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Director's Message

B. Singh (Ex. IES)

Engineering is one of the most chosen graduating field. Taking engineering is usually a matter of interest but this eventually develops into "purpose of being an engineer" when you choose engineering services as a carrier option.

Train goes in tunnel we don't panic but sit still and trust the engineer, even we don't doubt on signalling system, we don't think twice crossing over a bridge reducing our travel time; every engineer has a purpose in his department which when coupled with his unique talent provides service to mankind.

I believe *"the educator must realize in the potential power of his pupil and he must employ all his art, in seeking to bring his pupil to experience this power".* To support dreams of every engineer and to make efficient use of capabilities of aspirant, MADE EASY team has put sincere efforts in compiling all the previous years' ESE-Pre questions with accurate and detailed explanation. The objective of this book is to facilitate every aspirant in ESE preparation and so, questions are segregated chapterwise and topicwise to enable the student to do topicwise preparation and strengthen the concept as and when they are read.

I would like to acknowledge efforts of entire MADE EASY team who worked hard to solve previous years' papers with accuracy and I hope this book will stand up to the expectations of aspirants and my desire to serve student fraternity by providing best study material and quality guidance will get accomplished.

B. Singh (Ex. IES)
CMD, MADE EASY Group

Volume-I

ELECTRICAL ENGINEERING

Objective Solved Questions

of UPSC Engineering Services Examination

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■■■■

UNIT

I

Electrical Materials

Syllabus

Electrical engineering materials, crystal structures and defects, ceramic materials, insulating materials, magnetic materials-basics, properties and applications, ferrities, ferro-magentic materials and components, basics of solid state physics, conductors, photo-conductivity, basics of nano materials and superconductors.

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1 Introduction to Engineering Materials

1.1 Total number of electrons that can be accommodated in various electron states in a valence band of a given solid is equal to
(a) atomic number of the solid
(b) half the number of atoms in the solid
(c) the number of atoms in the solid
(d) twice the number of atoms in the solid

[ESE-2001]

1.2 What is the packing fraction of a BCC (body-centered cubic) unit cell?

(a) $\frac{\sqrt{3}\pi}{16}$ (b) $\frac{\sqrt{3}\pi}{8}$

(c) $\frac{\sqrt{3}\pi}{12}$ (d) $\frac{\sqrt{2}\pi}{8}$

[ESE-2006]

1.3 Elements can reach a stable atomic structure by
(a) losing electrons only
(b) gaining electrons only
(c) losing or gaining or sharing electrons
(d) collisions between atoms

[ESE-2006]

1.4 In a Hexagonal Close Packed (HCP) crystal structure, if 'a' and 'c' represent, respectively the short and long unit cell dimensions the (c/a) ratio should be
(a) 12.00 (b) 0.74
(c) 1.633 (d) 16.33

[ESE-2010]

1.5 Consider the following statements :
Secondary (or Molecular) bonds are
1. The attraction forces exist between atoms or molecules.
2. Stronger than primary bonds.
3. Can be divided as electrostatic bonds.
4. Weaker than primary bonds.

Which of the above statements is /are correct?
(a) 1 only (b) 2 and 3 only
(c) 1 and 4 only (d) 1, 2, 3 and 4

[ESE-2010]

1.6 **Assertion (A) :** Ionic bonds and covalent bonds are higher than metallic bonds.
Reason (R) : Ionic and covalent bonds are generally lower than other primary bonds.
(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) A is false but R is true

[ESE-2010]

1.7 The geometrical configuration of one molecule of C_{60}-buckminaterfullerene contains
(a) 12 hexagons and 20 pentagons of Carbon atoms
(b) 20 hexagons and 12 pentagons of Carbon atoms
(c) 20 hexagons and 20 pentagons of Carbon atoms
(d) 12 hexagons and 12 pentagons of Carbon atoms

[ESE-2011]

1.8 Einstein relation is referred between
(a) the diffusion constant and the mobility
(b) the conduction and diffusion currents
(c) the conduction and diffusion voltages
(d) none of the above

[ESE-2013]

