RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (Four Year) Degree in Applied Sciences /
B. Sc. (Joint Major) Degree in Chemistry and Physics

Fourth Year - Semester I Examination – October / November 2019

PHY 4209 – PHYSICS OF SEMICONDUCTOR DEVICES

Time: Two (02) hours

Answer all four questions

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

Some fundamental constants;

Electron rest mass $m_e = 9.1 \times 10^{-31}\ kg$

Electron volt $eV = 1.6 \times 10^{-19}\ J$

Elementary charge $e = 1.6\times10^{-19}\ C$

Boltzmann Constant $k = 1.38 \times 10^{-23}\ J\,K^{-1}$

Useful formulae;

$$E_F = \frac{E_C + E_V}{2} + kT\ln\left(\frac{N_V}{N_C}\right)^{1/2}$$

$$n(T) = N_C(T)e^{-(E_C - E_F)/kT}$$

$$p(T) = N_V(T)e^{-(E_F - E_V)/kT}$$

$$E_F = \frac{E_C + E_D}{2} + kT\ln\left(\frac{N_D}{2N_C}\right)^{1/2}$$

$$\sigma = ne(\mu_n + \mu_h)$$

$$D_n = \frac{kT}{e}\mu_n, \quad D_h = \frac{kT}{e}\mu_h$$

$$N_C = 2.5\times10^{19}\left(\frac{m_e^*}{m_e}\right)^{3/2}\left(\frac{T}{300}\right)^{3/2}$$

$$R = \rho\frac{l}{A}, \quad \rho = \frac{1}{\sigma}$$

$$f(E) = \frac{1}{e^{\frac{E-E_F}{KT}} + 1}$$

$$n_i = \sqrt{n_0 p_0}\, e^{\frac{-E_g}{2kT}}$$

Contd.

1. a) i. Derive an expression for the position of the Fermi level (E_F) 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)
(05 marks)

b) An electron in the Si conduction band is subjected to an electric field of 1 kV/cm for 0.1 ps.

i. If the effective mass of the electron is $m_e^* = 0.98\, m_e$, how far does the electron travel? (04 marks)

ii. Show that the GaAs devices are faster than the Si devices by calculating the distance that the electron move by applying the same field for the same time as above for a GaAs conduction band. The effective mass of the electron in GaAs is $m_e^* = 0.067\, m_e$. (06 marks)

2. At 300 K, a very pure sample of Si, Ge, and GaAs have the properties given in the following table

Sample	n_i cm^{-3}	μ_n cm^2/V s	μ_p cm^2/V s
Si	1.00 x 10^{10}	1400	460
Ge	2.00 x 10^{13}	4000	2000
GaAs	2.25 x 10^{6}	8500	430

a) i. Calculate the resistivity of Si, Ge and GaAs. (12 marks)

ii. The conductivity varies with the resistivity values calculated above. Compare the conductivity among the samples and give reasons for the differences.
(08 marks)

b) What is it meant by mobility of carriers in metals? (05 marks)

3. a) Considering the pattern of variation in the positions of Fermi level with temperature in an extrinsic semiconductor, we can conditionally single out three regions: the region of typical of low temperatures, the region of impurity depletion, and the region of transition to the intrinsic condition.

i. Draw a schematic graph showing the change in the position of the Fermi level with temperature in extrinsic n-type semiconductors. Clearly indicate the saturation temperature, intrinsic temperature, energy of the donor level (E_D) and the variation of Fermi level on your graph (09 marks)

Contd.

ii. Use the formula for the position of the Fermi level of an extrinsic semiconductor and the above graph to describe what is meant by low temperature region and high temperature region of an extrinsic semiconductor. (07 marks)

b) Si doped with $10^{14}\ cm^{-3}$ Sb is n-type at 400K, but similarly doped Ge is not. Why? (09 marks)

4. Write short notes on the following.

(a) Law of mass action (08 marks)

(b) Optical properties of quantum wells (09 marks)

(c) Capture levels or trapping levels. (08 marks)

..**END**.....