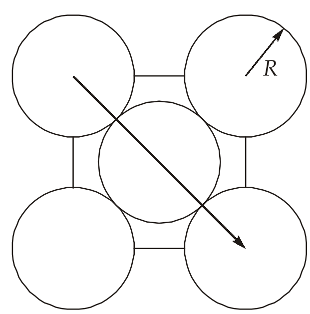
20. (b)

Unit Cell Geometry:



21. (c)

The bottom face-plane of the FCC unit cell represents [110] direction and is as shown below,



$$\text{LD} = \frac{\text{number of atoms centered on direction vector}}{\text{length of direction vector}}$$

$$\therefore \qquad \text{LD}_{110} = \frac{1/2+1+1/2}{R+2R+R} = \frac{2\text{ atoms}}{4R} = \frac{1}{2R}$$

22. (b)

A high degree of toughness is essential to ensure that the abrasive particles do not easily fracture.

23. (c)

Given,
$$D = 3 \times 10^{-7}\ \text{C/m}^2$$
$$V = 10\ \text{V}$$
$$l = 8.854 \times 10^{-3}\ \text{m}$$

Polarization, $P = D - \epsilon_0 E$

$$= D - \epsilon_0 \frac{V}{l}$$

$$= (3\times10^{-7}) - \frac{(8.854\times10^{-12})(10)}{(8.854\times10^{-3})}$$

$$= (3 \times 10^{-7}) - (10 \times 10^{-9})$$

$$= (3 \times 10^{-7}) - (0.1 \times 10^{-7})$$

$$= 2.9 \times 10^{-7}\ \text{C/m}^2$$

24. (d)

The Clausius-Mossotti equation provides a relationship between the dielectric constant of a material and the polarizability of its molecules given by

$$\frac{\epsilon_r - 1}{\epsilon_r + 2} = \frac{N\alpha}{3\epsilon_0}$$

25. (b)

Without considering internal field,

$$P = N\alpha E_i = N\alpha E = \varepsilon_0(\varepsilon_R - 1)E$$

$$\Rightarrow \quad \alpha = \frac{\varepsilon_0(\varepsilon_R - 1)}{N}$$

$$= \frac{8.854\times10^{-12}\times(4-1)}{8.854\times10^{28}}$$

$$= 3 \times 10^{-40}\ \text{F-m}^2$$

26. (d)

The magnetization of ferromagnetic material depends on temperature as,

$$M = \left[\frac{\mu_0 N D_m^2}{3KT}\right]H$$

27. (b)

Given,

$$l = 0.3\ \text{m}$$

$$i = 3\ \text{A}$$

$$N = 1000$$

$$B = \frac{\pi}{3}\times10^{-8}\ \text{Wb/m}^2$$

The magnetic field intensity due to solenoid is given by,

$$H = \frac{Ni}{l} = \frac{1000\times3}{0.3} = 10000\ \text{A/m}$$

When placed in pure oxygen environment, we have

$$B = \mu_0 H + \mu_0 M = \mu_0 H(1 + \chi)$$

$$\frac{\pi}{3}\times10^{-8} = 4\pi \times 10^{-7} \times 10000(1 + \chi)$$

$$\Rightarrow \quad \chi = -1 + \left(\frac{1}{1200000}\right)$$

$$\Rightarrow \quad \chi \approx -0.999$$

28. (c)

$$M = \chi H$$

$$\Rightarrow \quad \chi = \frac{M}{H} \rightarrow \text{Magnetic susceptibility}$$

Based on magnetic susceptibility the magnetic materials are of 5 types:

- Diamagnetic materials, (χ is negative and small)
- Paramagnetic materials, (χ is positive and small)
- Ferromagnetic materials, (χ is positive and very large)
- Antiferromagnetic materials, (χ is positive and very small)
- Ferrimagnetic materials, (χ is positive and large)

29. (a)

Given,

$$\mu_e = 0.0016 \text{ m}^2/\text{V-s}$$
$$\sigma = 4 \times 10^7 \ (\Omega\text{-m})^{-1}$$
$$I_x = 25 \text{ A}$$
$$B_z = 0.6 \text{ tesla}$$
$$d = 15 \text{ mm}$$