1.9 Match **List-I (Parameter)** with **List-II (Unit)** and select the correct answer using the codes given below:

List-I	List-II
A. Boltzmann constant	1. farad/meter
B. Permeability of free space	2. cm^2/ volt-second
C. Permittivity of free space	3. henry/meter
D. Mobility	4. cm^2/second
	5. electron volt/kelvin

Codes:

	A	B	C	D
(a)	5	2	1	4
(b)	1	2	5	4
(c)	5	3	1	2
(d)	1	3	5	2

[ESE-2006]

1.10 Assuming the Fermi level E_f to be independent of temperature, E_f may be defined as the level with an occupancy probability of

(a) 0% (b) 50%

(c) 75% (d) 100%

[ESE-2002]

1.11 Match **List-I** with **List-II** and select the correct answer :

List-I	List-II
A. Ga-As	1. Integrated circuit
B. Nichrome	2. Laser
C. Quartz	3. Busbar
D. Si	4. Heating element
	5. Oscillator

Codes:

	A	B	C	D
(a)	2	4	5	1
(b)	1	5	3	2
(c)	2	5	3	1
(d)	1	4	5	2

[ESE-2001]

1.12 Match **List-I** with **List-II** and select the correct answer using the code given below the lists:

List-I	List-II
A. Carbon (Diamond)	1. Conducting
B. Silicon	2. Semiconducting
C. Tin (Grey)	3. Insulating
D. Lead	

Codes:

	A	B	C	D
(a)	3	2	1	1
(c)	1	2	1	3
(c)	3	1	2	1
(d)	1	1	2	3

[ESE-2012]

1.13 Behaviour of conductors, semiconductors and insulators is explained on the basis of

(a) atomic structure

(b) molecular structure

(c) energy band structure

(d) all of the above

[ESE-2013]

1.14 What type of defect causes F-centers in a crystal?

(a) Stoichiometric defect

(b) Metal excess defect due to anion vacancies

(c) Metal excess defect due to extra cations

(d) Frenkel defect

[ESE-2017]

1.15 An atom in a crystal vibrates at a frequency, determined by

1. Crystal heat current
2. Crystal temperature
3. The stiffness of the bonds with neighbour atoms

Select the correct answer using the codes given below:

(a) 1 only (b) 2 only

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

[ESE-2017]

1.16 **Statement (I):** A lattice defect gets created whenever the periodicity or order of the crystal lattice gets disturbed.

Statement (II): Point defect, line defect, surface defect and volume defect create defect in lattice.

(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.

[ESE-2017]

1.17 In Face-Centered Cubic structure (FCC), what number of atoms is present in each unit cell?

(a) 18 (b) 16

(c) 14 (d) 12

[ESE-2018]

1.18 If (n) is lattice points per unit cell of the cubic system, (N) and (M) are the Avogadro's number and atomic weight, respectively, and (ρ) is the density of the element, then the lattice constant (a) is

(a) $\left(\frac{M\rho}{nN}\right)^{1/3}$ (b) $\left(\frac{NM}{n\rho}\right)^{1/3}$

(c) $\left(\frac{nM}{N\rho}\right)^{1/3}$ (d) $\left(\frac{N\rho}{nM}\right)^{1/3}$

[ESE-2018]

1.19 **Statement (I) :** Light is capable of transferring electrons to the free-state inside a material, thus increasing the electrical conductivity of the material.

Statement (II) : The increased electrical conductivity produced by light is called photo-conductivity.

[ESE-2018]

1.20 **Statement (I) :** When a solid surface is bombarded by electrons of appreciable energy, secondary emission occurs from the surface.

Statement (II) : The major application of the secondary emission is in voltage amplification.

[ESE-2018]

1.21 Materials in which the atomic order extends uninterrupted over the entirely of the specimen; under some circumstances, they may have flat faces and regular geometric shapes, are called

(a) Anisotropy (b) Crystallography

(c) Single crystals (d) Crystal system

[ESE-2019]

1.22 The saturation flux density for Nickel having density of 8.90 g/cm^3, atomic number 58.71 and net magnetic moment per atom of 0.6 Bohr magnetons is nearly

(a) 0.82 tesla (b) 0.76 tesla

(c) 0.64 tesla (d) 0.52 tesla

[ESE-2019]

1.23 Consider the following applications:

- High temperature heat engines.
- Nuclear fusion reactors.
- Chemical processing industry.
- Aeronautical and space industry.

