# 25PY101: Engineering Physics

Module 1 – Unit 1

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# Assignment 2: Carrier drift

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## 1 Drift under low field regime

Reference: Problem 5.9 [Neamen]

Under low field, the drift velocity $v_d$ of charge carrier is proportional to the applied electric field $E$

$$v_d = \mu E$$

where $\mu$ is the mobility of the carrier. This proportionality is valid only if the drift velocity is small compared to the thermal velocity $v_{th}$. This occurs in the **low field regime** where the applied field does not appreciably alter the thermal energy of the electron. Therefore, the low field regime is defined by [1]

$$\frac{v_d}{v_{th}} \ll 1.$$

**Problem:** A GaAs semiconductor resistor is doped with donor impurities at a concentration of $N_d = 2 \times 10^{15}\,\mathrm{cm}^{-3}$ and has a cross-sectional area of $5 \times 10^{-5}\,\mathrm{cm}^2$. A current of $I = 25\,\mathrm{mA}$ is induced in the resistor with an applied bias of $5\,\mathrm{V}$.

(a) Determine the length of the resistor.

(b) Using the results of part (a). calculate the drift velocity of electrons.

(c) What is the electric field induced in the semiconductor?

(d) What is the thermal velocity of electron at 300 K?

(e) What is the ratio of drift velocity to the thermal velocity?

(f) Is the drift motion in the low field regime?

[1] A common heuristic in semiconductor physics is to consider a ratio less than 0.1 as $\ll 1$.

## 2 Drift under high field regime

Reference: Section 5.1.4 – Velocity Saturation [Neamen]
When the electric field is high enough for the drift velocity to become comparable to the thermal velocity, the drift velocity saturates. This is the **high field regime**.
**Problem:** Use the velocity-field relations for Si and GaAs as shown in Figure. 2 to determine the transit time of electrons through a 1 µm distance in these materials for an electric field of [Hint: This is a log-log plot.]

(a) $1\,\mathrm{kV\,cm^{-1}}$

(b) $50\,\mathrm{kV\,cm^{-1}}$

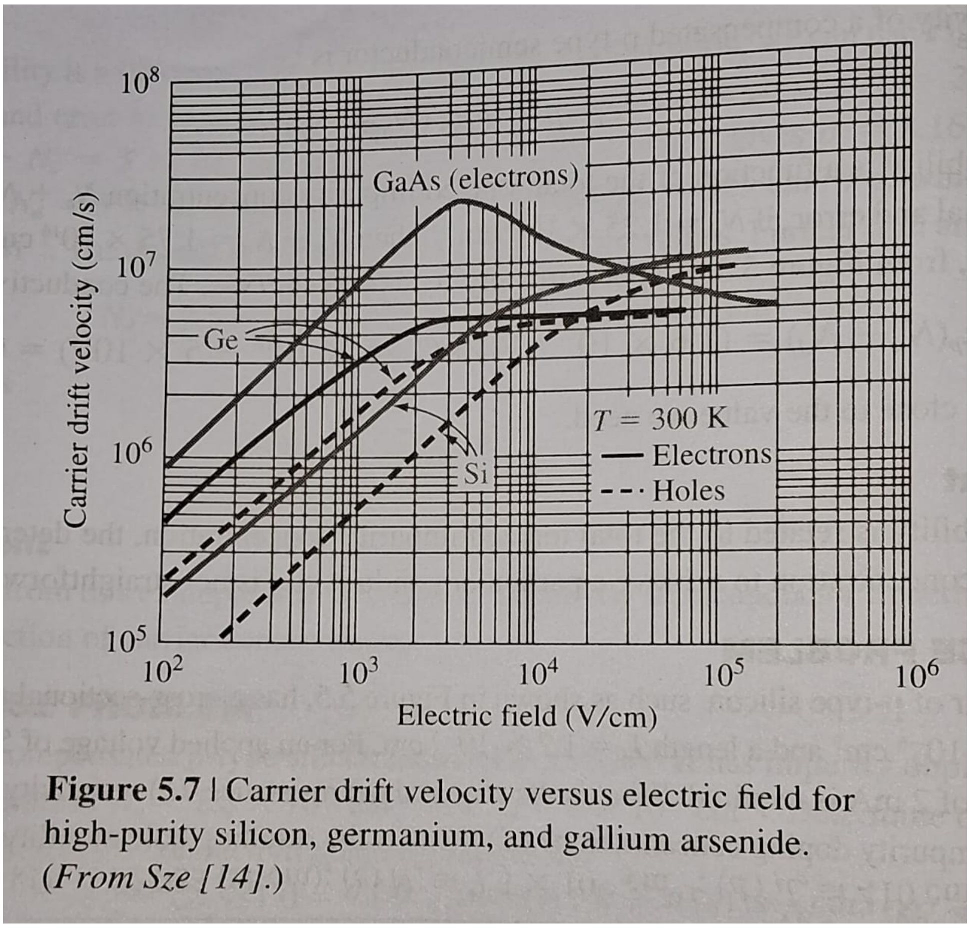


Figure 1: Taken from Neamen.

*End of Assignment*