# Practical Reports

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# Contents

# A Hall Probe Investigation

CPACs 1, 4 and 5 — 11$^{th}$ November 2019

## I History

The Hall effect is the production of a voltage difference across an electrical conductor, transverse to an electric current in the conductor and to an applied magnetic field perpendicular to the current. In 1879 Edwin Hall was exploring whether magnetic fields interacted with the conductors or the electric current itself, and discovered the Hall effect while he was working on his doctoral degree at Johns Hopkins University in Baltimore, Maryland.[3]
A Hall effect sensor is a device that is used to measure the magnitude of a magnetic field. Its output voltage is directly proportional to the magnetic field strength through it. Hall sensors are commonly used to time the speed of wheels and shafts.[4]

## II Method

### Method

1. Using a clamp stand, situate the Hall Probe between the two poles of the horse shoe magnet.
2. Record the value displayed on the meter.
3. Move the magnet 2cm further.
4. Record the value displayed on the meter alongside the distance from the Hall Probe.
5. Repeate steps 3 and 4 until the magnetic flux density is approximately zero.

**Diagram**

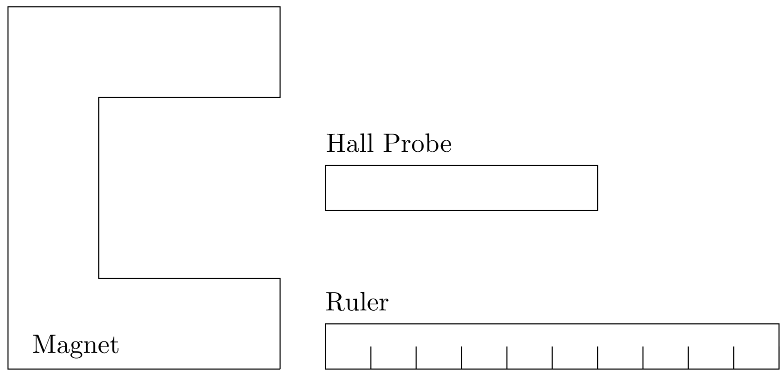


Figure 1: Circuit in Exp. A Method I

**Results**

| distance (cm) | magnetic flux density (mT) |
|---|---|
| 0 | 119.3 |
| 2 | 76 |
| 4 | 26.3 |
| 6 | 11.2 |
| 8 | 5.6 |
| 10 | 3.1 |
| 12 | 1.9 |
| 14 | 1.2 |
| 16 | 0.8 |
| 18 | 0.6 |
| 20 | 0.4 |
| 22 | 0.3 |
| 24 | 0.2 |
| 26 | 0.2 |
| 28 | 0.1 |
| 30 | 0.1 |
| 32 | 0 |

Figure 2: Table for Exp. A Method I

#### Graph

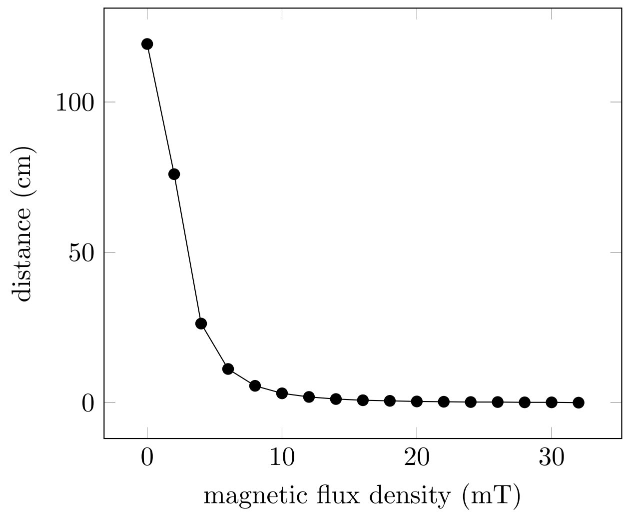


Figure 3: Graph for Exp. A Method I

#### Evaluation

The resolution of the Hall Probe is 0.1mT therefore the uncertainty in the magnetic flux density is $\mp 0.05mT$. There is a negligable uncertainty in the distance it was not measured but changed. As no numerical value was calculated using the data there is no way to find a final uncertainty. The precision of this experiment could be improved by using smaller angle increments to obtain more results. The accuracy could be improved by making sure there is no external magnetic field affecting the results.

#### Conclusion

The shape of the graph above is observed to be inversely proporional to the cube of the distance as expected.[2]

## III Method

#### Method

1. Using a clamp stand, situate the Hall Probe vertically between the two poles of the horse shoe magnet.
2. Record the value on the meter.
3. Rotate the magnet by 10 degrees.
4. Again record the value displayed on the meter alongside angle.

