Hall Effect

• Measure the Hall voltage for a semiconductor

• Investigate the relationship between the voltage and temperature
• When a current flows in a magnetic field, the path is deflected and a transverse voltage appears.

• $F = q (E + v \times B)$
Apparatus

Figure 8. Schematic of the Hall effect apparatus.
- Applied voltage: 10V
- Starting temperature at 190K
- Getting inconsistent data sets for multiple runs
- Consider coming in earlier to put in liquid nitrogen to let system stabilize before collecting data
- Applied voltage: 10V
- Starting temperature at 100K
- Came in 2 hrs earlier to fill dewar with liquid nitrogen
- Data samples came out better
- We expect the Hall voltage to decrease with increased temperature since the resistance increases
- E-field from Hall Effect divided by generated E-field
- We expect the E-field from the Hall Effect to decrease with temp causing the hall angle to decrease

-The mobility of the carrier
- Expected to decrease with temperature
Tips for future studies:
- Make sure to turn on the multimeter after the computer is on or else error signs might show up and the program will not run. If error sign is present, restart multimeter.
- Fill dewar before starting experiment to let system stabilize
- Heater increases temperature much faster at lower temperatures (use setting D to increase temp by 0.1 K per data point.
- After taking data, leave system alone because retaking data immediately after a run will result in bad data.

Error Analysis:
- Applied voltage slowly drops throughout experiment
- Heating of coils used to create magnetic field will result in a lower B-field due to more resistance in the wires
- unstable system

Ideas for future studies:
- Understand what causes fluctuations when system is not cooled beforehand
- See effects of different applied voltages
- theoretical study on Hall angle and Hall mobility
- check to see that our theoretical derivation is reasonable since some hand waving was involved (attached)
On page 8, the conductivity as a function of temperature is given by:

$$\sigma = c \frac{ne^2}{m^*} T^{-3/2}$$

Where \(n\) is the charge carrier density, \(e\) is the elementary charge, \(m^*\) is the effective mass of the carrier, \(T\) is the temperature, and \(c\) is some constant. Our group and the TA suspects that the formula should be constant times the expression, not constant equals the expression.

We know that the conductivity is related to resistivity through:

$$\sigma = \frac{1}{\rho}$$

Resistivity is related to the resistance through the relation:

$$\rho = R \frac{A}{l}$$

Where \(A\) is the cross-sectional area of the gallium arsenide crystal and \(l\) is the length.

Though this, we can relate the following:

$$\frac{1}{R} = \frac{A}{\rho l} = \frac{cAne^2}{lm^*} T^{-3/2}$$

The Hall Voltage is calculated by:

$$V_H = \frac{-IB}{dne}$$

Where \(B\) is the magnetic field, \(I\) is the current though the crystal, \(d\) is the thickness of the crystal, \(n\) is the charge carrier density, and \(e\) is the elementary charge.

We would also need the voltage applied, given by:

$$V_A = IR$$

Thus, the current though the crystal is:

$$I = \frac{V_A}{R} = c \frac{V_A An^2}{lm^*} T^{-3/2}$$

We now combine the current with the equation for Hall Voltage to get the Hall Voltage as a function of temperature. Note that we know that \(A\) is the cross section, which is \(A=d*w\).

$$V_H = \frac{-cB V_A An^2}{dne} \frac{1}{lm^*} T^{-3/2}$$
\[ V = -V_A \frac{cwBe}{lm^*} T^{-\frac{3}{2}} \]

We start with an applied voltage of 10V, \( w=0.00165\)m, \( e=1.6\times10^{-19}\)C, \( l=0.00289\)m, and the effective mass of GaAs is \( m^*=0.067m_e=6.1\times10^{-30}\)kg. Not having enough time to study the value of the constant, we set it to 3.0529E-10 to match the data set.

Plugging this into the equation, I get this graph for \( T=100\)K-140K: