COLLEGE OF ENGINEERING & TECHNOLOGY

Department: Electronics and Communications Engineering
Lecturer: Dr. Mostafa Fedawy.
Course Title: Electronic Devices I
Course Code: EC 233

Cairo Branch

Sheet 5

I. Indicate whether each of the following statements is true or false *(give reasons)*:

1- If an electronic system is in equilibrium, it must in a steady state.

2- If an electronic system is in steady state, it must be in equilibrium.

3- For a semiconductor in equilibrium, the current must be constant.

4- The diffusion coefficient and mobility of electrons in a semiconductor can have totally independent values.

II. Choose the correct answer justifying your choice:

1- When an external voltage is applied on an intrinsic semiconductor material ….
(a) mass action law $np = (n_i)^2$ can be applied (b) it will still be at equilibrium
(c) it will be p-type semiconductor (d) it will not be at equilibrium

2- When an n-type semiconductor material is heated ……..……
(a)Fermi Level position does not change (b) it will still be at equilibrium
(c) it will be p-type semiconductor (d) it will not be at equilibrium

3- The height from the bottom of the conduction band indicates the …..... of carriers
(a) kinetic energy (b) potential energy (c) total energy (d) mobility

4- The rise of the bottom of the conduction band in the +ve x direction indicates the presence of an external electric field which is …..... .
(a) in the +ve x direction (b) in the -ve x direction
(c) zero (d) normal to the x direction

5- The rise of the top of the valence band in the +ve x direction indicates the presence of an external electric field which is …..... .
(a) in the +ve x direction (b) in the -ve x direction
(c) zero (d) normal to the x direction

6- The bottom of the conduction band decreases in the +ve x direction. This means that the electrons are affected by an electric force which is ..... .
(a) in the +ve x direction (b) in the -ve x direction
(c) zero (d) normal to the x direction

7- The increase of the concentration of holes in the +ve x direction leads to a diffusion current which is ……..
(a) in the +ve x direction (b) in the -ve x direction
(c) zero (d) normal to the x direction

8- The increase of the concentration of electrons in the +ve x direction leads to a diffusion current which is …….....
(a) in the +ve x direction (b) in the -ve x direction
(c) zero (d) normal to the x direction

9- For a semiconductor at equilibrium,
(a) the Fermi level must be zero (b) the Fermi level must be constant in space
(c) the temperature must be zero (d) the doping must be zero

II.Solve the following problems:

Boltzmann constant $k = 8.617\times10^{-5}$ eV/K, Planck's constant h = 6.63×10^{-34} J.s, $\hbar = h / 2\pi$.

At 300 K:

Material	m_n^*/m_o	m_p^*/m_o	E_G (eV)	n_i (cm^{-3})
Silicon (Si)	1.1835	0.8048	1.12	1×10^{10}
Germanium (Ge)	0.55	0.36	0.66	2×10^{13}
Gallium Arsenide (GaAs)	0.066	0.52	1.42	2×10^{6}

1- An intrinsic Si sample is doped with donors from one side such that $N_d = N_o\exp[-ax]$
a) Find an expression for Ex (electric field) at equilibrium over the range for which $N_d >> n_i$. Also sketch Ex taking a = 1 $(mm)^{-1}$.

b) Sketch the variation of the semiconductor energy bands induced by the electric field computed in V/cm.

2- Figure 1 presents an energy band diagram of non-uniform silicon doped sample of length L, where x_1 is the middle point in the region from 0 to L/3.

