Lab report 4: The Hall effect

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February 22, 2021

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Abstract

This experiment dealt with the Hall effect in different experimental setups. One being an electromagnet, another being a permanent magnet magnetic cylinder. The first experiment demonstrated that due to the hysteresis loop in germanium, no single I value could return a single B value, therefore confirming the hall probe was required further. The remnant field was calculated to be $0.015 \pm 0.001T$.

The second experiment focused on the electromagnet in which it was verified that $V_H \propto BI$ according to the straight line graphs obtained. From these, a value of the Hall coefficient R_H of $0.01382 \pm 0.0004(m^3/C)$ was obtained which was much in line with the literature value of $10^{-2}(m^3/C)$. The sample was determined to be an n type semiconductor due to the negative sign of R_H returned by the compass. From this the value of carrier concentration could be calculated to be $(4.46 \pm 0.06) \times 10^{14} cm^{-3}$, agreeing with literature values in orders of magnitude of 10^{13}-$10^{18} cm^{-3}$. The values of conductivity(σ) and carrier mobility(μ) were also measured to respectively be $17.49 \pm 1.51S$(literature value being 20S) and $2450 \pm 240cm^2/VS$(literature value being $3900cm^2/VS$-same order of magnitude), which again, agreed with literature values.

The third experiment dealt with using a Halbach magic cylinder permanent magnet to calculate the same values. Those being R_H, N, σ, and μ which were respectively $(0.01435 \pm 0.0007m^3/C)$,$((3.58 \pm 0.01) \times 10^{14} cm^{-3})$,$15.75 \pm 0.3S$ and $2759.6 \pm 60cm^2/VS$. Once again these values are in sufficient agreement with literature but in this case we have a p type semiconductor(more hole as carriers) as determined by the compass. Finally the lock in amplifier was investigated. The phase shift effect on voltage was investigated showing a max value at 20° and a 0 value at 120° (difference of 90° as specified. It was found that at low currents, values of R, resistivity, become difficult to measure and values of R_H and N were also calculated using this. These values respectively being $0.4425 \pm 0.0152(m^3/C)$ and $((0.141 \pm 0.005) \times 10^{14} cm^{-3})$. While the N value here is fine in terms of order of magnitude R_H is somewhat large but this isn't major.

note: references to the bibliography are denoted by |**x**| where x corresponds to the index number of the bibliography entry.

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I. Theory

I. General derivation of useful equations

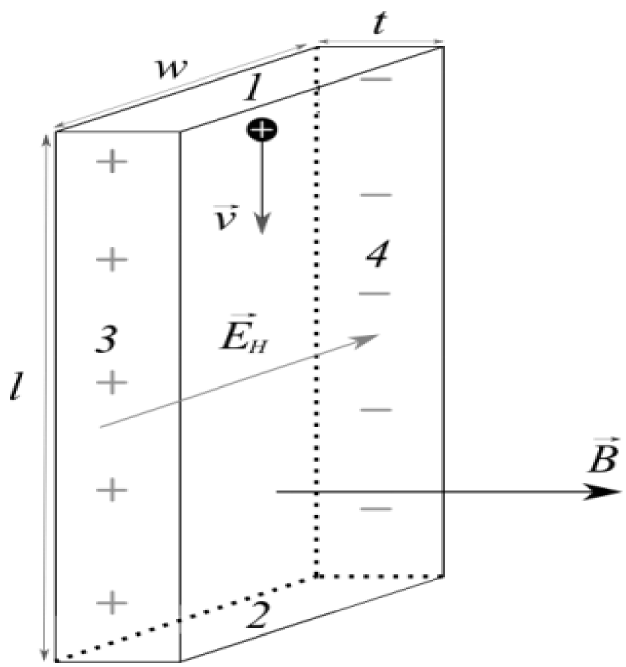

Figure 1: flow of holes|1|

When a metal or semiconductor is placed in a magnetic field $\vec{B}$ with a current density $\vec{J}$, a transverse electric field, known as the hall field $\vec{E_H}$ is created(this being known as the hall effect). This is given significance by the equation

$$\vec{E_H} = R_H\vec{B} \times \vec{J}$$

with R_H being the hall coefficient. Figure 1 shows such a transverse electric field being produced according to

$$\vec{F_B} = q\vec{v} \times \vec{B}$$

When the transverse forces are balanced

$$\vec{F_E} = -\vec{F_B}$$

$$q\vec{E_H} = -q\vec{v} \times \vec{B}$$

$$\vec{E_H} = \vec{B} \times \vec{v}$$

The current density is

$$\vec{J} = Nq\vec{v}$$

$$\vec{E_H} = \frac{1}{Nq}\vec{B} \times \vec{J}$$

Now comparing the 2 equations for $\vec{E_H}$

$$R_H\vec{B} \times \vec{J} = \frac{1}{Nq}\vec{B} \times \vec{J}$$

$$R_H = \frac{1}{Nq}$$

The current and Hall voltage through the material are given by

$$\vec{I} = wt\vec{J}$$

and $V_H = E_H w$ where w and t are the dimensions of the sample. For a given sample

$$V_H = \frac{R_H BI}{t}$$

$$V_H = \alpha_H BI$$

where $\alpha_H = R_H/t$
The conductivity of a sample can be found by utilising the equation

$$\sigma = Nq\mu$$

It can also be yielded by the equation

$$\sigma = 1/\rho$$

where $\rho = \frac{wtR_{12}}{l}$ The hall mobility can then be calculated from these values from the equation

$$\mu = R_H\sigma$$

II. The electromagnet

The image below represents the electromagnet utilised in the first set of measurements.