The Hall voltage is,

$$V_H = \frac{R_H I_x B_z}{d} = \frac{\left(\frac{-\mu_e}{\sigma}\right) I_x B_z}{d}$$

[The Hall coefficient, R_H for metals (Aluminium) is negative]

$$= \frac{-0.0016 \times 25 \times 0.6}{4 \times 10^7 \times 15 \times 10^{-3}}$$

$$= -4 \times 10^{-8} \text{ V}$$

30. (a)

When material is in normal state, thermal conductivity is high. When material enters into the superconducting state, then thermal conductivity decreases suddenly.

31. (c)

Given,

$$H_c(0) = 30000 \text{ A/m}$$
$$H_c(T) = 20000 \text{ A/m}$$

We know,

$$H_c(T) = H_c(0)\left(1 - \frac{T^2}{T_c^2}\right)$$

$$\Rightarrow \quad T = T_c\sqrt{1 - \frac{H_c(T)}{H_c(0)}}$$

$$T = T_c\sqrt{1 - \frac{20000}{30000}} = T_c\sqrt{1 - \frac{2}{3}} = T_c\sqrt{\frac{1}{3}}$$

$$\therefore \quad T = \frac{T_c}{\sqrt{3}}$$

32. (a)

Given,

$$L = 2.45 \times 10^{-8}\ W\Omega/K^2$$
$$A = 10 \times 10^{-4}\ m^2$$
$$dx = 25\ mm$$
$$\rho = 70\ n\Omega\text{-m}$$
$$Q = 10\ W$$

Using Fourier's law, $Q = kA\dfrac{dT}{dx}$ (From Lorentz law, $\dfrac{k}{\sigma} = LT \Rightarrow k = \dfrac{LT}{\rho}$)

$$\Rightarrow \quad dT = \frac{Qdx}{kA} = \frac{Qdx}{\frac{LTA}{\rho}}$$

$$\Rightarrow \quad dT = \frac{10\times 25\times 10^{-3}\times 70\times 10^{-9}}{2.45\times 10^{-8}\times(27+273)\times 10\times 10^{-4}}$$

$$= \frac{1.75\times 10^{-8}}{7.35\times 10^{-9}} \simeq 2.4\ K$$

33. (d)

In Bottom-up approach, large scale production is difficult and chemical purification of nanoparticles is required. Thus, only statements 1 and 2 are correct.

34. (c)

CNTs has low thermal expansion coefficient.

35. (a)

36. (d)

For ferromagnetic, and ferrimagnetic materials, the atomic thermal motions counteract the coupling forces between the adjacent atomic dipole moments, causing some dipole misalignment, regardless of whether an external field is present. This results in a decrease in the saturation magnetization for both ferro and ferrimagnets. The saturation magnetization is maximum at 0 K, at which temperature the thermal vibrations are at a minimum. With increasing temperature, the saturation magnetization decreases gradually and then abruptly drops to zero at what is called the Curie temperature T_c. Thus, Statement (I) is false but Statement (II) is true.

37. (a)

The penetration depth of the implanted particles is mainly determined by the ion energy. Ion implantation energies range from several hundred to several million electron volts, resulting in ion distributions with average depths from < 10 nm to 10 μm.

38. (b)

In monolithic IC's, complete circuit is fabricated on a single substrate. Therefore, R, L, C with large values can't be fabricated because it require large area of substrate.

