LAB 08 — 03/27/2025

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Introduction: Understanding magnetic fields is essential for the fields of electrical engineering and electromechanics. This phenomenon appears everywhere in our daily lives, though its impact is often not immediately visible. Appearing both in man made constructs and natural occurrences, we have benefitted from magnetic fields in many ways, ranging from driving a motor to protecting us from cosmic radiation. Within this lab, we investigate the visible impacts that magnetic fields have on their surroundings alongside their relationship with current flowing through a wire.

Problem 1: Field of a Bar Magnet

Materials: Compass and bar magnet.

Methods: Place the bar magnet on the board, draw an outline and the poles, then record the direction the compass points for multiple points around the bar magnet.

Results: The directions are accidentally going from South to North for the vector field drawing, but this was fixed in the field line drawing.

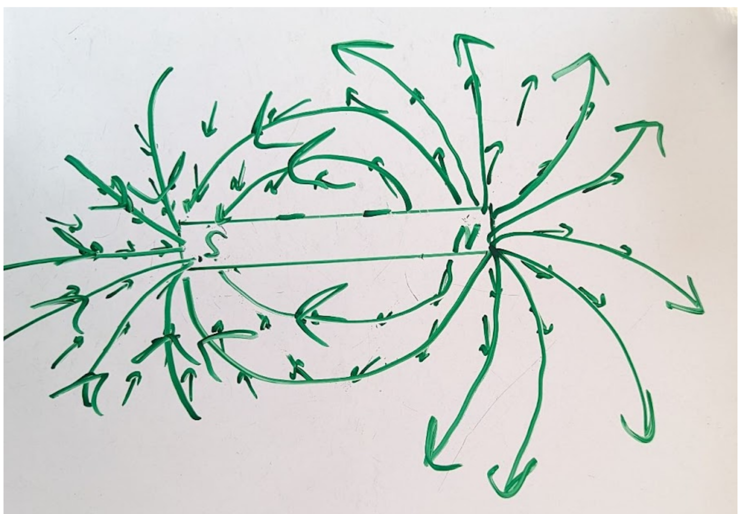

Figure 1: Magnetic field lines for the bar magnet

Analysis: The recorded field lines all originate from the North and terminate at the South, which follows from the nonexistence of magnetic monopoles. This principle is the foundation of why the divergence of the magnetic field is zero everywhere: for every origin of vectors, there must be an equivalent sink, so the vector field never diverges.

Problem 2: Field of an Electromagnet

Materials: Power supply, large coil of wire, compass, Phyphox Mobile App.

Methods: Place the electromagnet on its side and plug it in. Then, measure the magnetic field magnitude at various radii from the inner edge to the center and from the outer edge to some greater radius. Draw these values out. Next, place the electromagnet vertically and measure both the direction and magnitude of the magnetic field at the midway height (in the z-direction) at many different x and y positions. Draw these values out. Take a graph measurement of the magnetic field by moving a phone through the center of the coil multiple times. Measure the power supply voltage and current draw to calculate the resistance of the coil.

Results:

