INDIAN INSTITUTE OF TECHNOLOGY DELHI
PYL-102, MAJOR
Total Marks: 40, Time: 2hr

Date: 23-11-2017

Note: The symbols used have their usual meanings.
Please mention the color code in your copy (P: pink, G: green, W: white.)

1. In a magnetic material, domains are separated by domain walls. For what type of domain wall, the magnetization rotates in plane parallel to the plane of the wall?
A. Bloch Wall B. Neel wall C. Both Neel and Bloch wall

[0.5]

2. Which of the following is true for Hall effect of a semiconductor?
The Hall voltage
A. is directly proportional to charge carrier density B. is inversely proprtional to charge carrier density C. does not depend on carrier density D. inversely proportional to the applied magnetic field.

[0.5]

3. Mobility μ of charge carriers in a semiconductor depends on temperature following the relation $\mu \propto T^{1.5}$. The origin of such temperature dependence is due to
A. lattice scattering B. scattering due to crystal (point/interstitial, etc.) defects C. ionized impurity scattering D. carrier-carier interactions

[0.5]

4. A p-n junction of Si has donor doping concentration $N_d = 10^{16}\text{cm}^{-3}$ and acceptor doping level N_a=$5\times10^{17}\text{cm}^{-3}$. Calculate the maximum electric field in the depletion region. Assume that the depletion region extends to 300 μm in the n-region. The dielectric permittivity of Si is 15×10^{-12}F/m.

[2]

5. a) Explain the term dielectric polarization of a material.
b) Show that Polarization $\vec{P}$ of a material is given by $\vec{P} = (\epsilon - \epsilon_0)\vec{E}$ where ϵ and ϵ_0 are permittivity of the material and that of free space, respectively.
c) Considering local electric field of an isotropic material given by $\vec{E_l} = \vec{E} + \frac{1}{3\epsilon_0}\vec{P}$, find out a relation between dielectric constant and polarizability of a material.

[2+2+3]

6. Consider a p-n juncton diode where the given parameters, are $D_n = 25$ cm^2/s, $D_p = 10$ cm^2/s, $\tau_{p0} = \tau_{n0} = 5\times10^{-7}$s. If you were to design the diode such that $J_n = 20\text{A/cm}^2$ and $J_p = 5\text{A/cm}^2$ at applied bias V_a= 650 mV, what would be the required electron and hole doping concentraions?

(w)2.

[5]

7. Draw a schematic graph to show how under the Kronig Penney model the allowed and forbidden band width changes as a function of energy. Briefly explain the graph.

[1+1]

8. a) Mention the conditions under which a Schottky and Ohmic contacts are formed between a metal and an n-type semiconductor.

b) Draw an energy band diagram to show
i) Schottky barrier and
ii) built in potential for electrons
in a metal-semiconductor contact. Clearly indiciate all the relevant parameters in the diagram.

[1+2]

9. a) For an extrinsic semicoductor, show with a schematice diagram how the carrier concentration changes as a function of temperature. b) Explain the diagram

[1+3]

10. Show that the holes in a solid have positive charge and negative effective mass.

[2+2]

11. a) Explain in details the difference in the role of majority and minority carriers in a p-n junction diode and a Schottky diode.
b) How are the reverse saturation currents for a Schottky and p-n junction different? Explain in details.
c) A Schottky diode made from Ge and tungsten junction has a saturation curent density of 10^{-11} A/cm^2. If the cross sectional area of the diode is 5×10^{-4}cm^2, find out at what forward bias a current of 5 mA will be achieved. Consider the ideality factor to be unity.

Consider the diodes for room temperature applications.

[2+3+1.5]

12. An external magnetic field is applied to a magnetic material of intrinsic susceptibility χ_i. If the material of the given shape has a demagnatization factor of N, show that the measured susceptibility χ_m would be given by $\chi_m = \frac{\chi_i}{1+N\chi_i}$

[2]

13. a) Write the Hamiltonian for a ferromagnet placed in an external magnetic field $\vec{B}$. If $\vec{B_{mf}}$ is the molecular field acting in the system, show that the effective Hamiltonian can be written as $\hat{H} = g\mu_B \sum_i \vec{S_i} \cdot (\vec{B} + \vec{B}_{mf})$. All the symbols have their usual meanings.

[1+2]

$k_B = 1.38 \times 10{-}23$ J/K, $m_e = 9.11 \times 10^{-31}$kg, $h = 6.626 \times 10^{-34}$J-s, $\hbar = 1.054 \times 10^{-34}$J-s