5. Take measurements for angles up to 360 degrees.

**Diagram**

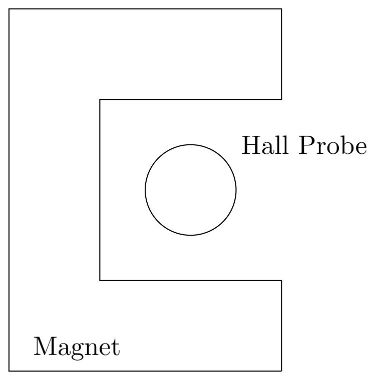


Figure 4: Diagram of Exp. A Method II

**Results**

| angle (deg) | magnetic flux density (mT) |
|---|---|
| 0 | 115.5 |
| 10 | 117.5 |
| 20 | 110.3 |
| 30 | 102.1 |
| 40 | 87.9 |
| 50 | 74.5 |
| 60 | 54.7 |
| 70 | 35.4 |
| 80 | 13.8 |
| 90 | -1.1 |
| 100 | -16.0 |
| 110 | -31.1 |
| 120 | -42.6 |
| 130 | -61.6 |
| 140 | -78.6 |
| 150 | -97.8 |
| 160 | -113.2 |
| 170 | -118.4 |
| 180 | -121.2 |
| 190 | -119.7 |
| 200 | -114.3 |
| 210 | -102.8 |
| 220 | -88.7 |
| 230 | -71.7 |
| 240 | -56.5 |
| 250 | -28.9 |
| 260 | -16.2 |
| 270 | 1.00 |
| 280 | 19.0 |
| 290 | 34.1 |
| 300 | 50.6 |
| 310 | 64.2 |
| 320 | 79.6 |
| 330 | 97.9 |
| 340 | 112.3 |
| 350 | 117.7 |
| 360 | 120.2 |

Figure 5: Table for Exp. A Method II

**Graph**

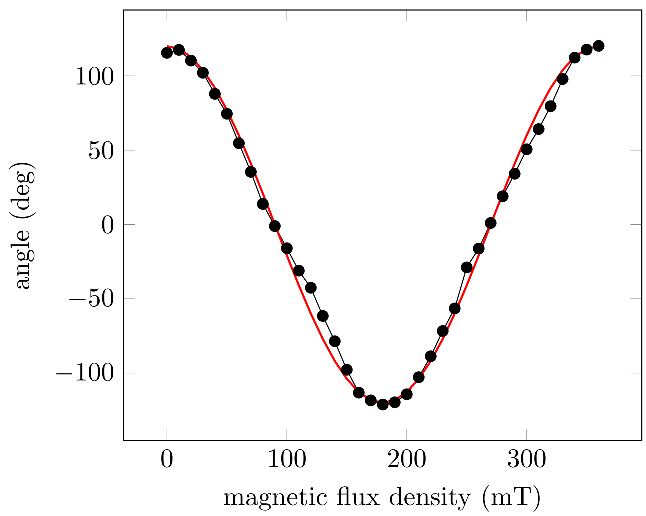


Figure 6: Graph for Exp. A Method II

**Analysis**

As our magnetic field is constant, the magnetic flux density can be defined as:

$$\Phi_B = BS\cos\theta,$$

where $B$ is the magnitude of the magnetic field, $S$ is the area of the surface and $\theta$ is the angle between the magnetic field lines. As shown by the red cosine curve on our graph, our data follows the same format.

**Evaluation**

The resolution of the Hall Probe is 0.1mT therefore the uncertainty in the magnetic flux density is $\mp 0.05mT$. There is a negligable uncertainty in the angle it was not measured but changed. As no numerical value was calculated using the data there is no way to find a final uncertainty. The precision of this experiment could be improved by using smaller angle increments to obtain more results. The accuracy could be improved by making sure there is no external magnetic field affecting the results.

**Conclusion**

The curve obtained by our experiment follows the expected cosine shape showing that valid results where produced.

# B Gas Laws

CPACs 1, 2, 3, 4 and 5 15$^{\text{th}}$ September 2019

## I Boyle's Law

### Abstract

The aim of this experiment is to investigate Boyle's Law which states that:

> *at a constant temperature the pressure, p, and volume, V, of a gas are inversely proportional.*

### Method

1. Loosen the vent screw and move the piston so that the metal disc at the head of the piston is at the centre of the volume scale.
2. Check that the pressure gauge reads an atmospheric pressure of approximately $1 \times 10^5$ Pa.
3. Tighten the vent screw so that you have a fixed mass of gas in the cylinder.
4. Take a series of readings both above and below atmospheric pressure.
5. Loosen the vent screw again and move the piston to the 3.0 mark.
6. Tighten the screw and repeat the measurements with the new mass of gas.

### Results

The following results were gained by following the method. Note that p is the starting position of the piston.