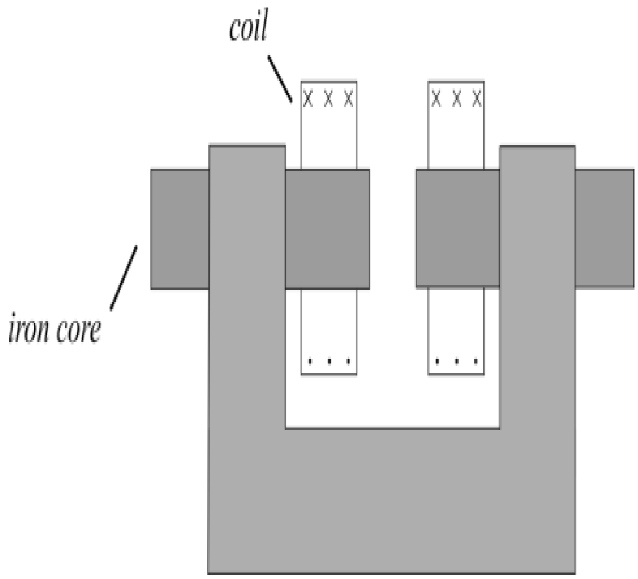

Figure 2: Cross section of the electromagnet. X's and dots indicate the direction of the coil winding. |1|

III. Hysteresis loops

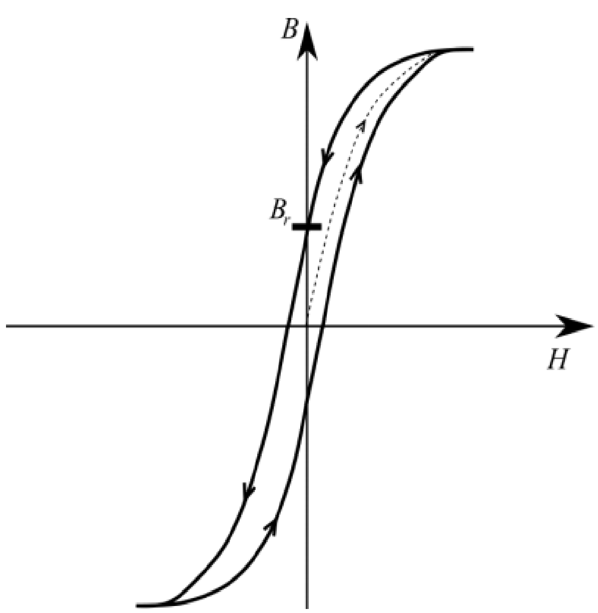

Figure 3: : A hysteresis loop for a soft ferromagnetic material. The dashed line indicates the initial B values of the material as H is increased from zero.|1|

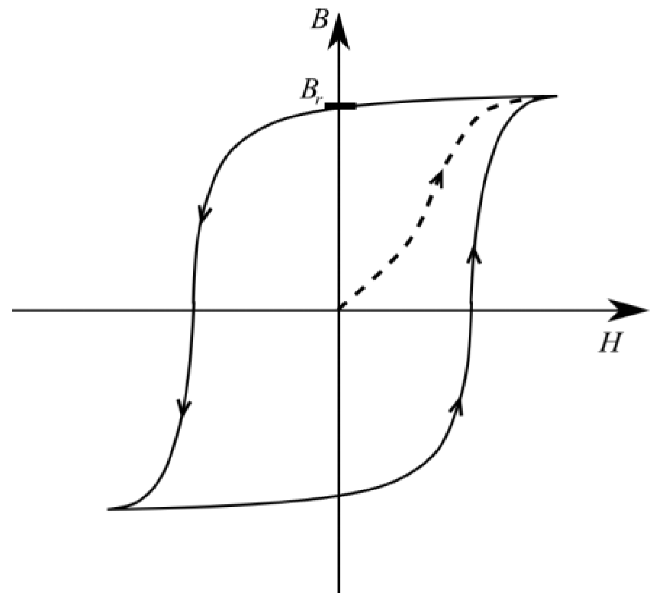

Figure 4: :A hysteresis loop for a hard ferromagnetic material. The dashed line indicates the initial B values of the material as H is increased from zero|1|

The figures above show varying hysteresis loops for soft and hard ferromagnetic materials. A hysteresis loop is a sort of magnetic memory left over from passing current through a ferromagnetic material (i.e) after increasing/decreasing the current or changing the polarity, a small magnetic field will be present at I=0. Soft ferromagnetic materials have thinner hysteresis loops and a small remnant field. Hard ferromagnetic materials have wide hysteresis loops and a large remnant field as shown.

IV. The Hallbach magic cylinder

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A Halbach array is a special arrangement of permanent magnets that increases the magnetic field on one side of the array while cancelling the field to near zero on the other side. This is achieved by having a spatially rotating pattern of magnetisation.

The rotating pattern of permanent magnets (on the front face; on the left, up, right, down) can be continued indefinitely and have the same effect. The effect of this arrangement is roughly similar to many horseshoe magnets placed adjacent to each other, with similar poles touching.

V. The lock in amplifier

.

The lock in amplifier is a method by which one can filter noise from the "true" signal buried within.

The lock in amplifier has a dc offset which is removed. This then causes a totally positive signal to be half below the x axis and half above it. The reference or target signal is then mixed with this noisy signal. We can then time average this mixed signal. This will remove the noise as half was below the axis and half above it effectively averaging to 0. The part of the original signal that is in phase with this new signal will then constructively interfere with it, yielding a signal at twice the size. This allows noise to be filtered out very effectively. Below is a diagram indicating the different signals spoken of

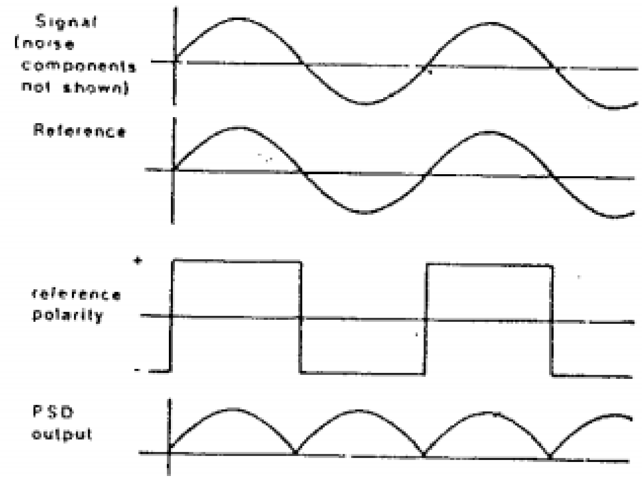

Figure 5: Sample of how signals in a lock in amplifier might appear|1|

VI. Determining carrier type

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The carrier type can be determined by the use of a compass. The compass will have a needle with a dial ranging from negative to positive values. If a circuit has more than electrons there will be a shift towards the positively charged end of the battery. This returns a negative reading on the compass since it is the opposite of conventional current flow(positive to negative). The opposite is true for the p type semiconductor(which returns a positive value).

