# RAJARATA UNIVERSITY OF SRI LANKA
## FACULTY OF APPLIED SCIENCES

B.Sc. (Joint Major) Degree in Chemistry & Physics

Fourth Year - Semester I Examination – October/November 2015

**PHY 4209 – PHYSICS OF ELECTRONIC DEVICES**

Answer all four questions — Time: Two hours

**Use of a non programmable calculator is permitted.**
**Unless otherwise specified, all the symbols have their usual meaning.**

Some fundamental constants;

Electron rest mass $m_e = m_0 = 9.1 \times 10^{-31}\ kg$
Elementary charge $e = 1.6 \times 10^{-19}\ C$
Electron volt $eV = 1.6 \times 10^{-19}\ J$
Permittivity of free space $\varepsilon_0 = 8.85 \times 10^{-12}\ C^2 N^{-1} m^{-2}$
Boltzmann Constant $k = 1.38 \times 10^{-23}\ J K^{-1}$



**(1)** (a) i. Derive the expression for the position of the Fermi level relative to the center of the band gap as a function of temperature in an intrinsic semiconductor. [10 marks]

ii. Calculate the displacement of $E_F$ from the center of the gap in *Si* at 300 K assuming $m_e^* = 1.1 m_e$ and $m_h^* = 0.56 m_e$. ($kT \sim 0.026$ eV at 300 K) [06 marks]

(b) The electron and hole mobilities in a *Si* sample are 0.135 and 0.048 $m^2 V^{-1} s^{-1}$ respectively. Determine the conductivity of intrinsic *Si* at 300 K, if the intrinsic carrier concentration is $1.5 \times 10^{16}$ atoms/$m^3$. The sample is then doped with $10^{23}$ phosphorus atoms/$m^3$. Determine the equilibrium hole concentration, conductivity and position of the Fermi level relative to the intrinsic level.

Hint: $E_F - E_i = kT \ln\left(\dfrac{n}{n_i}\right)$ [09 marks]

**Contd.**

**(2)** (a) Show that the curvature of the energy band in which the particle (electron or hole) moves is inversely proportional to the mass of the particle. [08 marks]

(b) A hypothetical energy band can be fitted approximately to the expression $E(k) = E_0[1 - \exp(-2a^2k^2)]$ where $a$ is the lattice constant of the crystal.

Calculate

i the effective mass at $k = 0$, [06 marks]

ii the value of $k$ for maximum electron velocity, and [05 marks]

iii the effective mass at the edge of the Brillouin zone. [06 marks]

**(3)** (a) *In* has a valency of III and is a metal. *Sb* is also a metal and has a valency of V. The compound *InSb* is a semiconductor with each atom bonding to four neighbors, just as in *Si*. Explain how this is possible and why *InSb* is a semiconductor and not just a metal alloy. [10 marks]

(b) If there are no acceptors and $N_d$ donors per unit volume are present in a doped semiconductor at very low temperature, then the density of electrons in the conduction band is $n(T) = N_d e^{-\Delta E/2kT}$ where $\Delta E$ is the binding energy of the donor level relative to the edge of the conduction band with the assumption of $\Delta E >> kT$. Explain why then the low temperature behavior of $n(T)$ changes to $n(T) = (N_d - N_a)e^{-\Delta E/kT}$, when there are $N_d$ donors and $N_a$ acceptors per unit volume with $N_a < N_d$. [15 marks]

**(4)** Write <u>short notes</u> on the following.

(a) The impact of heavy doping on the density of states. [09 marks]

(b) Kronig-Penny model [08 marks]

(c) Advantages of using quantum wells in optoelectronic applications. [08 marks]

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