### Graph

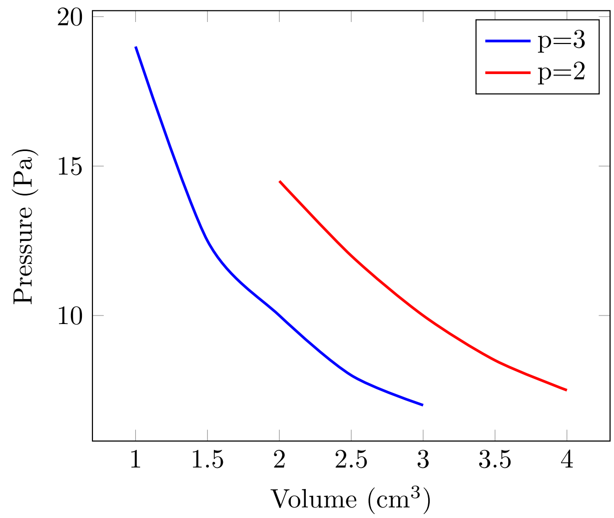


Figure 8: Graph for Exp. B Method I

### Analysis

In this experiment, the volume that the gas was contained in was reduced. As a result, its particles came closer together and collided more frequently with each other and the gas syringe causing the pressure to increase. The graph plotted was expected as Boyels law implies that $p = \frac{k}{V}$.

### Evaluation

As only two sets of data where measured, it is still unclear how the line of pressure against volume changes as the starting position of the piston within the gas syringe is changed. To improve this experiment more measurements from different starting positions should be used.

## II Charles's Law

### Abstract


The aim of this experiment is to determine a Celsius value for absolute zero by investigating Charles's Law which states that:

> *at a constant pressure, the volume, $V$, of a gas is directly proportional to its absolute temperature, $T$.*

**Method**

1. Ensure the syringe is fully closed and connect it to the flask.
2. Connect the flask to the rubber tubing making sure that the seal is airtight.
3. Suspend the flask using a clamp stand inside the large beaker and fill the beaker with water covering the flask.
4. Heat the water with Bunsen burner and take temperature and volume readings at regular intervals until the air in the flask is approximately 50°C.
5. Measure the total volume of the flask and tubing by submerging them in water and measuring the volume of the water removed.
6. The total volume at each temperature will therefore be the total volume previously recorded plus the measurement on the gas syringe.

**Safety**

As a Bunsen burner was used in this experiment the following safety precautions where taken:

- Safety goggles where worn.
- Participants where standing.

**Results**

The following results were gained by following the method.

| Volume ($cm^3$) | Temperature (°C) |
|---|---|
| 0 | 24 |
| 1 | 26 |
| 2 | 27 |
| 3 | 28 |
| 4 | 31 |
| 5 | 33 |
| 6 | 37 |
| 7 | 40 |

Figure 9: Table for Exp. B Method II

#### Graph

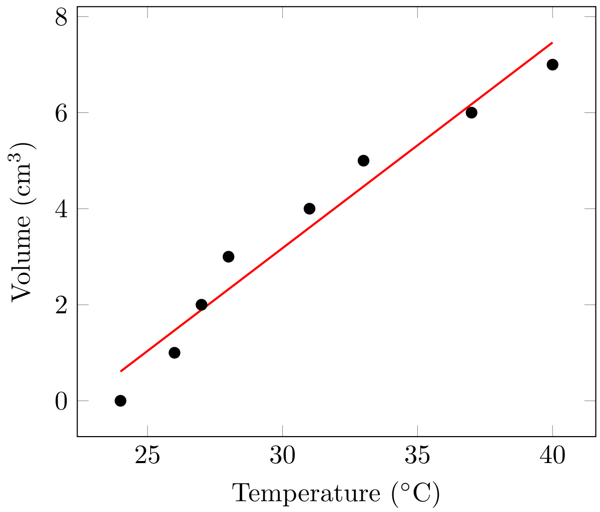


Figure 10: Graph for Exp. B Method II

#### Analysis

When you heat a gas the particles gain kinetic energy. At constant pressure, this means they move more quickly and further apart, and so the volume of the gas increases. It is intuitive that the value of absolute zero is the value at which the volume of an ideal gas is zero as the negative volume cannot exist in classical physics. As a result, we can determine the value of absolute zero by extrapolating our graph. To do this we find our gradient and y-intercept using a line of best fit:

$$m \approxeq 4.28253e - 1$$
$$c \approxeq -9.6687e0 + 166$$

Note that the volume of the flask and tubing has been added to the y-intercept. We can now find the value of absolute zero by finding the x-intercept:

$$0 = (4.28253e - 1)x + -9.6687e0$$
$$x = \frac{-9.6687e0 + 166}{4.28253e - 1} \approxeq -365.04°C$$

#### Evaluation

The last three data points measured were removed as at high temperatures the seal starts to leak.

| Pressure (Pa) | Temperature (°C) |
|---|---|
| 0.98 | 25 |
| 1.00 | 29 |
| 1.02 | 37 |
| 1.04 | 42 |
| 1.06 | 47 |
| 1.08 | 53 |
| 1.10 | 59 |
| 1.12 | 65 |
| 1.14 | 72 |
| 1.16 | 77 |
| 1.18 | 82 |

Figure 11: Table for Exp. B Method III

## III The Pressure Law

### Abstract

The aim of this experiment is to determine a Celsius value for absolute zero by investigating the Pressure Law which states that:

> *at constant volume, the pressure, $p$, of a gas is directly proportional to its absolute temperature, $T$.*


### Method

1. Heat the water in the beaker with a Bunsen burner and record the pressure against temperature.

2. Stop recording when the temperature reaches 100°C and turn off the Bunsen burner.

A few changes had to be made to the method:

- A jolly was used instead of a datalogger as it was certain that the volume inside the vessel would remain the same.

