Edward Auttonberry

**Lab 5: Magnetic Force**

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PHYS 262 – 001

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**Objective**

The objective of this lab is to confirm that magnetic objects placed in a magnetic field will experience a force.

**Theory**

We will be testing the theory that force is applied to an object generating a magnetic field by a separate magnetic field created from a current-carrying wire. This is projected by the equation

Eq. 5-1

This equation is gnostic to the direction of the various components at play, and can be adjusted to adopt a direction-agnostic form:

Eq. 5-2

For the purposes of this experiment, this can be simplified to

Eq. 5-3

Because the current and the magnetic field will be aligned approximately 90 degree angles, resulting no change in effect.

**Procedure**

For this experiment, we intended to measure the force imparted by a current through a wire on a magnet. For this we required a scale, a set of five modular PCB-embedded wires, a magnet assembly with a depression between the positive and negative terminals deep enough to cover the horizontal portion of the wires without any contact, a DC Power supply, a lab stand, and any component that could be attached to the lab stand that also can deliver DC power from the power supply to the modular PCB’s, which will be henceforth referred to as the “clamp”.

The magnet was placed on the scale and the scale was zeroed. The clamp was attached to the lab stand but not tightened. One of the five PCB modules was attached to the clamp, and the clamp was lowered and oriented such that the portion of the PCB wire that is horizontal to the ground was completely hidden by the magnet. Before attaching, the current output of the DC power supply was set to an initial 0.5 Amps, then switched back off.

The setup is now complete. With the DC power supply attached to the clamp, the power supply should be turned on. The current will pass through the horizontal portion of the PCB, which should be completely submerged in the magnetic field of the magnet. This will cause a force to be applied to the magnet either up or down depending on the direction of the current, which will be measurable based on the readings of the balance. This procedure was repeated for 5 different PCB modules with unique horizontal wire lengths, each at 5 different current magnitudes.

**Data**

Shown below are the raw results and parameters as collected from the materials at hand for the five runs (current adjusted) across the five different circuits.

|  |  |  |  |
| --- | --- | --- | --- |
| SF 37 Circuit | | | |
| Trial | I (Amps) | m (g) | L (mm) |
| 1 | 0.51 | 0.07 | 20 |
| 2 | 1 | 0.15 |  |
| 3 | 1.53 | 0.21 |  |
| 4 | 2 | 0.28 |  |
| 5 | 2.51 | 0.36 |  |

**Table 5-1.** The data collected from the set of runs concerning the SF 37 circuit, which boils down to the passing current, the constant length of the horizontal portion of the circuit, and the mass reading given by the balance.

|  |  |  |  |
| --- | --- | --- | --- |
| SF 38 Circuit | | | |
| Trial | I (Amps) | m (g) | L (mm) |
| 1 | 0.52 | 0.15 | 40 |
| 2 | 1 | 0.27 |  |
| 3 | 1.51 | 0.42 |  |
| 4 | 1.97 | 0.54 |  |
| 5 | 2.49 | 0.68 |  |

**Table 5-2.** The data collected from the set of runs concerning the SF 38 circuit, which boils down to the passing current, the constant length of the horizontal portion of the circuit, and the mass reading given by the balance.

|  |  |  |  |
| --- | --- | --- | --- |
| SF 39 Circuit | | | |
| Trial | I (Amps) | m (g) | L (mm) |
| 1 | 0.48 | 0.1 | 30 |
| 2 | 0.99 | 0.2 |  |
| 3 | 1.49 | 0.3 |  |
| 4 | 1.98 | 0.4 |  |
| 5 | 2.54 | 0.51 |  |

**Table 5-3.** The data collected from the set of runs concerning the SF 39 circuit, which boils down to the passing current, the constant length of the horizontal portion of the circuit, and the mass reading given by the balance.

|  |  |  |  |
| --- | --- | --- | --- |
| SF 40 Circuit | | | |
| Trial | I (Amps) | m (g) | L (mm) |
| 1 | 0.5 | 0.04 | 10 |
| 2 | 0.97 | 0.07 |  |
| 3 | 1.49 | 0.12 |  |
| 4 | 1.99 | 0.15 |  |
| 5 | 2.48 | 0.19 |  |

**Table 5-4.** The data collected from the set of runs concerning the SF 40 circuit, which boils down to the passing current, the constant length of the horizontal portion of the circuit, and the mass reading given by the balance.

