MANIPAL UNIVERSITY

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DEPARTMENT OF SCIENCES, M.Sc PHYSICS
II SEMESTER END SEMESTER EXAMINATIONS, APRIL 2017

SUBJECT: Introduction to Condensed Matter Physics [PHY 602]

(REVISED CREDIT SYSTEM)

Time: 3 Hours Date: 19-04-2017 MAX. MARKS: 50

Note: (i) Answer any FIVE FULL questions.
(ii) Missing data, if any, may suitably be assumed.

PHYSICAL CONSTANTS

Elementary charge = 1.60×10^{-19}C Electric constant [permittivity], $\varepsilon_0 = 8.85 \times 10^{-12}$F/m
Magnetic constant [permeability], $\mu_0 = 1.26 \times 10^{-6}$H/m
Electron mass = 9.11×10^{-31}kg Avogadro constant = 6.02×10^{23}mol^{-1}
Bohr magneton = 9.27×10^{-24}J/T Planck's constant = 6.63×10^{-34} J.s
Boltzmann constant = 1.38×10^{-23} J/K

1A. What are symmetry elements? Enumerate twenty three symmetry elements in a cubic crystal.

1B. Calculate the c/a ratio for an ideally close packed HCP crystal and show that it is equal to $\sqrt{8/3}$ or 1.63

1C. Calculate the cohesive energy per ion of NaCl molecule from the following data: Madelung constant = 1.748, n = 9, r_0 = 2.81 Å, ionization potential energy of sodium = 5.14 eV and electron affinity of Cl = 3.61 eV.

[5+3+2]

2A. Define atomic scattering factor? Derive the general expression for the atomic scattering factor using spherical polar coordinates.

2B. Calculate structure factor for base centered orthorhombic cell.

2C. The lattice parameter of copper (fcc) is 0.361 nm. The first order (111) plane appear at an angle of 21.7°. Find the wavelength of the X-ray used.

[5+3+2]

3A. Derive the dispersion relationship for vibrations of a one-dimensional diatomic lattice.

3B. Two parallel plates have equal and opposite charges. They are separated by a dielectric of 5 mm thick whose dielectric constant is 3. If the electric intensity in the dielectric is 10^6 V/m, calculate the free charge per unit area on the plate and the polarization P in the dielectric.

3C. A paramagnetic substance has 10^{28} atoms/m^3. Each atom has magnetic moment 1.8×10^{-23}Am^2. Determine the paramagnetic susceptibility at 300 K.

[5+3+2]

4A. Mention four important assumptions of classical free electron theory. Derive the expression for electrical conductivity of a conductor based on classical Drude's theory.

4B. Density of aluminium (trivalent) metal is 2.7×10^3 kg/m^3 and its atomic weight is 27. Calculate Fermi energy and Fermi velocity.

4C. The Fermi-level in a semiconductor is 0.35 eV above the valence band. What is the probability of *non-occupation* of an energy state at the top of the valence band, at 300 K?

[5+3+2]

5A. Arrive at the expression for Fermi level in n type semiconductor as $E_F = \frac{E_d + E_c}{2} + \frac{kT}{2} ln\left(\frac{N_d}{N_C}\right)$, *where* $N_C = 2\left[\frac{2\pi m_n^* kT}{h^2}\right]^{3/2}$ and N_d is the donor concentration. Using this, derive an expression for density of electrons in the conduction band of an n-type extrinsic semiconductor.

5B. The effective mass of hole and electron in intrinsic GaAs are respectively 0.48 and 0.067 times the free electron mass. The band gap energy of GaAs is 1.43 eV. How much above is the Fermi-level from the top of the valence band at 300 K?

5C. Show by a graph, the variation of energy, velocity and effective mass of the electron as a function of k.

[5+3+2]

6A. Describe the Lengevin's classical theory of diamagnetism and obtain the expression for susceptibility.

6B. There are 1.6 x 10^{20} molecules/m^3 in NaCl vapour. Determine the orientational polarization at room temperature (300 K) if the vapour is subjected to a field of 5 x 10^6V/m. Assume that the NaCl molecule consists of Na^+ and Cl^- ions separated by a distance of 0.25 nm.

6C. Distinguish between type I and type II superconductors.

[5+3+2]