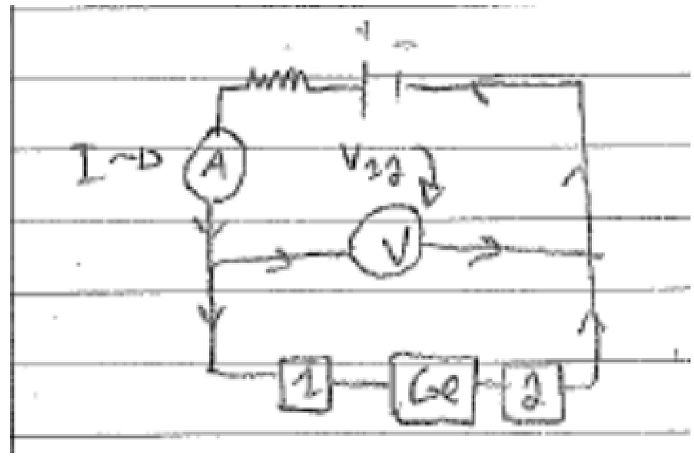

Figure 6: diagram of circuit with compass for first sample|1|

We would place the magnetic compass with the needle in the middle of this apparatus. In order to make the needle swing left in the negative direction the needle must be swung into the negative x direction. In order for the need to swing in the p type direction, the needle must go towards the positive x direction.

II. Experimental procedure

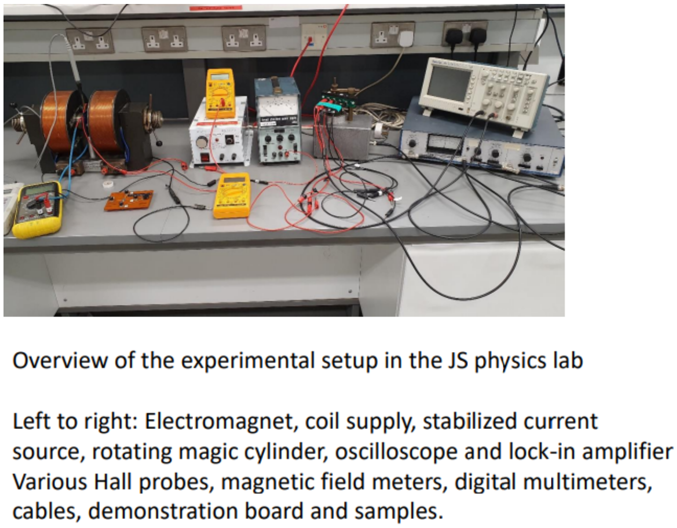

Figure 7: General Experimental setup|1|

I. Experiment 1:To investigate the characteristics of an electromagnet

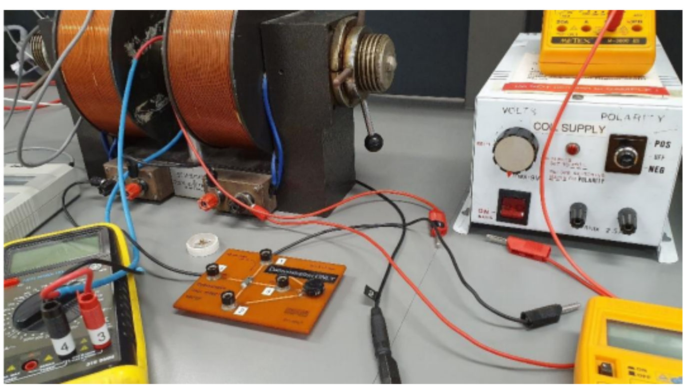

Figure 8: Specific equipment and setup for experiment 1|1|

The apparatus was set up as in the image above and a hall probe was used to measure the magnetic field across a set of coils through which current ran at different values(measured with the multimeter). Measurements of I vs B were taken for both polarities and for increasing and decreasing values, yielding 4 datasets all overlaid onto the same graph. The remnant magnetisation was calculated by taking the value of the magnetic field on either side of the x axis when x=0. This is the magnetisation that is "left over" so to speak.

II. Experiment 2:Measurements of V_H using the electromagnet

Figure 9: Specific equipment and setup for experiment 2|1|

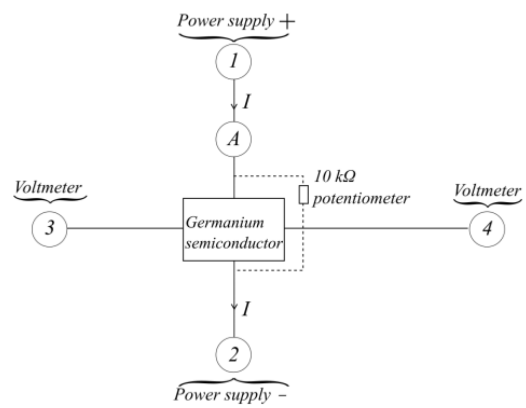

Figure 10: diagram of experiment 2 setup|1|

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The apparatus is setup as above and values of voltage are measured for changing magnetic field. This is repeated 3 times for current values of I=10mA,I=20mA and I=30mA respectively. The aims of this experiment are first of all to demonstrate a proportionality between V and BI which can be observed by the nature of the graph. The second is to determine the sign and magnitude of R_H given by the formula

$$R_H = t\alpha_H$$

where α is

$$\frac{m(slope of graph)}{I}$$

for each respective I value. An average R_H can then be found from these.

The final part of this experiment was to measure the carrier concentration and hence determine the charge mobility. Once R_H was found, the carrier concentration could be determined by utilising the formula

$$N = \frac{1}{R_H q}$$

The conductivity was also required to measure the mobility which was yielded by the formula

$$\sigma = \frac{l}{wtR_{12}}$$

. Where l, w and t are the length, width and thickness with values of 10mm, 5mm and 1mm and an error of 0.02mm and R_12 is the resistance measured across V_1 and V_2. This is then followed by

$$\mu = \frac{\sigma}{Nq}$$

III. Experiment 3:: Measurements of V_H using a magic cylinder permanent magnet.

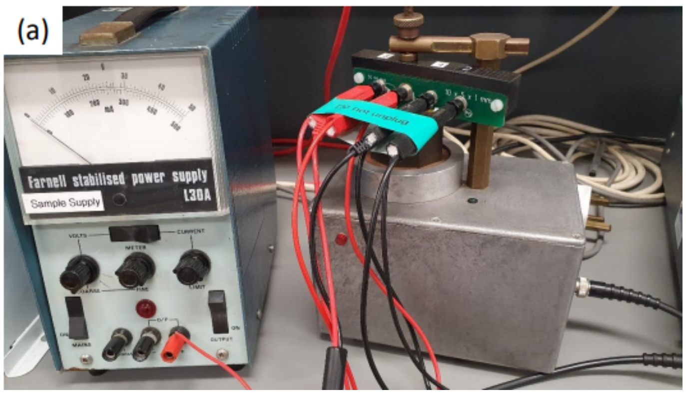

Figure 11: Rotating magic cylinder with electrical connections to germanium sample|1|

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The magic cylinder was rotated and measurements of voltage were taken for current values of 0,5,10,15,20 and 25 mA. This was done in both directions and the results were then tabulated.