Section B : Electromagnetics + Computer Organization and Architecture

39. (c)

Given, magnetic field is, $\vec{H} = 25\sin(2\times10^8 t + 6x)\hat{a}_y$ mA/m

$\in = ?$

Comparing the given expression with the standard expression

$$\vec{H} = H_0 \sin(\omega t + \beta x)\hat{a}_y,$$

We get,

$$\omega = 2 \times 10^8 \text{ rad/sec}$$
$$\beta = 6 \text{ rad/m}$$
$$V_p = \frac{\omega}{\beta} = \frac{2\times10^8}{6} = \frac{1}{3}\times10^8 \text{ m/s}$$
$$V_p = \frac{c}{\sqrt{\in_r}} = \frac{3\times10^8}{\sqrt{\in_r}} = \frac{1}{3}\times10^8$$
$$\sqrt{\in_r} = 9$$
$$\in_r = 81$$

40. (a)

- The poynting vector $(\vec{S} = \vec{E}\times\vec{H})$ represents the rate at which electromagnetic energy flows per unit area. It gives the direction and magnitude of energy transfer per unit area of an electromagnetic field.
- The divergence of the poynting vector is linked to the rate of energy transfer and dissipation. This is explained by the poynting theorem:

$$\vec{\nabla}\cdot\vec{S} + \frac{\partial u}{\partial t} = -\vec{J}.\vec{E} \quad \text{where} \quad u = \frac{1}{2}\left[\vec{E}.\vec{D} + \vec{B}.\vec{H}\right]$$

- The poynting theorem describes the conservation of energy in an electromagnetic system, stating that the energy lost in the field is equal to the energy dissipated as heat or transferred to other forms.
- The poynting vector is given by

$$\vec{S} = \vec{E}\times\vec{H}$$

which is the cross product of the electric field (E) and the magnetic field (H). It is perpendicular to both E and H and hence, lies in the direction of wave propagation.

41. (c)

From Faraday's law,

$$\vec{\nabla}\times\vec{E} = \frac{-\partial\vec{B}}{\partial t}$$

The tangential component of the electric field (E_t) must be continuous at the boundary

$$E_{1t} = E_{2t}$$

- From Ampere's law with current density $\left(\vec{\nabla}\times\vec{H}=\vec{J}+\frac{\partial\vec{D}}{\partial t}\right)$, the tangential component of the magnetic field (H_t) is discontinuous if surface current density (J_s) exists.

$$H_{1t} - H_{2t} = J_s$$

- From Gauss's law for electric fields $(\vec{\nabla}\cdot\vec{D}=\rho)$, the normal component of the electric flux density (D_n) is discontinuous if surface charge density (σ_s) exists.

$$D_{1n} - D_{2n} = \sigma_s$$

- From Gauss's law for magnetic fields $(\vec{\nabla}\cdot\vec{B}=0)$, the normal component of the magnetic flux density (B_n) is always continuous.

$$B_{1n} = B_{2n}$$

42. (b)

- A full 360° revolution on the Smith chart corresponds to moving a distance of $\frac{\lambda}{2}$ (half the wavelength) along the transmission line. This property is used to analyze impedance transformations.
- Clockwise movement on the Smith chart corresponds to moving towards the generator (decreasing distance from the load to the source). Conversely, counterclockwise movement represents moving towards the load.
- The Smith chart has multiple scales, such as Wavelengths Toward Generator, Wavelengths Toward Load, and reflection coefficient but depending on the problem, only one scale might be sufficient for practical use.
- The smith chart can indeed be used as an admittance chart by flipping it 180° (or rotating it). The transformation allows direct analysis of admittance instead of impedance.

43. (d)

$$Z_{in} = -jZ_0 \cot \beta l$$

We have,

$$Z_0 = 250\ \Omega,\ \lambda = \frac{c}{f} = \frac{3\times10^8}{400\times10^6} = 0.75\text{ cm}$$

$$\beta l = \frac{2\pi}{\lambda}\times l = \frac{2\pi\times0.1}{0.75} = 48°$$

$$Z_{in} = -j(250)\cot 48°$$

$$= -j225.1\ \Omega$$

$$\cong -j225\ \Omega$$

44. (b)

The radiation resistance of electrically short dipole ($l << \lambda$) is given by

$$R_{rad} = 80\pi^2\left(\frac{dl}{\lambda}\right)^2$$

$$= 80\pi^2\left(\frac{0.02\lambda}{\lambda}\right)^2 = 80\pi^2(0.02)^2$$

$$= 80\pi^2 \times \frac{4}{10^4}$$

Power radiated, $P_{rad} = \frac{1}{2}|I_0|^2 R_{rad}$

$$= \frac{1}{2} \times 9 \times 80\pi^2 \frac{4}{10^4}$$

$$= 144\,\pi^2 \text{ m W}$$

45. (c)