- The pressure gauge was regularly tapped to make sure the correct pressure was being read.

### Results

The following results were gained by following the method.

### Graph

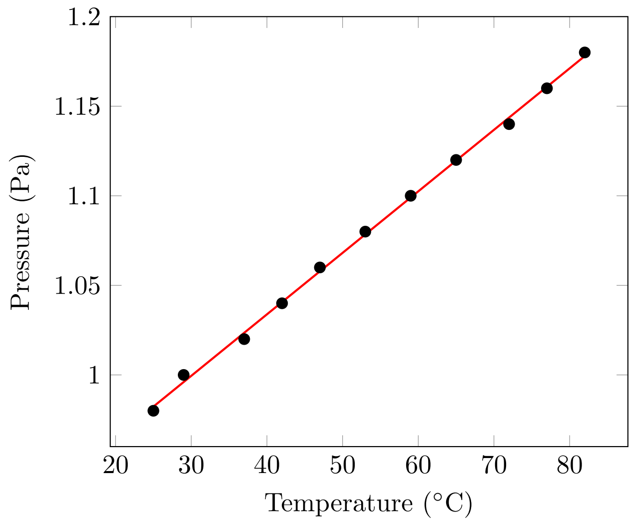


Figure 12: Graph for Exp. B Method III

### Analysis

When you heat a gas the particles gain kinetic energy. This means they move faster. If the volume doesn't change, the particles will collide with each other and their container more often and at higher speed, increasing the pressure inside the container. It is intuitive that the value of absolute zero is the value at which the pressure of an ideal gas is zero as negative pressure cannot exist in classical physics. As a result, we can determine the value of absolute zero by extrapolating our graph. To do this we find our gradient and y-intercept using a line of best fit:

$$m \approxeq 3.4328e - 3$$
$$c \approxeq 8.965e - 1$$

We can now find the value of absolute zero by finding the x-intercept:

$$0 = (3.4328e - 3)x + 8.965e - 1$$
$$x = \frac{-8.965e - 1}{3.4328e - 3} \approxeq -261.16°C$$

**Evaluation**

The uncertainty in the value of absolute zero calculated is:

$$\text{uncertainty}_p = \frac{0.02}{0.98} \cdot 100 = 2.04\%$$
$$\text{uncertainty}_T = \frac{1.0}{25} \cdot 100 = 4.00\%$$
$$\text{total uncertainty} = 2.04 + 4.00 = 6.04\%$$

The error in our value taking absolute-zero to be -273.15 [1] is:

$$\text{error} = \frac{274.15-261.16}{274.15} \cdot 100 = 3.46\%$$

As 3.46% is less than 6.04% the experiment was valid.

# C Resonance Tube

CPACs 1 and 4 $30^{th}$ September 2019

## I Method

1. Connect the loudspeaker to the $4\,\Omega$ output of the signal generator.
2. Set the signal generator to the 100 Hz - 1 kHz range, with the output turned down.
3. Adjust the water level in the tube so that it is between 20 cm and 40 cm from the top.
4. Set the frequency to 300 Hz and increase the output until you can just hear the note.
5. By lowering the funnel, allow the water level to drop, and listen carefully. You should hear the note suddenly get louder and then fainter as the water level passes through the resonance position.
6. Measure the distance, $l_1$, from the top of the tube to the resonance position. Now allow the water level to drop and find a second resonance position, $l_1$.
7. Repeat for different frequencies between 300 Hz and 600 Hz.

## II Results

The wavelength column was caclulated using the formula:

$$c = f \cdot \lambda$$

$$c = f \cdot 2 \cdot (l_2 - l_1)$$

| Frequency (Hz) | $l_1$ (cm) | $l_2$ (cm) | Speed (m/s) |
|---|---|---|---|
| 300 | 28 | 83 | 330 |
| 350 | 24 | 72 | 336 |
| 400 | 24 | 65 | 328 |
| 450 | 18 | 55 | 333 |
| 500 | 17 | 50 | 330 |
| 550 | 15 | 45 | 330 |
| 600 | 13 | 41 | 336 |

Figure 13: Table for Exp. C

## III Analysis

The average speed was $331.85\,\mathrm{m\,s^{-1}}$. The true speed of sound was calculated to be $344.08\,\mathrm{Hz}$ using the following equation with t as $22\,°\mathrm{C}$:

$$c = 331\sqrt{1 + \frac{t}{273}}$$

The percentage difference between the true and calculated speed of sound was:

$$\frac{344.08 - 331.85}{344} \cdot 100 = 3.55\%$$

The uncertainty in our speed of sound was:

$$\frac{0.1}{13} \cdot 100 \cdot 2 = 1.54\%$$

## IV Evaluation

As $1.54 < 3.55$ our results are not accurate. The main reason for this is that there was systematic error in our measurements of $l_1$ and $l_2$. This was because we left a gap between the speaker and tube and did not account for this in our calculations. Another reason could be that as we left a gap between the speaker and tube, not all the sound was directed down the tube.

