Teacher Notes – Exploring Electromagnets

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Aim

In this experiment, students will learn about electromagnets, how they are constructed and some of the factors affecting the strength of an electromagnet.

Students are required to learn about electromagnets in great detail in year 12. However, students from years 7 to 10 are required to learn about energy transformation and transfer; this activity will shed light on how energy can be transformed from electrical energy to magnetic energy.

This is a very engaging investigation as it provides an opportunity for the students to have a hands-on experience that involves energy transformations and magnetism. This is also a flexible and versatile experiment, and the teacher may adjust the experiment to suit their students' learning abilities.

Plan

This topic is new for students, so the experiment has been planned for them. If students require more guidance, allow sometime for them to watch a video on the construction of electromagnets. A good video can be watched on the following link: https://www.youtube.com/watch?v=aq1zGr8wE9U.

Discuss with students the risks of the experiment before they start. Make sure they know the coil can get quite hot and that they have to leave it cool before rewinding it. Students will use sharp materials such as nails, and scissors. They have to be careful with handling them.

It is a good idea to ask students to write the safety precautions before starting the experiment. Discuss this list with them to make sure they are aware of all the hazards involved.

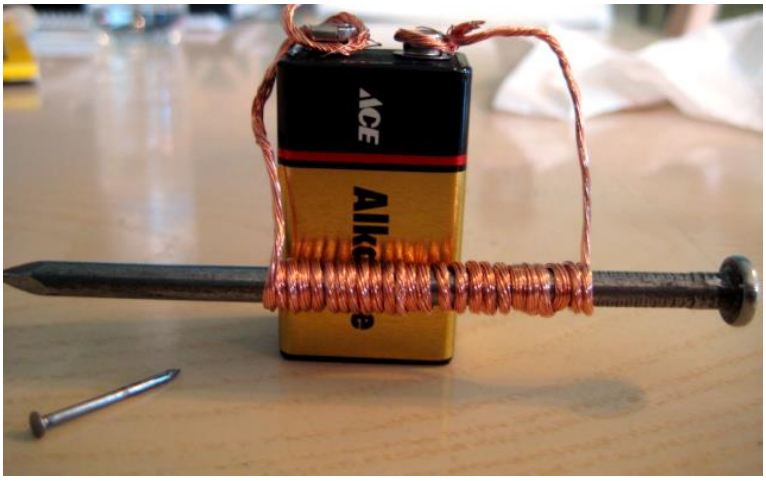

Figure 1: a photo of an electromagnet, showing a coil around an iron nail and connected to a battery

Conduct

The experiment is a mix of prescribed inquiry and guided inquiry, where the question and procedure are provided while the students are guided through their analysis, reasoning and justification.

Students will construct an electromagnet using a battery, a copper wire, a tape and an iron nail.

The experiment involves two parts in order to test the following two independent variables: number of turns in the coil and the supplied voltage. The dependent variable for both cases is the strength of the electromagnet. To test for the number of turns in the coil, the students will vary the number of turns 3 times by increments of 10 and count the number of paper clips attracted in each variation. To test for the voltage, students will conduct the experiment with one battery and count the number of paper clips attracted then connect a second battery in series (positive end of one battery to the negative end of the second battery) and count the number of paper clips attracted.

For junior and middle classes, students should understand that the strength of the electromagnet is reflected in its ability to attract the metal clips. The stronger the electromagnet, the higher the number of clips attracted to the electromagnet.

For senior classes, they can learn about the magnetic field around the magnet and how it can be represented by lines, where by the closer the lines the higher the strength of the magnet. It is worth adding an extension to the experiment by using iron filings around the electromagnet and watching how the iron filings arrange themselves in a manner depicting the magnetic field lines.

Teachers can ask students to take photos of each step of the experiment to include in their final report.

Figure 2: The iron filings around the electromagnet depicts the magnetic field lines.

