Final Semester 2020

Course: PH302 Full Marks: 30

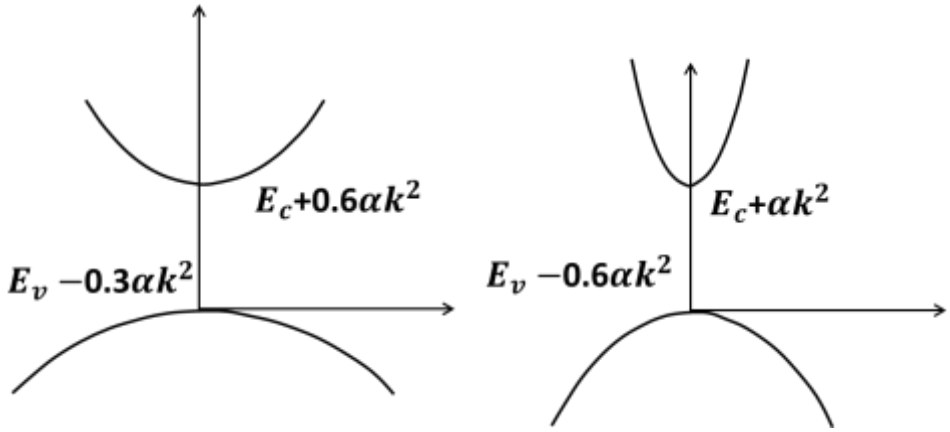
General instructions:

Give the answer with proper explanation, without which the answer will be considered as incomplete. Use the given parameters of a particular problem to calculate required numerical values.

[1] Suppose a FCC crystal (lattice constant of conventional cell is 4Å) is formed by trivalent atoms. If a thin sheet (area 2 cm^2) of this crystal is used as a capacitor plate (separation from other plate of the capacitor is 100 nm and air serves as dielectric) and the capacitor is charged (at T=0) with a voltage 50V, calculate the percentage change in electrical conductivity of the plate due to charging. [Marks 6]

[2] Isotropic compression of solid (hence contraction of lattice constant) alters the electronic dispersion relation from figure 3A to figure 3B. Calculate the net change in Fermi energy (chemical potential) at a temperature T due to this process.

[Marks 3]



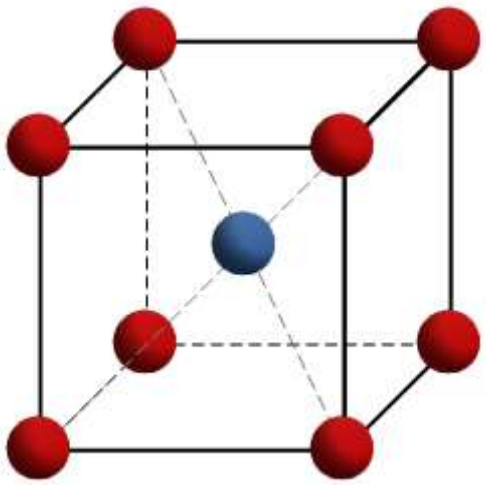
[3] For silicon at T=300K, Intrinsic carrier concentration $(n_i) = 1.45 \times 10^{10}\ cm^{-3}$. Silicon bandgap ($E_g = 1.12\ eV$) The silicon is doped at room temperature (300K) with Arsenic atoms (penta-valent), so that donor concentration is (N_D) =6× 10^{16} cm^{-3}.

Find the equilibrium concentration of electrons, holes and shift of the chemical potential (Fermi level) with respect to intrinsic chemical potential due to doping. [Marks 1+1+2]

[4] Calculate the energy position of donor level with respect to conduction band minima of Germanium using the below given parameters.

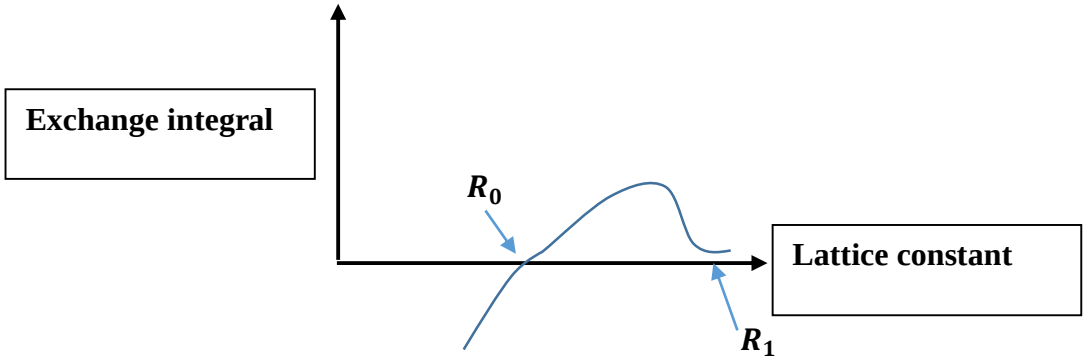
Ionization potential of hydrogen is -13.6eV, dielectric constant of Germanium is 11.2 and effective mass of electron in conduction band 0.12 m, where m is the mass of free electron. [Marks 2]

[5] Consider a hypothetical alloy of Iron and chromium having cubic unit cell (lattice constant 5 Å) as shown below. In this metallic allow Iron and Chromium remain in +2 and +3 ionic state. Calculate magnetization (magnetic moment per unit volume) of this allow at 400 ^{o}C if the crystal behaves as a paramagnetic material at this temperature. [Marks 10]



Corner spheres represent 'Chromium ions' and the sphere at the center represents 'Iron ion'

[6] Exchange integral of a solid as a function of lattice constant is shown below



A crystal with lattice constant R $(> R_1)$ is isotopically compressed, so that its lattice constant decreases with increase in pressure without changing the crystal structure. Explain with proper justification how its magnetic property will change with the pressure. [Marks 3]

[7] Why it is impossible to flow arbitrarily large current in a superconductor? [Marks 2]

Given: Boltzmann Constant (k_B)=8.61×10^{-5} eV/K. Permittivity of free space 8.85 x 10^{-12} farad per meter (F/m).