# D Beta Radiation Absorption

CPACs 1, 3 and 4 $7^{\text{th}}$ December 2019

## I Method

1. Record the background count over 1000 seconds and calculate counts per second, I.
2. Set up the apparatus as shown in the diagram.
3. The Geiger tube should be at a fixed distance of 20cm from the source and this distance should not be altered during the experiment.
4. Record the count rate, $I_0$, with no absorber present.
5. Use a pair of Vernier callipers or a micrometer screw gauge to record the thickness, x, of one of the absorbers.
6. Plot a graph of $\ln I$ against x.
7. Determine the absorption coefficient, $\mu$, for Aluminium from your graph and the equation $\ln I = \ln I_0 - \mu \cdot x$

## II Safety

To reduce the risk of the beta source damaging tissue, the beta source was directed at a wall. A sign was also erected to warn other students to keep clear of the surrounding area.

## III Results

The average background radiation was calculated to be:

$$\frac{368}{1000} = 0.368cps$$

This value was subtracted from each count rate measured.

| Absorber thickness (mm) | $I_1$ (cps) | $I_2$ (cps) | $I_{average}$ (cps) |
|---|---|---|---|
| 0.00 | 3.19 | 3.10 | 3.15 |
| 0.24 | 1.67 | 1.37 | 1.52 |
| 0.81 | 0.68 | 0.71 | 0.70 |
| 1.23 | 0.54 | 0.57 | 0.56 |
| 2.02 | 0.48 | 0.43 | 0.46 |
| 3.12 | 0.30 | 0.32 | 0.31 |

Figure 14: Table for Exp. D

## IV Graph

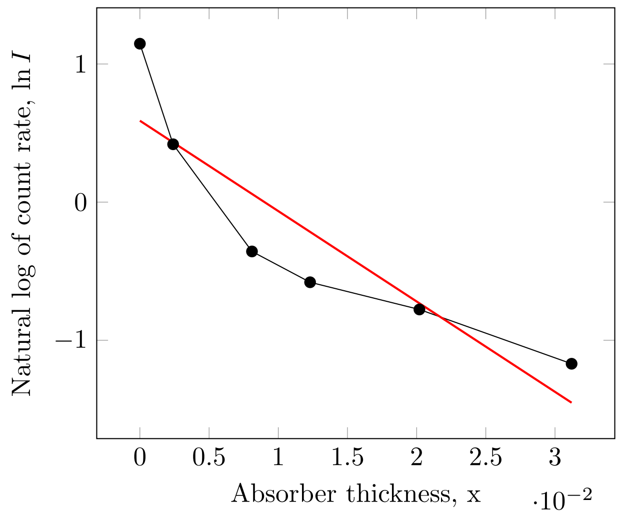


Figure 15: Graph for Exp. D

## V Analysis

The gradient of the graph is -6.543e1. By consulting the equation mentioned in the method we can conclude that the value of $\mu$ is 65 to three significant figures. As we could not find a trusted value for $\mu$, no comparisons can be made. It can however be concluded that the results of the experiment are untrustworthy as they do not appear to have a linear relationship. A possible justification for the fact that the count rate at a $3.12mm$ thickness is lower than the background count rate is that the aluminium is also absorbing some background radiation.

## VI Conclusion

From the results measured it can be concluded that the experiment roughly followed the trend expected. To increase the accuracy of the experiment the count rate should be recorded over a 200 second period. Furthermore, the distance between the source and detector should be increased.

# E Capacitor Discharge

CPACs 1 and 4 $11^{\text{th}}$ December 2019

## I Method

1. Set up the apparatus as shown in the diagram below.
2. Press switch 1 to charge the capacitor.
3. Press switch 3 to discharge the capacitor through G.
4. Record the maximum deflection $\theta_1$.
5. Press switch 1 to charge the capacitor again.
6. Insert plug 2 fr a measured time, t seconds, to partially discharge the capacitor.
7. Remove plug 2.
8. Press 3 to discharge the capacitor and record the new maximum deflection $\theta_2$.
9. Repeat with plug 2 being inserted for longer time intervals.
10. Plot a graph of $\ln \dfrac{\theta_1}{\theta_2}$ against t to find C.

