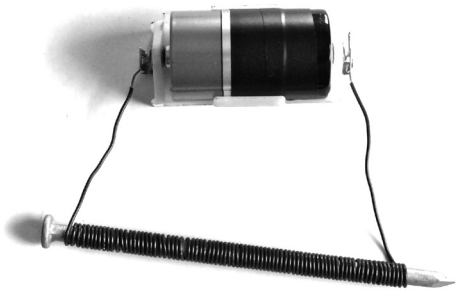
Lab Handout

Lab 11. Design Challenge

Which Electromagnet Design Is Best for Picking Up 50 Paper Clips?

FIGURE L11.1

Electromagnet made from a D-cell battery, a copper wire, and an iron nail



Introduction

Electromagnets are formed when a wire is wrapped around a metal core and electricity flows through the wire. When electricity flows through the wire, a magnetic field is produced, which is then concentrated in the metal core. It is possible to make a simple electromagnet by wrapping copper wire around an iron rod or nail and then connecting the wire to a small battery (see Figure L11.1). When electricity from the battery flows through the wire, the magnetic field from the electric current causes the iron core to have magnetic properties.

The iron core of an electromagnet is a key component for making the device work. The atoms of iron contain a large number of electrons. Within the iron core, the atoms and their electrons are moving about in random directions. However, when the atoms are exposed to the magnetic field from the electric current in the wire, the atoms and electrons change their orientations and movement to align with the magnetic field of the electric current. This rearrangement of the atoms amplifies the magnetic field from the wire and results in a stronger electromagnet. When the electric current stops (by turning it off or disconnecting the battery), the atoms in the iron core go back to their random motion and positions and no longer have magnetic properties.

There are three main parts required to build an electromagnet: the iron core, copper wire, and an electricity source. Changes in each of these pieces of the electromagnet will influence the overall strength of the magnet. The more powerful the source of electricity, the more electric current there will be flowing through the wire. The larger the iron core, the more atoms there are that can be aligned to help amplify the magnetic force. The number of times the wire is wrapped around the iron rod will also influence the strength of the electromagnet.

Electromagnets are used in many different contexts, ranging from small applications, such as the audio speakers in a cell phone, to large applications, such as picking up old cars in a junkyard. In each of these contexts, the electromagnet must be strong enough to accomplish its intended purpose but not so strong that it has unintended effects on nearby materials. In some cases, an electromagnet may be used to pick up a specific weight or even a specific amount of objects. If an electromagnet is designed for a specific task, it must have the right combination of properties, including the amount of electricity, the size of the iron core, and the number of times the wire is wrapped around the iron core so that it has a consistent and predictable performance.

Your Task

Use what you know about magnetic fields and cause-and-effect relationships to design a small electromagnet that can be used for a specific task. Your specific design challenge is as follows: The International Paperclip Company (IPC) needs an electromagnet that will pick up approximately 50 paper clips to help fill and package a single box of clips. For the IPC to keep their customers happy and the company's costs consistent, the electromagnet must reliably pick up between 47 and 53 paper clips. The IPC would also like to spend as little money as possible to construct their new electromagnet, while making sure that their new electromagnet will accomplish its task.

The guiding question of this investigation is, **Which electromagnet design is best for picking up 50 paper clips?**

Materials

You may use any of the following materials during your investigation:

- Batteries (different sizes)
- Copper wire
- Iron nails (different sizes)
- Paperclips
- Gauss meter (optional)
- Safety glasses or goggles

Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on activity, and takedown.
2. Given that the electromagnet setup will generate heat, disconnect the wire from the battery when not actively collecting data, to prevent skin burn.
3. Use caution when wrapping the copper wire around the nail. It is possible that the loose end will swing around during the wrapping process and present a hazard.
4. Use caution in handling the wire end or nails. They are sharp and can cut or puncture skin.
5. Wash hands with soap and water after completing the lab activity.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to design and test an electromagnet that is capable of picking up 50 paper clips. You must also consider the cost of the materials that are used in your electromagnet. You will need to systematically test how changes to each part of the electromagnet influence the strength of the magnet and its ability to accomplish

its intended task. To complete this design challenge, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it.

To determine *what type of data you need to collect,* think about the following questions:

- How will you determine the strength of the electromagnet?
- What information or measurements will you need to record?
- What parts of the electromagnet will you change and what parts will you keep consistent?
- What design factors will you consider when building your electromagnet?

To determine *how you will collect your data,* think about the following questions:

- What equipment will you need to collect the data you need?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect?
- How will you organize your data?

To determine *how you will analyze your data,* think about the following questions:

- How will you determine which parts of the electromagnet have the biggest impact on its strength?
- What type of table or graph could you create to help make sense of your data?
- How will you determine if one electromagnet design is better than another?

When you design your electromagnet for the IPC, it will be important to take into account the amount of materials you use, how much they cost, and how often the components will need to be replaced. Table L11.1 includes information about the different materials that might be used in making your electromagnet.

TABLE L11.1

Cost information for electromagnet materials

Item	Cost
Battery, 1.5 v, size D	$0.99/each
Battery, 1.5 v, size C	$0.89/each
Battery, 1.5 v, size AA	$0.45/each
Copper wire	$0.07/30 cm
Iron core	$0.015/cm

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

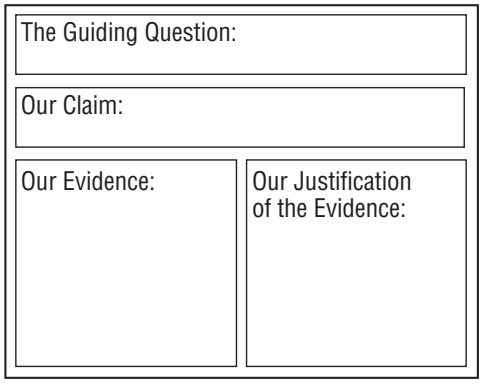
- why it is important to understand cause-and-effect relationships,
- how defining a system under study and making a model of it is helpful in science,
- how scientists use different methods to answer different types of questions, and
- the role of imagination and creativity in science.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a *claim*, *evidence* to support your claim, and a *justification* of the evidence. The claim is your group's answer to the guiding question. The evidence is an analysis and interpretation of your data. Finally, the justification of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L11.2.

FIGURE L11.2

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the arguments developed by their classmates. This is similar to how scientists present their arguments to other scientists at conferences. If you are responsible for critiquing your classmates' arguments, your goal is to look for mistakes so these mistakes can be fixed and they can make their argument better. The argumentation session is also a good time to think about ways you can make your initial argument better. Scientists must share and critique arguments like this to develop new ideas.

To critique an argument, you might need more information than what is included on the whiteboard. You will therefore need to ask the presenter lots of questions. Here are some good questions to ask:

- How did you collect your data? Why did you use that method? Why did you collect those data?

- What did you do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- How did you group analyze the data? Why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your analysis? How do you know that your interpretation of your analysis is appropriate?
- Why did your group decide to present your evidence in that way?
- What other claims did your group discuss before you decided on that one? Why did your group abandon those alternative ideas?
- How confident are you that your claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most acceptable and valid answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable and valid!