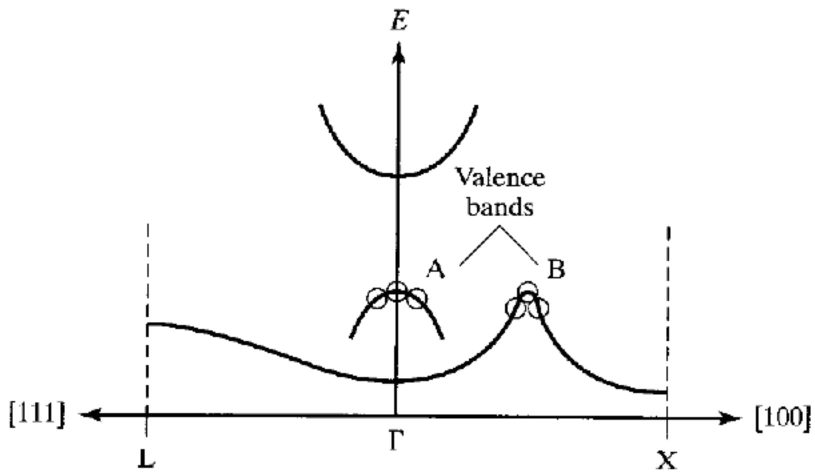
Assignment 2 (Maximum Marks: 50)

General Instructions:

1) The submission deadline is 27th August 2018 (Monday), 11:59pm.
2) Please state clearly the assumptions and the values of the constants used while solving the problems.
3) Please submit Matlab codes along with the solutions in PDF format.

Q. 1) The E-k plot of a material is as shown in the figure below:



Which set of holes, band A or band B will exhibit greater [100] direction effective mass? **(2 marks)**

Q. 2) The E-k band diagram of 1D periodic lattice can be defined as $E_k = E_o - 2E_1\cos(ka)$, where $E_o = 2E_1$. An electric field of magnitude $-\xi_o$ is applied across the solid. Derive and plot the expressions for the group velocity and the trajectory of the electron movement in the solid under the effect of electric field. Comment on the movement of electrons. **(3+2 = 5 marks)**

Q. 3) The E-k relationship characterizing an electron confined to a two-dimensional surface layer is of the form $E - E_C = \frac{\hbar^2 k_x^2}{2m_x} + \frac{\hbar^2 k_y^2}{2m_y}$.

a) If DOS of the material is $\frac{m^*}{\pi\hbar^2}$, then find the value of m^*.

b) An electric field is applied in x-y plane at a 45° angle to x-axis. Assuming electron to be at rest initially, find the acceleration of the electron along with its direction. **(2+3 = 5 marks)**

Q. 4) Find the density of states for 0D and 1D materials and plot DOS vs E for each case. Give some examples for these systems. **(3+3+1+1 = 8 marks)**

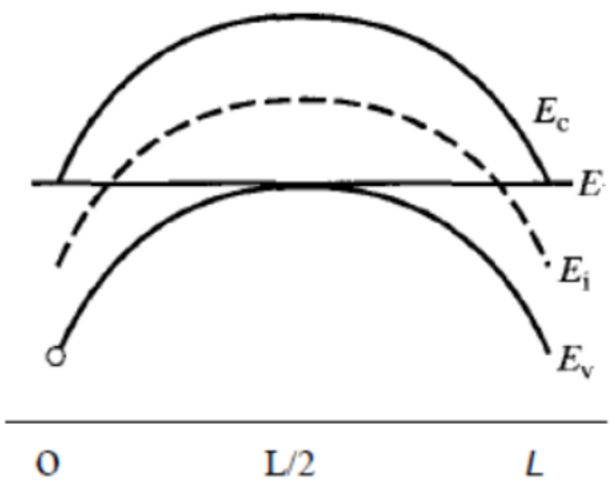
Q. 5) The dispersion relation of electrons in a 2D material is given as $E = \hbar v_F |k|$. Find the expression for density of states for the material. **(4 marks)**

Q. 6) In InSb at 300 K, E_g = 0.18 eV (smallest band gap of all the semiconductor compounds), $m_n^* = 0.0116m_o$, $m_p^* = 0.4m_o$ and $n_i = 1.6 \times 10^{16}$ /cm^3. Find the position of intrinsic Fermi level (E_i) and comment on its position. Draw the energy band diagram indicating the position of E_i. **(4 marks)**

Q. 7) Calculate a general expression for electron concentration for a silicon sample doped with a shallow donor dopant density N_d/cm^3. At what temperature, the electron concentration will exceed the donor concentration by 5%? (Note: You may want to use a software to solve the final equation. Please explain the method used.) **(4 marks)**

Q. 8) Silicon is used as dopant to GaAs by adding a concentration of 10^{10} cm^{-3}. Find the number of electrons and holes in the material assuming that silicon acts as fully ionized dopants with 20% replacing Ga, and 80% replacing As atoms. Use $n_{i,GaAs} = 2.5 \times 10^6$ cm^{-3}. **(4 marks)**

Q. 9) For the band diagram given below, answer the following questions:



a) Is the semiconductor in equilibrium? Justify.
b) Sketch the electrostatic potential, electric field, potential and kinetic energies as a function of x inside the semiconductor.

Assume E_F as the reference level and particle shown in hollow circle moves back and forth between x = 0 and x = L without changing the total energy. **(2+6 = 8 marks)**

Q. 10) Write a Matlab code to compare and plot the difference in the charge carrier statistics (f(E)) vs E calculated using Fermi-Dirac and Maxwell-Boltzmann equations with variation in

1) temperature ranging from 0 K to 400 K.

2) ($E-E_F$) varying from 0 eV to 0.7 eV

Calculate the range of temperature and ($E-E_F$) where the error in the Maxwell-Boltzmann distribution w.r.t. to Fermi-Dirac distribution is less than 5%. **(3+3 = 6 marks)**