I. Expectations

In this experiment, we will investigate the Lorentz force, the force on a current due to a magnetic field and the current, is described by the following relationship:

$$F = BIL$$

where F is the force on the wire, B is the magnetic field, I is the current through the wire, and L is the length of the wire affected by the magnetic field. Note that this equation only applies when the current is perpendicular to the magnetic field.

In the experiment, however, the wire will be fixed, and so the weight deviation is the force imposed **on the magnet (source of magnetic field) by the wire,** while the equation describes the force on the wire by the magnetic field. Due to Newton's 3rd law, we know that this force is in equal in magnitude and opposite in direction to each other—the force on the *magnet;* the weight deviation, is opposite in direction to the direction obtained by the Left Hand Rule.

As in the experiment the length of the wire in the magnetic field (L) and the strength of the magnetic field (B) will be fixed, we will presumably observe a directly proportional relationship between the force on the wire, and the current.

II. Methodology

Procedure:

1. Set up apparatus according to Diagram 1 in Section III.
2. Zero the balance with the magnet on, without any current.
3. Put current through wire in adequate intervals, and note the deviation in weight measured by the balance.

Notable Apparatus:

- Digital Balance
- Magnet
- Thick Wire
- Ammeter
- Power Supply

III. Diagram

Attached: [Diagram 1: Investigation of the Lorentz force using magnets, wire, and a balance]

IV. Table

The direction of the force **on the wire** (F), magnetic field (B), and current (I) is positive as drawn in the diagram at point A. As investigated in section I, the force on the wire is equivalent to the weight deviation, but in opposite direction and equal magnitude to the Lorentz force on the wire.

The length of the magnet is measured to be **0.050 ± 0.001m**, and the length of the wire affected by the magnetic field is assumed to be the same length (although, this may not be accurate; discussed in section IIX

The **current through the wire** is measured by a digital ammeter, which outputs the current value with an uncertainty of ± 0.01. However, due to the fact that there were constant minor fluctuations in the measured value, this is taken account and the uncertainty is taken to be **± 0.03.**

The digital balance was zeroed to the "mass" of the magnet (and the metal plate it is attached to). **This "mass deviation" of the magnet is *not* a real change in mass;** rather, a result obtained due to the balance's prediction that it will be used on earth. In order to get the real deviation of weight (the net downward force on the magnet), the gravitational field strength (assumed to be $9.81 N \cdot kg^{-}1$) must be multiplied. The uncertainties are propagated accordingly. In this case, the uncertainty of the "mass" is taken to be **± 0.02,** also due to constant fluctuations in the balance's output.

For example, when a 5.00 ± 0.03 A current was going through the wire, the balance showed a -2.14 ± 0.02g difference in weight. As $w = m \cdot g$, where *w=weight, m=mass, g=gravitational field strength*, $\Delta w = \Delta m \cdot g$ holds true as well; therefore the weight deviation is:

$(2.14 \pm 0.02) \cdot 10^{-3} \cdot 9.81 = -0.0210 \pm 0.0002$

As investigated in section I, the force on the wire is in the opposite direction; therefore, the force on the wire due to the magnet is:

0.0210 ± 0.0002 N

Table 1. Lorentz Force on Wire due to Current and Magnetic field

Raw Data		*Processed Data*	
Current through Wire / A	**Perceived Mass Deviation / g**	**Weight Deviation / N**	**Lorentz Force on Wire / N**
± 0.03	**± 0.02**	**± 0.0002**	**± 0.0002**
−5.00	2.19	0.0215	−0.0215
−4.75	2.09	0.0205	−0.0205
−4.50	1.97	0.0193	−0.0193
−4.25	1.87	0.0183	−0.0183
−4.00	1.75	0.0172	−0.0172
−3.75	1.65	0.0162	−0.0162
−3.50	1.54	0.0151	−0.0151
−3.25	1.43	0.0140	−0.0140
−3.00	1.32	0.0129	−0.0129
−2.75	1.21	0.0119	−0.0119
−2.50	1.11	0.0109	−0.0109
−2.25	0.99	0.0097	−0.0097
−2.00	0.89	0.0087	−0.0087
−1.75	0.77	0.0076	−0.0076
−1.50	0.66	0.0065	−0.0065
−1.25	0.56	0.0055	−0.0055
−1.00	0.45	0.0044	−0.0044
−0.75	0.33	0.0032	−0.0032
−0.50	0.22	0.0022	−0.0022
−0.25	0.11	0.0011	−0.0011
0.00	0.00	0.0000	0.0000
0.25	−0.08	−0.0008	0.0008
0.50	−0.17	−0.0017	0.0017
0.75	−0.30	−0.0029	0.0029
1.00	−0.41	−0.0040	0.0040

