§ 1 Introduction

In this lab we will observe the existence of an electric field produced by a changing magnetic field.

§ 2 Background

Faraday's Law can be written as

$$\oint \vec{E} \cdot d\vec{\ell} = -\frac{d}{dt}\vec{B} \cdot \vec{A}$$

Where $\mathcal{E}$ is the induced EMF (voltage).

$$\mathcal{E} = \oint \vec{E} \cdot d\vec{\ell} = E2\pi r \quad \text{and} \quad \phi_B = \int \vec{B} \cdot d\vec{A} = B\pi r^2$$

where r is the radius of the loop and B is the average field strength through the loop. So that Faraday's law becomes

$$E2\pi r = -\frac{d}{dt}B\pi r^2 \longrightarrow E = -\frac{r}{2}\frac{dB}{dt}$$

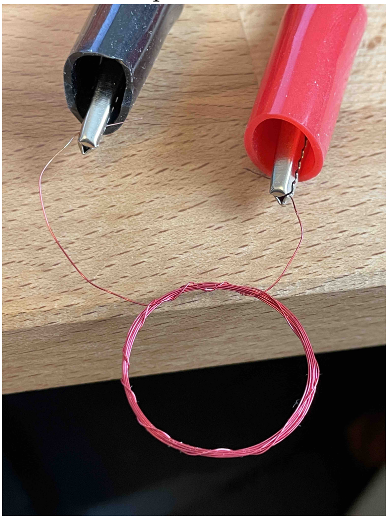
But the current density is $J = \sigma E$ so that the current is $I = aJ = a\sigma E$ where a is the cross-sectional area of the wire.

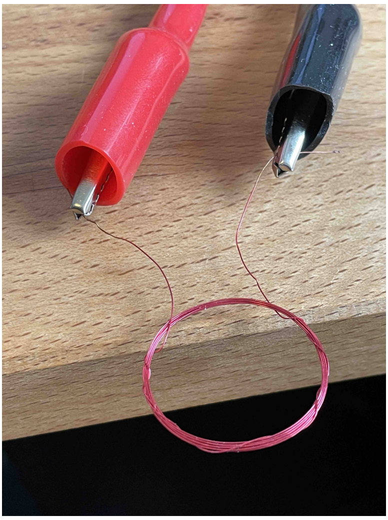
$$I = -\frac{a\sigma r}{2}\frac{dB}{dt}$$

§ 3 Setup

Find the coil of wire, and burn the ends. This will burn up the insulating coating on the wire. Wipe off the burnt coating with a tissue. Alternatively if you don't have a flame, you scrape the wire to remove the coating.

The coils were wound in two ways. Connect them to the leads of the DMM as shown below for your type of coil. The position of the coil at the edge of the table is important, so make sure the DMM leads are placed so that the setup is stable.





When the coil is connected DMM leads as shown, use the DMM to measure the resistance. If the resistance is greater than 2Ω then the ends need to be burned and cleaned again.

Change the connection of the red lead on the DMM so that you are ready to measure current (μA). Now bring the magnet near the coil and then quickly take it away while watching the meter. You should see a current as you are taking the magnet away. If you do not check the connections.

▷ Question 1

Look at the way your circuit is connected and decide if the current measurement on the meter will be positive or negative for a current going clockwise around your loop.

§ 4 Measurements

1) Start with the magnet under the coil with it oriented so that the current is pointed upward. Now move the magnet downward so that the field strength decreases. Note if the current is positive or negative, and the implied direction (CW or CCW) of the current.
2) Now quickly bring the magnet back toward the coil (still with the field up) so that the field is upward and increasing. Note if the current is positive or negative and the implied direction (CW or CCW) of the current.
3) Now turn the magnet over so that the field is downward. Start with the magnet close and then move away, so that the field is down and decreasing. Note if the current is positive or negative and the implied direction (CW or CCW) of the current.
4) Now return the magnet to being close to the coil so that the field is down and increasing. Note if the current is positive or negative and the implied direction (CW or CCW) of the current.

§ 5 Data analysis

For each of the four cases above do the following.

- Determine the direction of the change in the magnetic field.
$$\Delta\vec{B} = \vec{B}_f - \vec{B}_i$$
Make a qualitative drawing of the vector subtraction of $\vec{B}_f$ and $\vec{B}_i$.
- Determine which direction of current in the loop would make a magnetic field in the middle of the loop that is opposite in direction to $\Delta\vec{B}$. This is a right-hand-rule thing.
- Compare the direction of current that would would produce an opposed $\Delta\vec{B}$ with your measured direction of current.

▷ QUESTION 2
Did your observed current oppose the change in the magnetic field in all four cases? If not which cases did and which did not?

▷ QUESTION 3
Given that the induced electric field (and thus current) is proportional to the rate of change of the magnetic field with time, what could you do to maximize the current? Try your idea out and see what is the largest current you can get.