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Electrical Engineering : Volume-1
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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 career 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

Contents

■■■■

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).

(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-2012]

2.32 Orientational polarization is
(a) inversely proportional to temperature and proportional to the square of the permanent dipole moment.
(b) proportional to temperature as well as to the square of the permanent dipole moment.
(c) proportional to temperature and inversely proportional to the square of the permanent dipole moment.
(d) inversely proportional to temperature as well as to the square of the dipole moment.

[ESE-2013]

2.33 Ferro-electric materials have a
(a) high dielectric constant which varies non-linearly.
(b) low dielectric constant and is non-linear.
(c) high dielectric constant which varies linearly.
(d) low dielectric constant but linear.

[ESE-2013]

2.34 In a piezoelectric crystal oscillator, the oscillation or tuning frequency is linearly proportional to the
(a) mass of the crystal
(b) square root of the mass of the crystal
(c) square of the mass of the crystal
(d) inverse of the square root of the mass of the crystal

[ESE-2013]

2.35 Which of the following are piezoelectric substances?
1. Barium Titanate
2. Lead Titanate
3. Lead Zirconate
4. Cadmium Sulphate

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

[ESE-2013]

2.36 **Statement (I):** The dielectric constant of a substance, under the influence of alternating electric fields is, in general, a 'complex' quantity.

Statement (II): The 'imaginary' part of the dielectric constant is a measure of the dielectric loss in the substance.
(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-2013]

2.37 **Statement (I):** Electrostriction occurs due to piezoelectricity which in the reverse effect i.e. the production of polarization on application of mechanical stress if the lattice has no centre of symmetry.

Statement (II): When an electric field is applied to a substance it becomes polarized, the electrons and nuclei assume new geometric positions and the mechanical dimensions of the substance are altered.
(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-2013]

2.38 The imaginary part of dielectric constant determines
(a) component of current which is in phase with the applied field
(b) component of energy absorbed per m^3
(c) amount of applied field
(d) component of voltage which is in phase with the applied field

[ESE-2014]

2.39 Enameled wires are preferred to cotton-covered wires to
(a) withstand higher temperature
(b) improve heat dissipation
(c) reduce the resistivity
(d) increase the mechanical strength

[ESE-2015]

2.40 Which one of the following materials is used for cable insulation?
(a) Phenol formaldehyde
(b) Polytetrafluoroethylene
(c) Polyvinyl chloride
(d) Acrylonitrile butadiene styrene

[ESE-2015]

2.41 A parallel plate capacitor is made of two circular plates separated by a distance of 5 mm and with a dielectric with dielectric constant of 2.2 between them. When the electric field in the dielectric is 3×10^4 V/m, the charge density of the positive plate will be, nearly
(a) 58.5×10^4 C/m^2 (b) 29.5×10^4 C/m^2
(c) 29.5×10^{-4} C/m^2 (d) 58.5×10^{-4} C/m^2

[ESE-2017]

2.42 When an alternating voltage of a given frequency is applied to a dielectric material, dissipation of energy occurs due to
1. Continual change in the orbital paths of the electrons in the atomic structure.
2. A small conduction current through the dielectric.
3. Eddy currents.

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

[ESE-2018]

2.43 A barium titanate crystal is inserted in a parallel plate condenser of area 10 mm × 10 mm. The plates having a separation of 2 mm, give a capacitance of 10^{-9} F. If the value of $\varepsilon_0 = 8.854 \times 10^{-12}$ Fm^{-1}, the relative dielectric constant of the crystal will be nearly
(a) 2640 (b) 2450
(c) 2260 (d) 2080

[ESE-2020]

2.44 Which one of the following statements is NOT correct regarding dielectric loss?
(a) The loss increases proportionately with the frequency of applied voltage.
(b) Presence of humidity increase the loss.
(c) Temperature rise normally decreases the loss.
(d) Voltage increase causes increased dielectric loss.

[ESE-2021]

2.45 **Statement I :** The inorganic materials are used to manufacture suspension insulators for high-voltage overhead lines and bushings on high-voltage transformers and switchgear.
Statement II : The ceramic and glass materials are formed into a series of flanged discs to decrease the creepage distance along the surface of the complete insulator.
(a) Both Statement (I) 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-2021]

2.46 A good insulating material should possess which of the following characteristics?
1. High dielectric strength
2. Low permittivity
3. Low thermal strength

Select the correct answer using the code given below:
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE-2022]

■■■■

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)

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

So as a ↑ denominator increases
So E_i decreases.
where a is interatomic distance.