Raw Data		*Processed Data*	
Current through Wire / A	**Perceived Mass Deviation / g**	**Weight Deviation / N**	**Lorentz Force on Wire / N**
± 0.03	**± 0.02**	**± 0.0002**	**± 0.0002**
1.25	−0.51	−0.0050	0.0050
1.50	−0.62	−0.0061	0.0061
1.75	−0.73	−0.0072	0.0072
2.00	−0.83	−0.0081	0.0081
2.25	−0.94	−0.0092	0.0092
2.50	−1.05	−0.0103	0.0103
2.75	−1.17	−0.0115	0.0115
3.00	−1.27	−0.0125	0.0125
3.25	−1.38	−0.0135	0.0135
3.50	−1.50	−0.0147	0.0147
3.75	−1.60	−0.0157	0.0157
4.00	−1.72	−0.0169	0.0169
4.25	−1.82	−0.0179	0.0179
4.50	−1.94	−0.0190	0.0190
4.75	−2.04	−0.0200	0.0200
5.00	−2.14	−0.0210	0.0210

V. Graph

Attached: [Graph 1. Lorentz force on wire against Current through wire]

VI. Processing

The graph is plotted as the force **on the wire** against the current; therefore, the value of the gradient is equivalent to:

$$B \cdot L = \textbf{(Gradient)}$$

Using our worst-fit lines, we can calculate the range of the gradient of the function of the graph:

$$\frac{0.040}{9.55} \leq \textbf{(Gradient)} \leq \frac{0.0387}{8.95}$$

$$0.004188 \leq \textbf{(Gradient)} \leq 0.004324$$

$$\textbf{(Gradient)} = 0.00426 \pm 0.00006\ T \cdot m$$

As $\dfrac{\textbf{(Gradient)}}{L} = B,$

$$B = \frac{0.00426 \pm 0.00006}{0.050 \pm 0.001} = 0.085 \pm 0.003$$

And therefore,

***B* = 0.085 ± 0.003 T**

VII. Conclusion

The graph shows a linear, positive correlation, **revealing a direct proportionality** between the force on a current in a magnetic field and the current (for a fixed magnetic field and current length), as predicted by the theory.

Also, according to the range of gradient obtained from the worst fit lines, we have computed that the magnetic field strength of the magnet is **0.085 ± 0.003 T, in the positive direction as shown in the Diagram 1.**

According to "Information on MRI Technique". [www.nevusnetwork.org/mritech.htm. Nevus Network. Accessed 2018-04-15], the strength of a household refrigerator magnet is in the order of $10^{-3}T$; the magnet used in the experiment felt* a bit stronger than a typical refrigerator magnet, which lends plausibility to the value obtained.

** This is nowhere near accurate or scientific; however, no literature value or measurement could be obtained, and therefore a reasonable approximation is made.*

IIX. Evaluation

A crucial flaw in this experiment is the assumption that the magnetic field simply *ends* at the end of the magnet; this is not true, as two plane magnets with different poles form a magnetic field that is stronger at the center, weaker at the ends (the bulge effect), and continues on indefinitely, however small. This error yields a fairly large unreliability to the conclusion data. (Still, this real-world effect may possibly be less important, if the fact that the bulge effect and indefinite continuation of the magnetic field cancels out, is considered) This uncertainty is difficult to be taken into account numerically, neither can its direction of influence be assessed. However, attempts can be made to reduce its impact; for example, using a much longer magnet will reduce the impact of the bulge effect and the irregularities in the field on the measured data.

Apart from this error, the current through wire showed an absolute uncertainty of ± 0.03, and relative uncertainty of 0.60% - 12%, while the mass deviation showed ±0.02, and 0.93% - 25%. (However, it is important to note that the high relative uncertainties are caused by the small absolute values in some of the raw data; as the magnetic field value is calculated from the gradient of the graphs, this is insignificant.)

These uncertainties were caused by a fluctuation in the current; therefore, a stabilized power supply, or a smoothing capacitor can be utilized in order to smooth the current. If these components are used effectively, the smallest absolute uncertainty would be ±0.005 A for the current, and ± 0.005g for the mass deviation, both uncertainty values stated in the equipment. This can further reduce the uncertainty in the gradient, although it is difficult to numerically assess a improvement in the gradient.

Another possibility is to use a power supply that can supply a higher current; if the maximum current applied had been 10A, and the absolute uncertainty had been reduced to ±0.005, the relative uncertainty can be reduced to an impressive 0.5%, minimum. Further improvements than this require more advanced equipment, infeasible in the current laboratory setting.