Hall Effect
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Abstract: The Hall coefficient of copper was determined to be (5.15 +-0.03475)*10e-11 mm cubed per coulomb which was within 1 percent of the expected value found by N.J Simon, E. Drexler, and R.P. Reed at 5.11 * 10e-11 mm cubed per coulomb[2]. The charge carrier sign for copper was determined to be negative, minus(-), showing that the carriers for copper are electrons.

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I. INTRODUCTION

In a crystal lattice, the collisions of electrons create an electrical resistance. If an magnetic field is applied perpendicular to an electric field then the electrons and current carriers will deflect sideways. A potential difference will appear along with an electric field that appears in that same direction. This method is able to determine the magnetic field and the material's current carriers[1].

II. MEASUREMENTS AND PROCEDURES

Img 1: Hall Experiment Setup with operating Magnet.

To begin collecting data, first, we needed to measure the resistivity of copper at 5 different currents. These currents ranged from 1 to 5 Amps. By measuring the voltage across the transverse conductors on the board we were able to measure the voltage and calculate the resistance and resistivity at five different currents and temperatures. Once the temperatures were found the setup was moved to the large operating magnet that would produce a magnetic field with the circuit board in between the magnets. A Gauss meter was used to measure direction and strength of the magnetic field by placing it within the cardboard that held the circuit setup.

The magnetic field ranged from 0.162T to 0.875T. A power supply was connected to the board by providing a constant current and a voltmeter was used to measure the Hall voltage of the setup which is measured in milliVolts. There were 3 pairs of wires. Red/white, black/white, and green/ white. Green/white were supplied the current, black/white measured the hall voltage, and red/white was used in the initial setup as the transverse conductors. To minimize error in our experiment the leads and wires were wrapped tightly together to avoid any external interference to reduce noise.

$$V = IR \tag{1}$$

$$\rho = \frac{wtR}{l} \tag{2}$$

$$\begin{aligned} R &= R_0 + \alpha(T - T_0) \\ T &= \frac{R - R_0}{\alpha} + T_0 \end{aligned} \tag{3}$$

$$\begin{aligned} R_H &= \frac{1}{nq} \\ n &= \frac{1}{R_H q} \end{aligned} \tag{4}$$

$$\mu = \frac{R_H}{\rho} \tag{5}$$

$$R_H = \frac{V_H t}{IB} \tag{6}$$

EQ(1)'s relationship is used to calculate the resistance of the wires at the respective currents. Then in EQ(2) we are able to use that relationship from EQ(1) to find the resistivity of copper for the dimensions of the copper on the board. Then in EQ(3) we can solve for the temperature that the board is operating at using the relationship

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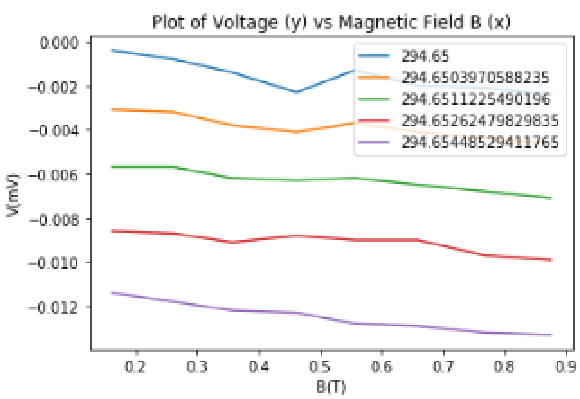
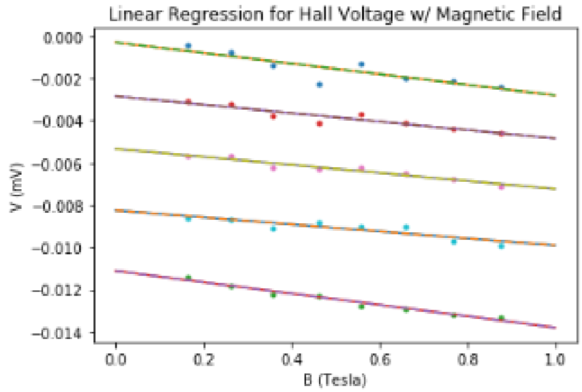
between R, the resistance, alpha, the coefficient of resistance measured at 6.8*10-3/K, and the the initial room temperature. Then after measurements were collected and the Hall coefficient was found EQ(4) was used to determine the carrier density and EQ(5) was used to find the carrier mobility. Equation 6 is used to solve for the Hall voltage using the slope taken from the performed linear regression.