Which one of the materials will be used for these applications?

(a) Zironia (b) Alumina

(c) Ceramic (d) Silicon carbide

[ESE-2019]

1.24 Consider the following statements:

1. The rules for series and parallel combinations of capacitors are opposite to those for resistors.
2. The rules for series and parallel combinations of inductors are same as those for resistors.
3. An inductor is a short circuit to dc currents.

Which of the above statements are correct?

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

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

[ESE-2019]

1.25 **Statement-I:** When a non-linear resistor, in series with a linear resistor, both being non-inductive, is connected to a voltage source, the current in the circuit cannot be determined by using Ohm's law.

Statement-II: If the current-voltage characteristic of the non-linear resistor is known, the current-voltage characteristics of the series circuit can be obtained by graphical solution.

[ESE-2019]

1.26 Which of the following statements regarding an atom are correct?

1. If two atoms with similar ionization potential form a bond, then this bond will most probably be either covalent or metallic.
2. When atoms with different ionization potentials form a bond, the bond will be mainly ionic.
3. If the atom or molecule already has its outer shells completely full, then the bonding between the atoms or molecules will be a secondary bond when it solidifies.

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

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

[ESE-2020]

Answers Introduction to Engineering Materials

1.1 (a)	1.2 (b)	1.3 (c)	1.4 (c)	1.5 (c)	1.6 (c)	1.7 (b)	1.8 (a)	1.9 (c)	
1.10 (b)	1.11 (a)	1.12 (a)	1.13 (c)	1.14 (b)	1.15 (d)	1.16 (b)	1.17 (c)	1.18 (c)	
1.19 (b)	1.20 (b)	1.21 (c)	1.22 (c)	1.23 (d)	1.24 (d)	1.25 (b)	1.26 (d)	1.27 (a)	
1.28 (b)	1.29 (c)	1.30 (c)	1.31 (b)	1.32 (d)					

Explanations Introduction to Engineering Materials

1.1 (a)

Atomic number represents the total number of valence electrons present in various energy state in valence band.

1.2 (b)

Packing fraction of BCC $= \frac{\sqrt{3}\pi}{8} = 0.68$.

1.3 (c)

Elements can reach a stable state by losing or gaining or sharing of e^{-s} so as to complete its octet.

For e.g. in NaCl, Na $\rightarrow$ loses electron for completing its octet

Cl gain e^- for completing its octet

In Si csystal $\rightarrow$ one Si atom shares its outer $4e^-$ with other 4 Si atoms to complete its octet.

1.4 (c)

$$\frac{c}{a} = \sqrt{\frac{8}{3}} = 1.633$$

1.5 (c)

Secondary or molecular bonds are either ion-dipole interaction, dipole-dipole interaction or vanderwalls are weaker than primary bonds (ionic, covalent).

1.7 (b)

It contains 20-hexagons and 12-pentagons of carbon atoms.

1.8 (a)

Einstein relation: $D = \left(\frac{KT}{e}\right)\mu$

1.9 (c)

$K_B \rightarrow$ eV/°C

$\mu \rightarrow$ Henry/meter; $\in$ = Farad/meter

Mobility $\rightarrow$ cm^2/sec

1.10 (b)

Fermi-Dirac probability function $F(E)$ is given by

$$F(E) = \frac{1}{1+e^{(E-E_F)/kT}}$$

where, E_F = Fermi level

if $E = E_F$ then $F(E) = \frac{1}{2}$ for any value of temperature. Thus, the fermi level represents the energy state with 50% probability of being filled if no forbidden band exists.

1.11 (a)

Quartz $\rightarrow$ used for high frequency oscillation.

Si $\rightarrow$ used in integrated circuit because of two regions.

(i) at high temperature it reacts with oxygen and form SiO_2 which is a very good dielectric.

(ii) High power handling capacity.

GaAs $\rightarrow$ is a direct band gap material having larger carrier life time so suitable for designing of laser.

Nichrome $\rightarrow$ used as heating element.

1.12 (a)

In the given list Tin (grey) and lead are the conducting materials.

