RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

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

Fourth Year - Semester I Examination – March/April 2014

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 and physical data;

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 $= 1.38 \times 10^{-23}\ J K^{-1}$

(1) (a) i. Show that according to band theory, a solid formed from an element with an odd number of electron per atom cannot have an energy gap, and therefore must be a metal. [08 marks]

ii. State any mechanism by which a gap could appear in such a solid. [04 marks]

(b) i. Can an electron possesses negative effective mass? Justify [06 marks]

ii. Carbon, Silicon, and Germanium have the same crystal structure, but the band gap decreases from 5.5 eV to 1.12 eV to 0.67 eV. Why? [07 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) 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. If $n_0 = 10^{16} cm^{-3}$ in doped Si at 300K, where is the Fermi level relative to the intrinsic level E_i? (kT ~ 0.026 eV at 300K) [08 marks]

(b) In an n-type semiconductor at 300K, 30% of the donor atoms are ionized. Does the Fermi level lie above or below the donor level? Which way does the Fermi level move if the temperature increases. [07 marks]

(4) Write short notes on the following.

(a) Optical properties of quantum wells. [10 marks]

(b) Kronig-Penny model [07 marks]

(c) Charge carriers in semiconductors. [08 marks]

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