24

RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (Four Year) Degree in Applied Sciences

Fourth Year - Semester I Examination – October/November 2017

PHY 4209 – PHYSICS OF ELECTRONIC 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;

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

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

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

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

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

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

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

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

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

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 $m_e^* = 1.1m_e$ and $m_h^* = 0.56m_e$. ($kT \sim 0.026$ eV at 300 K) [06 marks]

(b) The effective mass of an electron at the lower conduction band edge of a semiconductor is three times higher than that of holes at the upper valence band edge. How far is the Fermi level located from the middle of the forbidden energy gap, assuming that the semiconductor is intrinsic? Explain why the band gap (E_g) should be greater than 8 kT for your calculation. [09 marks]

(2) At 300 K, a very pure sample of Ge has a resistivity of 3.9 Ωm. The mobilities of electrons and holes are 0.38 m^2/Vs and 0.18 m^2/Vs respectively. At thermal equilibrium, the electron concentration $(n_0) = 5.2 \times 10^{23}\, m^{-3}$ and holes concentration $(p_0) = 2.3 \times 10^{23}\, m^{-3}$ for Ge.

(a) i. Calculate the intrinsic carrier density and thus the band gap of Ge at room temperature. [12 marks]

ii. The sample is then doped with 10^{22} m^{-3} Boron. What are the concentrations of electrons and holes and what is the new resistivity of the sample? [08 marks]

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

(3) (a) What are the impacts of heavy doping on

(i) Density of states

(ii) Density of carriers

(iii) Position of Fermi levels in semiconductors. [15 marks]

(b) Consider a Si sample doped with Phosphorous at a doping density $10^{16}\ cm^{-3}$.

(i) Calculate the fraction of ionized donors at 300 K.

(ii) How does this fraction change if the doping density is $10^{18}\ cm^{-3}$?

You may use: $E_C - E_F = 0.045\ eV$, $N_C = 2.8 \times 10^{19}\ cm^{-3}$ [10 marks]

(4) Write short notes on the following.

(a) Fick's 1st Law [08 marks]

(b) Optical properties of quantum wells [08 marks]

(c) Compensated semiconductors [09 marks]

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