Maximising field in both directions, the magic cylinder was rotated and values of voltage were measured for the same values of current. These were tabulated and a resistivity, and μ were calculated as before.

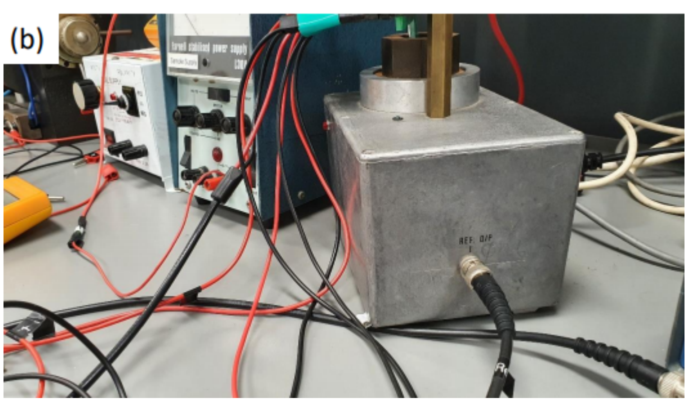

Figure 12: Reference signal out from integrated rotational sensor in magic cylinder setup|1|

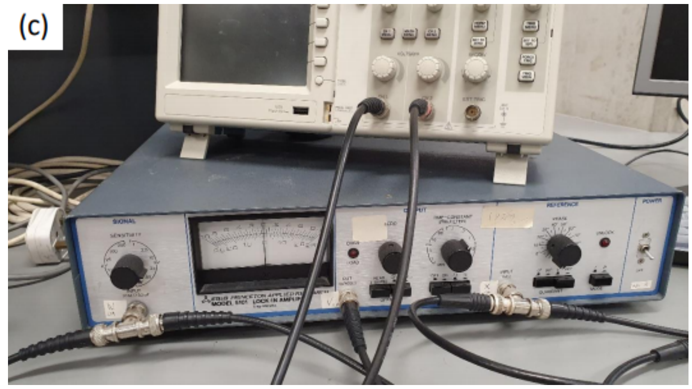

Figure 13: Lock-in amplifier with reference signal from rotating magic cylinder magnet

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The apparatus was setup with the reference signal connected as in figures 6 and 7. To measure the effect of the phase setting, θ, the voltage was measured and plotted over a range of 180°. The value of θ at which the output is a maximum was then determined from the graph. It was also verified that the maximum output of the voltage signal was equal to the RMS value of the equal signal.

Note that the phase setting for maximum output may not stay constant, so for each separate measurement of V_H this setting was recorded and found. This was done by looking for the value of θ giving zero output and then adding 90°. V_H was measured for I= 5,10,15,20mA. From this R_H and N were determined.

Because of its noise rejection capability, the LIA can give a much greater signal/noise ratio. To measure this ratio, V_H was measured for I=1,0.5,0.1mA. These results were tabulated along with values of θ and V_H/I.

III. Results and discussion

I. Experiment 1: To investigate the characteristics of an electromagnet

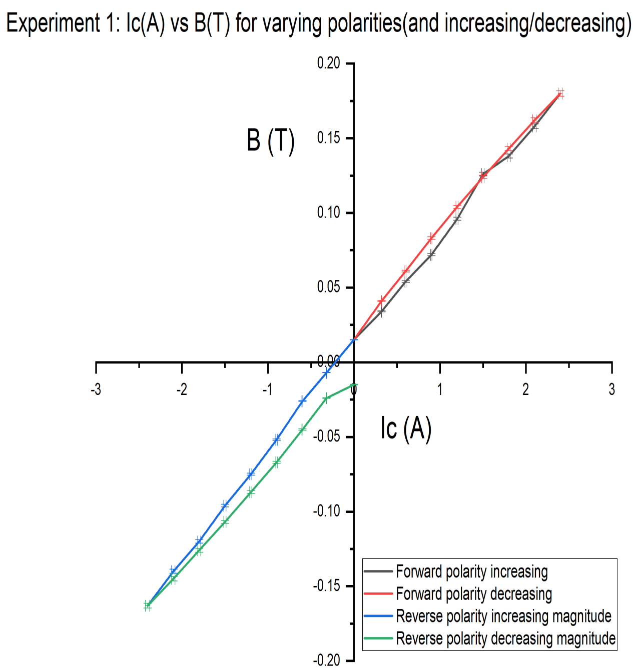

Figure 14: I_C vs B for different conditions

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It is clear from the graph above that varying that there is no unique B value for a given I_C value. Due to the presence of a hysteresis loop, a separate calibration would be necessary for each polarity and when considering whether the current is increasing or decreasing. In subsequent measurements of V_H we measured,therefore, directly with the Hall probe gaussmeter.

It should be noted that the value of the remnant magnetisation can be found at $\pm 0.015T$. This signifies the point at which the magnetic field should be zero but is not, due to remaining or "remnant" magnetisation.

II. Experiment 2: Measurements of V_H using the electromagnet

II.1 To show that $V_H \propto BI$

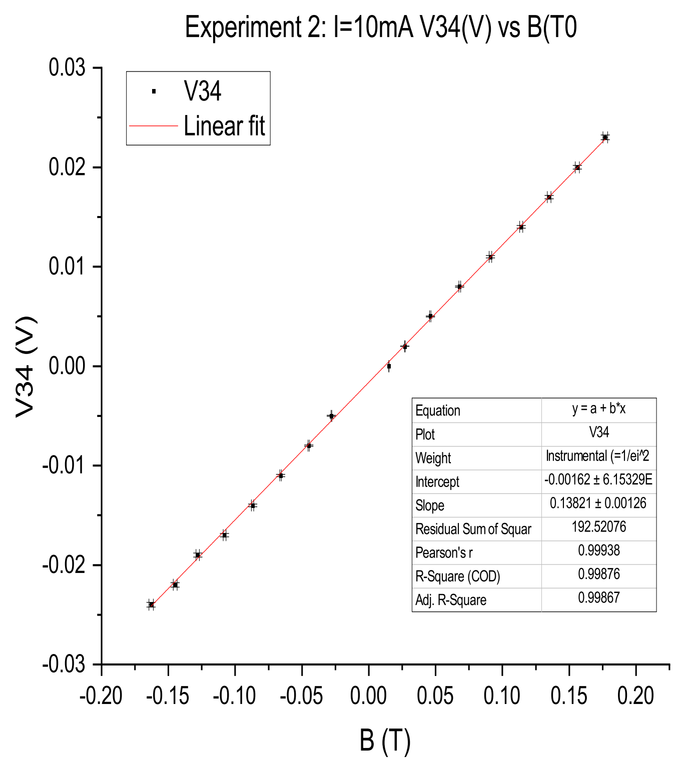

Figure 15: $V_{34}(V)$ vs B(T) for I = 10mA

$$V_{34} = \alpha_H BI + \beta I$$

$$y = mx + c$$

$$m = 0.13821 \pm 0.00126 (V/T), c = -0.00162 \pm 0.000615 (T)$$

$$\frac{m}{I} = \alpha_H = \frac{0.13821 \pm 0.00126}{10 \times 10^{-3}} = 13.821 \pm 0.126 (V/TA)$$