- The radiation pattern of an antenna is a graphical representation of the power radiated (or received) by the antenna as a function of spatial direction. It shows how the radiated power varies with angle.
- An isotropic antenna is an idealized antenna that radiates uniformly in all directions. Its radiation pattern is a perfect sphere, with equal power in every direction.
- A dipole antenna radiates maximum power perpendicular to its axis and has nulls along the direction of the dipole axis. This is a key characteristic of dipole antennas.
- In the far field, the radiation pattern of an antenna is determined by the current distribution along the antenna. The phase and amplitude of the current determine the resulting electromagnetic fields. The far field is proportional to the Fourier transform of the current.

46. (a)

- TE modes: The electric field is perpendicular to the direction of propagation i.e. no electric field in the direction of propagation.
- TM modes: The magnetic field is perpendicular to the direction of propagation i.e. no magnetic field in the direction of propagation.
- TE_{10} is the fundamental mode in a rectangular waveguide with $a > b$ because it has the lowest cutoff frequency.
- For a TEM wave to exist, there must be at least two conductors in the transmission system. Since there is only one conductor present in a hollow rectangular waveguide, it does not support the transverse electromagnetic (TEM) mode of propagation.

47. (c)

Given, $f = 1.12 f_{c10} = 1.12 \times \frac{c}{2a}$

$$a = 1.12 \times \frac{c}{2f} = \frac{1.12 \times 3 \times 10^8}{2 \times 4 \times 10^9} = 4.2 \text{ cm}$$

The next higher-order mode is TE_{01} having cut-off frequency, $f_{c01} = \frac{c}{2b}$. We have,

$$f = 0.85 f_{c01} = 0.85 \times \frac{c}{2b}$$

$$b = \frac{0.85c}{f} = \frac{0.85 \times 3 \times 10^8}{2 \times 4 \times 10^9} = 3.187 \text{ cm}$$

48. (b)

A superscalar processor is designed to execute multiple instructions per clock cycle by using multiple pipelines. This enables parallel instruction execution, significantly improving performance.

Key points about superscalar processors:

- They have multiple functional units or pipelines.
- Capable of fetching, decoding and executing multiple instructions concurrently.
- Instructions can be issued out of order, but their completion ensures correct program behaviour.

49. (b)

Given, 16-bit instruction and 64 registers . Hence, $\log_2 64 = 6$ bits are required to represent register in an instruction.

I-type instruction format:

16-bit

Opcode	Register	AM
6-bit	6-bit	4-bit

R-type instruction format:

16-bit

Opcode	Register	Register
4-bit	6-bit	6-bit

Assume there is X number of R type instructions. Since R Type contains 4-bit opcode, $2^4 - x$ opcode remains after all opcode assignment of R type instructions. So, maximum $[2^4 - x] \times 2^2$ instructions possible for I type i.e.

$$8 = (16 - x) \times 2^2$$
$$8 = 64 - 4x$$
$$4x = 64 - 8 = 56$$
$$x = \frac{56}{4} = 14$$

50. (c)

Given,

40 distinct instructions $\Rightarrow$ $\lceil \log_2 40 \rceil = 6$ bits for opcode

24 registers $\Rightarrow$ $\lceil \log_2 24 \rceil = 5$ bits for register operand

The 32-bit instruction format is given as below,

32-bit

opcode	Register	Register	Immediate
6-bit	5-bit	5-bit	16-bit

The number of bits for immediate operand field is (32 – 6 – 5 – 5) = 16 bits.

51. (d)

Number of stages, $k = 5$

Pipeline cycle time, t_p = max (stage delay + Buffer delay)

= max(160 + 5)

= 165 ns

Number of instructions, n = 100 (finite)

$\therefore$ Execution time = $(k + n - 1)t_p$

= (5 + 100 – 1) × 165 ns = 17160 ns

52. (a)

The size of the physical address space is 4 GB = 2^{32} B, hence the physical address is of 32 bits.

