CONTENTS

S.NO.	TOPIC	PAGE NO.
	Volume-1	
1.	**Network Theory**	**01 - 246**
	Volume-2	
1.	Basics Electronics	01 - 106
2.	Measurement	107 - 180
	Volume-3	
1.	Material Science	01 - 30
2.	EDC	31 - 60
3.	Computer Fundamental	61 - 84
4.	Communications	85 - 136
5.	Digital Electronics	137 - 186
6.	Microprocessor	187 - 228
	Volume-4	
1.	Control System	01 - 68
2.	Signals and Systems	69 - 100
3.	EMFT	101 - 136

DIELECTRIC PROPERTIES OF MATERIAL

CHAPTER 2

OBJECTIVE QUESTIONS

1. The number of atoms in volume of one cubic meter of hydrogen gas is 9.8×10^{26}. The radius of the hydrogen atom is 0.53 Å. Calculate the polarizability and relative permittivity.

(a) 1.66×10^{-35} F-m^2, 1.18

(b) 1.66×10^{-38} F-m^2 , 1.018

(c) 1.66×10^{-41} F-m^2, 1.0018

(d) 1.66×10^{-45} F-m^2, 1.00018

2. The dielectric constant of Helium, measured at 0°C and 1 atmospheric is $\epsilon_r = 1.0000684$. Under these conditions the gas contains 2.7×10^{25} atoms per m^3. Calculate the displacement x when a Helium atom is subjected to a field of 10^6 V/m.

(a) 7.5×10^{-17} m (b) 7.5×10^{-16} m

(c) 7.5×10^{-15} m (d) 7.5×10^{-14} m

3. What is the atomic polarizability of argon? Its susceptibility at 273 K and 1 atmospheric pressure is 4.35×10^{-4}, N = 2.7×10^{25} atom/m^3.

(a) 7.46×10^{-38} Farad m^2 (b) 5.13×10^{-30} Farad m^2

(c) 1.43×10^{-40} Farad m^2 (d) 1.11×10^{-42} Farad m^2

4. Which one of the following is the correct statement? The orientational polarizability in a polyatomic gas is proportional to

(a) Temperature T (b) 1/T

(c) T^2 (d) Independent of T

5. Match List-I (Polarization process) with List-II (Approximate frequency) and select the correct answer using the codes given below the lists :

	List-I		List-II
A.	Electronic polarization	**1.**	10^2 Hz
B.	Ionic polarization	**2.**	10^2 Hz
C.	Orientational polarization	**3.**	10^{13} Hz
D.	Space-charge polarization	**4.**	10^{15} Hz

Codes :	A	B	C	D
(a)	1	2	3	4
(b)	4	3	2	1
(c)	1	3	2	4
(d)	4	2	3	1

6. A long narrow rod has an atomic density 5×10^{28} atoms/m^3. Each atom has a polarizability of 10^{-40} farad m^2 each. Find the internal electric field when an axial field of 1 V/m is applied.

(a) 1.55 V/m(b) 2.23 V/m(c) 1.23 V/m(d) 3.23 V/m

7. The following data refers to a dielectric material $\epsilon_r = 4.94$, $n^2 = 2.69$, where n is the index of refraction. Calculate the ratio between electronic and ionic polarizabilities for this material.

(a) 1.736 (b) 2.736 (c) 0.736 (d) 3.736

8. On the application of the field $\bar{E}$, the modified field due to polarization P in solids and liquids having cubic symmetry is given by

(a) $\bar{E} + \frac{\bar{P}}{\epsilon_0}$ (b) $\bar{E} - \frac{\bar{P}}{\epsilon_0}$ (c) $\bar{E} + \frac{\bar{P}}{3\epsilon_0}$ (d) $\bar{E} - \frac{\bar{P}}{3\epsilon_0}$

9. Match List-I (Insulating Material) with List-II (Application) and select the correct answer using the codes given below:

	List-I		List-II
A.	Steatite	**1.**	Ceramic capacitor
B.	Rutile (Titaniumdioxide)	**2.**	Piezoelectric application
C.	Barium titanate	**3.**	Insulating materials for machine windings
D.	Teflon	**4.**	High frequency insulator

Codes :	A	B	C	D
(a)	4	3	2	1
(b)	2	1	4	3
(c)	4	1	2	3
(d)	2	3	4	1

10. The following properties are associated with ferroelectric materials :

1. Its susceptibility is negative.

2. The susceptibility is expressed as

$$\chi = \frac{C}{T - T_c}$$

where C = Curie constant and T_c = Curie temperature.

3. It has permanent dipoles oriented randomly.

Which of the above statements is/are correct?