|  |  |  |  |
| --- | --- | --- | --- |
| SF 41 Circuit | | | |
| Trial | I (Amps) | m (g) | L (mm) |
| 1 | 0.49 | 0.19 | 30 |
| 2 | 1 | 0.4 |  |
| 3 | 1.49 | 0.6 | Effective L (mm) |
| 4 | 2.01 | 0.82 | 60 |
| 5 | 2.5 | 1.02 |  |

**Table 5-5.** The data collected from the set of runs concerning the SF 41 circuit, which boils down to the passing current, the constant length of the horizontal portion of the circuit, and the mass reading given by the balance. The measured length does not reflect the “actual” length of the circuit, because this length permeates both sides of the PCB, causing the force to be effectively experienced twice, doubling the “effective length”.

**Analysis**

With the data for each configuration presented as the bare collected results, we can transform this into information to obtain a theoretical magnitude for the magnetic field generated by the magnet. Due to the lack of a Tesla meter, we are not able to obtain an experimental value to the magnetic field strength.

**SF 37 Circuit**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SF 37 Circuit | | | | | |
| **Trial** | **M [kg]** | **F [N]** | **IL** | **B [T]** | **σ(B) [T]** |
| 1 | 0.00007 | 0.000686 | 0.0102 | 0.0672549 | 0.00234192 |
| 2 | 0.00015 | 0.00147 | 0.02 | 0.0735 |  |
| 3 | 0.00021 | 0.002058 | 0.0306 | 0.0672549 |  |
| 4 | 0.00028 | 0.002744 | 0.04 | 0.0686 |  |
| 5 | 0.00036 | 0.003528 | 0.0502 | 0.07027888 |  |

**Table 5-6.** Experimentally derived magnetic field strengths calculated based on the force experienced by the magnet as current was passing through.

Graphing the experienced force against the current-distance proportion, a “typical” magnetic field strength can be pinpointed for this run.

**Figure 5-1.** The force felt by the magnet at each current level plotted against that current-meter configuration. Because the length portion of the current-meter value is constant for the configuration, this is essentially Force vs. Current.

Based on this regression, the real magnetic field strength lies somewhere in the range of

**0.0695 ± 0.00234192 Tesla**.

**SF 38 Circuit**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SF 38 Circuit | | | | | |
| **Trial** | **M [kg]** | **F [N]** | **IL** | **B [T]** | **σ(B) [T]** |
| 1 | 0.00015 | 0.00147 | 0.0208 | 0.07067308 | 0.0015688 |
| 2 | 0.00027 | 0.002646 | 0.04 | 0.06615 |  |
| 3 | 0.00042 | 0.004116 | 0.0604 | 0.0681457 |  |
| 4 | 0.00054 | 0.005292 | 0.0788 | 0.06715736 |  |
| 5 | 0.00068 | 0.006664 | 0.0996 | 0.06690763 |  |

**Table 5-7.** Experimentally derived magnetic field strengths calculated based on the force experienced by the magnet as current was passing through.

Graphing the experienced force against the current-distance proportion, a “typical” magnetic field strength can be pinpointed for this run.

**Figure 5-2.** The force felt by the magnet at each current level plotted against that current-meter configuration. Because the length portion of the current-meter value is constant for the configuration, this is essentially Force vs. Current.

Based on this regression, the real magnetic field strength lies somewhere in the range of

**0.0664 ± 0.0015688 Tesla**.

**SF 39 Circuit**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SF 39 Circuit | | | | | |
| **Trial** | **M [kg]** | **F [N]** | **IL** | **B [T]** | **σ(B) [T]** |
| 1 | 0.0001 | 0.00098 | 0.0144 | 0.06805556 | 0.00090007 |
| 2 | 0.0002 | 0.00196 | 0.0297 | 0.06599327 |  |
| 3 | 0.0003 | 0.00294 | 0.0447 | 0.06577181 |  |
| 4 | 0.0004 | 0.00392 | 0.0594 | 0.06599327 |  |
| 5 | 0.00051 | 0.004998 | 0.0762 | 0.06559055 |  |

**Table 5-8.** Experimentally derived magnetic field strengths calculated based on the force experienced by the magnet as current was passing through.

Graphing the experienced force against the current-distance proportion, a “typical” magnetic field strength can be pinpointed for this run.