Carbon (diamond) is a insulating materials and silicon a semiconducting material hence option (a) is correct.

1.13 (c)

Based on energy band structure conductors, semiconductor and insualtor is classified.

1.14 (b)

F-centers are non-stoichiometric defect where electrons are trapped in anion vacancies and produced by the exposure of an alkali metal halide crystal to the alkali metal vapour.

2 Dielectric Properties of Materials

2.1 By inserting a slab of dielectric material between the plates of a parallel plate capacitor, the energy stored in the capacitor has increased three times. The dielectric constant of the material is
(a) 9 (b) 3
(c) 1/3 (d) 1/9 **[ESE-2001]**

2.2 When a dielectric is subjected to an alternating electric field of angular frequency 'ω', its power loss is proportional to
(a) ω (b) ω^2
(c) $1/\omega$ (d) $1/\omega^2$ **[ESE-2001]**

2.3 For a given dielectric, with increase in temperature the ionic polarizability
(a) increases (b) decreases
(c) remains same (d) fluctuates
[ESE-2001]

2.4 A piezoelectric crystal has an Young's modulus of 130 GPa. The uniaxial stress that must be applied to increase its polarization from 500 to 510 Cm^{-2} is
(a) 1.171 GPa (b) 1.182 GPa
(c) 2.6 GPa (d) 2.55 GPa
[ESE-2001]

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

(a) $\vec{E} + \frac{\vec{P}}{\epsilon_0}$ (b) $\vec{E} - \frac{\vec{P}}{\epsilon_0}$

(c) $\vec{E} + \frac{\vec{P}}{3\epsilon_0}$ (d) $\vec{E} - \frac{\vec{P}}{3\epsilon_0}$

[ESE-2002]

2.6 The complex dielectric constant of a material is given by the expression:

$$\epsilon = \epsilon' - j\epsilon''$$

If a parallel plate capacitor with area 'A' and separation 'd' is formed with this material as a dielectric, the loss factor will be
(a) $(A\epsilon')/(d\epsilon'')$ (b) ϵ''/ϵ'
(c) $\tan^{-1}[(A\epsilon')/(d\epsilon'')]$ (d) $\tan^{-1}[(d\epsilon'')/(A\epsilon')]$
[ESE-2002]

2.7 At optical frequencies, the major contribution to the total polarization comes from
(a) space charge polarization
(b) orientational polarization
(c) ionic polarization
(d) electronic polarization
[ESE-2002]

2.8 Which of the following is piezoelectric material?
(a) Quartz (b) Silica sand
(c) Corundum (d) Polystyrene
[ESE-2002]

2.9 Which one of the following is NOT true for Sulphur hexafluoride gas?
(a) It is electronegative in nature
(b) It has high dielectric strength
(c) It is non-toxic
(d) It is highly inflammable
[ESE-2003]

2.10 Which one of the following materials has the highest dielectric strength?
(a) Polystyrene (b) Marble
(c) Cotton (d) Transformer oil
[ESE-2003]

2.11 The losses in a dielectric subject to an alternating electric field are determined by
(a) Real part of the complex dielectric constant
(b) Imaginary part of the complex dielectric constant
(c) Absolute value of the complex dielectric constant

(d) Ratio of the magnitudes of the real and imaginary parts of the complex dielectric constant

[ESE-2003]

2.12 In a solid or liquid dielectric with externally applied electric field, as the interatomic distance increases the internal field E_i,
(a) Increases
(b) Decreases
(c) Remains unaltered
(d) Increases or decreases based on temperature

[ESE-2003]

2.13 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 (ϵ_r^*) represented by?
(a) $4 + j0.016$ (b) $4 - j0.016$
(c) $4 + j0.001$ (d) $4 - j0.001$

[ESE-2004]

2.14 Which one of the following statements is **not** correct?
(a) Vacuum can act as a dielectric material
(b) Piezoelectric materials can act as transducers
(c) Quartz crystal is a ferroelectric material
(d) The dielectric constant of dielectrics depends on the frequency of the applied field

[ESE-2004]

2.15 What are the materials which exhibit electric polarization even in the absence of an applied electric field called ?
(a) Ferromagnetic (b) Paramagnetic
(c) Ferroelectric (d) Anti-ferroelectric

[ESE-2005]

2.16 The relative dielectric constant of solid dielectrics in the alternating field is
(a) maximum at the power frequencies and decreases to unity at frequencies in the ultraviolet range.
(b) maximum at the power frequencies and decreases to zero at frequencies in the ultraviolet range.
(c) unity at the power frequencies and increases to its maximum value at frequencies in the ultraviolet range.
(d) independent of frequency variations.