(a) 1 only (b) 1 and 3 (c) 2 only (d) 1, 2 and 3

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11. A dielectric material has the real part of the dielectric constant (ϵ_r') as 4 and its loss tangent is 0.004. What is the complex dielectric constant (ϵ_r^*) represented by?

(a) 4 + j0.016 (b) 4 – j0.016

(c) 4 + j0.001 (d) 4 – j0.001

12. A solid specimen of dielectric has relative permittivity ϵ_r = 4.2 and loss angle tan δ = 0.001 at 50 Hz frequency. If it is subjected to an electrical stress of 50 kV/cm, what is the heat generated in the specimen due to dielectric loss?

(a) 291 W/cm^3 (b) 5.82 mW/cm^3

(c) 19.5 W/cm^3 (d) 0.291 mW/cm^3

13. A solid specimen of dielectric has a dielectric constant of 4.8, and tan δ = 0.001 at a frequency of 50 Hz. If it is subjected to an alternating field of 60 kV/cm. Calculate the heat generated in the specimen due to dielectric loss.

(a) 1.480 mW/cm^3 (b) 2.480 mW/cm^3

(c) 3.480 mW/cm^3 (d) 0.480 mW/cm^3

14. For an applied voltage V(t) = V_0 cos ωt, the current through the lossy condenser is given by

(a) $(\varepsilon_0\varepsilon_r'' \omega V_0)$ cos ωt + $(\varepsilon_0\varepsilon_r' V_0\omega)$ sin ωt

(b) $(\varepsilon_0\varepsilon_r'' \omega V_0)$ cos ωt – $(\varepsilon_0\varepsilon_r' V_0\omega)$ sin ωt

(c) $(\varepsilon_0\varepsilon_r'' \omega V_0)$ sin ωt – $(\varepsilon_0\varepsilon_r' V_0\omega)$ cos ωt

(d) $(\varepsilon_0\varepsilon_r'' \omega V_0)$ sin ωt + $(\varepsilon_0\varepsilon_r' V_0\omega)$ cos ωt

15. A solid contains 5×10^{26} identical atoms per m^3, each with a polarisability of 2×10^{-40} Fm^2. Calculate the ratio of internal field to applied field (Assume Lorentz Law).

(a) 2.003 (b) 0.003 (c) 1.003 (d) 3.003

16. A parallel plate condenser has an area of 10 cm^2 and a separation of 0.1 mm. Polyethylene is used as dielectric. An AC voltage of frequency 1 MHz and amplitude = 2 volts, is applied to the condenser. Real part of ε'_r = 2.25 and loss tangent tan $\delta = 4 \times 10^{-4}$. Calculate the energy dissipated per second and find the elements of equivalent parallel RC such that R = X_C.

(a) 10^{-7} J/s, 10 MΩ (b) 10^{-7} J/s, 20 MΩ

(c) 10^{-6} J/s, 20 MΩ (d) 10^{-6} J/s, 10 MΩ

Linked Questions 17 & 18

An electrolytic condenser consisting of an oxidised aluminium sheet with an effective surface area of 400 cm^2, has a capacitance = 8 mF.

17. What is the field strength if ε_r = 8 and potential difference = 10V between A_1 and the electrolyte?

(a) 2.8×10^7 V/m (b) 2.8×10^6 V/m

(c) 2.8×10^8 V/m (d) 2.8×10^5 V/m

18. Calculate the total dipole moment P induced in the oxide layer and its susceptibility χ.

(a) 1.5×10^{-11}, 0.1×10^{-7}

(b) 2.5×10^{-11}, 0.1×10^{-8}

(c) 3.5×10^{-11}, 0.1×10^{-9}

(d) 2.5×10^{-11}, 0.1×10^{-6}

19. A material (ε_r = 6) having power factor of 0.05, is 1.2 cm thick and 75 sq cm area. At 30 MHz it requires 1200 watts for heating. Determine the voltage and current while heating. If the voltage is to be limited to 1500 volts, determine the possible frequency.

(a) 50 MHz (b) 60 MHz (c) 70 MHz (d) 40 MHz

20. A quartz piezoelectric crystal of thickness t = 2 mm and of voltage sensitivity g = 0.055 Vm/N is subjected to a pressure = 1.5 MN/m^2. Calculate the voltage output. Also find its charge sensitivity, if its permittivity $\varepsilon = 40.6 \times 10^{-12}$ F/m.