$$\beta = \frac{c}{I} = \frac{-0.00162 \pm 0.000615}{10 \times 10^{-3}} = -0.162 \pm 0.0615 (\Omega)$$

$$R_H = t\alpha_H = ((1 \times 10^{-3}) \pm (0.02 \times 10^{-3})(13.821 \pm 0.126)$$

$$R_H = 0.013821 \pm 0.0004 (m^3/C)$$

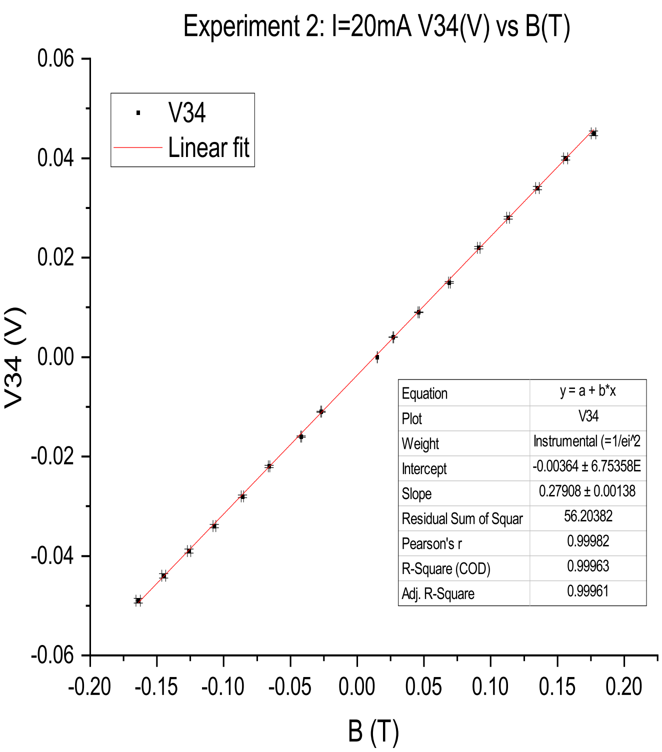

Figure 16: $V_{34}(V)$ vs B(T) for I = 20mA

$$V_{34} = \alpha_H BI + \beta I$$

$$y = mx + c$$

$$m = 0.27908 \pm 0.00138 (V/T), c = -0.00364 \pm 0.000675 (T)$$

$$\frac{m}{I} = \alpha_H = \frac{0.27908 \pm 0.00138}{20 \times 10^{-3}} = 13.954 \pm 0.0069 (V/TA)$$

$$\beta = \frac{c}{I} = \frac{-0.00364 \pm 0.000675}{20 \times 10^{-3}} = -0.182 \pm 0.03375 (\Omega)$$

$$R_H = t\alpha_H = ((1 \times 10^{-3}) \pm (0.02 \times 10^{-3})(13.954 \pm 0.0069)$$

$$R_H = 0.013954 \pm 0.000285 (m^3/C)$$

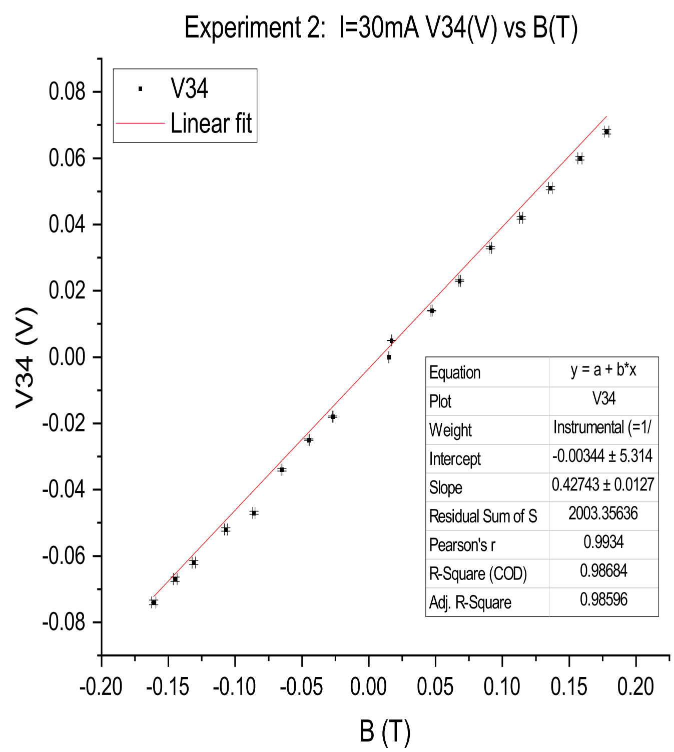

Figure 17: $V_{34}(V)$ vs B(T) for I = 30mA

$$V_{34} = \alpha_H BI + \beta I$$

$$y = mx + c$$

$$m = 0.42743 \pm 0.00127 (V/T), c = -0.00344 \pm 0.0005314 (T)$$

$$\frac{m}{I} = \alpha_H = \frac{0.42743 \pm 0.00127}{30 \times 10^{-3}} = 14.247 \pm 0.423 (V/TA)$$

$$\beta = \frac{c}{I} = \frac{-0.00344 \pm 0.000675}{30 \times 10^{-3}} = -0.1146 \pm 0.01771 (\Omega)$$

$$R_H = t\alpha_H = ((1 \times 10^{-3}) \pm (0.02 \times 10^{-3})(14.247 \pm 0.423)$$

