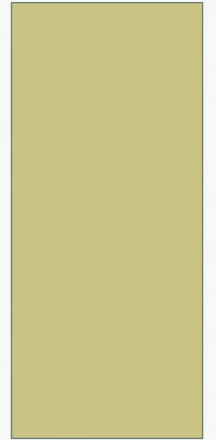


EC233

ELECTRONIC DEVICES 1

SHEET 5 SOLUTIONS



THERMAL EQUILIBRIUM

At thermal equilibrium:

No external effects

No change with time

No electric current

No change in the Fermi level with space (will be proved hereinafter)

PART I:

TRUE OR FALSE

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

- If an electronic system is in equilibrium, it must be in a steady state. ✓
- If an electronic system is in steady state, it must be in equilibrium. ✗
- For a semiconductor in equilibrium, the current must be constant. ✗
- The diffusion coefficient and mobility of electrons in a semiconductor can have totally independent values. ✗

PART II:

CHOOSE THE CORRECT ANSWER

- 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
- .

PART II:

CHOOSE THE CORRECT ANSWER

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

- (b) in the -ve x direction
- (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

- (b) in the -ve x direction
- (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

- (b) in the -ve x direction
- (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

- (b) the Fermi level must be constant in space
- (d) the doping must be zero

PART III:

PROBLEM 1

An intrinsic Si sample is doped with donors from one side such that $N_d = N_0 \exp[-ax]$:

- a) Find an expression for ε_x (electric field) at equilibrium over the range for which $N_d \gg n_i$. Also sketch ε_x taking $a = 1 \text{ (mm)}^{-1}$.
- b) Sketch the variation of the semiconductor energy bands induced by the electric field computed in V/cm.

PART III:

PROBLEM 1

- At equilibrium:

$$J_n = J_{drift} + J_{diffusion} = 0$$

$$J_n = qn\mu_n\varepsilon + qD_n \frac{dn}{dx} = 0$$

$$\varepsilon_x = -\frac{D_n}{n\mu_n} \frac{dn}{dx} \quad \text{-----1}$$

Since $N_d \gg n_i$: $n \approx N_d = N_0 \exp[-ax]$:

$$\frac{dn}{dx} = -aN_0 \exp[-ax]$$

Substituting with both n and $\frac{dn}{dx}$ in 1:

$$\varepsilon_x = -\frac{-D_n}{N_0 \exp(-ax)\mu_n} aN_0 \exp(-ax) = \frac{D_n a}{\mu_n}$$

PART III:

PROBLEM 1

$$\varepsilon_x = \frac{D_n a}{\mu_n}$$

For $a = 1 \text{ mm}^{-1}$: $\varepsilon_x = \frac{D_n a}{\mu_n} = 25 \text{ mV}(1 \times 10^3) = 25 \text{ V/m}$

PART III:

PROBLEM 1

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

Since ϵ_x is positive, ***Slope***($E_{c/v/i}$) is also positive.



Before Diffusion



After Diffusion