TAG	SET	WORD
20-bit	7-bit	5-bit

← 32-bit →

Word offset = 5 bits [$\because$ Word length = 32 = 2^5 bits]

$$\because \quad \text{\# blocks} = \frac{16\text{ kB}}{8\text{ words}} = \frac{16 \times 2^{10} \times 8\text{ bits}}{8 \times 32\text{ bits}} = 512\text{ blocks}$$

$$\text{\#sets} = \frac{512}{4} = 128 \Rightarrow \text{SET offset} = \log_2 128 = 7\text{ bits}$$

$\therefore$ #TAG bits = 32 – (7 + 5)

= 20 bits

53. (a)

Using pre-emptive SRTF algorithm, the process with the smallest amount of time remaining until completion is selected to execute. Thus, the Gantt chart will be,

P_1	P_2	P_4	P_1	P_3

0 3 6 8 12 17

Process	AT	BT	CT	TAT	WT
P_1	0	7	12	12	5
P_2	3	3	6	3	0
P_3	5	5	17	12	7
P_4	6	2	8	2	0

$$\text{Average waiting time} = \frac{5+0+7+0}{4} = \frac{12}{4} = 3\text{ ms}$$

54. (c)

Optimal page replacement policy: In Optimal page replacement a page which will be farthest accessed in future will be replaced first.

✓	✓	✓	✓	×	×	✓	✓	×	×	✓
		3	4	4	4	4	4	4	4	4
	2	2	2	2	2	2	2	2	2	2
1	1	1	1	1	1	5	3	3	3	6
1	2	3	4	2	1	5	3	2	4	6

∴ 7 page faults.

55. (a)

$\{V \to W, VW \to X, Y \to V, Y \to X, Y \to Z\}$

$\{V \to W, V \to X, Y \to V, Y \to X, Y \to Z\}$

$Y \to X$ is redundant FD from above set as it can be implied as $Y \to V$ and $V \to X$.

Hence, $\{V \to W, V \to X, Y \to V, Y \to Z\}$ is minimal set of functional dependencies equivalent to R.

56. (d)

The ACID properties of database transactions are given as below:

- **Atomicity (A):** If any part of the transaction fails and the entire transaction fails, the entire transaction is rolled back to ensure no partial changes occur.
- **Durability (D):** After a transaction is committed, its changes are saved permanently, even in the event of a system failure.
- **Isolation (I):** Isolation ensures that the execution of one transaction does not interfere with others, but it does not mean transactions must run sequentially. Transactions can run concurrently, but isolation ensures they behave as if executed one after the other.
- **Consistency (C):** Consistency ensures that a transaction transforms the database from one valid state to another while maintaining database integrity constraints.

57. (a)

- In pre-emptive scheduling, the CPU can be taken away from a running process before it completes, allowing the OS to switch to a different process (e.g., a higher-priority one or a time-sliced process in round-robin scheduling)
- Pre-emptive scheduling improves CPU utilization by allowing high-priority processes to interrupt lower-priority ones.

Section C : Advanced Comm.-2 + Electronic Measurements & Instrumentation-2

58. (b)

Given data, Eccentricity $(e) = 0.15$

Semi-major axis $(a) = 9000$ km

Earth's mean radius $(R_E) = 6371$ km

Gravitational constant of earth $(\mu) = 3.986 \times 10^5\ \text{km}^3/\text{s}^2$

