Hall Effect

KDSMIL001 PHY2004W PHyLAB 2

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Contents

1 Introduction

The Hall Effect is a well known effect that tells us a lot about the way that electric charge conducts in materials. We will use it to determine some properties of the material we're using, which is the p-type semiconductor germanium.

2 Theory

If we have a block of material that conducts electricity and we put some current through it there will be some kind of charge carrier moving through the material. Depending on the material this could be either electrons, which are negatively charged, or positively charged "holes". If the material in question is placed within a magnetic field these moving charges will feel a force in a direction perpendicular to their movement, dictated by

$$\vec{F} = q\vec{v} \times \vec{B} \tag{2.1}$$

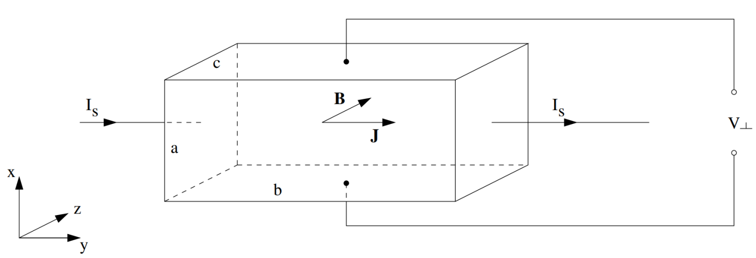
Because this force is perpendicular to the direction of movement of the charge carriers, we will see some charge build-up on one side of the material, and a lack of charge on the other. This means we can measure the voltage drop across the sides of the material. This voltage is governed by the equation

$$V_{\perp} = R_H I_S B / c \tag{2.2}$$

where B is the strength of the magnetic field, I_S is the applied current, and $R_H \equiv \frac{1}{nq}$ is known as the Hall coefficient, with n being the number of charge carriers in the material and q being the amount of charge each carrier can carry.
We can also measure the voltage drop across the length of the material, in the direction the current is flowing. That voltage is given by

$$V_{\parallel} = \frac{I_s b}{\sigma a c} \tag{2.3}$$

where σ is the electrical conductivity of the material. a, b, and c as well as the general set-up of the material is shown below.



By knowing all the other values, we can find values for R_H and σ.
Since we are using germanium, which is a semiconductor, the definition for R_H is

slightly different, it even depends on what type of charge carrier the semiconductor has. For p-type semiconductors, which germanium is, the Hall coefficient is given by

$$R_H = \frac{1.4}{ne} \tag{2.4}$$

with e being the charge on an electron, $e = 1.60217662 \times 10^{-19}\,\mathrm{C}$.

Now all this theory is based on the idea that the material in question stays at the same temperature, since in semiconductors both the number of charges and their mobility within the material are dependent on temperature. The problem is that as we drive a current through the germanium, it is going to heat up thanks to Joule heating. Equation 2.2 and Equation 2.3 are both linear, but since we expect values to change depending on the temperature of the material, we can expect to see some deviation from linearity.

3 Apparatus

- DC power supply.
- 500 Ω resistor.
- Multimeter set to 200 mA scale.
- Multimeter set to 200 mV scale.
- Multimeter set to 20 V scale. (All multimeters have $\pm 1\%$ error.)
- A piece of germanium. (See Figure 3.1.)
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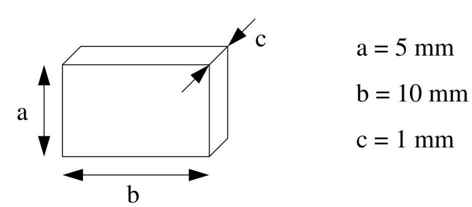

Figure 3.1: The dimensions of the sample of germanium used

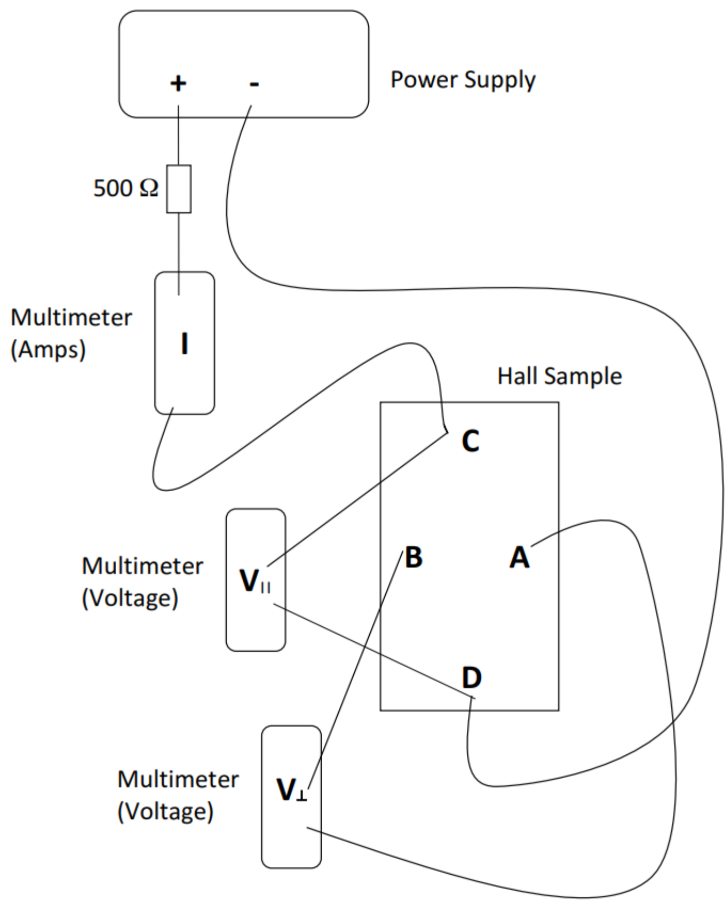

Figure 3.2: The set-up of the circuit