2.13 (b)

$$\tan\delta = \frac{\epsilon_r''}{\epsilon_r'} \text{ and } \epsilon_r^* = \epsilon_r' - j\epsilon_r''$$

$$\epsilon_r'' = 4 \times 0.004 = 0.016$$

$$\Rightarrow \quad \epsilon_r = 4 - j0.016$$

2.14 (c)

Quartz crystal is a piezoelectric material.

2.15 (c)

Ferroelectric materials exhibit hysteresis effects similar to those observed in ferromagnetic materials.

2.16 (a)

At high frequencies dielectric constant is a complex quantity. Imaginary part is responsible for dielectric loss and it is high at power frequencies and decreases to unity at ultraviolet frequencies.

2.17 (a)

$$\text{Loss} = \frac{1}{2}\epsilon_0\epsilon_r''\,\omega\,E_0^2 \text{ so loss} \propto \omega$$

$\therefore$ Loss increases as ω increases

2.18 (c)

Electronic polarizability

$$\alpha_e = 4\pi\varepsilon_0 R^3$$

So, $\alpha_e \propto R^3$

2.19 (a)

$$\text{Loss} = \frac{1}{2}\epsilon_0\epsilon_r''\,\omega\,E_0^2$$

Dielectric loss $\propto \omega$

$$\Rightarrow \quad \propto f$$

2.20 (b)

$$\alpha_0 = \frac{\rho_p^2}{3KT} \Rightarrow \alpha_0 \propto \frac{1}{T}$$

where, ρ_p = Permanent dipole moment.

2.21 (c)

Quartz and $BaTiO_3$ both are piezoelectric material so exhibits piezoelectricity property.

2.22 (d)

$$V = gtP$$
$$= 12 \times 10^{-3} \times 2 \times 10^{-3} \times 0.5 \times 10^6$$
$$V = 12\,\text{V}$$

2.24 (d)

$$W = \text{loss} = \frac{1}{2}\epsilon_0\epsilon_r''\omega\frac{V^2}{d^2}$$

$$W \propto \omega$$
$$W \propto V^2$$

2.25 (c)

Ferroelectric material shows property of spontaneous polarization.

2.26 (c)

Piezo-electric crystal get stressed when voltage is applied and vice-versa.

2.28 (d)

10^{12} Hz (Visible range) – electronic polorizotion

2.29 (b)

High permittivity ceramic is used for capacitors of a few μF to few hundred μF.

2.30 (c)

Common Piezo-electric materials are Rochelle salt, ammonium dihydrogen phosphate, lithium sulphate Barium titanate, quartz and ceramics.

2.31 (a)

Application of an electric field causes relative displacement of these charges, leading to the creation of dipoles and hence polarization.

2.32 (a)

Orientation polarization

$$P = \frac{Np_p^2 E}{3KT}$$

2.33 (a)

Ferroelectric material shows spontaneous polarization and electric hysteresis. This shows that high dielectric strength and varies non-linearly.

2.34 (d)

Since, $\omega \propto \frac{1}{\sqrt{LC}}$

either series or parallel.

Piezoelectric in electrical equivalent in series

$$\omega \propto \frac{1}{\sqrt{m}}$$

2.39 (a)

Enameled wires are preferred to cotton-covered wires to withstand higher temperature.

2.41 (*)

Given parallel plate capacitor of area A and distance between plates is 5 mm. $\epsilon_r = 2.2$ and $E = 3 \times 10^4$ V/m.

Since, $C = \frac{\varepsilon A}{d}$

and $Q = CV = C\,Ed$

$$Q = \frac{\varepsilon A}{d} \cdot E \cdot d$$

Charge density

$$= \frac{Q}{A} = \varepsilon E$$

$$= 2.2 \times 8.8 \times 10^{-12}\ \text{F/m} \times 3 \times 10^4\ \text{V/m}$$

$$= 58.08 \times 10^{-8}\ \text{C/m}^2$$

2.43 (c)

$$C = \frac{\epsilon_r \epsilon_0 A}{d}$$

$$\Rightarrow \quad \epsilon_r = \frac{c \cdot d}{\epsilon_0 A}$$

$$\Rightarrow \quad \epsilon_r = \frac{10^{-9} \times 2 \times 10^{-3}}{8.854 \times 10^{-12} \times 100 \times 10^{-6}}$$

$$= 2258.8$$

Nearest option (c).

2.44 (c)

$$W = 2\pi f V^2 \epsilon_o \epsilon_r \tan\delta$$

Additionally, W increases with increase in temperature and humidity.

2.45 (b)

The correct reason for statement-I is that in inorganic materials (specially ceramics), the bonding is predominantly ionic, which gives very high insulation resistance and negligible leakage current, with high mechanical strength.

2.46 (a)

A good insulating material should have-

- High dielectric strength
- Low permittivity
- High thermal strength

■■■■