The perigee distance r_p is given by:

$$r_p = a(1 - e)$$

$$r_p = 9000 \times (1 - 0.15) = 9000 \times 0.85 = 7650 \text{ km}$$

Perigee height h_p is: $h_p = r_p - R_E = 7650 - 6371 = 1279$ km

59. (c)

$$\left[\frac{C}{N}\right]_D = [\text{EIRP}] + \left[\frac{G}{T}\right]_D - [\text{Losses}]_D - [B] - [K]$$

$$[\text{EIRP}]_D = \left[\frac{C}{N}\right]_D - \left[\frac{G}{T}\right]_D + [\text{Losses}]_D + [B] + [K]$$

$$[B] = 10\log_{10}[25 \times 10^6]$$

$$= 10[6 + 2\log_{10} 5] = 60 + 20 \times 0.7$$

$$= 60 + 14 = 74 \text{ dB-Hz}$$

$$[K] = -228.6 \text{ dBW/K-Hz}$$

$\therefore$
$$[\text{EIRP}]_D = 20 - 30 + 250 + 74 - 228.6$$

$$= 85.4 \text{ dBW}$$

60. (d)

$$D = R\sqrt{3N}$$

$$= 5\sqrt{3 \times 7} = 5 \times \sqrt{21} = 5 \times 4.58$$

$$\cong 23 \text{ km}$$

61. (d)

- Soft handoff allows the mobile station to be connected to multiple base stations simultaneously reducing call drops.
- It provides smoother transitions between cells, making handoff faster.
- However, interference levels may increase due to simultaneous connections.

62. (a)

Given data,

$$f = 12 \text{ GHz}$$

$$[\text{FSL}] = 206 \text{ dB}$$

$$[\text{AA}] = 2 \text{ dB}$$

$$\left[\frac{G_r}{T_s}\right] = 19.5 \text{ dB/K}$$

$$[\text{RFL}] = 1 \text{ dB}$$

$$[\text{EIRP}] = 48 \text{ dBW}$$

$$[\text{APL}] = 1 \text{ dB}$$

Transmission path loss $[\text{TPL}] = [\text{FSL}] + [\text{AA}] + [\text{APL}]$

$$[\text{TPL}] = 206 + 2 + 1$$

$$[\text{TPL}] = 209 \text{ dB}$$

We have,

$$[C/N_0] = [\text{EIRP}] - [\text{TPL}] - [\text{RFL}] + \left[\frac{G_r}{T_s}\right] + 228.6$$

$$= 48 - 209 - 1 + 19.5 + 228.6$$

$$[C/N_0] = 86.1 \text{ dB}$$

63. (b)

The radius of first Fresnel zone (n = 1) is,

$$F_1 = \sqrt{\frac{n\lambda D_1 D_2}{D_1 + D_2}}$$

Here, $$\lambda = \frac{c}{f} = \frac{3\times10^8}{6\times10^9} = 0.05 \text{ m}$$

$$D_1 = D_2 = 25 \text{ km (assuming midpoint)}$$

$$F_1 = \sqrt{\frac{1\times0.05\times25\times25\times10^6}{50\times10^3}} = 25 \text{ m}$$

64. (a)

- Ionospheric effects impact satellite links (especially below 3 GHz)
- Propagation delay in terrestrial system is lower than in satellite links.
- Frequency reuse planning is essential in both but more critical in terrestrial networks as multiple links are operating within close proximity.
- Satellite links do suffer from rain attenuation, particularly at higher frequencies (Ku, Ka and V bands).

65. (c)

- Cell breathing is a load balancing technique where the coverage area of base stationschanges dynamically based on the number of users connected. When a cell becomes overloaded, it shrinks, and neighboring cells expand to accommodate users from the overloaded cell, effectively distributing the load. Thus, it can lead to call drops at the cell edges if users suddenly move out of coverage.
- Frequency division multiple access (FDMA) allocates a unique frequency band or channel to each user. Thus, for an FDMA system, the capacity of a cell is equal to the number of channels allocated to it.
- If a cell has L potential subscribers and is able to handle N simultaneous users, then
  1. If $L < N$, the system is referred to as non-blocking and all calls can be handled all the time.
  2. If $L > N$, the system is blocking, a subscriber may attempt a call and find the capacity of the cell full and therefore, be blocked.