$$R_H = 0.014247 \pm 0.049 (m^3/C)$$

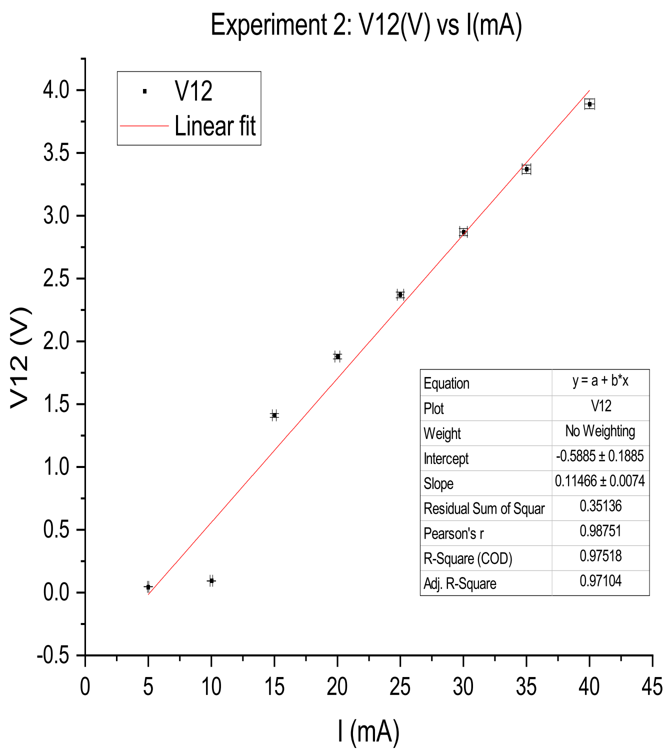

Figure 18: I(mA) vs $V_{12}(V)$ to determine conductivity

Ohm's law is given by the relation V=IR. Since the slope of this graph is equal to V_12/I, this must signify the resistivity of the germanium sample. The slope is equal to

$$m = 0.11466 \pm 0.0074$$

, in other words. The Y axis being in V as opposed to mV must be taken into account, however, so we multiply by a factor of 10^3 to obtain

$$m = 114.66 \pm 7.4$$

$$R_{12} = 115 \pm 7(\Omega)$$

II.2 To measure the magnitude and sign of R_H and hence determine the concentration and type of charge carriers in the germanium crystal.

I have taken an average of the R_H here to be used for subsequent calculations.

$$\frac{0.013954 + 0.013821 + 0.014247}{3} = 0.014007 \pm 0.000177(m^3/C)$$

with the error here being the standard deviation between the three results. The sign of R_H is negative as determined by the compass and therefore, the needle must be in the negative x direction. This means that we have electrons or as the charge carriers for this sample or rather, the sample is an n type semiconductor.

$$R_H = -0.014007 \pm 0.000177(m^3/C)$$

Literature values of R_H for germanium generally seem to be around the order of 10^{-2} which matches what we have above|3|.
Now, keeping in mind that $R_H = 1/Nq$ where N is the concentration of charge carrier in the crystal and q is 1.6×10^{-19} I can solve for N, returning

$$N = \frac{1}{R_H q} = \frac{1}{(1.6 \times 10^{-19})(0.014 \pm 0.0002)}$$

$$N = (4.46 \pm 0.06) \times 10^{20} m^{-3}$$

Putting this into more commonly used units we obtain

$$N = (4.46 \pm 0.06) \times 10^{14} cm^{-3}$$

This is quite in line with literature values which have Germanium at carrier concentrations ranging from orders of $10^{13} - 10^{18}$|2| at room temperature. This must also mean the value of R_H was correct.

II.3 To measure the conductivity and obtain the carrier mobility

The conductivity is given by the formula

$$\sigma = \frac{l}{wtR_{12}}$$

Where the values of l,w and t are 10mm,5mm and 1mm respectively with errors of 0.02mm and R_H is already known.

$$\sigma = \frac{(10 \times 10^{-3}) \pm (0.02 \times 10^{-3})}{((5 \times 10^{-3}) \pm (0.02 \times 10^{-3}))((1 \times 10^{-3}) \pm (0.02 \times 10^{-3}))(115 \pm 7)}$$

$$\sigma = (17.49 \pm 1.51)S$$

where S= 1 siemann= $1m^{-1}\Omega^{-1}$. The literature value of the conductivity of germanium at room temperature is 20S|4| which lines up very well with what was calculated here.From this, we can then determine the carrier mobility by utilising the formula

$$\mu = \frac{\sigma}{Nq} = \frac{(17.49 \pm 1.51)}{((4.46 \times 10^{20}) \pm (0.06 \times 10^{20}))(1.6 \times 10^{-19})}$$

$$\mu = (0.245 \pm 0.024)\frac{m^2}{VS}$$

In standardised units this is

$$2450 \pm 240\frac{cm^2}{VS}$$

The literature value for the electron mobility is given as $3900\frac{cm^2}{VS}$|2|. This is quite different from the obtained value but keep in mind the amount of doping of the sample of germanium we have is unknown. The order of magnitude is what actually carries significance here and that holds for both.

III. Experiment 3: Measurements of V_H using the magic cylinder permanent magnet

III.1 Stationary magic cylinder

The error is 1% of the value(digital instrument)

I(mA)	$V_{34}(B)(V)$	$V_{34}(-B)(V)$	$V_{12}(V)$	V_H	V_0	V_0/V_{12}
5	0.021	-0.008	0.62	0.0245	0.0065	0.010
10	0.043	-0.016	1.24	0.0295	0.0135	0.0108
15	0.064	-0.023	1.87	0.0435	0.0205	0.0109
20	0.086	-0.030	2.52	0.0580	0.0280	0.011
25	0.108	-0.037	3.15	0.0725	0.0355	0.0112

Table 1: Data used for experiment 2 graphs 4

III.2 Maximising field in both directions(+/-) while checking for misalignment

The error is 1% of the value(digital instrument)

I(mA)	$V_{34}(+)$	$V_{34}(-)$	V_{12}	V_H	V_0	V_0/V_{12}	α_H
5	0.0240	-0.008	0.62	0.026	0.008	0.0129	30.59
10	0.048	-0.0268	1.25	0.0308	0.014	0.0112	18.12
15	0.0648	-0.0224	1.87	0.0436	0.0212	0.0113	17.09
20	0.0880	-0.030	2.52	0.0590	0.0290	0.0115	17.35
25	0.108	-0.038	3.16	0.073	0.035	0.0111	17.18

The value of R_{12} for this table(calculated using V_{12}/I was found to be

$$R_{12} = 127 \pm 0.6(\Omega)$$

The average value of

$$\alpha_H = 17.435 \pm 0.4(V/TA)$$

where the error is calculated using the standard deviation of the given values. It should be said that I calculated this average using the last four values of α_H. It is clear the 5mA datapoint is an outlier and this may be because values are hard to measure with low currents.