## II Diagram

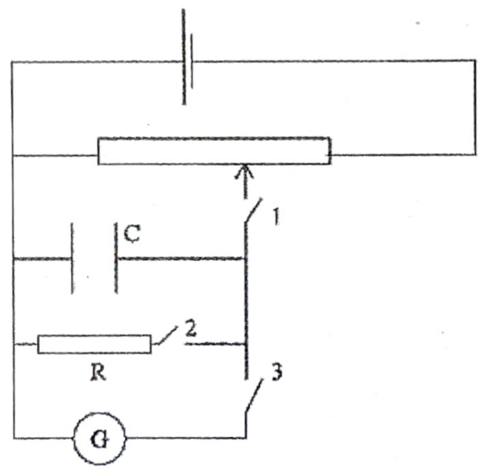


Figure 16: Diagram for Exp. E

## III Results

| t (s) | $\theta_{n,1}$ (°) | $\theta_{n,2}$ (°) | $\theta_{n,avg}$ (°) |
|---|---|---|---|
| 0 | 12.4 | 12.6 | 12.5 |
| 10 | 8.10 | 8.10 | 8.10 |
| 20 | 5.50 | 5.70 | 5.60 |
| 30 | 4.20 | 4.00 | 4.10 |
| 40 | 3.00 | 2.90 | 2.95 |
| 50 | 2.10 | 2.00 | 2.05 |
| 60 | 1.50 | 1.40 | 1.45 |
| 70 | 1.20 | 1.10 | 1.15 |

Figure 17: Table for Exp. E

## IV Graph

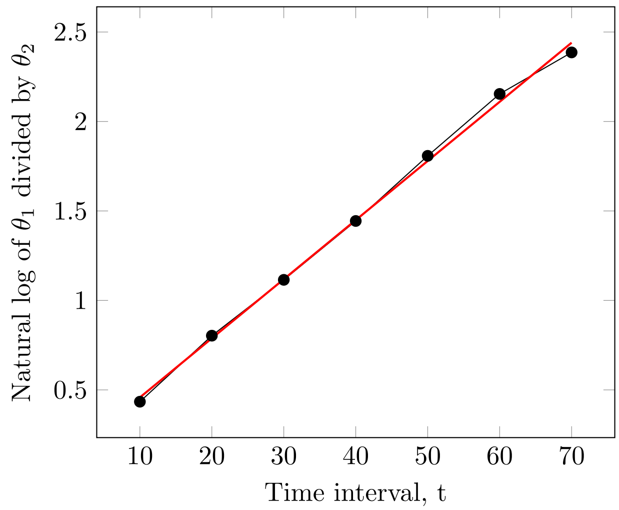


Figure 18: Graph for Exp. E

## V Analysis

We know that the capacitance is equivalent to:

$$\frac{t}{R \cdot \ln \frac{\theta_1}{\theta_2}}.$$

This can be rearanged to give:

$$\ln \frac{\theta_1}{\theta_2} = \frac{t}{C \cdot R}.$$

Using the gradient of our graph we can conclude that:

$$m = \frac{1}{C \cdot R},$$

Which gives a capacitance of:

$$C = \frac{1}{3.30392e - 2 \cdot 10^6} C = 2.9\mu F$$

The capacitor is known to have a value of around $2\mu F$, however, as no true value was found, no comparisons can be made.

## VI Evaluation

To improve this experiment a digital galvanometer should be used as there would be no error in measuring the maximum deflection. This would decrease uncertainty.

# VII Conclusion

This experiment produced valid results as the value obtained was expected and in the correct order of magnitude.

# F Specific Latent Heat of Fusion in Ice

CPACs 1 and 4 $21^{st}$ January 2020

## I Abstract

In this experiment the specific latent heat of fusion in ice was experimentally found using two differant methods.

### Equiptment

- Large plastic funnel
- Beakers
- Low-voltage heater
- Clamp and stand
- Mercury thermometer
- Low-voltage power supply
- Ammeter
- Voltmeter
- Stopwatch
- Top-pan balance
- Switch
- Variable resistor
- Ice cubes
- Stopwatch

### Method

1. Position a funnel filled with ice above a plastic beaker sitting on a top-pan balance.
2. Clamp a low-voltage electrical heater maximising the surface contact between the ice and the heater.
3. Connect the heater to the circuit and record the current and voltage.
4. Once the rate of melting of the ice is steady, zero the top-pan balance and start a stopwatch.

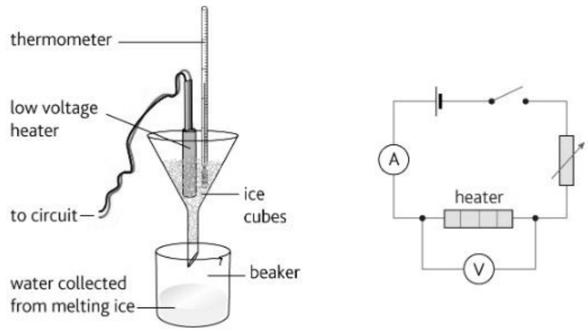


Figure 19: Diagram for Exp. B

**Diagram**

**Results**

The following results where recorded:

| | |
|---|---|
| Time Period | 600s |
| Mass of Water | 44.99g |
| Current | 2.55A |
| Voltage | 8.06V |

**Calculation**

Electrical energy supplied to heater is:

$$E = I \cdot V \cdot tE = 2.55 \cdot 8.06 \cdot 600 = 12331.8J$$

The specific latent heat of fusion is defined to be:

$$L = \frac{Q}{m}$$

From the data in our experiment we obtain a specific latent heat of fusion of:

$$L = \frac{12331.8}{0.004499} = 274100Jkg^{-1}$$

**Evaluation**

The specific latent heat of fusion for water is 334,000 $Jkg^{-1}$
As a result the percentage difference is:

$$\frac{334000 - 274100}{334000} = 17.9\%$$

As all data was recorded electronically there is negligable percentage error in the measurements.