Iron filings are very small so they can be accidently inhaled or penetrate the skin. Make sure students are aware of these hazards and that they wear safety goggles, and gloves while using them.

Teachers may like to add the below activity as an extension to the experiment, allowing students to apply what they have learnt about electromagnets. Students are asked to build an electromagnetic gripper arm similar to the figure below. The arm will be tested by observing how many paper clips can be moved from one pile to another in 30 seconds. The piles will be carefully marked out and any paper clips falling outside the marked areas will not be counted.

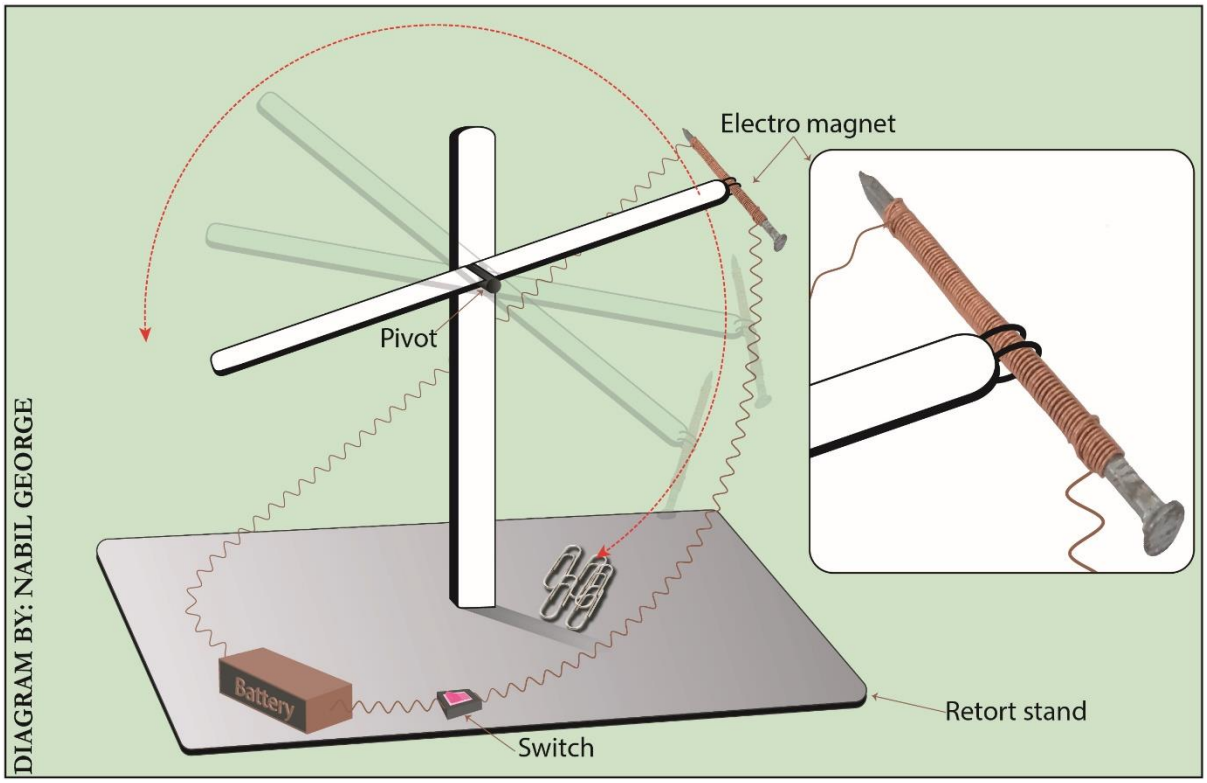

Figure 3: An electromagnetic gripper

The challenge is to construct a strong enough electromagnet (students have to think how to increase its strength). Mainly four factors affect the strength: (1) the type of metal core which magnifies the field created. While neodymium cores make the strongest fields, iron cores make very strong fields and steel cores make weak fields. (2) The number of loops in the wire wrapped around the core, as more loops make a stronger field. (3) The voltage provided by the battery, as the higher the voltage, the more current will flow and the stronger the magnetic field produced. Students can connect batteries in series to increase the voltage. (4) The wire size and material, as the greater the size, the lower the resistance and the more current that can pass through. Also, some materials have their own inherent resistance to current. The aim is to use a material with good conductivity, and students can search for the best material to use.