Table 2: Maximising fields both directions

These values are not consequentially different so I will use the values obtained from the oscilloscope for further calculations, though either set of values is serviceable. The values of α_H calculated above were determined using the formula $V_H = \alpha_H BI$, rearranging to obtain $\alpha_H = V_H/BI$.

III.3 Resulting values

From this value of α_H, a corresponding value of R_H could be calculated. It should be noted, however, that the values obtained in the graphs for experiment 2 had values of α_H which were around 14 V/TA, which is slightly different from the value obtained and indeed the value obtained could be even further off if we had used all 5 datapoints in the calculation and not cut out the obvious outlier.

$$R_H = t\alpha_H = ((1 \times 10^{-3}) \pm (0.02 \times 10^{-3}))((17.435) \pm (0.4))$$

$$R_H = 0.017435 \pm 0.0007(m^3/C)$$

, This hall coefficient is positive as determined by the magnetic compass needle which pointed in the positive x direction. This means we have a p type semiconductor sample where the majority carriers are holes. as before

$$N = \frac{1}{R_H q} = \frac{1}{(0.017435 \pm 0.0007)(1.6 \times 10^{-19})}$$

$$N = (3.58 \pm 0.01) \times 10^{20} m^{-3}$$

In more commonly used units this is

$$N = (3.58 \pm 0.01) \times 10^{14} cm^{-3}$$

This value is of the same order of magnitude as that previously obtained and isn't too far off. If we continue calculating relevant values..

$$\sigma = \frac{l}{wtR_{12}}$$

$$\sigma = \frac{(10 \times 10^{-3}) \pm (0.02 \times 10^{-3})}{((5 \times 10^{-3}) \pm (0.02 \times 10^{-3}))((1 \times 10^{-3}) \pm (0.02 \times 10^{-3}))(127 \pm 0.6)}$$

$$\sigma = (15.75 \pm 0.3)S$$

Once again, the value of the conductivity is reasonably close to the literature value of 20S|4|, given that we don't know the doping of the sample and knowing that the order of magnitude is more what's relevant.

$$\mu = \frac{\sigma}{Nq}$$

$$\mu = \frac{(15.75 \pm 0.3)}{(1.6 \times 10^{-19})((3.58) \pm (0.01)10^{20})}$$

$$\mu = 0.27496 \pm 0.00601 \frac{m^2}{VS}$$

In standardised units for carrier mobility, this comes out as

$$\mu = 2749.6 \pm 60 \frac{cm^2}{VS}$$

The literature value for the carrier mobility of germanium at room temperature for holes was found to be $1900 \frac{cm^3}{VS}$|2|. Once again, it's hard to know how many impurities are within the sample given so this answer isn't totally unexpected.

III.4 Effects of phase on voltage using the lock in amplifier

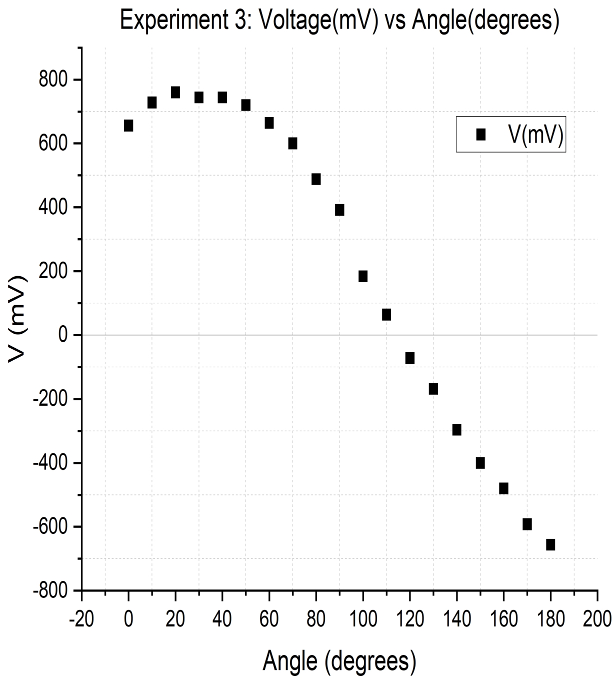

Figure 19: The effect of phase on output voltage(lock in amplifier) angles vs V

The difference between the 0 point and the maximum is 90° as expected (i.e 20° is the max value and 120° is the zero point) and the RMS value is 63mV. Therefore, the oscilloscope functioned for our purposes.

III.5 Using phase setting for maximal response

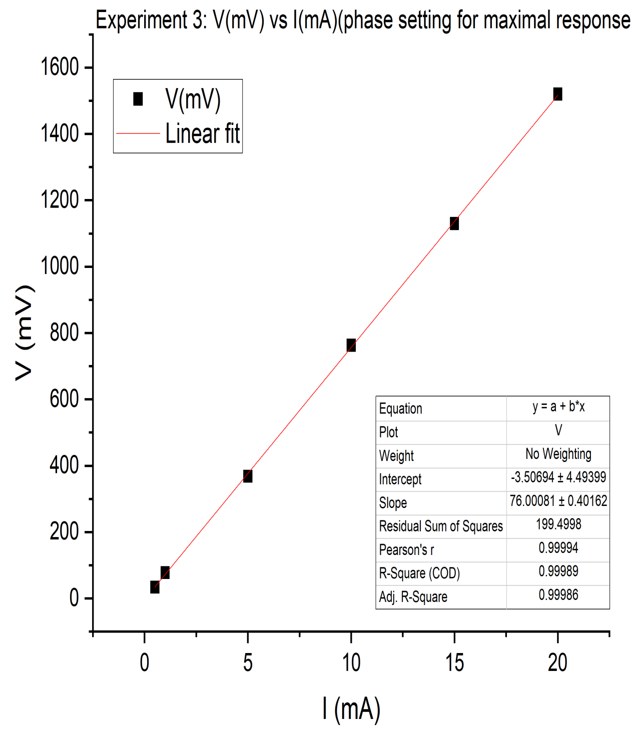

Figure 20: I(mA) vs V(mV) setting for maximal response

The error is 1% of the value(digital instrument)

$I(mA)$	$\theta(V=0)$	θ_{max}	$V_H(\theta_{max})(mV))$	V_H/I	α_H
5	110	20	368	73.6	432
10	115	25	763	76.3	448
15	122.5	22.5	1130	75.3	442.94
20	117.5	27.5	1520	76	447.05