**Analyis**

# G Search Coil Investigation

CPACs 1, 2, 4 and 5 $\hfill$ 27$^{\text{th}}$ January 2020

## I Abstract

The aim of this experiment is to investigate the magnetic field produced by a Helmholtz coil as well as the respective emf induced in a Search coil.

## II Equiptment

- Search coil magnetometer
- Helmholtz coil
- Signal generator
- Oscilloscope
- Teltron Stand

## III Methods

**Distance Method**

1. Connect the Helmholtz coil to the signal generator.
2. Connect the search coil to the oscilloscope.
3. Using clamp stands position the search coil in the center of the Helmholtz coil such that maximum emf is induced.
4. Move the search coil along the axis through the Helmholtz coil by increments of 1cm for the first 10cm and increments of 2cm after that.
5. Record the maximum voltage displayed on the oscilloscope for each distance.
6. Plot a graph of distance, x, against voltage, v.

**Angle Method**

1. Connect the Helmholtz coil to the signal generator.
2. Connect the search coil to the oscilloscope.
3. Using clamp stands position the search coil in the center of the Helmholtz coil such that maximum emf is induced.
4. Rotate the Helmholtz coil in the z-axis in $10°$ increments for values between $-90°$ and $90°$.

5. Record the maximum voltage displayed on the oscilloscope for each angle.

6. Plot a graph of angle, $\theta$ against voltage, v.

## IV Derivation

The formula for the on-axis field due to a Helmholtz coil is given by the Biot-Savart law[5] to be:

$$B\left(x\right)=\frac{\mu_0\cdot n\cdot I\cdot r^2}{2\left(r^2+x^2\right)^{3/2}}$$

Where:

- $\mu_0$ is the permeability constant
- $n$ is the number of turns
- $I$ is the coil current
- $r$ is the coil radius
- $x$ is the coil distance, on-axis, to the point

The voltage produced by the signal generator is modelled by:

$$V=20\cdot\sin\left(5\times10^3\cdot t\right)$$

The resistance of the Helmholtz coil is estimated to be:

$$R=\frac{\rho L}{A}=\frac{1.72\times10^{-8}\cdot320\cdot2\pi\cdot0.075}{\pi\cdot0.0003^2}\approx9.173\,\Omega$$

As a result, the Helmholtz coil current at a time, $t$, is:

$$I\left(t\right)=\frac{V\left(t\right)}{R}=\frac{20\cdot\sin\left(5\times10^3\cdot t\right)}{9.173}$$

This gives a magnetic field of:

$$B\left(x,t\right)=\frac{0.246\,658\times10^{-5}\cdot\sin\left(5\times10^3\cdot t\right)}{\left(0.075^2+x^2\right)^{3/2}}$$

The induced voltage in the search coil magnetometer is described by Faraday's law of Induction[6]:

$$e=-N\frac{\mathrm{d}\Phi}{\mathrm{d}t}$$

With N being the number of terms. By Gauss's law[7] for magnetism, the magnetic flux is:

$$\Phi_B=\mathbf{B}\cdot\mathbf{S}=BS\cos\theta$$

Where $\theta$ is the angle between the axes of the Helmholtz coil and Search coil and $\cdot$ is the dot product. The surface area of the Search coil is:

$$S = 2\pi \cdot 0.00508 \cdot 2\pi \cdot 0.005 \cdot 5000 \approx 986.96\,\mathrm{m}^2$$

Taking the derivitive of the magnetic flux with respect to time gives:

$$\frac{\mathrm{d}\Phi_B}{\mathrm{d}t} = \frac{0.246\,658 \times 10^{-5} \cdot \sin\left(5 \times 10^3 \cdot t\right)}{\left(0.075^2 + x^2\right)^{3/2}} \cdot 5 \times 10^3 \cdot 986.96 \cdot \cos\theta$$

Hence the maximum voltage measured should be:

$$e_{max}\left(x\right) = 320 \cdot \frac{0.246\,658 \times 10^{-5}}{\left(0.075^2 + x^2\right)^{3/2}} \cdot 5 \times 10^3 \cdot 986.96 \cdot \cos\theta$$

## V Results

In order to match the expected and observed voltages, a correction factor of $5.08 \times 10^{-6}$ was used.

