Answer ALL Questions
(10 X 10 = 100 Marks)

1. Explain the materials based on the energy band and their properties with suitable diagrams and examples. How does temperature affect the probability functions in energy bands? **[10]**

2. Consider the BCC unit cell of an iron (Fe) crystal.
   a) How many atoms are there per unit cell? **[2]**
   b) If R is the radius of the Fe atom, with lattice parameter 'a' is given by $a = 4R/\sqrt{3}$; Calculate the Atomic Packing Factor (APF) for the BCC structure. **[3]**
   c) Calculate the atomic concentration (number of atoms per unit volume) in Fe, given that the atomic mass of Fe is 55.85 g/mol, its density is 7.87 g/cm^3, and the atomic radius of Fe is 0.124 nm. **[5]**

3. Explain temperature dependence of conductivity for n-type semiconductors with relevant characteristics. **[10]**

4. For a given silicon crystal, the atomic concentration is 5×10^{22} cm^{-3}, $n_i = 1.0 \times 10^{10}$ cm^{-3}, $\mu_e = 1400$ cm^2 V^{-1} s^{-1}, and $\mu_h = 450$ cm^2 V^{-1} s^{-1}.
   I) Find the resistance of a 1 cm^3 pure silicon crystal. **[2.5]**
   II) What is the resistance when the silicon crystal is doped with arsenic if the doping is 1 in 10^9, i.e one part per billion (ppb)? **[2.5]**
   III) What is the resistance when silicon crystal is doped with boron instead of arsenic? **[2.5]**
   IV) Analyse how conductivity and resistivity vary with the doping. **[2.5]**

5.a) Explain the diamagnetic and paramagnetic materials based on their properties and discuss their key characteristics with suitable examples. **[10]**

OR

5.b) Describe hard and soft magnetic materials and compare their hysteresis loop with saturation magnetism, retentivity and coercivity. Also, discuss their key applications. [10]

6. Explain superconducting materials with the Meissner effect and discuss their properties with suitable examples. Also, describe the characteristics of type-1 and type-2 of superconductors. [10]

7. Calculate the dielectric loss per unit volume (W/cm^3) of material A and B at 60 Hz frequency from the given Table. Assume that the applied electric field is 50 kV/cm. Suggest which materials are good and poor for the manufacturing of cables. [10]

Material	ε_r'	$tan\delta$
A	2.5	4×10^{-4}
B	8.5	1×10^{-3}

8. Consider a KCl crystal, which has one $K^+ - Cl^-$ pair per unit cell and a lattice parameter a = 0.314 nm. The electronic polarizability of K^+ and Cl^- ions is 2.5×10^{-40} F·m^2 and 3.8×10^{-40} F·m^2, respectively. The mean ionic polarizability per ion pair is 5.5×10^{-40} F·m^2. Calculate the dielectric constant of KCl at low frequencies and optical frequencies. [10]

9. a) The cauchy dispersion relation for Si with coefficients [5]
$n_{-2} = -2.04 \times 10^{-8}, n_0 = 3.4186, n_2 = 8.15 \times 10^{-2}, n_4 = 1.25 \times 10^{-2}$.
Calculate the photon energy (in eV) and refractive index of Si at 1450 nm, one of the main communication wavelengths.

b) For GaAs, from $\lambda = 0.89$ to 4.1 μm, the refractive index is given by the following dispersion relation. [5]

$$n^2 = 7.10 + \frac{3.78\,\lambda^2}{\lambda^2 - 0.2767}$$

Where λ is in microns (μm). What is the refractive index of GaAs for light with a photon energy of 1eV?

10.a) Explain the construction and working of flexible solar cells in detail. [10]

OR

10.b) Classify various types of energy storage for engineering applications. Also, explain the construction and workings of flexible energy storage in detail. [10]

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