[ESE-2006]

2.17 With increase in applied frequency, the dielectric loss in a material will
(a) increase (b) decrease
(c) remain constant (d) become zero

[ESE-2006]

2.18 The electronic polarisability of an inert gas atom is proportional to which one of the following?
(a) R (b) R^2
(c) R^3 (d) R^4
(Where R is the radius of the atom)

[ESE-2008]

2.19 In the case of a dielectric subjected to an alternating electric field of frequency f, the dielectric loss is proportional to which one of the following?
(a) f (b) f^2
(c) $1/f$ (d) $1/f^2$

[ESE-2008]

2.20 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

[ESE-2008]

2.21 Quartz and $BaTiO_3$ exhibit which of the following properties?
(a) Magnetostriction (b) Ferromagnetism
(c) Piezoelectricity (d) Ferroelectricity

[ESE-2009]

2.22 A barium titanate crystal has a thickness of 2 mm. Its voltage sensitivity is 12×10^{-3} Vm/N. It is subjected to a pressure of 0.5 MN/m^2. What is the voltage generated?
(a) 3 V (b) 6 V
(c) 5 V (d) 12 V

[ESE-2009]

2.23 Match **List-I** with **List-II** and select the correct answer using the code given below

List-I
A. Ferroelectric material
B. Anti Ferroelectric material
C. Ferrites
D. Ferro-magnetic

List-II

1. Neel temperature
2. Magnetostrictive transducers
3. Magnetocaloric effect
4. Cannot be shaped by ordinary machining process

Codes:

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

[ESE-2010]

2.24 Consider the following statements
Factors affecting the dielectric loss are
1. directly proportional to the frequency of supply voltage.
2. inversely proportional to the supply frequency.
3. inversely proportional to the square of the supply voltage.
4. directly proportional to the square of the supply voltage.

Which of the above statements are correct?
(a) 1 and 3 only (b) 2 and 3 only
(c) 2 and 4 only (d) 1 and 4 only

[ESE-2010]

2.25 The property/characteristic of ferroelectric materials is
(a) Dielectric relaxation
(b) Dielectric breakdown
(c) Spontaneous polarization
(d) Spontaneous magnetization

[ESE-2010]

2.26 Consider the following statements Piezoelectric materials serve as:
1. A source of ultrasonic waves.
2. When electric field is applied, the mechanical dimensions of the substances are not at all altered.
3. Converts electrical energy to mechanical and vice versa.
4. Converts thermal energy to electrical energy.

Which of these statements is/are correct?
(a) 1 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2, 3 and 4

[ESE-2010]

2.27 Consider the following statements :
Piezoelectric materials
1. Crystal can be shown as electrical equivalent circuit similar to an inductor and a capacitor (Tank circuit).
2. Quartz, Rochelle salt, tourmaline.
3. Used in voltage stabilizers.
4. This exhibits the reverse effect electrostriction.

Which of these statements are correct?
(a) 1, 2 and 4 only (b) 1 and 2 only
(c) 2 and 4 only (d) 1, 2, 3 and 4

[ESE-2010]

2.28 At a measuring frequency of 10^{12} Hz, the dielectric constant of a material will be due to
(a) Electronic polarization
(b) Ionic polarization
(c) Electronic, Ionic and Orientational polarization
(d) Electronic and Ionic polarization

[ESE-2010]

2.29 High permittivity ceramic is used for capacitors of
(a) A few pF to a few hundred pF
(b) A few μF to a few hundred μF
(c) A few nF to a few hundred nF
(d) A few mF to a few hundred mF

[ESE-2011]

2.30 The following material is not used for making a piezoelectric transducer
(a) Rochelle salt
(b) Barium titanate
(c) Chromium sulphide
(d) Quartz

[ESE-2012]

2.31 **Statement (I):** Polarization is due to the application of an electric field to dielectric materials.
Statement (II): When the dipoles are created, the dielectric is said to be polarized or in a state of polarization.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).

