# Assignment 1

Semiconductor Materials

## Problem 1

A piece of Si material is doped with phosphorus at a concentration of $N_D = 1 \times 10^{15}$ dopants per $cm^3$. What is the equilibrium concentration of mobile holes in the material at room temperature? Give your answer in units of carriers per $cm^3$.

Given information (available in workspace):

- $n_i = 1.5 \times 10^{10}$ carriers per $cm^3$
- $N_D = 1 \times 10^{15}$ donors per $cm^3$

## Problem 2

A piece of Si is doped with boron at a concentration of $1 \times 10^6$ dopants per $cm^3$. What is the equilibrium concentration of mobile holes in the material at room temperature? Give your answer in carriers per $cm^3$.

Given information (available in workspace):

- $n_i = 1.5 \times 10^{10}$ carriers per $cm^3$
- $N_A = 1 \times 10^6$ donors per $cm^3$

## Problem 3

A piece of intrinsic single-crystal Si is 2 mm long, 100 µm wide and 100 µm thick. What is its resistance?

Given information (available in workspace):

- $n_i = 1.5 \times 10^{10}$ carriers per $cm^3$
- $q = 1.6 \times 10^{-19}$ Coulombs per carrier
- $L = 2$ mm
- $W = 100$ µm (remember to convert to cm!)
- $t = 100$ µm (remember to convert to cm!)
- $\mu_n = 1.35 \times 10^3$ $cm^2/(V * s)$
- $\mu_p = 4.8 \times 10^2$ $cm^2/(V * s)$

## Problem 4

A piece of extrinsic single-crystal Si is doped with Boron at a concentration of $N_A = 1 \times 10^{13}$ acceptors per $cm^3$, AND is doped with Phosphorous at a concentration of $N_D = 1 \times 10^{16}$ donors per $cm^3$. What is the concentration of mobile holes in the material? Give your answer in units of carriers per $cm^3$, and round to two significant figures.

Given information (available in the workspace):

- $n_i = 1.5 \times 10^{10}$ carriers per cm$^3$
- $N_A = 1 \times 10^{13}$ carriers per cm$^3$
- $N_D = 1 \times 10^{16}$ carriers per cm$^3$

## Problem 5

A Si device is connected in a circuit such that the total current is 1mA. At a position $x$ in the material, the total diffusion current is 400µA. What is the total drift current at position $x$? Give your answer in µA.

## Problem 6

A homogeneous intrinsic semiconducting material has an intrinsic mobile carrier concentration of $n_i = 1 \times 10^{11}$ carriers per cm$^3$, giving it a resistivity of 46 kΩ/cm. Under strong illumination, the material absorbs photons which increase the carrier concentration to $1 \times 10^{14}$ carriers per cm$^3$. What is the new resistivity after illuminating the material?

## Problem 7

A semiconducting material has a mobile electron concentration given by $n(x) = N_0 \exp(-x/100\text{nm})$, where $N_0 = 1 \times 10^{12}$ electrons per cm$^3$. What is the electron diffusion current density at position $x = 1$µm? Give your answer in A/cm$^2$.

Given Information (available in the workspace):

- $U_T = 26$ mV
- $\mu_n = 1.1$ k cm$^2$/V $*$ s
- $N_0 = 1 \times 10^{12}$ carriers per cm$^3$

## Problem 8

A piece of intrinsic silicon carries an electron drift current density of Jn=1 uA/cm$^2$. If the mobility of electrons is $\mu_n = 1.5$ k cm$^2$/V $*$ s, calculate the electric field strength in the material. Give your answer in V/cm.

Given information (available in the workspace):

- $\mu_n = 1.5$ k cm$^2$/V $*$ s
- $n_i = 1.5 \times 10^{10}$ electrons per cm$^3$
- $q = 1.6 \times 10^{-19}$ Coulombs per electron