Ask the students to measure the voltage of the batteries by using a multimeter; the way to do this is to connect a resistor to the battery and measure the voltage drop across this resistor. A good video to show you how to do this is available with the following link:
https://www.youtube.com/watch?v=HcikzMG7mMU

The thickness of the core and the wire can be measured using a Vernier caliper. A link on how to use the Vernier caliper is here: https://www.youtube.com/watch?v=FNdkYIVJ3Vc

The electromagnet should have the ability to be switched on and off, therefore a switch has to be connected to the circuit. The figure above shows a possible place to put the switch.

Students can make a video of the operation of the arm gripper to be presented in a science fair or to be uploaded on YouTube.

Analyse

They can plot a graph with number of coils on the x-axis and the number of paper clips picked up on the y-axis. Different students may mention different factors; however, the best answer should include: the material of the coil and its thickness, the material of the core and its thickness, and the voltage used.

The independent variable in this experiment is the number of turns of the coil.

Students should be able to observe that increasing the number of turns increases the strength of the magnetic field produced.

The independent variable in Experiment 2 is the voltage used. Results should show that the magnetic field strength is higher when using two batteries rather than one.

For the senior students' extra experiment (iron filings):

Students can attach a photo of the magnetic field lines, which are more intense at the two ends of the coil. The photo will also show that the spacing between the lines gets bigger as the distance from the electromagnet increases.

For the extension experiment (the arm gripper):

Students can make a table to show the number of clips collected for each group.

Group	Material of coil	Thickness of coil	Material of core	Thickness of core	Number of turns	Number of batteries	Voltage used	Number of paper clips collected

Analysing the results of the table should show how certain materials make more efficient electromagnets. Normally ferromagnetic materials and neodymium are the best. Students should also find that the bigger the thickness of the core and the wire, the higher the magnetic field strength.

Problem solving and discussion

Students are expected to explain the reason of their observations. The more the number of turns on the coil, the greater is the magnetic field strength. This is because each turn is responsible for producing a magnetic field, so the total magnetic field is the sum of each magnetic field produced by each turn.

Increasing the voltage increases the strength of the magnetic field. Magnetic field is directly proportional to the current which in turn is directly proportional the potential difference across the ends of the wire.

Students may get unexpected results, contrary to what should happen. This could be due to the fact that the battery used is running out of power. They should be able to discuss any discrepancies in the results.

Conclusion

Students can make videos of the production of magnetic field lines and the gripper they have constructed. This can also be exhibited in a science fair.

References

Link to figure 1 https://www.flickr.com/photos/cobalt_grrl/2256696466/in/photolist-4rqaeL-ccMGtd-a6B8iE-7niq7Y-9Tv4E-4vX5tm-7tNTcB-7tSPyy-7tNT42-21XQWb-21TuV6-21XUJq-21XRLG-21XSsu-21Txoz-21XWm5-21XXby-21TvJD-21TAAn-7tSPNA-drNv7r-zRh2Ud-PtNiz4-paCc3F-essaQG-6d9oxi-9MiitY-8v5mhG-8R2Wkb-is4ZUy-9YafmZ-ps6E7d-7KqJEE-obm32g-essbQN-7d27ZV-f6LLzv-mbXsUz-ercr3e-mbXsgk-eMbn9q-4j6JQu-2i6scv-mbXrmp-dYSqRU-7hvcVL-68xUri-eWJsZu-qSgzuW-nj9rTA/ Author Gina Clifford. Licence https://creativecommons.org/licenses/by-sa/2.0/