(a) 155 V, 2.23 pC/N (b) 166 V, 1.23 pC/N

(c) 175 V, 2.23 pC/N (d) 165 V, 2.23 pC/N

Linked Questions for 21-23

A $BaTiO_3$ pick-up has dimensions $5 \times 5 \times 1.25$ mm^3. The force acting on it = 5N. The charge sensitivity = 150 pC/N and its permittivity = 12.5×10^{-9} F/m, also Y(Young's modulus) = 12×10^6 N/m^2.

21. The strain is

(a) 0.0167 (b) 0.167 (c) 0.3167 (d) 0.2167

22. The voltage generated is

(a) 1V (b) 2V (c) 3V (d) 4V

23. The value of capacitance is

(a) 200 pF (b) 250 pF (c) 300 pF (d) 360 pF

24. A Piezoelectric crystal with dimensions 5 mm × 5 mm × 1.5 mm and voltage sensitivity = 0.055 Vm/N is used for force-measurement F. Calculate F, if 100 volts is developed.

(a) 10N (b) 20N (c) 30N (d) 40N

25. A quartz crystal has a charge sensitivity of 2 pC/N, ε_r = 4.5, diameter of 10 mm and thickness, 2 mm. Find the output voltage due to an applied force of 100N. (Young's modulus = 9×10^{10} N/m^2).

(a) 137.8V (b) 147.8V (c) 157.8V (d) 127.8V

26. Read the following statements with respect to the Relative permittivity or dielectric constant

1. It is the ratio of permittivity of vacuum to the permittivity of dielectric fluid

2. Its value is greater than unity

3. It is one of the material property

4. Lower the dielectric constant then higher the storing capacity

Of the above the correct statements are:

(a) 1, 2, 3 & 4 (b) 1, 2

(c) 2, 3 (d) 3, 4

27. A solid specimen of dielectric has relative permittivity ϵ_r = 4.2 and loss angle tan δ = 0.001 at 50 Hz frequency. If it is subjected to an electrical stress of 50 kV/cm, what is the heat generated in the specimen due to dielectric loss?

(a) 291 W/cm^3 (b) 5.82 mW/cm^3

(c) 19.5 W/cm^3 (d) 0.291 mW/cm^3

28. ***Statement (I):*** Quartz crystals can be used both for the generation of ultrasonic waves as well as for their detection.

Statement (II): When ultrasonic waves fall on a quartz crystal, the crystal undergoes mechanical vibrations and hence ultrasonic waves can be detected.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)

(c) Statement (I) is true but Statement (II) is false

(d) Statement (I) is false but Statement (II) is true

29. ***Assertion (A):*** Electronic polarization is independent of temperature.

Reason (R): It is found in materials having no interaction among the molecules.

(a) Both A and B are true and R is the correct explanation of A.

(b) Both A and B are true but R is not a correct explanation of A.

(c) A is true but R is false

(d) A is false but R is true

30. What does quality factor of a dielectric mean?

(a) It is related to the value of permittivity of the material

(b) It is related to breakdown voltage of the dielectric

(c) It is related to the resistivity of the material

(d) It is related to the ratio between maximum stored energy and average power dissipated in the dielectric

31. Consider the following statements regarding all insulating material connected to an A.C. signal:

1. The dielectric constant decreases with frequency

2. The dielectric constant increases with frequency

3. Atomic polarization decreases with frequency

Which of these statements is/are correct ?

(a) 3 alone (b) 1 alone (c) 1 and 3 (d) 2 and 3

32. Read the following statements with respect to the Ferro electricity

1. It develops large amount of spontaneous polarization even without any external electric field

2. $BaTiO_3$ gives a large amount of spontaneous polarization

3. Ferroelectric materials have certain percentage of Iron

4. Ferroelectric materials will not develop any hysteresis behavior

Of the above the correct statements are:

(a) 1, 2 & 3 (b) 1, 2 (c) 2, 3 (d) 3, 4

33. A dielectric material has the real part of the dielectric constant $(\in_r')$ as 4 and its loss tangent is 0.004. What is the complex dielectric constant $(\in_r^*)$ represented by?

(a) 4 + j0.016 (b) 4 – j0.016

(c) 4 + j0.001 (d) 4 – j0.001

34. Which one of the following is the correct statement? The orientation polarizability in a polyatomic gas is proportional to

(a) Temperature T (b) 1/T

(c) T^2 (d) independent of T

35. Match List-I (Polarization process) with List-II (Approximate frequency) and select the correct answer using the codes given below the lists:

	List-I		**List-II**
A.	Electronic polarization	**1.**	10^3 Hz
B.	Ionic polarization	**2.**	10^2 Hz
C.	Orientation polarization	**3.**	10^{13} Hz
D.	Space-charge polarization	**4.**	10^{15} Hz

Codes :	**A**	**B**	**C**	**D**
(a)	1	2	3	4
(b)	4	3	2	1
(c)	1	3	2	4
(d)	4	2	3	1

36. Consider the following statements related to ferroelectric materials above the curie temperature

1. It is in the paramagnetic state

2. Its electric susceptibility is inversely proportional to its temperature

3. Magnitude of electric susceptibility goes down by a factor of few hundreds in comparison to the value below the curie temperature

Which of the statements given above are correct?