Answers Dielectric Properties of Materials

2.1 (b)	2.2 (a)	2.3 (c)	2.4 (c)	2.5 (c)	2.6 (b)	2.7 (d)	2.8 (a)	2.9 (d)	
2.10 (a)	2.11 (b)	2.12 (b)	2.13 (b)	2.14 (c)	2.15 (c)	2.16 (a)	2.17 (a)	2.18 (c)	
2.19 (a)	2.20 (b)	2.21 (c)	2.22 (d)	2.23 (c)	2.24 (d)	2.25 (c)	2.26 (c)	2.27 (d)	
2.28 (d)	2.29 (b)	2.30 (c)	2.31 (a)	2.32 (a)	2.33 (a)	2.34 (d)	2.35 (c)	2.36 (a)	
2.37 (d)	2.38 (b)	2.39 (a)	2.40 (c)	2.41 (*)	2.42 (b)	2.43 (c)	2.44 (c)	2.45 (b)	
2.46 (a)									

Explanations Dielectric Properties of Materials

2.1 (b)

$$W_E = \frac{1}{2}CV^2 = \frac{1}{2}\int \epsilon_o \epsilon_r E^2 d\nu \Rightarrow W_E \propto \epsilon_r$$

2.2 (a)

$$W(\text{dielectric loss}) = \frac{\omega}{2}\cdot\epsilon_0\cdot\epsilon_r'' E_0^2 \text{ i.e. } (\propto \omega)$$

2.3 (c)

Electronic and ionic polarizability remain constant with respect to temperature but orientational polarizability is inversely proportional to the temperature.

2.4 (c)

$$\text{Uniaxial stress } (p) = Y\cdot\frac{\Delta C}{C}$$

$$q = CV \Rightarrow \text{ polarisation } P = \frac{q}{A} = \frac{C}{A}\cdot V$$

where A is area of the crystal capacitor.

$$\therefore \quad \Delta P = \left(\frac{V}{A}\right)\times \Delta C$$

$$\Rightarrow \quad \frac{\Delta P}{P} = \frac{\Delta C}{C}$$

$$\Rightarrow \text{ stress } (p) = Y\cdot\frac{\Delta P}{P} = 130\times\frac{10}{500} = 2.6 \text{ GPa}$$

2.5 (c)

In the case of solids and liquids, internal field $\vec{E}_i$ is not equal to the applied field $\vec{E}$,

(for gases $\vec{E}_i = \vec{E}$); and $\vec{E}_i = \vec{E} + \left(\frac{\gamma}{E_0}\right)\vec{P}$.

For cubic symmetry, $\gamma = \frac{1}{3}$

$$\therefore \quad \vec{E}_i = \vec{E} + \frac{\vec{P}}{3\epsilon_0}$$

2.6 (b)

Loss factor $\tan\delta = \frac{\epsilon''}{\epsilon'}$

2.7 (d)

The dielectric losses in the radio frequency region are usually due to dipole rotation (i.e. oriental polarisation) or to ions (i.e., ionic polarisation) jumping from one equilibrium position to another. But, the losses in the optical region, are associated with the electrons (i.e. electronic polarisabilities).

2.8 (a)

Quartz is a piezoelectric material used for high frequency oscillation

2.9 (d)

SF_6 gas is a colourless, odourless, non-toxic and non-inflammable dielectric gas.

2.10 (a)

Polystyrene has highest dielectric strength among all the given options.

2.11 (b)

The losses in a dielectric subject to an alternating electric field is loss

$= \frac{1}{2}\epsilon_0\epsilon_0''\omega E_0^2$, where dielectric constant

$$\epsilon_r^* = \epsilon_r' - j\epsilon_r''$$

loss $\propto \epsilon''$ i.e. proportional to absolute value of complex dielectric constant.

2.12 (b)

$$E_i = \frac{E_{\text{applied}}}{1 - \frac{1.2\alpha_e}{\pi\varepsilon_0 a^3}}$$