Table 3: Data used for experiment 3 graphs 2- Using phase setting for maximal response-1

These values of α_H are wildly different to those obtained via the stationary magic cylinder but let's continue. As before, an average value of α_H can be calculated with the error being the standard deviation in order to yield a value of R_H.

$$\alpha_H = 442.5 \pm 6.35(V/TA)$$

$$R_H = t\alpha_H = ((1 \pm 0.02) \times 10^{-3})(442.5 \pm 6.35) = 0.4425 \pm 0.0152(m^3/C)$$

$$N = \frac{1}{R_H q} = \frac{1}{(0.4425 \pm 0.0152)(1.6 \times 10^{-19})}$$

$$N = (1.41 \pm 0.05) \times 10^{-19}$$

In order to compare this to the previous answer, let's change the order of magnitude

$$N = (0.141 \pm 0.005) \times 10^{20} m^{-3}$$

or rather ..

$$N = (0.141 \pm 0.005) \times 10^{14} cm^{-3}$$

The answer obtained using the stationary magic cylinder had a carrier concentration that was 26 times larger than the one obtained here. This difference is not egregious since we are dealing with very large orders of numbers here. The order is within range of expected values for germanium.

The error is 1% of the value(digital instrument)

$I(mA)$	θ_{max}	$V_H(V)$	$V_H/I(V/A)$
1	15	78	78
0.5	10	34	68

Table 4: Data used for experiment 3 graphs 2- Using phase setting for maximal response-2

The significance of these two datapoints here is that the value of V_H/I is less uniform the lower the current goes and this is also apparent in the 5mA value. There is deviation from the standard value of 76 V/A.

IV. Error Analysis

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The errors in this experiment were calculated using the device specified errors and propagating these in the given formulae. The method of error propagation was the standard addition of fractional uncertainty when multiplying different elements with different errors. The error of any average quantity found here was taken to be the standard deviation of that distribution.

V. Conclusion

In conclusion, the experiment seems to have been largely successful. It was determined that the first germanium sample was an electron carrier(n-type semiconductor) and the values of R_H,σ,N and μ all matched up quite well with the literature obtained. A proportionality between V and BI was also obtained by the straight line relations observed.

The second sample was found to be a holes carrier(p-type semiconductor) with the relevant values once again conforming to literature. This was verified for the stationary magic cylinder, the cylinder maximised in both directions and for the lock in amplifier.

References

[1] TrinityCollegeDublin/Schoolofphysics/JSlabs[*"The Hall effect" 2020*]

[2] [*"Room temperature properties of semiconductors: Si and Ge"*] https://www.ecse.rpi.edu/~schubert/Educational-resources/Materials-Semiconductors-Si-and-Ge.pdf

[3] [*"Hall effect measurements for determining the band gap energy of undoped germanium, including the conductivity, charge carrier type, concentration and mobility for n-type and p-type doped germanium"*] http://hassan-mirza.com/wp-content/uploads/2017/11/hall-effect-ge.pdf

[4] http://courses.washington.edu/mse170/lecture_notes/luscombeW09/week10.pdf page 2/20 Conducitvity comparison [*"Electrical conductivity"*]

A. Appendix

I. Datatables used to form graphs

The error is 1% of the value(digital instrument)

$I_c(A)$	B(T)	$I_c(A)$	B(T)	$I_c(A)$	B(T)	$I_c(A)$	B(T)
0	0.015	2.4	0.180	0	0.015	-2.4	-0.163
0.32	0.034	2.1	0.162	-0.32	-0.007	-2.1	-0.145
0.6	0.054	1.8	0.143	-0.6	-0.026	-1.8	-0.126
0.9	0.072	1.5	0.124	-0.9	-0.052	-1.5	-0.107
1.2	0.096	1.2	0.104	-1.2	-0.075	-1.2	-0.087
1.5	0.116	0.9	0.083	-1.5	-0.096	-0.9	-0.067
1.8	0.138	0.6	0.061	-1.8	-0.120	-0.6	-0.045
2.1	0.158	0.32	0.041	-2.1	-0.140	-0.32	-0.024
2.4	0.180	0	0.015	-2.4	-0.163	0	0.015

Table 5: Data used for experiment 1 graph

The error is 1% of the value(digital instrument)

	$10mA$		$20mA$		$30mA$	
$I_c(A)$	$V_{34}(V)$	$B(T)$	$V_{34}(V)$	$B(T)$	$V_{34}(V)$	$B(T)$
-2.4	-0.024	-0.163	-0.049	-0.164	-0.074	-0.161
-2.1	-0.022	-0.145	-0.044	-0.145	-0.067	-0.145
-1.8	-0.019	-0.128	-0.039	-0.126	-0.062	-0.131
-1.5	-0.017	-0.108	-0.034	-0.107	-0.052	-0.107
-1.2	-0.014	-0.087	-0.028	-0.086	-0.047	-0.086
-0.9	-0.011	-0.066	-0.022	-0.066	-0.034	-0.065
-0.6	-0.008	-0.045	-0.016	-0.042	-0.025	-0.045
-0.36	-0.005	-0.028	-0.011	-0.027	-0.018	-0.027
0	0	0.015	0	0.025	0	0.015
0.36	0.002	0.027	0.004	0.027	0.005	0.027
0.6	0.005	0.046	0.009	0.046	0.014	0.047
0.9	0.008	0.068	0.015	0.069	0.023	0.068
1.2	0.011	0.091	0.022	0.091	0.033	0.091
1.5	0.014	0.114	0.028	0.113	0.042	0.114
1.8	0.017	0.135	0.034	0.135	0.051	0.136
2.1	0.020	0.156	0.040	0.156	0.060	0.158
2.4	0.023	0.177	0.045	0.177	0.068	0.178

Table 6: Data used for experiment 2 graphs 1,2 and 3

The error is 1% of the value(digital instrument)

V_{12}	I(mA)
—	0
0.466	5
0.936	10
1.41	15
1.88	20
2.37	25
2.86	30
3.37	35
3.89	40

Table 7: Data used for experiment 2 graphs 4

The error is 1% of the value(digital instrument)

θ	V(mV)	θ	V(mV)
0	656	100	184
10	728	110	64
20	760	120	-72
30	744	130	-168
40	744	140	-296
50	720	150	-400
60	664	160	-480
70	600	270	-591
80	488	280	-656
93	392		

Table 8: Data used for experiment 3 graphs 1- Rotating magic cylinder and setting phase of lock in amplifier