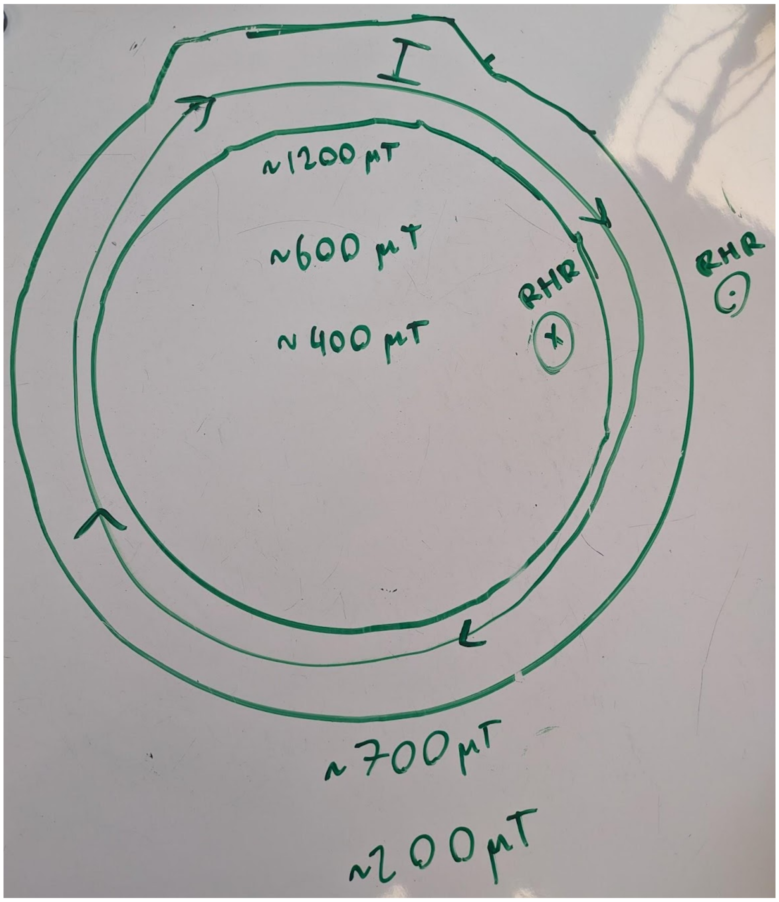

Figure 2: Magnetic field values at different radii for coil

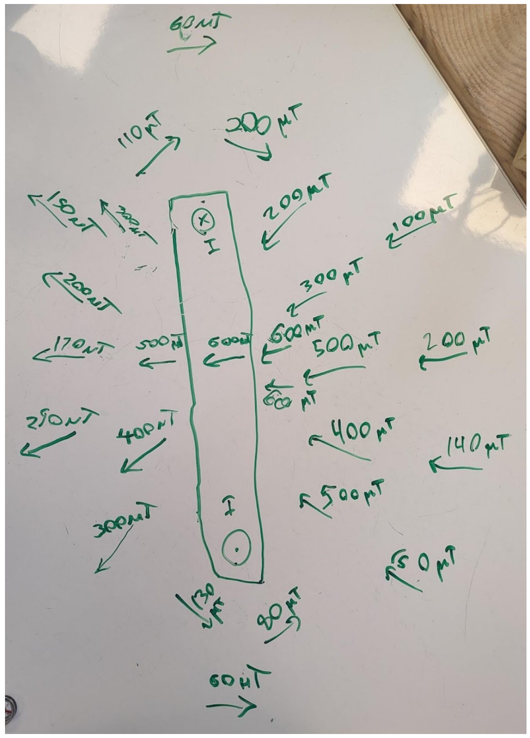

Figure 3: Magnetic field values at different positions from coil

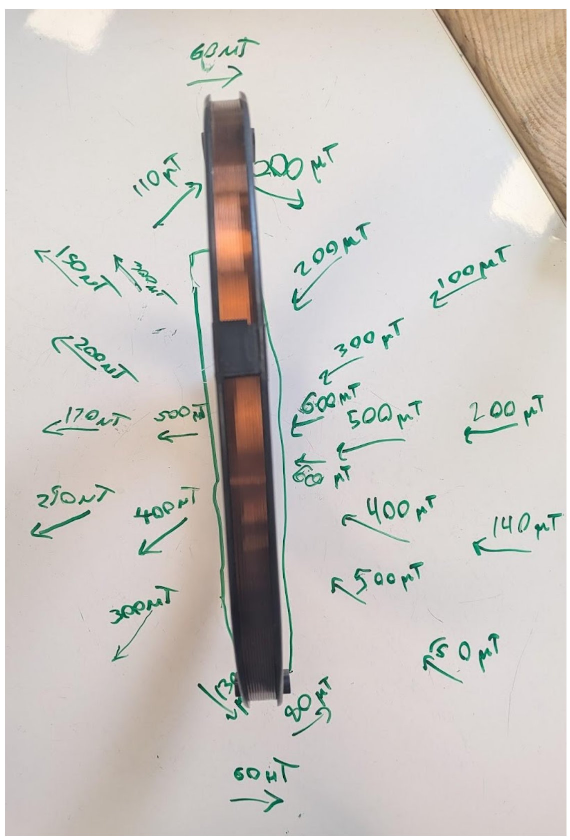

Figure 4: Figure 3 with coil in image

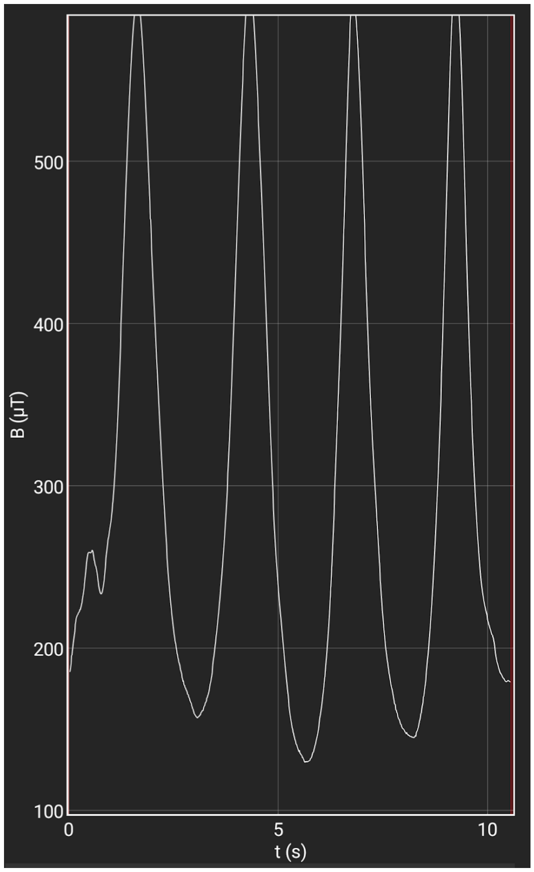

Figure 5: Graph of magnetic field through midline of coils

Analysis: The resistance of the large coil was determined using two different equations, firstly, $R = \frac{V}{I}$ was used to determine that the resistance of the system, including the coil, was 2Ω. The second equation was $R = \rho\frac{L}{A}$ where $A = 2\pi r$ because the wire is circular and $L = \pi dn$ because there are *n* loops with a length equal to their circumference. Through this, the resistance was determined to be 0.762Ω. The discrepancy is likely due to internal resistance in the supply and other wires. The North and South poles of the electromagnet both exist on the axis of the coil and are very close. A North pole will never be found by itself because no magnetic mono-poles exist. The magnetic field of a collection of coils is given by $B = \frac{\mu_0 n I a^2}{2(x^2+a^2)^{\frac{3}{2}}}$. In the equations, a is the radius of the coil, *n* is the number of loops, and *x* is the distance from the center of the coil. Applying this to our coil results in a magnetic field strength at the axis in the center of 544.5µT. This is close to our measured value.

Problem 3: Forces on Currents

Materials: Gencon power supply, loop of wire, permanent magnet, wire–magnet apparatus.