**Figure 5-3.** The force felt by the magnet at each current level plotted against that current-meter configuration. Because the length portion of the current-meter value is constant for the configuration, this is essentially Force vs. Current.

Based on this regression, the real magnetic field strength lies somewhere in the range of

**0.0652 ± 0.00090007 Tesla**.

**SF 40 Circuit**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SF 40 Circuit | | | | | |
| **Trial** | **M [kg]** | **F [N]** | **IL** | **B [T]** | **σ(B) [T]** |
| 1 | 0.00004 | 0.000392 | 0.005 | 0.0784 | 0.00302542 |
| 2 | 0.00007 | 0.000686 | 0.0097 | 0.07072165 |  |
| 3 | 0.00012 | 0.001176 | 0.0149 | 0.07892617 |  |
| 4 | 0.00015 | 0.00147 | 0.0199 | 0.07386935 |  |
| 5 | 0.00019 | 0.001862 | 0.0248 | 0.07508065 |  |

**Table 5-9.** Experimentally derived magnetic field strengths calculated based on the force experienced by the magnet as current was passing through.

Graphing the experienced force against the current-distance proportion, a “typical” magnetic field strength can be pinpointed for this run.

**Figure 5-4.** The force felt by the magnet at each current level plotted against that current-meter configuration. Because the length portion of the current-meter value is constant for the configuration, this is essentially Force vs. Current.

Based on this regression, the real magnetic field strength lies somewhere in the range of

**0.0748 ± 0.00302542 Tesla**.

**SF 41 Circuit**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SF 41 Circuit | | | | | |
| **Trial** | **M [kg]** | **F [N]** | **IL** | **B [T]** | **σ(B) [T]** |
| 1 | 0.00019 | 0.001862 | 0.0294 | 0.063333333 | 0.00121421 |
| 2 | 0.0004 | 0.00392 | 0.06 | 0.065333333 |  |
| 3 | 0.0006 | 0.00588 | 0.0894 | 0.065771812 |  |
| 4 | 0.00082 | 0.008036 | 0.1206 | 0.066633499 |  |
| 5 | 0.00102 | 0.009996 | 0.15 | 0.06664 |  |

**Table 5-10.** Experimentally derived magnetic field strengths calculated based on the force experienced by the magnet as current was passing through.

Graphing the experienced force against the current-distance proportion, a “typical” magnetic field strength can be pinpointed for this run.

**Figure 5-4.** The force felt by the magnet at each current level plotted against that current-meter configuration. Because the length portion of the current-meter value is constant for the configuration, this is essentially Force vs. Current.

Based on this regression, the real magnetic field strength lies somewhere in the range of

**0.0675 ± 0.00121421 Tesla**.

**Conclusions**

In this experiment, we have attempted to verify the idea that a current passing through a magnetic field will result in a force being imparted on the field’s source. To this end, we tested for this effect using the scenario of a wire on a collection of unique PCBs by passing a current through those wires as the horizontal portions are well submerged in a magnet’s magnetic field. Doing this for each PCB at a range of different currents, the following compilation of results has been gathered:

|  |  |  |
| --- | --- | --- |
| Composite Results | | |
| **β1(B) [T]** | **σ(B) [T]** | **σ(β1) [T]** |
| 0.06954371 | 0.00234192 | 0.00338091 |
| 0.06637559 | 0.0015688 |  |
| 0.06520029 | 0.00090007 |  |
| 0.07481996 | 0.00302542 |  |
| 0.06754409 | 0.00121421 |  |

**Table 5-11.** The list of experimentally derived magnetic field strength retrieved across all five experiment configurations using a linear estimate (B1), and how these linear estimates vary individually (σ(B)) and comparatively (σ(β1)).

Each of the above experiment configurations were performed with one parameter that, in ideal situations, is constant: the magnetic field strength. Because of this, we expect to see that the final magnetic field strength estimate for all 5 situations is significantly similar. Based on the results in Table 5-11, this seems to be the case: the standard deviation for the linear estimate of magnetic field strength across all configurations varies minimally when certain environment details are considered: these magnetic field tests were not isolated from the other experiments occurring in the room, from earth’s magnetic field, or from various electromagnetic interference brough on by the many active electronic devices (cell phones, laptops, DC power supplies) in fair proximity to the experiment. Given that, we feel that this experiment upholds the suggested theory.