Learning Objective: Carrier, Dopant, Carrier Concentration, Doping

Problem 1. Silicon (Si) is doped with 2×10^5 atoms/cm^3 of Boron and 2×10^{15} atoms/cm^3 of Phosphorous at $T = 300$ K.

(a) The doped Silicon is p-type or n-type?

(b) Calculate the **intrinsic carrier concentration** of Silicon, using the constants given in Table 1.

(c) Calculate the **electron and hole concentration**.

(d) Suppose the doped Silicon described above has a length of 2 μm and a cross-sectional area of 1.5 μm^2. Calculate the **current through the Silicon sample** if 2.5 V voltage is applied. (use $\mu_n = 1320$ cm^2/V/s, $\mu_p = 460$ cm^2/V/s)

Learning Objective: Resistivity, Conductivity, Drift Current

Problem 2. Suppose a doped Silicon (Si) sample has a resistivity $\rho = 0.67$ Ω·cm at $T = 300$ K. (Use $\mu_n = 1000$ cm^2/V/s, $\mu_p = 400$ cm^2/V/s)

(a) Calculate the **conductivity** of the doped Silicon material.

(b) Suppose the doped Silicon sample is *n-type*, calculate the **minimum concentration of Boron and Phosphorous atoms** being added.

(c) Suppose the doped Silicon sample is *p-type*, calculate the **minimum concentration of Boron and Phosphorous atoms** being added.

Learning Objective: Diffusion Current

Problem 3. The total current in a semiconductor sample is composed of electron drift current and hole diffusion current at 300 K, where the total current density is 4.8 A/cm^2. The electron concentration is 10^{16} cm^{-3}. The hole concentration is given by

$$p(x) = 10^{15}\exp\left(-\frac{x}{L}\right)\ \text{cm}^{-3}$$

where $x \geq 0$ and $L = 12$ μm. (Use $\mu_n = 1000$ cm^2/V/s, $\mu_p = 480$ cm^2/V/s)

(a) Determine the **hole diffusion current density** as a function of x.

(b) Determine the **electron drift current density** as a function of x.

Table 1: Semiconductor Constants (Textbook Table 1.3)

Material	E_g (eV)	B (cm^{-3} K$^{-3/2}$)
Silicon (Si)	1.1	5.23×10^{15}
Gallium Arsenide (GaAs)	1.4	2.10×10^{14}
Germanium (Ge)	0.66	1.66×10^{15}