Methods/Procedures: Connect the Gencon to the wire and turn it to run a current through the wire. Record the direction the wire moves.

Results:

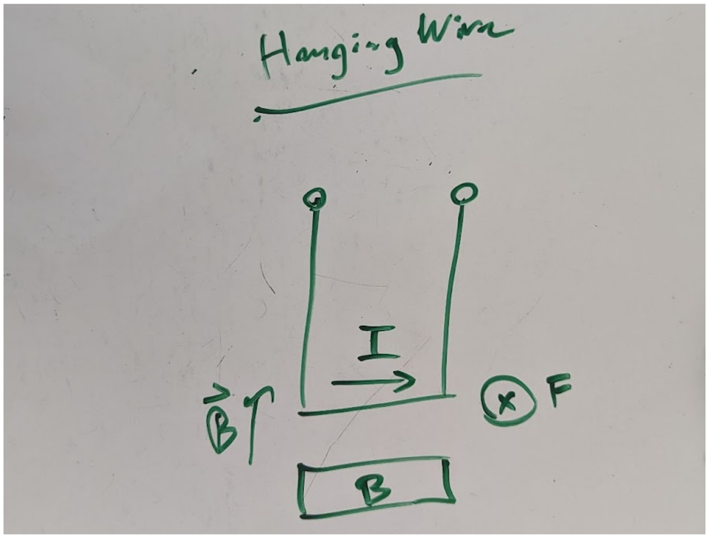

Figure 6: Diagram of force, current, and magnetic field w.r.t. wire

Analysis: Since the wire visibly moved in the direction relative to the current as shown in figure 6, the magnetic field likely points upwards, according to the right hand rule. The right hand rule is a tool to show the direction of the resultant of a cross product. For the force on a current carrier, the equation is $\vec{F} = I\vec{l} \times \vec{B}$. Since the force and direction of the current were known, the direction of $\vec{B}$ could be found. If the crank were turned the other direction, the direction of current would change so the direction of the force would change.

Conclusion: Through this lab we visualized magnetic fields through the use of a compass and a magnetometer built into a smartphone. Through this we demonstrated that the field always originates from the North pole and terminates at the South, Helping us to understand that the divergence of the field must always equal 0. We also proved that magnetic fields can be created through the flow of current, which can also interact with pre-existing magnetic fields. Understanding these concepts has allowed us to create machinery converting between electrical energy and mechanical energy. Without this understanding it is very likely we would not be able to rely on electricity as a form of energy transportation between systems, vastly increasing the complexity and scale of said systems which may no longer be viable for the applications we are so reliant on today.