25PY101: Engineering Physics

Module 1 – Unit 1

Course instructor: Dr. Sreekar Guddeti

October 25, 2025

Assignment 3: Hall effect

---

1 Characterization of extrinsic semiconductor

Reference: Section 5.4 The Hall effect [Neamen]

The Hall coefficient R_H is defined as the Hall field E_H per unit current density j_x per unit magnetic field B_z

$$R_H := \frac{E_H}{j_x B_z} \tag{1}$$

For an extrinsic semiconductor, R_H is related to the majority carrier concentration $n($ or $p)$ by

$$R_H = \begin{cases} -\frac{1}{ne} & \text{for n-type} \\ +\frac{1}{pe} & \text{for p-type} \end{cases} \tag{2}$$

The mobility μ is related to R_H and conductivity σ by

$$\mu = \begin{cases} -\sigma R_H & \text{for n-type} \\ +\sigma R_H & \text{for p-type} \end{cases} \tag{3}$$

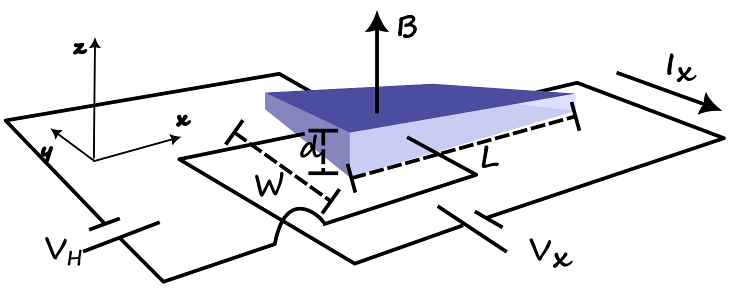

Figure 1: Hall effect measurement geometry.

Problem: Consider a Si sample at 300 K. A Hall effect device has been fabricated with the following geometry –

- $d = 5 \times 10^{-3}\,\mathrm{cm}$

- $W = 5 \times 10^{-2}\,\text{cm}$
- $L = 0.50\,\text{cm}$

The electrical parameters measured are –

- $I_x = 0.50\,\text{mA}$
- $V_x = 1.25\,\text{V}$
- $B_z = 6.5 \times 10^{-2}\,\text{T}$
- The Hall field is $E_H = -16.5\,\text{mV}\,\text{cm}^{-1}$

Determine the following –

(a) the Hall voltage

(b) the conductivity type

(c) majority carrier concentration

(d) majority carrier mobility

2 Characterization of intrinsic semiconductor

Reference: ChatGPT In an intrinsic semiconductor, there is parity between electron and hole concentrations i.e. $n = p$. However, there is a difference in the mobility of electron μ_n and hole μ_p. Usually the electron mobility is higher than the hole mobility.
Statement 1: The contribution of negative Hall voltage from electrons is more than the contribution of negative Hall voltage from electrons.

(a) For a given longitudinal electric field E_x, which carrier type will drift at higher velocity?

(b) Is Statement 1 true? Is yes, prove it. If no, prove otherwise.

(c) The effective Hall coefficient for intrinsic semiconductor is

$$R_H = \frac{p\mu_p^2 - n\mu_n^2}{e(p\mu_p + n\mu_n)^2} \tag{4}$$

(d) Using above expression, show that R_H is usually negative for intrinsic semiconductor.

(e) Calculate R_H for Si at 300 K.

(f) Show that the expression for R_H in Equation. 4 reduces to Equation. 2 for the case of extrinsic semiconductor.

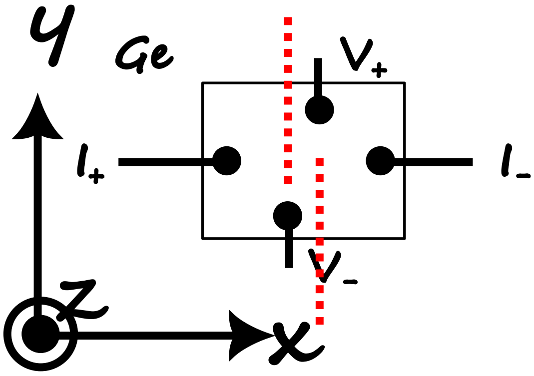

Figure 2: Misaligned voltage probes due to limitation in fabrication capacity.

3 Hall effect measurement geometry

Reference: Problem 5.52 [Neamen]
In fabricating a Hall effect device, the two points at which the Hall voltage is measured may not be lined up exactly perpendicular to the current I_x as shown in Figure. 3.
Problem: Discuss this misalignment will have on the Hall voltage. Show that a valid Hall voltage can be obtained from two measurements –

(i) First with the magnetic field n the $+z$ direction,

(ii) then in the $-z$ direction.

Useful information

	Si	GaAs
μ_n ($\mathrm{cm^2\,V^{-1}\,s^{-1}}$)	1350	8500
μ_p ($\mathrm{cm^2\,V^{-1}\,s^{-1}}$)	480	400

Table 1: Mobility of carriers in Si and GaAs at 300 K.

	Si	GaAs
n_i ($\mathrm{cm^{-3}}$)	1.5×10^{10}	1.8×10^{6}

Table 2: Intrinsic carrier concentration in Si and GaAs at 300 K.

End of Assignment