(a) 1, 2 & 3 (b) 1 & 2 (c) 2 & 3 (d) 1 & 3

37. Which one of these has lowest dielectric strength

(a) dry air (b) wet air (c) cotton (d) paper

38. What is the atomic polarizability of argon? Its susceptibility at 273 K and 1 atmospheric pressure is 4.35×10^{-4}, N = 2.7×10^{25} atom/m^3

(a) 1.45×10^{-40} (b) 1.45×10^{-30}

(c) 1.43×10^{-20} (d) None

39. When does $BaTiO_3$ loose its ferro electric properties?

(a) Above 0°K

(b) Above its curie point

(c) Above room temperature

(d) Above its melting point

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40. What are the materials which exhibit electric polarization even in the absence of an applied electric field?

(a) Ferromagnetic

(b) Paramagnetic

(c) Ferroelectric

(d) Anti-ferroelectric

41. Consider the following statements with respect to a quartz crystal:

1. Quartz displays ferroelectric behaviour.

2. Quartz is used in electric oscillator circuits.

3. Quartz crystal is formed by repeating silicate tetrahedrons.

Which of the statements given above are correct?

(a) 1, 2 and 3 (b) Only 1 and 2

(c) Only 2 and 3 (d) Only 1 and 3

42. The correct relation is

(a) $P = \varepsilon_0(\varepsilon_r - 1)E$ (b) $P = \left(\frac{\varepsilon_0}{\varepsilon_r - 1}\right).E$

(c) $P = \left(\frac{\varepsilon_0}{\varepsilon_r + 1}\right).E$ (d) $P = \varepsilon_0(\varepsilon_r + 1)\ E$

43. Which one of the following material is not a piezo-electric material?

(a) $BaTiO_3$ (b) Quartz

(c) Rochelle salt (d) Yttrium garnet

44. If ε_r' and ε_r'' are the real and imaginary part of complex dielectric constant ε_r , and δ is loss angle, then

(a) $\tan\delta = \frac{\varepsilon_r'}{\varepsilon_r''}$ (b) $\tan\delta = \frac{\varepsilon_r''}{\varepsilon_r'}$

(c) $\tan\delta = \varepsilon_r', \varepsilon_r''$ (d) $\tan\delta = 1 - \varepsilon_r'$

45. The polarization P in a solid dielectric is related to the electric field E and the electric flux density D by the relation

(a) $E = \varepsilon_0 D + P$ (b) $D = E + \varepsilon_0 P$

(c) $D = \varepsilon_0 E + P$ (d) $D = \varepsilon_0(E + P)$

46. Consider the following statement, the dielectric constant of an insulator depends on

1. Applied voltage

2. Frequency of AC field

3. Temperature

4. Maximum current density in insulator.

Which of these statement are correct

(a) 1 and 2 (b) 2 and 3

(c) 3 and 4 (d) 1, 2, 3 and 4

47. The effective quality factor of the equivalent electrical circuit of the quartz crystal is of the order of

(a) 20 (b) 200 (c) 2,00,000 (d) 2000

48. Which capacitor store higher amount of energy?

(a) Air capacitor (b) Paper capacitor

(c) Mica Capacitor (d) Plastic film Capacitor

49. ***Assertion (A) :*** Ferroelectric Materials have spontaneous polarization.

Reason (R) : Above Curie temperature, $\varepsilon = \frac{C}{(T-\theta)}$ for ferro electric materials.

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true, but R is not the correct explanation of A

(c) A is true, but R is false

(d) R is true, but A is false

50. The apparent capacitance at a high angular frequency ω of an air cored capacitor having capacitance C and inductance L is given by

(a) $C_{app} = \frac{C}{1+\omega^2 LC}$ (b) $C_{app} = \frac{C}{1-\omega^2 LC}$

(c) $C_{app} = \frac{L}{1-\omega^2 LC}$ (d) $C_{app} = \frac{L}{1+\omega^2 LC}$

51. Which of the following is the example for piezo-electric materials.

(a) Lead zirconate (b) Copper

(c) Potassium niobate (d) None of these

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