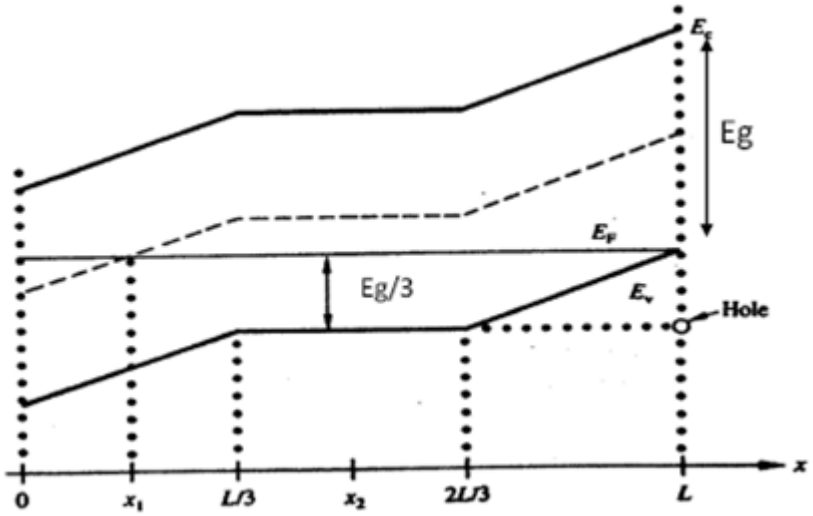

Figure 1

1- The semiconductor type at point x_1 is
(a) Extrinsic (b) Intrinsic (c) Degenerate

2- The semiconductor is degenerate
(a) Near x = 0 (b) Nowhere (c) L/3< x < 2 L/3 (d) Near x = L

3- Do equilibrium conditions prevail? Justify.
(a) Yes (b) No (c) Can't be determined

4- Draw the electric field distribution inside the semiconductor

5- Draw the electrostatic potential inside the semiconductor

6- The hole drift current density (Jpdrift) flowing at $x = x_1$ is

(a) Zero (b) $\mu_p n_i E_g/L$ (c) $3\mu_p n_i E_g/L$ (d) $q\mu_p N_D (kT/q)/L$

7- The electron current density (J_n) flowing at $x = x_1$ is

(a) Zero (b) $\mu_n n_i E_g/L$ (c) $3\mu_n n_i E_g/L$ (d) $D_n [n(x_2) - n(0)]/L$

8- The position of maximum potential energy for electrons is

(a) Near x = 0 (b) at x= L/3 (c) at x= x_1 (d) at x = L

9- At $x = x_2$, p = ? (Hint: use from table n_i, E_g, k for T=300 ^oK)

(a) $7.63 \times 10^6/cm^3$ (b) $1.31 \times 10^{13}/cm^3$ (c) $10^{10}/cm^3$ (d) $1.72 \times 10^{16}/cm^3$

3- Figure 2 presents an energy band diagram of semiconductor sample of length 3L. Answer the following questions:

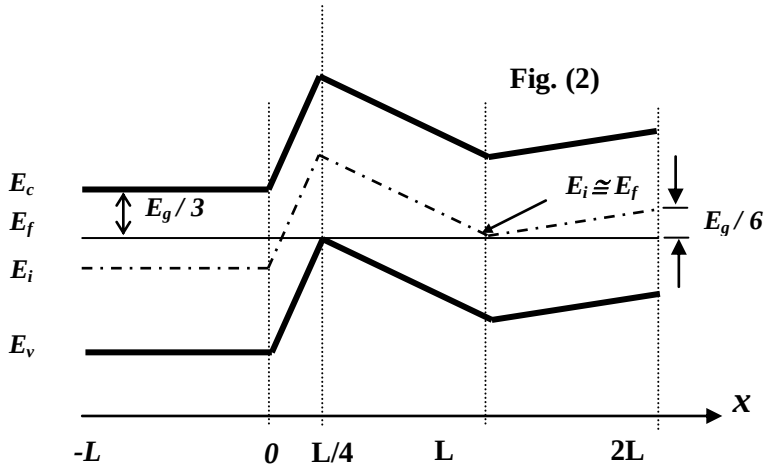

Figure 2

1. Roughly sketch n and p versus x.
2. Plot the electric field inside the semiconductor as a function of x.
3. Sketch the electrostatic potential (V) inside the semiconductor as a function of x.
4. What is the direction of the electron diffusion current at x = L/2?
5. Is the sample connected to external voltage source? Explain how you arrived at your answer.

This work had been prepared with the help of Dr. Wael Fikry and Dr. Tarek Abd El_Kader.

Good Luck ☺