PYL 102: PRINCIPLES OF ELECTRONIC MATERIALS
MAJOR (20.11.2015)

TOTAL MARKS: 40 **DURATION: 90 Minutes**

Q.1. The lattice parameters in real space for a two dimensional rectangular lattice are given by $a=0.2\times10^{-9}$ m and $b=0.4\times10^{-9}$ m.
(i) Calculate dimensions of the first Brillouin zone.
(ii) Show that the total number of electrons between zero and Fermi energy (E_F) is given by $N_0(E_F) = \frac{ab}{2\pi}k_F^2$; where k_F is the radius of the Fermi circle. **[2+4]**

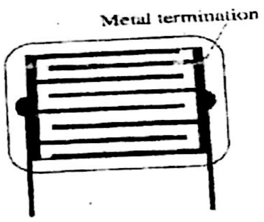
Q.2. In a simple cubic, free electron metal the spherical Fermi surface just touches the first Brillouin zone. Calculate the number of conduction electrons per atom in this metal. The density of state for this metal is given as **[4]**
$$D(E) = \frac{V}{4\pi^2}\left(\frac{2m}{\hbar^2}\right)^{3/2} E^{1/2}.$$

Q.3. Show and discuss variation of electron concentration (n) in the conduction band as a function of temperature (T) for an n-type semiconductor. **[4]**

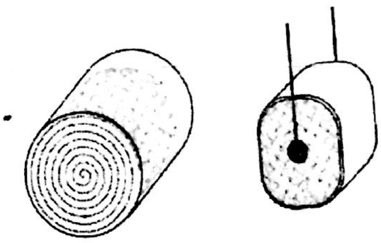
Q.4. Consider the CsCl crystal which has one Cs^+-Cl^- pair per unit cell and a lattice parameter "a" of 0.412 nm. The electronic polarizability of Cs^+ and Cl^- ions is 3.35×10^{-40} Fm^2 and 3.4×10^{-40} Fm^2, respectively, and the mean ionic polarizability per ion pair is 6×10^{-40} Fm^2. What is the dielectric constant at low frequencies (near infrared) and that at optical frequencies? Assume Clausius-Mossotti equation to be valid for both electronic and ionic polarizabilities. (Given $\epsilon_0 = 8.85\times10^{-12}$ Fm^{-1}). **[5]**

Q.5. (a) What are the factors/parameters, which increase/decrease the capacitance of a capacitor?

(b) The following figures show schematic designs of a multilayer ceramic capacitor and a polymer film capacitor. How these two designs help in increasing the capacitance of respective capacitors?



Multilayer ceramic capacitor



Polymer film capacitor

(c) Why the dielectric loss is less in capacitors, which use polystyrene films as compared to the ones that use high dielectric ceramics? **[2+4+2]**

Q.6. (a) Using logical arguments and relevant diagram, show that paramagnetic susceptibility (Pauli paramagnetism) in metals is essentially independent of temperature.
(b) A system of electron spins is placed in a magnetic field of 2 Tesla (Wb/m^2) at a temperature T. The number of spins parallel to the magnetic field is twice as large as the number of anti-parallel spins. Determine T. Assume that Boltzmann statistics is applicable in the aforementioned system. (Given $\mu_B = 9.27\times10^{-24}$ Am^2, $k=1.38\times10^{-23}$ Joule/°K$=8.61\times10^{-5}$ eV/°K) **[4+4]**

Q.7. Consider dysprosium (Dy), which is a rare earth metal with a density of 8.54 gm/cm^3 and atomic mass of 162.50 gm mol^{-1}. The isolated atom has the electron structure $[Xe]4f^{10}6s^2$. What is the spin magnetic moment in the isolated atom in terms of number of Bohr magnetons? If the saturation magnetization of Dy near absolute zero temperature is 2.4×10^6 A m^{-1}, what is the effective number of spins per atom in the ferromagnetic state? What is the order of magnitude for the exchange interaction in eV per atom in Dy if the Curie temperature is 85 K?
(Given: $\mu_B = 9.27\times10^{-24}$ Am^2 ; $N_A = 6.022\times10^{23}$ mol^{-1}) **[5]**