**Tables**

| distance, x (m) | expected Voltage, e (V) | observed Voltage, v (V) |
|---|---|---|
| -0.20 | 0.03 | 0.00 |
| -0.18 | 0.04 | 0.00 |
| -0.16 | 0.05 | 0.04 |
| -0.14 | 0.07 | 0.04 |
| -0.12 | 0.10 | 0.08 |
| -0.10 | 0.15 | 0.12 |
| -0.09 | 0.18 | 0.16 |
| -0.08 | 0.22 | 0.20 |
| -0.07 | 0.27 | 0.24 |
| -0.06 | 0.32 | 0.28 |
| -0.05 | 0.39 | 0.36 |
| -0.04 | 0.47 | 0.44 |
| -0.03 | 0.54 | 0.52 |
| -0.02 | 0.61 | 0.60 |
| -0.01 | 0.66 | 0.64 |
| 0.00 | 0.68 | 0.68 |
| 0.01 | 0.66 | 0.64 |
| 0.02 | 0.61 | 0.56 |
| 0.03 | 0.54 | 0.48 |
| 0.04 | 0.47 | 0.40 |
| 0.05 | 0.39 | 0.32 |
| 0.06 | 0.32 | 0.28 |
| 0.07 | 0.27 | 0.24 |
| 0.08 | 0.22 | 0.16 |
| 0.09 | 0.18 | 0.12 |
| 0.10 | 0.15 | 0.12 |
| 0.12 | 0.10 | 0.08 |
| 0.14 | 0.07 | 0.04 |
| 0.16 | 0.05 | 0.04 |
| 0.18 | 0.04 | 0.00 |
| 0.20 | 0.03 | 0.00 |

Figure 20: Data from Method I

| angle, $\theta$ (°) | expected Voltage, e (V) | observed Voltage, v (V) |
|---|---|---|
| -70 | 0.23 | 0.24 |
| -60 | 0.34 | 0.36 |
| -50 | 0.44 | 0.44 |
| -40 | 0.52 | 0.52 |
| -30 | 0.59 | 0.60 |
| -20 | 0.64 | 0.64 |
| -10 | 0.67 | 0.68 |
| 0 | 0.68 | 0.68 |
| 10 | 0.67 | 0.68 |
| 20 | 0.64 | 0.64 |
| 30 | 0.59 | 0.60 |
| 40 | 0.52 | 0.52 |
| 50 | 0.44 | 0.44 |
| 60 | 0.34 | 0.36 |
| 70 | 0.23 | 0.24 |

Figure 21: Data from Method II

**Graphs**

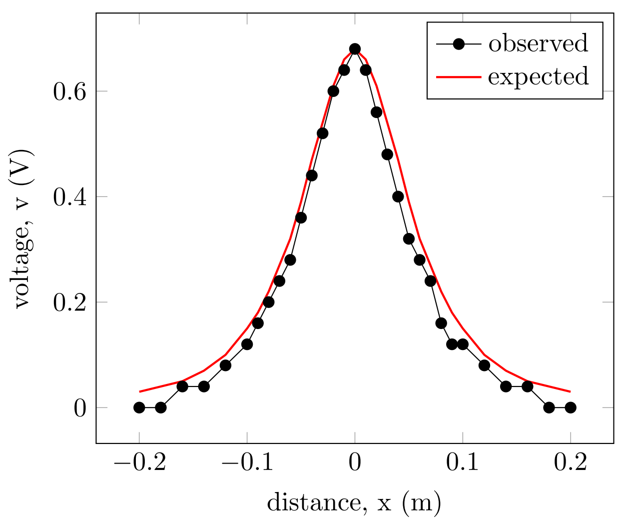


Figure 22: Graph for Method I

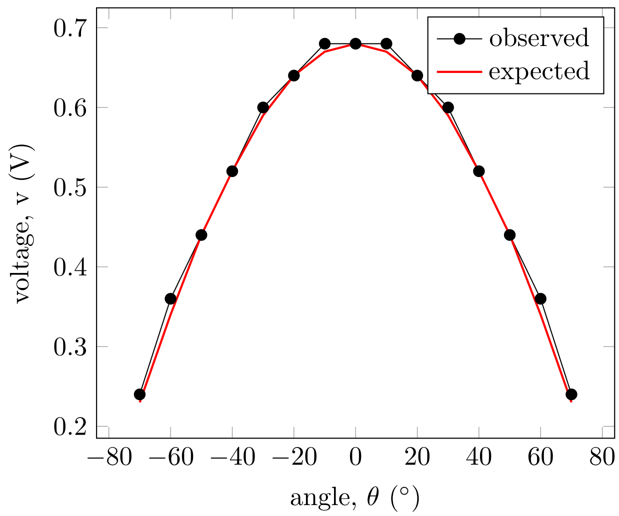


Figure 23: Graph for Method II

# VI Evaluation

As seen in the graphs above, with the use of a correction factor, our predictions are almost a perfect fit for the data. The correction factor is small enough to remove the need for any calculation of uncertainty. The Resistance of the Helmholtz coil, and surface area of the Search coil where cruedly approximated. This is the most likely reason for the large correction factor. Although the constants derived where incorrect, the data followed the expected shape therefore partially confirming the Biot-Savart law and Faraday's law of Induction. This experiment could be improved through the use of more accurate equiptment, i.e. using a digital protractor. In addition to this, important constants such as the resistance in the coils should be experimentally found instead of being approximated.

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