66. (d)

For strain gauge,

$$\Delta R = GF \times \frac{\Delta L}{L} \cdot R$$

where, $$\text{strain, } \in = \frac{\Delta L}{L} = 10^{-6}$$

$\therefore$ $$0.0004 = GF \times 10^{-6} \times 100$$

$$4 \times 10^{-4} = GF \times 10^{-6} \times 100$$

$$GF = \frac{4\times10^{-4}}{10^{-6}\times100} = \frac{4\times10^{-4}}{10^{-4}} = 4$$

67. (c)

For a strain gauge,

$$\text{Resistance, } R = \frac{\rho L}{A}$$

$$\Delta R = \frac{\rho}{A}\Delta L$$

$$\therefore \quad \Delta R \propto \Delta L$$

As the area of strain gauge is very small,

$$\therefore \quad \frac{\Delta R}{R} \propto \frac{\Delta L}{L}$$

$$\therefore \quad \frac{\Delta R}{R} = \text{constant}(k) \times \frac{\Delta L}{L}$$

For the high strain applied to the gauge, change in resistance remains constant.

$\therefore$ Option (c) satisfies.

68. (a)

The sensitivity of the capacitive transducer is very high i.e. a small displacement between the plates results in a measurable change in capacitance. Thus, capacitive transducers require small force for operation. Hence, statement 3 is not correct.

69. (d)

We know that, for piezoelectric crystal, charge developed is

$$Q = d \times F$$

where d: crystal charge sensitivity

F: Force applied

$$\therefore \quad F = \frac{\text{Area} \times Y}{t} \times \Delta t$$

We have, $$\text{Young's Modulus } (Y) = \frac{\text{Stress}}{\text{Strain}} = \frac{\text{Force/Area}}{\Delta t / t}$$

where, $$\text{Area} = 1.25 \text{ m} \times 1.25 \text{ m}$$

$$t = 1.25 \text{ m (given in figure)}$$

$$F = \frac{1.25 \times 1.25 \times 1 \times 10^5}{1.25} \times 0.5$$

$$F = 0.625 \times 10^5 \text{ N}$$

$$\therefore \quad Q = 2 \times 10^{-12} \times 0.625 \times 10^5 \text{ C}$$

$$Q = 1.25 \times 10^{-7} \text{ C}$$

$$\Rightarrow \quad Q = 125 \text{ nC}$$

70. (d)

Given,

$$\text{Voltage difference} = 160 \text{ mV} - 15 \text{ mV} = 145 \text{ mV}$$

$$\text{pH difference} = 7 - 4 = 3$$

$\therefore$

$$\text{Sensitivity of pH transducer} = \frac{\text{Voltage difference}}{\text{pH difference}} = \frac{145 \text{ mV}}{3} = 48.33 \text{ mV/pH}$$

71. (d)

In a LVDT,

$$V_{out} = \frac{\text{Core displacement} \times V_{max}}{\text{Length}}$$

The stoke length indicates the maximum linear displacement the core can have from its null position, which results in the maximum output voltage. Thus,

$$V_{max} = \pm 40 \frac{\text{mV}}{\text{mm}} \times 150 \text{ mm} = \pm 6 \, V$$

For a core displacement of 120 mm,

$$V_{out} = \frac{120 \text{ mm} \times 6}{150} = 4.8 \text{ V}$$

72. (a)

The successive approximation technique is most widely used in a single channel data acquisition system. This is due to the fact that it offers a good combination of resolution and high speed. It has higher speed than integrating and counter-type ADCs, and higher resolution than flash ADCs.

73. (b)

Given,

$$l_1 = 55 \text{ cm}; \; l_2 = 85 \text{ cm}$$

For potentiometer,

$$\frac{E}{C_0} = \frac{l_2}{l_1}$$

$\therefore$

$$E = C_0 \times \frac{l_2}{l_1} = 1.1 \times \frac{85}{55} = 1.7 \text{ V}$$

74. (a)

Potentiometer transducers requires a large force to move their sliding contacts i.e. wiper. There is wear and tear due to movement of the wiper which reduces the life span of the transducer.

75. (a)

The Doppler frequency shift is given by

$$f_d = \frac{v f_c}{c}$$

Thus, the Doppler shift is directly proportional to the carrier frequency and is thus, more significant at higher frequencies in microwave communication.

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