For the respective equations V is the voltage, I is the current, B is the magnetic field, R is the resistance, rho is the resistivity, n is the carrier density, mu is the carrier mobility, T is the temperature, w is the length of the board, t is the thickness of the copper, and l is the length of the board.

III. GRAPHICAL AND STATISTICAL ANALYSIS



The data collected in this experiment measured the hall voltage in milliVolts and was plotted with the corresponding fields for each data set. There were 8 sets or conditioned fields that the board was subjected to. The provided current to the board was from 1 to 5 amps so that with the change in current the temperature would also change. Each line in these plots have relatively similar trends which the observation that can be made here from the data and from the graphs is that the slope or "shape" of each line is primarily straight. To see how the data best fits these graphs the next step would be to take a line of best fit for each set.



The slope of the linear regression is what we will use in EQ(6). The units of the slope is measured in milli-Volts/T which is converted to Volts/T in the analysis. The slope of each line was relatively similar as the variation in trends isn't overwhelmingly drastic in change.

T_0	l(m)	w(m)	t(m)		
294.65	0.08081	0.02481	0.00001		
Temp(K)	Current(A)	R(Ω)	Slope	Slope Err	
294.65	1	0.007627	-0.0025	0.000637	mV/B
294.6504	2	0.007654	-0.002	0.000324	mV/B
294.6511	3	0.007703	-0.00189	0.000214	mV/B
294.6526	4	0.007805	-0.00165	0.000361	mV/B
294.6545	5	0.007932	-0.00268	0.000202	mV/B
RH (mm^3/C)		n	μ	Sign	ρ
-2.50E-11		2.50E+27	0.010664	minus(-)	2.34E-08
-9.98E-12		6.25E+27	0.004247		2.35E-08
-6.31E-12		9.89E+27	0.002668		2.37E-08
-4.13E-12		1.51E+28	0.001724		2.40E-08
-5.36E-12		1.16E+28	0.0022		2.44E-08
Avg(Weighted)					Avg ρ
-5.15E-11	+/0.03475E-11				2.38E-08

Table: Hall Statistics

The observed resistivity of the copper was found to be 2.38 * 10e-8 Ohm-meters at 21.5C (294.65K). The measured Hall Coefficient was calculated using a weighted average from the results of EQ(6) and was found to be (5.15 +-0.03475)*10e-11 mm cubed per coulomb which was within 1 percent of the expected value found by N.J Simon, E. Drexler, and R.P. Reed at 5.11 * 10e-11 mm cubed per coulomb[2]. The charge carrier sign was negative since most metal typically have electrons as the charge carrier. The carrier density and mobility were found and can be observed in the Hall statistic data table which were found at the 5 varying currents.

IV. CONCLUSION

The Hall coefficient of copper was observed to be (5.15 +-0.03475)*10e-11 mm cubed per coulomb. The resistivity of copper was observed to be 2.38*10e-8 Ohm-meters. The observed charge carriers for copper was determined to be electrons.

[1] Adrian C. Melissinos *:Experiments in Modern Physics Date Accessed: 11/19/2021*

[2] N. J. Simon, E. Drexler, and R. P. Reed *:Properties of Copper and Copper Alloys at Cryogenic Temperatures Date Accessed: 11/19/2021*